

Senior 2 Science

A Foundation for
Implementation

SENIOR 2 SCIENCE

A Foundation for Implementation

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INTRODUCTION

Background

Senior 2 Science: Manitoba Curriculum Framework of Outcomes (2001) (hereinafter referred to as the *Science Framework*) and *Senior 2 Science: A Foundation for Implementation* present student learning outcomes for Senior 2 science. These learning outcomes are the same for students in English, French Immersion, Français, and Senior Years Technology Education programs and result from a partnership involving two divisions of Manitoba Education and Youth: School Programs and Bureau de l'éducation française. Manitoba's science student learning outcomes are based on those found within *Common Framework of Science Learning Outcomes K to 12* (Council of Ministers of Education, Canada). The latter, commonly referred to as the *Pan-Canadian Science Framework (PCSF)*, was initiated under the Pan-Canadian Protocol for Collaboration on School Curriculum (1995), and was developed by educators from Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories, the Yukon Territory, Ontario, and the Atlantic Provinces.

Student learning outcomes are concise descriptions of the knowledge and skills [and attitudes] that students are expected to learn in a course or grade level in a subject area (Manitoba Education and Training, *A Foundation for Excellence*, 1995).

The *Science Framework* provides the basis for learning, teaching, and assessing science in Manitoba. It also serves as a starting point for future development of curriculum documents, support materials, learning resources, assessment tools, and professional learning for teachers. *Senior 2 Science: A Foundation for Implementation* (2003) complements the *Science Framework*, providing support for its implementation, including suggestions for instruction and assessment.

Vision for Scientific Literacy

Global interdependence; rapid scientific and technological innovation; the need for a sustainable environment, economy, and society; and the pervasiveness of science and technology in daily life reinforce the importance of scientific literacy. Scientifically literate individuals can more effectively interpret information, solve problems, make informed decisions, accommodate change, and achieve new understandings. Science education makes possible the development of **scientific literacy** and helps build stronger futures for Canada's young people. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities to become lifelong learners, and to maintain a sense of wonder about the world around them.

Senior 2 Science: A Foundation for Implementation is designed to support and promote the vision for scientific literacy as articulated in the *Pan-Canadian Science Framework* (Council of Ministers of Education, Canada) and in *Senior 2 Science: Manitoba Curriculum Framework of Outcomes* (Manitoba Education and Training, 2001).

Diverse learning experiences based on the *Pan-Canadian Science Framework* will provide students with many opportunities to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, careers, and their future (Council of Ministers of Education, Canada, *Common Framework of Science Learning Outcomes K to 12*, 1997).

Goals for Canadian Science Education

Several goals promoting scientific literacy within Canadian science education were developed as part of the *Pan-Canadian Science Framework*; these goals are addressed through Manitoba science curricula. It is hoped that science education will:

- encourage students at all grades to develop a critical sense of wonder and curiosity about scientific and technological endeavours;
- enable students to use science and technology to acquire new knowledge and solve problems, so they may improve the quality of their own lives and the lives of others;
- prepare students to critically address science-related societal, economic, ethical, and environmental issues;
- provide students with a proficiency in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies appropriate to their interests and abilities; and
- develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology, and the environment.

Beliefs about Learning, Teaching, and Assessing Science

To promote scientific literacy among future citizens, it is crucial to recognize how students learn, how science can best be taught, and how learning can be assessed. Students are curious, active learners who have individual interests, abilities, and needs. They come to school with various personal and cultural experiences and prior knowledge that generate a range of attitudes and beliefs about science and life.

Students learn most effectively when their study of science is rooted in concrete learning experiences related to a particular context or situation, and applied to their world where appropriate. Ideas and understandings that students develop should be progressively extended and reconstructed as students grow in their experiences and in their ability to conceptualize. Learning involves the process of linking newly constructed understandings with prior knowledge and adding new contexts and experiences to current understandings.

Changing Emphases in Science Education Content Delivery*

The *National Science Education Standards* envision change throughout the system. The science content standards [or student learning outcomes] encompass the following changes in emphases:

LESS EMPHASIS ON	MORE EMPHASIS ON
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned

Changing Emphases to Promote Inquiry

LESS EMPHASIS ON	MORE EMPHASIS ON
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in context
Individual process skills such as observation or inference	Using multiple process skills—manipulation, cognitive, procedural
Getting an answer	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Individuals and groups of students analyzing and synthesizing data without defending a conclusion	Groups of students often analyzing and synthesizing data after defending conclusions
Doing few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content
Concluding inquiries with the result of the experiment	Applying the results of experiments to scientific arguments and explanations
Private communication of student ideas and conclusions to teacher	Management of ideas and information
	Public communication of student ideas and to classmates

* Reproduced from National Research Council, *National Science Education Standards* (Washington, DC: National Academy Press, 1996) 113. Reproduced by permission.

Development of scientific literacy is supported by instructional environments that engage students in the following processes:

- **scientific inquiry:** students address questions about natural phenomena, involving broad explorations as well as focused investigations;
- **technological problem solving (design process):** students seek answers to practical problems requiring the application of their science knowledge in various ways; and
- **decision making:** students identify issues and pursue science knowledge that will inform their decisions.

It is through these processes that students discover the significance of science in their lives and come to appreciate the interrelatedness of science, technology, society, and the environment.

Each of these processes can be a starting point for science learning, and may encompass the exploration of new ideas, the development of specific investigations, and the application of ideas that are learned.

To achieve the vision of scientific literacy, students must become increasingly engaged in the planning, development, and evaluation of their own learning experiences. They should have the opportunity to work cooperatively with other students, to initiate investigations, to communicate their findings, and to complete projects that demonstrate their learning.

At the beginning of instructional design, teachers and students should identify expected student learning outcomes and establish performance criteria. It is important that these criteria correspond with provincial student learning outcomes. This communication between students and teachers helps to identify clearly what needs to be accomplished, thereby assisting in the learning process.

When students are aware of expected outcomes, they will be more focused on learning and more likely to assess their own progress. Furthermore, they can participate in creating appropriate assessment and evaluation criteria. Assessment methods must be valid, reliable, and fair to students.

MANITOBA FOUNDATIONS FOR SCIENTIFIC LITERACY

The Five Foundations

To develop scientifically literate students, Manitoba science curricula are built upon five foundations for scientific literacy that have been adapted from the *Pan-Canadian Science Framework* to address the needs of Manitoba students, and include:

- A. Nature of Science and Technology
- B. Science, Technology, Society, and the Environment (STSE)
- C. Scientific and Technological Skills and Attitudes
- D. Essential Science Knowledge
- E. Unifying Concepts

In the following pages, each foundation is described and accompanied by general learning outcomes, which further define expectations for student learning. These general learning outcomes represent the goals of science learning in Kindergarten to Senior 4.

A. Nature of Science and Technology

Students will learn that science and technology are creative human activities with long histories in all cultures.

Science is a way of learning about the universe. This learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over that evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science argue that there is no set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theories, knowledge, experiments, and processes anchored in the physical world.

Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science. Scientists submit models and solutions to the assessment of their peers who judge their logical and experimental soundness by reference to the body of existing knowledge (Larochelle and Désautels, 1992).

Scientific theories are being tested, modified, and refined continually as new knowledge and theories supersede existing ones. Scientific debate on new observations and hypotheses that challenge accepted knowledge involves many participants with diverse backgrounds. This highly complex interplay, which has occurred throughout history, is fuelled by theoretical discussions; experimentation; social, cultural, economic, and political influences; personal biases; and the need for peer recognition and acceptance. Students will realize that while some of our understandings about how the world works are due to revolutionary scientific developments, many of our understandings result from the steady and gradual accumulation of knowledge.

Technology results mainly from proposing solutions to problems arising from attempts by humans to adapt to the environment. Technology may be regarded as "... a tool or machine; a process, system, environment, epistemology, and ethic; the systematic application of knowledge, materials, tools, and skills to extend human capabilities ...” (Manitoba Education and Training, *Technology As a Foundation Skill Area: A Journey Toward Information Technology Literacy*, 1998). Technology refers to much more than the knowledge and skills related to computers and their applications. Technology is based on the knowledge of concepts and skills from other disciplines (including science) and is the application of this knowledge to meet an identified need or solve a problem using materials, energy, and tools (including computers). Technology also has an influence on processes and systems, on society, and on the ways people think, perceive, and define their world.

The *Science Framework* and *Senior 2 Science: A Foundation for Implementation* are designed to emphasize both the distinctions and relationships between science and technology. Figure 1 illustrates how science and technology differ in purpose, procedure, and product, while at the same time relate to each other.

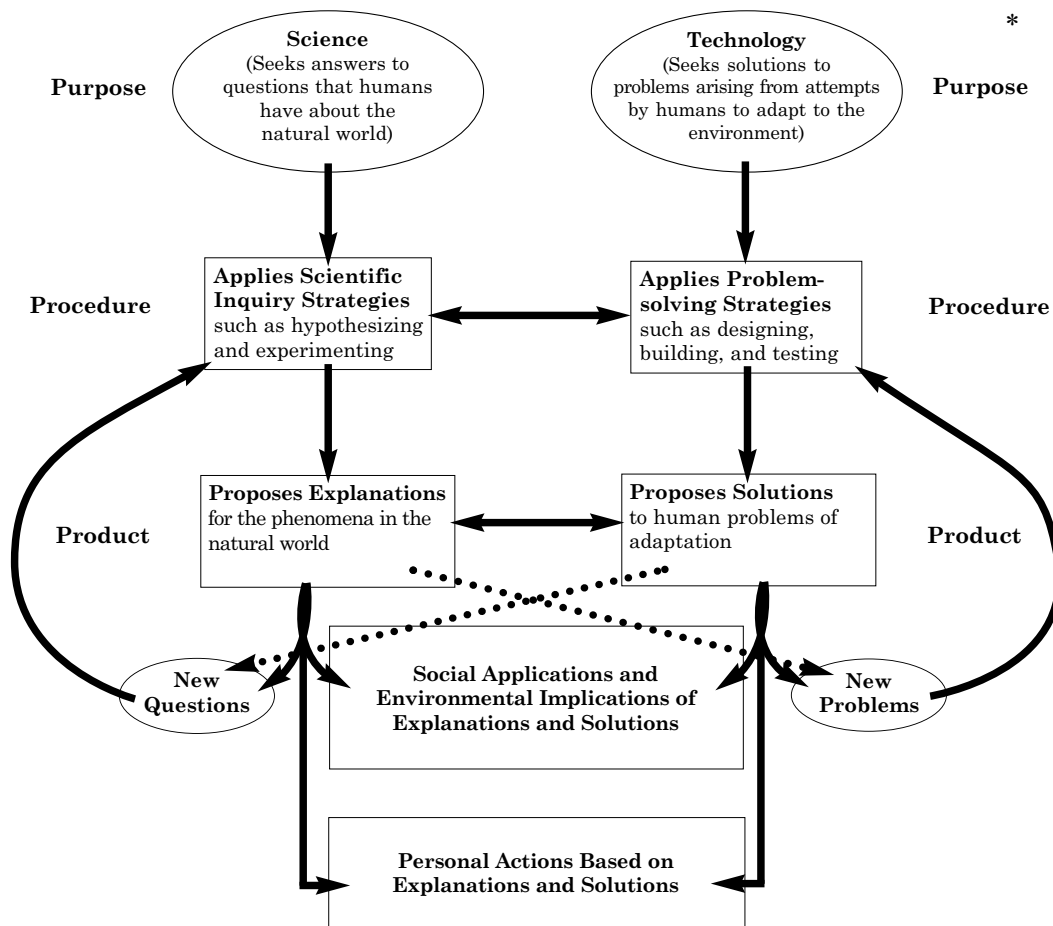


Figure 1: Science and Technology: Their Nature and Interrelationships*

* Adapted from Rodger W. Bybee et al., *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction* (Rowley, MA: The NETWORK, Inc., 1989).

The following **General Learning Outcomes** (GLOs) have been developed to further define expectations related to this foundation area. (For a complete listing of Science GLOs, see Appendix 6.11.)

Nature of Science and Technology General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will

- A1. recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena
- A2. recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop
- A3. distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values
- A4. identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations
- A5. recognize that science and technology interact with and advance one another

B. Science, Technology, Society, and the Environment (STSE)

Understanding STSE is an essential component of scientific literacy. By examining the historical context, students come to appreciate ways in which cultural and intellectual traditions have influenced the questions and methodologies of science, and how science, in turn, has influenced the wider world of ideas.

Today, most scientists work in industry, where projects are more often driven by societal and environmental needs than by pure research. Many technological solutions have evoked complex social and environmental issues. Students, as future citizens, must recognize the potential of scientific literacy to inform and empower decision making of individuals, communities, and society as a whole.

Scientific knowledge is necessary, but not sufficient, for understanding the relationships among science, technology, society, and the environment. To understand these relationships fully, it is essential that students consider the values related to science, technology, society, and the environment.

To achieve scientific literacy, students must also develop an appreciation for the importance of sustainable development. To this end, *Senior 2 Science: A Foundation for Implementation* integrates the Sustainable Development Strategy developed by the Province of Manitoba (see Figure 2). Educators are encouraged to consult *Education for a Sustainable Future* (Manitoba Education and Training, 2000), a document that outlines ways of incorporating precepts, principles, and practices to foster appropriate learning environments that would help direct students toward a sustainable future.

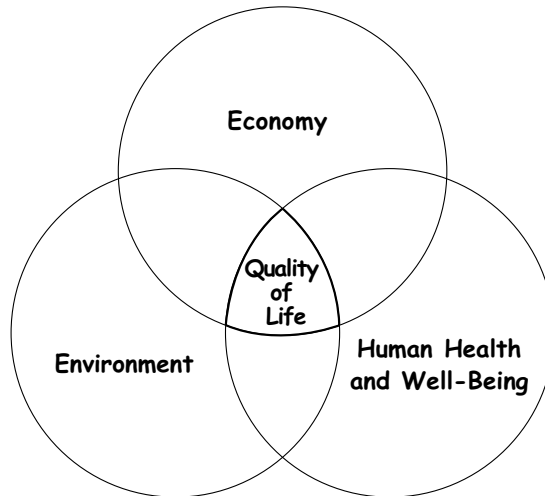


Figure 2: Sustainable Development

Sustainable development is a decision-making model that considers the needs of both present and future generations, and integrates and balances the **impact of economic activities**, the **environment**, and the **health and well-being of the community**.

Sustainable human health and well-being is characterized by people coexisting harmoniously within local, national, and global communities, and with nature. A sustainable society is one that is physically, psychologically, spiritually, and socially healthy. The well-being of individuals, families, and communities is of considerable importance.

A sustainable environment is one in which the life-sustaining processes and natural resources of the Earth are conserved and regenerated.

A sustainable economy is one that provides equitable access to resources and opportunities. It is characterized by development decisions, policies, and practices that respect cultural realities and differences, and do not exhaust the Earth's resources. A sustainable economy is evident when decisions, policies, and practices are carried out to minimize their impact on the Earth's resources and to maximize the regeneration of the natural environment.

Decisions or changes related to any one of the three components—human health and well-being, the environment, or the economy—have a significant impact on the other two components and, consequently, on our **quality of life**. Decision making must take into account all three components to ensure an equitable, reasonable, and sustainable quality of life for all.

Sustainable Development, Social Responsibility, and Equity

Sustainable development supports principles of social responsibility and equity. Williams (1994) believes that the concept of equity is essential to the attainment of sustainability. This includes equity among nations, within nations, between humans and other species, as well as between present and future generations.

Sustainable development is, at the same time, a decision-making process, a way of thinking, a philosophy, and an ethic. Compromise is an important idea that underlies the decision-making process within a sustainable development approach. In order to achieve the necessary balance between human health and well-being, the environment, and the economy, some compromises will be necessary.

There can be no greater contribution or more essential element to long-term environmental strategies leading to sustainable development that respects the environment ... than the education of future generations in matters relating to the environment (UNESCO, 1988).

Public awareness and understanding of the concept of sustainable development and its practices are essential. If we are to change our way of life we must equip present and future generations with the knowledge and training to put sustainable development into effect (Sustainability Manitoba, 1994).

As students advance from grade to grade, they identify STSE interrelationships and apply decision-making skills in increasingly demanding contexts, as outlined in the following ways:

- **complexity of understanding**—from simple, concrete ideas to abstract ideas; from limited knowledge of science to more in-depth and broader knowledge of science and the world;
- **applications in context**—from contexts that are local and personal to those that are societal and global;
- **consideration of variables and perspectives**—from one or two that are simple to many that are complex;
- **critical judgment**—from simple right or wrong assessments to complex evaluations; and
- **decision making**—from decisions based on limited knowledge, made with the teacher’s guidance, to decisions based on extensive research, involving personal judgment and made independent thinking.

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area.

Science, Technology, Society, and the Environment (STSE) General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will

- B1. describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally
- B2. recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time
- B3. identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social
- B4. demonstrate a knowledge of and personal consideration for a range of possible science- and technology-related interests, hobbies, and careers
- B5. identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally

C. Scientific and Technological Skills and Attitudes

A science education that strives for scientific literacy must engage students in answering questions, solving problems, and making decisions. These processes are referred to as Scientific Inquiry, Technological Problem Solving (Design Process), and Decision Making (see Figure 3). While the skills and attitudes involved in these processes are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

	Scientific Inquiry	Technological Problem Solving (Design Process)	Decision Making
Purpose:	Satisfying curiosity about events and phenomena in the natural world.	Coping with everyday life, practices, and human needs.	Identifying different views or perspectives based on varying information.
Procedure:	What do we know? What do we want to know?	How can we do it? Will it work?	What are the alternatives or consequences? Which choice is best at this time?
Product:	Knowledge about events and phenomena in the natural world.	An effective and efficient way to accomplish a task or meet a need.	A defensible decision in a particular circumstance.

	Scientific Question	Technological Problem	STSE Issue
Example:	Why does my coffee cool so quickly? <i>An Answer:</i> Heat energy is transferred by conduction, convection, and radiation, to the surrounding environment.	How can I keep my coffee hot? <i>A Solution:</i> A foam cup will keep liquids warm for a long time. So will an insulated cup.	Should we use foam cups or ceramic mugs for our meeting? <i>A Decision:</i> Since we must use disposable cups for the meeting, a biodegradable type will be chosen.

Figure 3: Processes for Science Education*

Each of these *processes* is described on the following page. *Attitudes*, an important element of each process, are also examined.

*Adapted with permission of the Minister of Education, Province of Alberta, Canada, 1999.

Scientific Inquiry

Scientific inquiry is a way of learning about the universe. It involves posing questions and searching for explanations of phenomena. Although no single “scientific method” exists, students require certain skills to participate in science-related experiences.

Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, and collecting, analyzing, and interpreting data are fundamental to scientific inquiry—as are attitudes such as curiosity, skepticism, and creativity. These skills are often represented as a cycle. This cycle involves posing questions, generating possible explanations, and collecting and analyzing evidence to determine which of these explanations is most useful and accurate in accounting for the phenomena under investigation. New questions may arise to re-ignite the cycle. It must be noted, however, that many scientific inquiries (past and present) do not necessarily follow a set sequence of steps, nor do they always start at the “beginning” of the cycle; scientists can be creative and responsive to scientific challenges as they arise.

Technological Problem Solving

Technological problem solving seeks solutions to problems arising from attempts by humans to adapt to or change the environment. In Kindergarten to Grade 8 science, students have been developing these skills using a cycle of steps called the **design process**. This design process includes the proposing, creating, and testing of prototypes, products, and techniques in an attempt to reach an optimal solution to a given problem. Feedback and evaluation are built into this cycle. In Senior Years science, these technological problem-solving skills are incorporated into a decision-making process.

STSE Issues and Decision Making

Students, as individuals and global citizens, are required to make decisions. Increasingly, the types of issues they face demand an ability to apply scientific and technological knowledge, processes, and products to the decisions they make related to Science, Technology, Society, and the Environment (STSE). The decision-making process involves a series of steps that may include

- clarifying the issue
- critically evaluating all available research
- generating possible courses of action
- making a thoughtful decision
- examining the impact of the decision
- reflecting on the process

Students should be actively involved in decision-making situations as they progress through their science education. Not only are decision-making situations important in their own right, but they also provide a relevant context for engaging in scientific inquiry, problem solving, and the study of STSE relationships (see Figure 4).

DECISION-MAKING MODEL FOR STSE ISSUES

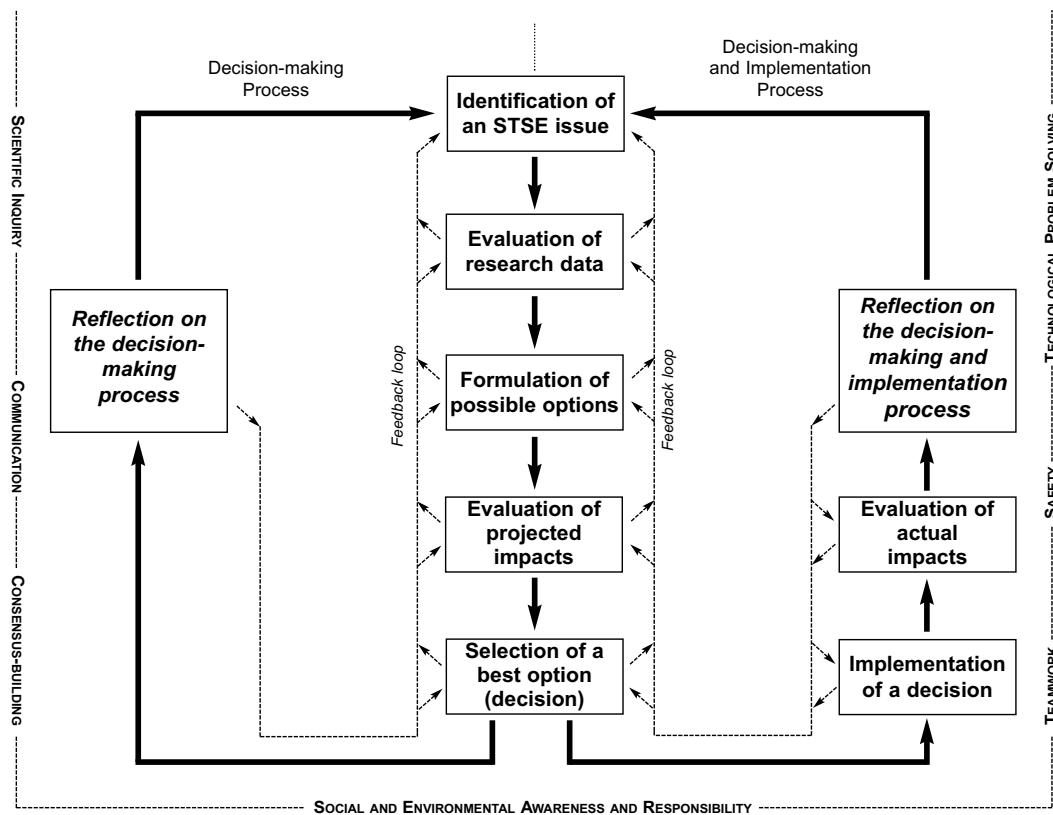


Figure 4: Decision-Making Model for STSE Issues

Attitudes

Attitudes refer to generalized aspects of behaviour that are modeled for students. Attitudes are not acquired in the same way as skills and knowledge. They cannot be observed at any particular moment, but are evidenced by regular, unprompted manifestations over time. Development of attitudes is a lifelong process that involves the home, the school, the community, and society at large. The development of positive attitudes plays an important role in students' growth, affecting their intellectual development and creating a readiness for responsible application of what they learn.

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area.

Scientific and Technological Skills and Attitudes General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will

- C1. recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations
- C2. demonstrate appropriate scientific-inquiry skills when seeking answers to questions
- C3. demonstrate appropriate problem-solving skills when seeking solutions to technological challenges

- C4. demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information
- C5. demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind
- C6. employ effective communication skills and use information technology to gather and share scientific and technological ideas and data
- C7. work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities
- C8. evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life

D. Essential Science Knowledge

The subject matter of science includes theories, models, concepts, and principles that are essential to an understanding of life science, physical science, and Earth and space sciences. While *Senior 2 Science: A Foundation for Implementation* is not strictly aligned with these disciplines, the learning outcomes are intended to help develop important concepts from each of these areas.

Life science deals with the growth and interactions of life forms within their environment in ways that reflect their uniqueness, diversity, genetic continuity, and changing nature. Life science includes the study of organisms (including humans and cells), ecosystems, biodiversity, biochemistry, and biotechnology, to name a few.

Physical science, which encompasses chemistry and physics, deals with matter, energy, and forces. Matter has structure, and interactions exist among its components. Energy links matter to gravitational, electromagnetic, and nuclear forces of the universe. The laws of conservation of mass and energy, momentum, and charge are addressed by physical science.

Earth and space science brings local, global, and universal perspectives to students' knowledge. The Earth exhibits form, structure, and patterns of change, as does our surrounding solar system and the physical universe beyond. Earth and space science includes fields of study such as geology, hydrology, meteorology, and astronomy.

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area.

Essential Science Knowledge General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will

- D1. understand essential life structures and processes pertaining to a wide variety of organisms, including humans
- D2. understand various biotic and abiotic components of ecosystems, as well as their interaction and interdependence within ecosystems and within the biosphere as a whole
- D3. understand the properties and structures of matter as well as various common manifestations and applications of the actions and interactions of matter

- D4. understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts
- D5. understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them
- D6. understand the composition of the universe, the interactions within it, and the implications of humankind's continued attempts to understand and explore it

E. Unifying Concepts

An effective way to create linkages within and among science disciplines is to use unifying concepts—the key ideas that underlie and integrate all science knowledge and extend into areas such as mathematics and social studies. Unifying concepts help students construct a holistic understanding of science and its role in society. The following four unifying concepts were used in the development of the *Science Framework* and *Senior 2 Science: A Foundation for Implementation*.

Similarity and Diversity

The concepts of similarity and diversity provide tools for organizing our experiences with the world. Beginning with informal experiences, students learn to recognize attributes of materials, organisms, and events that help to make useful distinctions between and among them. Over time, students adopt accepted procedures and protocols for describing and classifying objects, organisms, and events they encounter, thus enabling them to share ideas with others and to reflect on their own experiences.

Systems and Interactions

An important part of understanding and interpreting the world is the ability to think about the whole in terms of its parts and, alternately, about parts in terms of how they relate to one another and to the whole. A system is a collection of components that interact with one another so that the overall effect is often different from that of the individual parts, even when these are considered together. Students will study both natural and technological systems.

Change, Constancy, and Equilibrium

The concepts of constancy and change underlie most understandings of the natural and technological world. Through observations, students learn that some characteristics of living things, materials, and systems remain constant over time, whereas others change. Through formal and informal studies, students develop an understanding of the processes and conditions in which change, constancy, and equilibrium take place.

Energy

The concept of energy provides a conceptual tool that brings together many understandings about natural phenomena, materials, and the processes of change. Energy, whether transmitted or transformed, is the driving force of both movement and change. Students learn to describe energy in terms of its effects and, over time, develop a concept of energy as something inherent within the interactions of materials, the processes of life, and the functioning of systems.

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area.

Unifying Concepts General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will

- E1. describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world
- E2. describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems
- E3. recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved
- E4. recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them

Conceptual Organizer

The Conceptual Organizer on the following page (Figure 5) provides a graphical representation of the different components of the science curriculum. It summarizes the relationships among the Manitoba Foundations for Scientific Literacy, and shows how they helped to develop the general and specific student learning outcomes in Kindergarten to Senior 4. The detail of the thematic clusters in Grades 5 to Senior 2 appears in the exploded view.

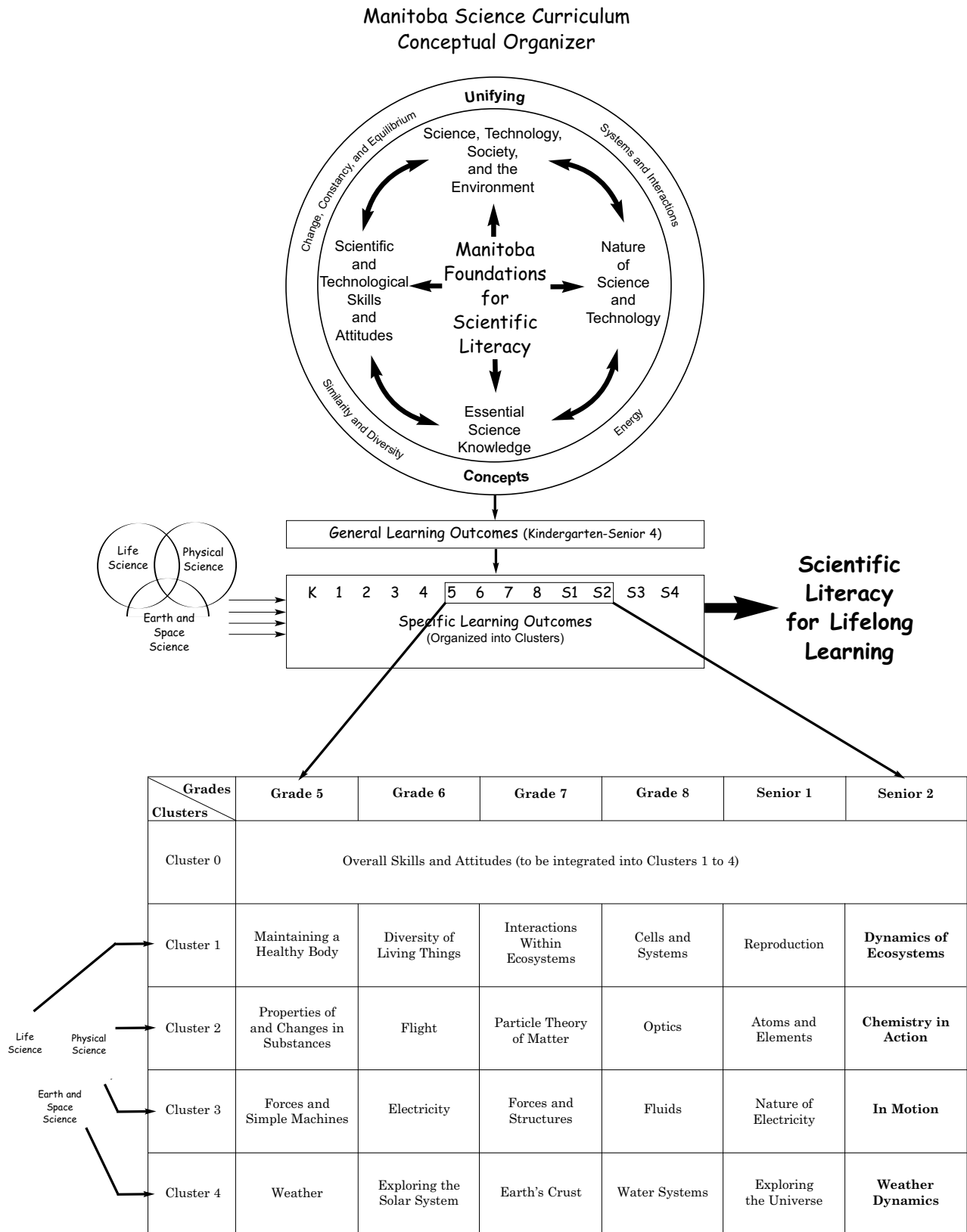


Figure 5: Manitoba Science Curriculum Conceptual Organizer and Details of Cluster Titles, Grades 5 to Senior 2 Science

IMPLEMENTATION OF SENIOR 2 SCIENCE

The Senior 2 Student and the Science Learning Environment

Each year, teachers make a myriad of decisions regarding course content, learning materials and resources, and instructional and assessment methods. Successful learning is more likely to occur if these decisions are informed by teachers' understanding of their students and the ways they learn.

Teachers seeking to learn about their students need to be knowledgeable in various areas, including the following:

- **How people learn:** In recent decades, cognitive psychology, brain-imaging technology, multiple intelligences theory, and constructivist learning theory have transformed our understanding of learning. Teachers need to engage in ongoing professional development and to update their knowledge of the processes of learning.
- **The ways in which student populations are changing:** The students whom teachers encounter today are different in many respects from students a generation ago. Students are more likely to be living with a single parent or stepfamily. More have part-time jobs. Students are more sophisticated in their knowledge and use of information technology, and much of their understanding of the world comes from television. Classrooms are more likely to be ethnically diverse.
- **The developmental characteristics of Senior 2 students:** The characteristics of adolescent learners, and the particular situation of Senior 2 students in middle adolescence, have many implications for teachers.
- **The unique qualities of each student:** Family relationships, academic and life experiences, personality, interests, learning approaches, rate of development, and language proficiency all influence a student's ability to learn. Teachers can gain an understanding of the unique qualities of each student through ongoing interaction, observation, and assessment.

Characteristics of Senior 2 Learners

If a symbolic line could be drawn between childhood and adulthood, it would be drawn for many students during their Senior 2 year. These students begin to assume many of the responsibilities associated with maturity. Many take their first part-time job. Many embark on their first serious romantic relationship. For many, acquiring a driver’s licence is a significant rite of passage.

Although many Senior 2 students handle their new responsibilities and the many demands on their time with ease, others experience difficulty. Senior 2 can be a key year for at-risk students. External interests may seem more important than school. Because of their increased autonomy, students who in previous years had problems managing their behaviour at school may now express their difficulties through poor attendance, alcohol and drug use, or other behaviours that place them at risk. Students struggling to control their lives and circumstances may make choices that seem contrary to their best interests. Being aware of what their students are experiencing outside school is important for teachers at every level.

Although the huge developmental variance evident in Grade 6 through Senior 1 is narrowing, students in Senior 2 can still demonstrate a development range of up to three years. Adolescents also change a great deal in the course of one year or even one semester. Senior 2 teachers need to be sensitive to the classroom dynamic, and recognize when shifts in interests, capabilities, and needs are occurring, so they can adjust learning activities for their students.

There are, however, some generalizations that can be made about Senior 2 students. The following chart identifies some common characteristics observed in educational studies (Glatthorn, 1993; Maxwell and Meiser, 1997) and by Manitoba teachers, and discusses the implications of these characteristics for teachers.

Senior 2 Learners: Implications for Teachers*	
Characteristics of Senior 2 Learners	Accommodating Senior 2 Learners
<i>Physical Characteristics</i>	
<ul style="list-style-type: none"> Some Senior 2 students, particularly males, are still in a stage of extremely rapid growth, and experience a changing body image and self-consciousness. Senior 2 students are able to sit still and concentrate on one activity for longer periods than previously, but still need interaction and variety. Many students come to school tired, as a result of part-time jobs or activity-overload. 	<ul style="list-style-type: none"> Be sensitive to the risk students may feel in public performances, and increase expectations gradually. Provide students with positive information about themselves. Put physical energy to the service of active learning, instead of trying to contain it. Provide variety; change the pace frequently; use kinesthetic activities. Work with students and families to set goals and plan activities realistically so that school work assumes a higher priority.

(continued)

* Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) 4–6.

Senior 2 Learners: Implications for Teachers (continued)	
Characteristics of Senior 2 Learners	Accommodating Senior 2 Learners
<i>Cognitive Characteristics</i>	
<ul style="list-style-type: none"> • Senior 2 learners are increasingly capable of abstract thought, and are in the process of revising their former concrete thinking into fuller understanding of principles. • Students are less absolute in their reasoning, more able to consider diverse points of view. They recognize that knowledge may be relative to context. • Many basic learning processes have become automatic by Senior 2, freeing students to concentrate on complex learning. • Many students have developed specialized interests and expertise, and need to connect what they are learning to the world outside school. 	<ul style="list-style-type: none"> • Teach to the big picture. Help students forge links between what they already know and what they are learning. • Focus on developing problem-solving and critical-thinking skills, particularly those related to STSE and decision making. • Identify the skills and knowledge students already possess, and build the course around new challenges. Through assessment, identify students who have not mastered learning processes at Senior 2 levels, and provide additional assistance and support. • Encourage students to develop scientific literacy skills through exploring areas of interest. Cultivate classroom experts, and invite students with individual interests to enrich the learning experience of the class.
<i>Moral and Ethical Characteristics</i>	
<ul style="list-style-type: none"> • Senior 2 students are working at developing a personal ethic, rather than following an prescribed set of values and code of behaviour. • Students are sensitive to personal or systemic injustice. They are often idealistic and impatient with the realities that make social change slow or difficult. • Students are shifting from an egocentric view of the world to one centred in relationships and community. • Students have high standards for adult competency and consistency, and are resistant to arbitrary authority. 	<ul style="list-style-type: none"> • Explore the ethical meaning of situations in life and in scientific contexts. Provide opportunities for students to reflect on their thoughts in discussion, writing, or representation. • Explore ways literacy activities can effect social change, and link to the continuum of science technology, society, and the environment. • Provide opportunities for students to make and follow through on commitments, and to refine their interactive skills. • Explain the purpose of every activity. Enlist student collaboration in developing classroom policies. Strive for consistency.

(continued)

Senior 2 Learners: Implications for Teachers (<i>continued</i>)	
Characteristics of Senior 2 Learners	Accommodating Senior 2 Learners
<i>Social Characteristics</i>	
<ul style="list-style-type: none"> • Senior 2 students continue to be intensely concerned with how peers view their appearance and behaviour. Much of their sense of self is still drawn from peers, with whom they may adopt a “group consciousness,” rather than making autonomous decisions. • Peer acceptance is often more important than adult approval. Adolescents frequently express peer identification through slang, musical choices, clothing, body decoration, and behaviour. • Crises of friendship and romance, and a preoccupation with sex can distract students from academics. • Although Senior 2 students may have an aloof demeanour, they still expect and welcome a personal connection with their teachers. 	<ul style="list-style-type: none"> • Ensure that the classroom has an accepting climate. Model respect for each student. Use language activities that foster student self-understanding and self-reflection. Challenge students to make personal judgements about situations in life and their natural environment. • Foster a classroom identity and culture. Ensure that every student is included and valued. Structure learning so that students can interact with peers, and teach strategies for effective interaction. • Open doors for students to learn about science relationships through poetry, film, and fiction, and to explore their experiences and feelings in language. Respect confidentiality, except where a student’s safety is at risk. • Nurture a relationship with each student. Try to find areas of common interest with each one. Respond with openness, empathy, and warmth.
<i>Psychological and Emotional Characteristics</i>	
<ul style="list-style-type: none"> • It is important for Senior 2 students to see that their autonomy and emerging independence is respected. They need a measure of control over what happens to them in school. • Students need to understand the purpose and relevance of activities, policies, and processes. Some express a growing sense of autonomy through questioning authority. Others may be passive and difficult to engage. • Students at this stage may be more reserved, aloof, and guarded than previously, both with teachers and with peers. • Students with a history of difficulties in school may be sophisticated in their understanding of school procedures, and resistant to efforts to help. • Senior 2 students have a clearer sense of identity than they have had in previous years, and are capable of being more reflective and self-aware. 	<ul style="list-style-type: none"> • Provide choice. Allow students to select many of the texts they will explore and the forms they will use to demonstrate their learning. Teach students to be independent learners. Gradually release responsibility to students. • Use students’ tendency to question authority to help them develop critical thinking. Negotiate policies, and demonstrate a willingness to make compromises. Use student curiosity to fuel classroom inquiry. • Concentrate on getting to know each student early in the year. Provide optional and gradual opportunities for self-disclosure. Engage common interests in science-related hobbies through mutual interests. • Learn to understand each student’s unique combination of abilities and learning approaches. Select topics, themes, and learning opportunities that offer students both a challenge and an opportunity to succeed. Make expectations very clear. • Allow students to explore themselves through their work, and celebrate student differences.

Fostering a Will to Learn—Linking Language and Scientific Literacy

All literate individuals have moments of deep concentration when they lose themselves in the world of a text, or moments of satisfaction and pleasure in using language to express themselves forcefully and with precision. Experiences like these nurture a commitment to literacy. Ideally, the learner pursues every learning experience for its own sake, and will value improved scientific literacy.

Experiences of intense involvement are optimal opportunities for teaching engagement in learning, and teachers should endeavour to ensure they happen frequently in the classroom. Not every necessary learning task, however, can be intrinsically rewarding to every learner. Being a successful learner also requires a high degree of what Corno and Randi (1997) call “sustained voluntary effort”—an attitude that is expressed in committing oneself to less interesting tasks, persisting in solving problems, paying conscientious attention to detail, managing time, self-monitoring, and making choices between competing values, such as the desire to do well on a homework assignment and the desire to spend the evening with friends. The willingness to make this sustained effort constitutes motivation.

Motivation is a concern of teachers, not only because it is essential to classroom learning, but also because volition and self-direction are central to lifelong learning. Science courses seek both to teach students how to read, write, and use science-related language in novel ways, and to foster the desire to do so. Motivation is not a single factor that students either bring or do not bring to the classroom. It is multi-dimensional, individual, and often comprises both intrinsic and extrinsic elements. Students hold certain presuppositions about science learning that affect the way they learn. Teachers can promote certain attitudes and skills to facilitate students’ engagement in each learning task, while recognizing and affirming entry-level abilities.

In considering how they can foster motivation, teachers may explore students’ appreciation of the value (intrinsic and extrinsic) of learning experiences and their belief about their likelihood of success. Good and Brophy (1987) suggest that these two elements can be expressed as an equation; the effort students are willing to expend on a task is a product of their expectation of success and of the value they ascribe to success.

Expectancy	x	Value	=	Motivation
(the degree to which students expect to be able to perform the task successfully if they apply themselves)		(the degree to which students value the rewards of performing the task successfully)		

Teachers may, therefore, want to focus on ensuring students can succeed if they apply reasonable effort, and on helping students recognize the value of classroom learning experiences. The following chart provides teachers with suggestions for fostering motivation.

Fostering Motivation*

Ways to Foster Expectations of Success

- Help students to develop a sense of self-efficacy.

- Help students to learn about and monitor their own learning processes.

- Assign tasks of appropriate difficulty, communicating assessment criteria clearly, and ensuring that students have clear instruction, modeling, and practice so they can complete the tasks successfully.

- Help students to set specific and realistic personal goals and to learn from situations where they do not attain their goals, and celebrate student achievements.

Best Practice and Research

- Schunk and Zimmerman (1997) found that students who have a sense of self-efficacy are more willing to participate, work harder, persist longer when they encounter difficulties, and achieve at a higher level than students who doubt their learning capabilities. Teachers foster a sense of self-efficacy first by teaching students that they can learn how to learn. Students who experience difficulty often view the learning process as mysterious and outside their control. They believe that others who succeed in school do so entirely because of natural, superior abilities. It is highly motivating for these students to discover that they, too, can learn and apply the strategies that successful students use when learning. Second, teachers foster student self-efficacy by recognizing that each student can succeed, and communicating that belief to the student. Silver and Marshall (1990) found that a student's perception that he or she is a poor learner is a strong predictor of poor performance, overriding natural ability and previous learning. All students benefit from knowing that the teacher believes they can succeed and will provide the necessary supports to ensure that learning takes place.

- Research shows that students with high metacognition (students who understand how they learn) learn more efficiently, are more adept at transferring what they know to other situations, and are more autonomous than students who have little awareness of how they learn. Teachers enhance metacognition by embedding—into all aspects of the curriculum—instruction in the importance of planning, monitoring, and self-assessing. Turner (1997) found that teachers foster a will to learn when they support “the cognitive curriculum with a metacognitive and motivational one” (199).

- A methodology for thorough instruction of learning strategies is found on pages 37 and 38 of this overview.

- Research shows that learning is enhanced when students set goals that incorporate specific criteria and performance standards (Foster, 1996; Locke and Latham, 1990). Teachers promote this by working in collaboration with students in developing assessment rubrics (see Appendix 5: Developing Assessment Rubrics in Science).

* Reproduced from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) 8–9.

Fostering Motivation (*Continued*)

Ways to Foster Expectations of Success	Best Practice and Research
<ul style="list-style-type: none"> • Offer choices. 	<ul style="list-style-type: none"> • Intrinsic motivation is closely tied to students' self-selection of texts, topics, activities, and creative forms. Teachers need to support students in the search for learning resources that are developmentally appropriate and of high interest, and encourage students to bring the world views they value into the classroom. Self-selection allows students to build their learning on the foundation of their personal interests and enthusiasm.
<ul style="list-style-type: none"> • Set worthwhile academic objectives. 	<ul style="list-style-type: none"> • Rather than asking students to execute isolated skills or perform exercises that are without context, teachers need to embed instruction in meaningful events and activities that simulate real-world settings, and ensure that students share performances and products with a peer audience.
<ul style="list-style-type: none"> • Help students to learn about and monitor their own learning processes. 	<ul style="list-style-type: none"> • In teaching specific learning strategies, teachers need to focus on the usefulness of each strategy for making meaning of information or for expressing ideas of importance to students. Teachers need to emphasize the importance of scientific literacy to the richness and effectiveness of students' lives, and de-emphasize external rewards and consequences such as marks.
<ul style="list-style-type: none"> • Ensure that scientific literacy experiences are interactive. 	<ul style="list-style-type: none"> • A community that encourages students to share their learning with each other values literacy. Teachers who model curiosity, enthusiasm, and pleasure in books, films, and other texts related to science and who share their own reading, writing, and experiences, foster motivation for scientific literacy learning.

Creating a Stimulating Learning Environment

A vital science class grows out of, and is reflected in, a stimulating and inviting physical environment. While the resources and physical realities of classrooms vary, a well-equipped science classroom offers or contains a variety of resources that help stimulate learning.

Ways to create a stimulating learning environment include the following:

- Designing seating arrangements that reflect a student-centred philosophy and that lend themselves to flexible grouping. Moveable tables or desks allow students to interact in various configurations. Desks arranged in a circle for whole-class discussions convey the importance of each speaker.
- Maintaining a media-rich environment. Having a school library does not preclude the need for a classroom library of books for self-selected reading. The classroom library may include science periodicals, newsletters, teen magazines, science-fiction literature, and students' published work. It may also include a binder of student reviews and recommendations, and may be decorated by student-designed posters or book jackets. Classroom reference materials could include dictionaries/encyclopedias of science, books of facts, software and CD-ROM titles, past exams collated into binders, and manuals. The reference area of the classroom may be designated as an editing station.

- Providing access to a computer, television, video cassette recorder, and CD/DVD-ROM, if possible.
- Exhibiting posters, Hall of Fame displays, murals, banners, and collages that celebrate student accomplishments. Change these frequently to reflect student interests and active involvement in the science classroom.
- Displaying items and artifacts, such as plants, photographs, art reproductions, maps, newspaper and magazine clippings, fossils, and musical instruments, to stimulate inquiry and to express the link between the science classroom and the larger world.
- Posting checklists, processes, and strategies to facilitate and encourage students' independent learning.
- Providing a bulletin board for administrative announcements and schedules.
- Involving students in classroom design.
- Providing interaction with animals (e.g., emphasizing zoological displays, providing aquariums).

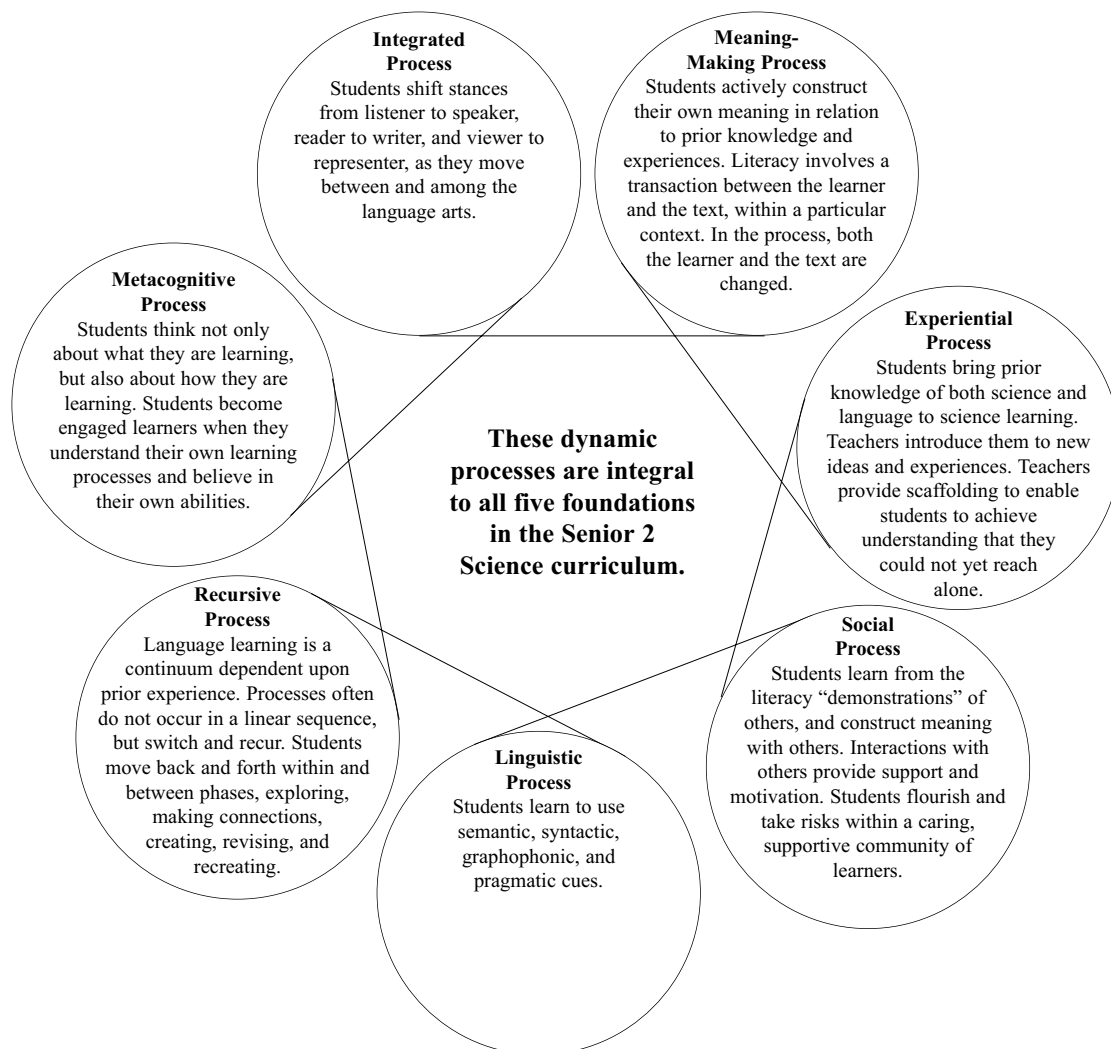
Language Learning Connected to Science

Science curricula involve all aspects of language and literacy development. Halliday (Strickland and Strickland 203) suggests that as students actively use the language arts, they engage in three kinds of language learning, which can be linked to broader scientific literacy.

- **Students learn language:** Language learning is a social process that begins at infancy and continues throughout life. Language-rich environments enhance and accelerate the process. Terminology-rich science has a role in new language development.
- **Students learn through language:** As students listen, read, or view, they focus primarily on making meaning from the text at hand. Students use language to increase their knowledge of the world.
- **Students learn about language:** Knowledge of language and how it works is a subject in and of itself; nevertheless, science as a discipline of inquiry relies on a particular use of language for effective communication. Consequently, students also focus on language arts and the role it has when applied to science.

Scientific literacy learning is dynamic and involves many processes. The following chart identifies some of the dynamic processes that form the foundation for effective literacy learning in science classrooms.

Dynamic Processes in Literacy Learning Integrated into Science



Diversity in the Classroom

Students come from a variety of backgrounds and have distinct learning requirements, learning and thinking approaches, and prior knowledge and experiences. Their depth of prior knowledge varies, reflecting their experiences inside and outside the classroom. Some entry-level knowledge held by students may be limited or incorrect, impeding new learning. For new learning to occur, it is important for teachers to activate prior knowledge, correct misconceptions, and encourage students to relate new information to prior experiences.

Manitoba’s cultural diversity provides opportunities for embracing a wealth of culturally significant references and learning resources in the Senior Years science classroom. Students from various backgrounds bring socially constructed meanings, references, and values to science learning experiences, as well as their unique learning approaches. As noted in *Senior Years Science Teachers’ Handbook* (hereinafter referred to as *SYSTH*), “To be effective, the classroom must reflect, accommodate, and embrace the cultural diversity of its students” (Manitoba Education and Training 7.13).

Toward this end, *Senior 2 Science: A Foundation for Implementation* acknowledges and supports cultural diversity. Included in this document are a range of instructional strategies and conceptual links to appropriate communities and their resources (e.g., Aboriginal communities, agricultural communities). Teachers are encouraged to relate the natural habitats of surrounding communities to particular science learning outcomes. The careful selection of learning resources that acknowledge cultural, racial, and gender differences will allow students to affirm and strengthen their unique social, cultural, and individual identities. To provide a meaningful learning environment for all requires that teachers be sensitive to the diverse backgrounds represented in the Senior Years classroom.

Instructional Philosophy

The learning environment should employ a variety of instructional strategies that include the collection and analysis of data from both laboratory and outdoor observations (especially in the case of the biodiversity and weather components), fieldwork, the use of living organisms in a caring manner, group and individual instruction, a diversity of questioning techniques, a focus on current major issues, and a resource-based approach to learning. Senior 2 science programming should foster critical thinking skills and promote the integration of knowledge and application of facts to real-life situations.

In general, science should be taught as a way of thinking that has rules for judging the validity of answers applicable to everyday life. Science should be portrayed as intense human activity, full of trial and error, that is influenced by cultural priorities and perspectives. The myth of total objectivity that often permeates scientific dialogue also needs to be exposed. Among the natural sciences, truth is no longer viewed as an objective reality awaiting discovery; rather, it is placed in the context of something always to be sought. In recognition of the tentative nature of current knowledge claims, “scientific truth” is not a goal that can be reached in absolute terms.

Students should be encouraged to make distinctions between what is observable and testable, as well as the abstract deductions, models, and themes that flow from evolving scientific research and thinking.

Conceptual knowledge in science must also be integrated with principles from other disciplines. Social, historical, and political implications must be included, with an opportunity for students to develop a facility to communicate ideas effectively through verbal and written expression. Finally, students should be provided with an opportunity to develop an awareness of the options available to them for careers and vocations in the wide diversity of sciences.

Ethical Issues

For many students and teachers, the study of scientific concepts may lead to issues and questions that go beyond the traditional curriculum. For example, the application of population biology research to the reintroduction of species into former habitats, or the implementation of international protocols related to global climate change, raise questions of ethics, values, and responsible use of industrial products. These are among the important issues about which science is often called upon for advice. The environmental consequences of the industrial applications of chemistry or climate change raise issues of considerable merit. Due to the fact that these issues are derived from the study of science, they should be addressed, but it must be made clear to students that science only provides the background for (what is hoped will be) informed personal and social decisions. Teachers must handle these questions with sensitivity and clarity of purpose.

Concerns may be expressed by some students and parents because the evolutionary perspective of modern life science conflicts with personal beliefs. These individuals have a right to expect that science and the educational system will respect those beliefs. Teachers should explain to students that science is only one way of learning about the universe and our unique place embedded in it, and that other explanations, in addition to those of the traditional western sciences, have been put forth.

In some cases, individual teachers may choose to discuss alternative viewpoints on these matters with their science classes. However, because these viewpoints are not derived from the disciplines of science, they are not addressed directly in the science curriculum.

The Responsible Use of Animals in the Science Classroom

The curriculum encourages science teachers to foster a respect for life and to teach about the interrelationship and interdependency of all living things. Furthermore, a stewardship approach emphasizes that humans must care for the fragile web of life that exists on this planet.

The use of live animals and the dissection of animals is a well-established practice in the teaching of life sciences in particular. Well-constructed learning activities conducted by thoughtful teachers can illustrate important and enduring principles in the life sciences. However, teachers must carefully consider the educational objectives and available alternatives before using animals in the classroom.

Interactive multimedia materials such as computer simulations, tutorials, videodiscs, and videotapes can substitute for the use of animals in the classroom. However, these alternatives must satisfy the objectives of teaching scientific methodology and fundamental biological concepts. If, in the judgment of the teacher, available alternatives do not meet these objectives, dissection may be used, provided that no student is forced to participate. In the event that a student chooses not to participate in a dissection, the student is to be given assignments of comparable complexity and rigour.

Implementing alternative methods does not mean excluding animals from the classroom. Certain instructional strategies allow for the continued use of animals but with a modified approach (e.g., observation in behaviour studies and experimentation with invertebrates). In these cases, prudent and responsible use of these animals is essential.

Learning Resources

Traditionally, the teaching of science in Senior Years has largely been a textbook-centred exercise. The use of a single textbook as the sole resource for the teaching and learning of science severely restricts the development of knowledge, skills, and attitudes that are critical for today's students. Furthermore, it promotes the idea that all answers are enshrined in a textbook. The successful implementation of Senior 2 Science (20F) depends on a resource-based learning approach, in which textbooks are used only as one of many reference sources. Research suggests that we should provide a wide range of learning resources for structuring teaching and learning experiences. These include human resources, textbooks, magazines/periodicals, films, audio and video recordings, computer-based multimedia resources, the Internet, and other materials. While a teacher may choose to use a particular text as a primary resource, we encourage teachers to model the use of various resources for their students.

Resources referenced in this curriculum include two recommended textbooks, student learning activities outlined in a set of appendices, multimedia learning resources, and other print reference material such as *Senior Years Science Teachers' Handbook: A Teaching Resource* (Manitoba Education and Training, 1997) and *Science Safety: A Kindergarten to Senior 4 Resource Manual for Teachers, Schools, and School Divisions* (Manitoba Education and Training, 1997). Recommended learning resources for Senior 2 science are listed in Senior 2 Science Learning Resources: *Annotated Bibliography*, available online at <<http://www.edu.gov.mb.ca/ks4/learnres/science/s2scbib.pdf>>.

The choice of textbook(s) and multimedia learning resources, including video, software, CD-ROMs, microcomputer-based laboratory (MBL) probeware, calculator-based laboratory (CBL) probeware, and the Internet, will depend on the local situation, reading level of the students, background of the teacher, community resources, and availability of other materials. A concerted effort should be made to use appropriate learning resources from a wide variety of sources. Not all curricular outcomes can be achieved by using any one text as some topics require using other references or supports.

Using This Curriculum Document

This curriculum, consisting of four thematic clusters and one skills and attitudes cluster, is designed to build on what students know and are able to do as a result of their studies in Kindergarten to Senior 1 science.

Teachers are asked to be sensitive to the varying backgrounds of their students and to adapt instruction as necessary. Clusters do not need to be taught in the same sequence as they appear in the document. For example, it may be advantageous to document biodiversity in the spring or fall. Teachers should use their own discretion to provide opportunities for students to achieve learning outcomes in contexts that differ from those presented in this curriculum document. In all cases, however, the foundations, themes, and interdisciplinary nature of science should be emphasized.

Senior 2 Science (20F) provides a solid foundation for further study of Senior Years science courses and has a multidisciplinary focus. Accordingly, the curriculum includes topics that are deemed to be relevant to students' needs and interests, or are prerequisites to the further study of science at the Senior Years level.

Senior 2 Science (20F) assumes 110 hours of instructional time (see Scope, Sequence, and Time Allotments that appear with each Specific Learning Outcome or cluster of outcomes). Some time may need to be allocated to reviewing material from the appropriate sections of the Grades 5–Senior 1 curricula, but formal review of previous years’ work is to be avoided. Teachers need to use a variety of strategies for activating prior knowledge to determine appropriate learning strategies for their students.

Preparing a Lesson

The format of *Senior 2 Science: A Foundation for Implementation* allows teachers to view the four major columns, namely **Prescribed Learning Outcomes, Suggestions for Instruction, Suggestions for Assessment, and Suggested Learning Resources**. The learning outcomes in the first column should guide teachers to make relevant decisions about instruction, assessment/evaluation, and appropriate learning resources. The document also contains Cluster 0 outcomes (Overall Skills and Attitudes) in **Prescribed Learning Outcomes**. These are based on the suggestions made for instruction. **Suggestions for Instruction** provides possible avenues or actions for student learning. Teachers should use their own professional judgment when deciding which strategies to use. It is NOT intended that teachers use all the suggested strategies. **Suggestions for Assessment** outlines a number of possible strategies beyond simple pencil-and-paper testing. Resources to support the prescribed outcomes are detailed in the final column, **Suggested Learning Resources**. It is hoped that this format will provide a useful “map” for teachers (i.e., a clear indication of what students are to know and be able to do, as well as a resource for strategies and materials to help students achieve these learning outcomes).

Science curricula in the past have been primarily focused on presenting a breadth of knowledge (i.e., a large amount of content) deemed essential. While this curriculum continues to be concerned with students acquiring relevant knowledge, it is also equally concerned both with fostering the development of various skills (context-based process skills, decision-making skills, problem-solving skills, laboratory experimental skills, critical-thinking skills, independent learning skills), and with effecting a change of attitude. In broad terms, these learning outcomes describe what we expect students to know and be able to do as a result of their studies.

In many instances, the **Suggestions for Instruction** columns begin by describing the probable **Entry-Level Knowledge** of students based on studies cited in previously published Manitoba curricula. Teachers are encouraged to determine entry levels of their students and select or develop approaches and materials to enable each student to achieve success. Many educators believe that time spent at this task has the greatest effect on student learning.

Senior 2 Science (20F) is driven by learning outcomes and process rather than by a single textbook. This design empowers teachers to plan appropriate learning experiences based on the nature of their students, school, and community. We encourage teachers to seek their own comfort level with the curriculum, to share approaches and experiences with colleagues, and to use it to develop and extend student experiences and understandings in new ways.

Promoting Strategic Learning

Many of the language tasks science students perform are problem-solving tasks, such as finding sources of information for an inquiry project, making meaning of a difficult text, or organizing a body of information. To solve problems, students require a strategic mindset; when confronted with a problem, students survey a number of possible strategies, select the one that seems likely to work best for the situation, and try an alternative method if the first one does not produce results.

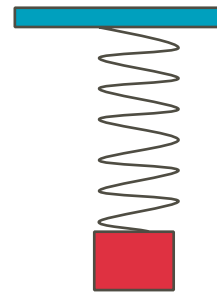
Strategic learners in the sciences need to have not only a strategic mindset, but also a repertoire of strategies for making meaning, for processing information, and for expressing ideas and information effectively. Whereas *skills* are largely unconscious mental processes that learners use in accomplishing learning tasks, *strategies* are systematic and conscious plans, actions, and thoughts that learners select or invent and adapt to each task. Strategies are often described as “knowing what to do, how to do it, when to do it, and why it is useful.”

Immersing students in language-rich environments and encouraging them to produce texts are essential in language learning, but these initiatives alone are not sufficient to ensure the development of proficient scientific literacy skills in all students. Students need methodical instruction in the strategies that adept learners use in approaching science tasks. The four-column section of this document includes numerous learning, teaching, and assessment strategies, and identifies professional resources that present additional strategies and approaches.

The Modes of Representation

Visual Mode

To illustrate these modes of representation, consider an example. A 0.5-kg mass is suspended from a spring (Figure 1). If we suspend a 1.0-kg mass and a 1.5-kg mass from identical springs, we perceive the relationship between the force that acts on the spring and the stretch of the spring. This is what we would call the visual mode of representing a relationship. Its basis is in the “real” world and our perceptions of this world.



In the visual mode we formulate a relationship between two variables and then test our hypothesis by observation and experimentation. As the force increases, the stretch increases. Sometimes, we can even determine the exact relationship. In this case, since the masses in Figure 1 line up in a straight line, the applied force and stretch must increase in some predictable proportion. Figure 2 shows how the visual mode can be applied to tracking a hurricane over time.

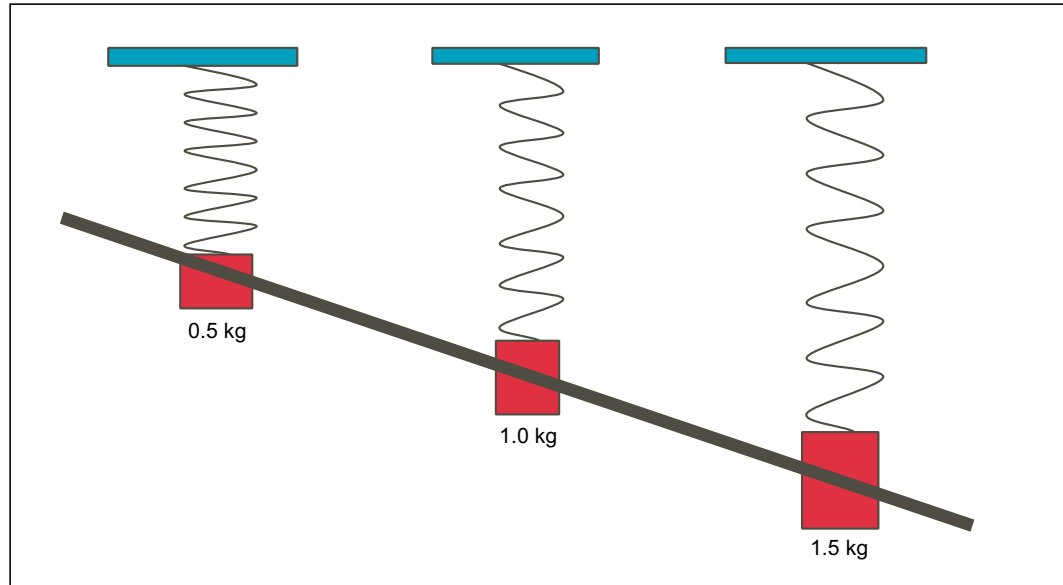
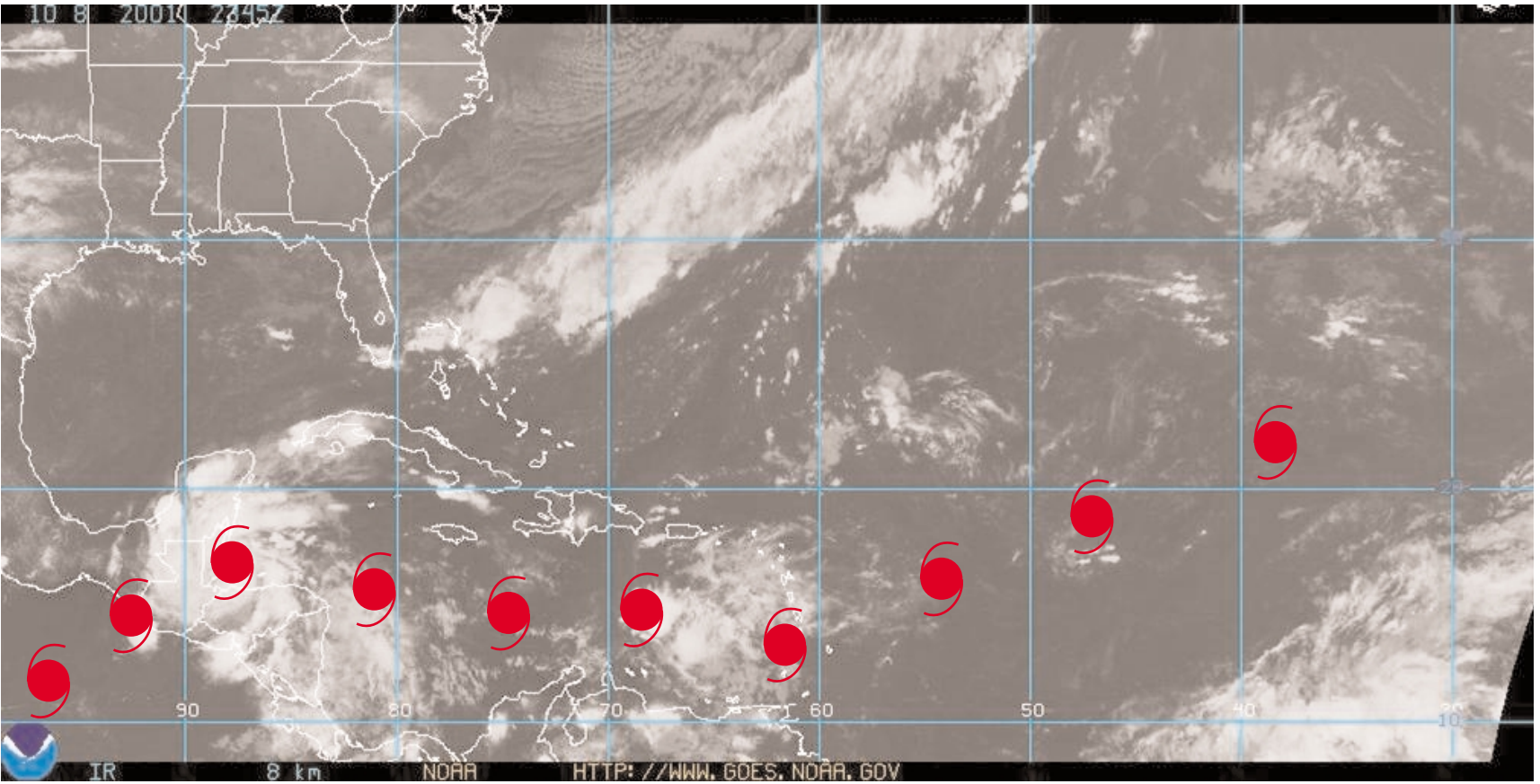


Figure 1

The visual mode embodies more than conjecture and observation. It incorporates critical and creative thinking as we build and modify models of nature that act as a foundation for our investigations. The “real” world is conceptualized by a set of guiding assumptions we imagine to be true. We may internalize a model to aid this conceptualization, and then we test this model using experiments. A successful model has explanatory and predictive capabilities. A model may incur discrepant events, which may force us to reconsider and modify our model. Our model may be falsified, in which case we abandon the model in search of a more complete and accurate model. For instance, the model of electric charge provides a foundation for the examination of electric phenomena. Historically, the fluid and particle models of charge accounted for experimental observations. However, as our ideas about the structure of matter evolved, the particle model provided a more reliable, predictive, and robust explanatory model.

Although we can make some general descriptions of relationships (as force increases, stretch increases), we cannot always determine an exact relationship, using the visual mode of representation. Therefore, we quantify the characteristics and compare the numbers. This is called the numerical mode of representation.



Satellite image courtesy of NOAA. All rights reserved.

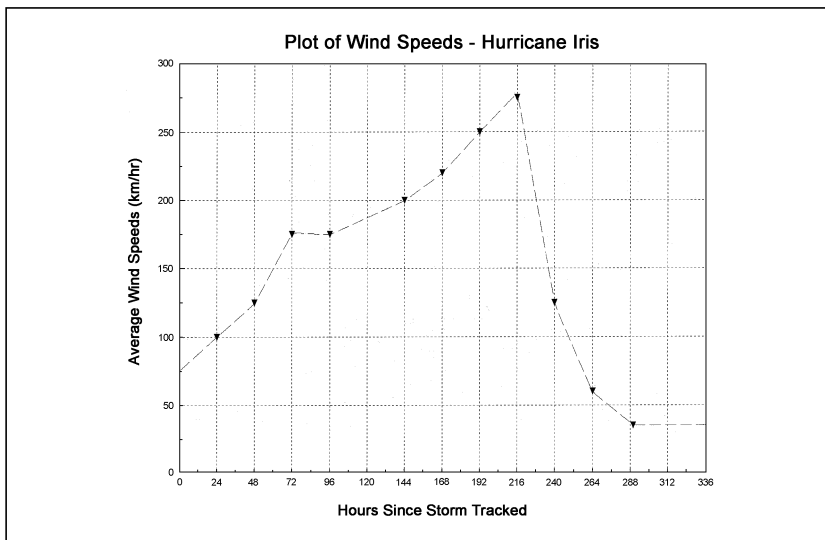
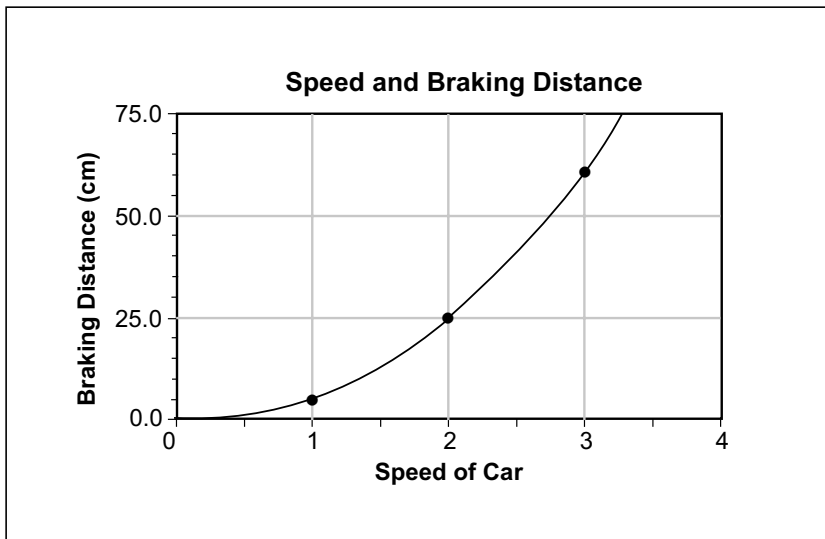
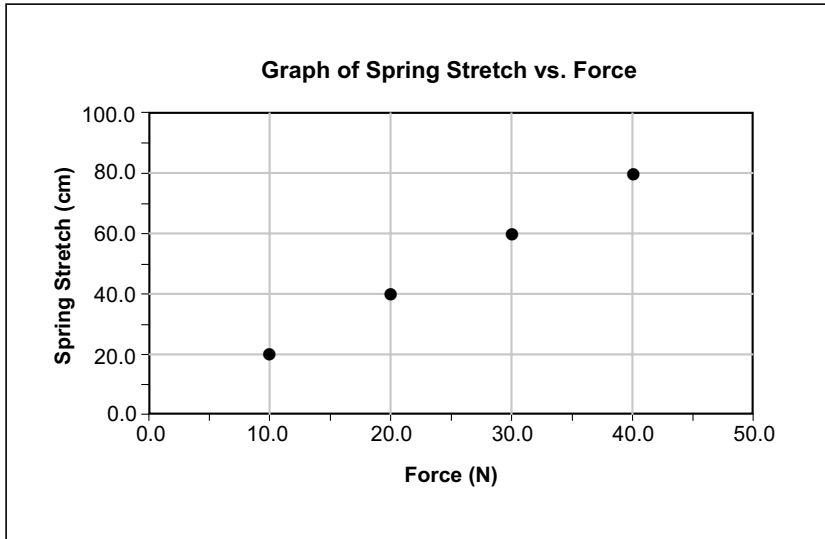
Numerical Mode

In the numerical mode of representation, we operationally define fundamental properties and use measurement to collect data. We can then examine the data to determine an exact relationship. The numerical mode dictates an understanding of proportioning and numerical patterns (e.g., if F doubles, X doubles, and if F triples, X triples). This suggests a direct proportion, and we can formulate our law. However, in most cases, the collection of data results in systematic errors. Determining the relation by inspection of the data can be very difficult. A picture, however, is worth a thousand numbers. Graphing the data usually gives a clearer picture of the relationship. It could be looked upon, for students, as a preparation for examining closely a “picture of the numbers.”

F (N)	X (m)
5.0	0.2
10.0	0.4
15.0	0.6
20.0	0.8

Graphical Mode

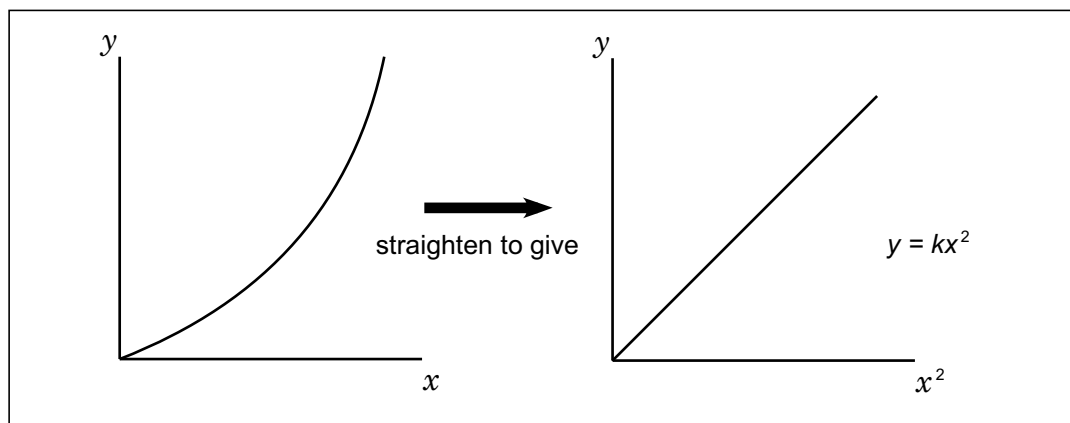
The graphical mode of representation is a mathematical picture of the relationship. Fortunately, there are a limited number of pictures one needs to know to determine relationships. In fact, at the introductory Senior 2 Science level, it is only necessary to know three pictures: a straight line, a power curve, and an inverse curve. At Senior 2, only linear relationships are treated quantitatively. Other relationships are examined qualitatively and do not require analytical techniques. By adjusting the data to “straighten the curve,” we can determine the exact relationship and formulate a law that can be represented in a symbolic manner. At Senior 2, this level of treatment is considered optional. Ability to express the nature of a relationship in a “storytelling,” qualitative manner is considered optimal for most students. Samples of graphical representations appear on the next page.



Symbolic Mode

The fourth mode of representation is the **symbolic mode**. We represent the relationship as an algebraic formula, which can be applied to other physical events that are similar in nature.

For instance,



Therefore, we can represent relationships in four different modes: visual, numerical, graphical, and symbolic. In this model, students are able to function in each mode to demonstrate complete understanding and mastery of a concept.

The Importance of the Modes of Representation

It is easy to become caught up in a single mode, especially the symbolic, when it comes to the teaching and learning of physical concepts (e.g., motion). Students memorize equations and notation, learn to substitute for variables, and arrive at numeric solutions.

Meaningful connections between the symbolic and physical/conceptual modes are difficult to make in a decontextualized setting. Students taught exclusively in the symbolic mode often know how to arrive at “cookbook” answers, but they rarely understand or retain any of the concepts.

Students need to develop their understanding of relationships more completely, and develop skills in each mode of representation. Students should be able to transfer between modes both fluidly and with facility. Moving through the modes is not necessarily done in order. A “real scientist” can begin investigations in any mode and transfer easily through any combination of modes. Students who demonstrate a complete understanding of physical/conceptual relationships should be able to move from mode to mode in any order.

While fluency with the modes of representation provides a solid foundation for physics education, it is, of itself, not complete when it comes to portraying the nature of scientific activity. Albert Einstein, while developing his theory of relativity, conceptualized an hypothesis and then deduced a series of laws symbolically from a set of fundamental assumptions about time and space. He left it to others to observe, then refute or confirm his propositions. Historical perspectives, and an understanding of the nature of science, will move students toward a more philosophically valid treatment of physics.

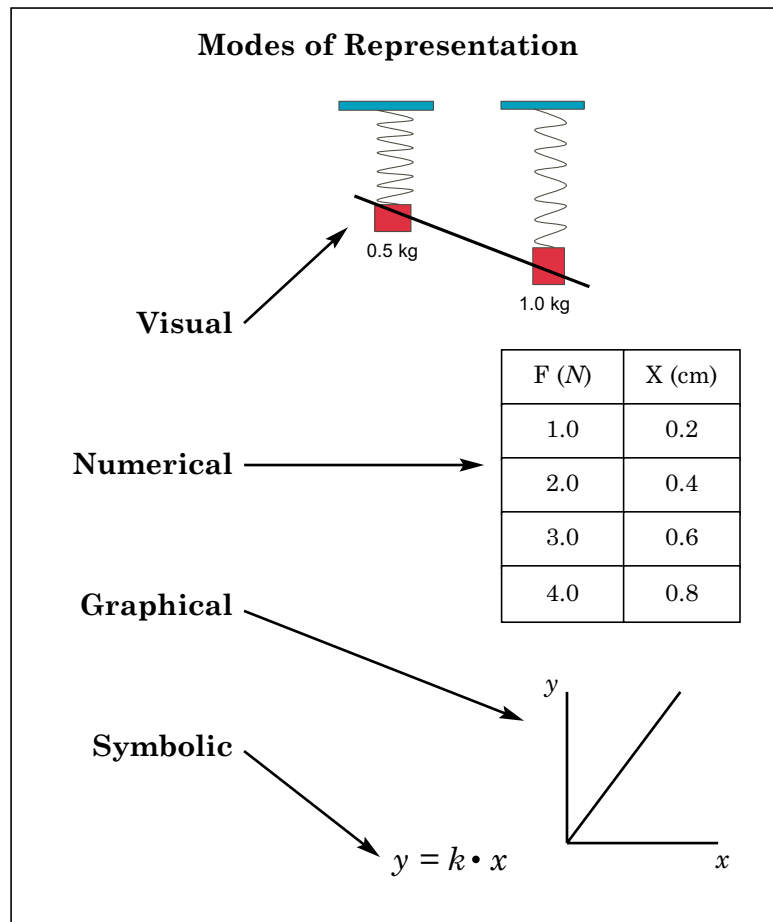
To Sum Up the Modes of Representation for Senior 2 Science Teachers

Visual: encourage students to discuss the representations they see and experience

Numeric: use student-generated measurements, always in the context of activities

Graphical: carefully plot graphs; get the “picture of the numbers,” not “this is a picture of the world”

Symbolic: emphasize the concept first, then initially apply formulas as word definitions; only then work “type” problems using formulas; ideally, formulas are memorized only in certain instances



Scaffolding: Supporting Students in Strategic Learning

Many scientific literacy tasks involve a complex interaction of skills. The most effective way to learn, however, is not by breaking down the tasks into manageable parts and teaching the skills separately and in isolation. In fact, this approach may be counter-productive. Purcell-Gates (1996) uses the analogy of learning to ride a bicycle, a skill that requires children to develop an intuitive sense of balance while also learning to pedal and steer. Children do not learn to ride a bicycle by focusing on only one of these skills at a time. Instead, they observe others who can ride a bicycle successfully, and then make an attempt themselves. In the early stages of learning to ride, a child counts on someone to provide support—to hold the bicycle upright while the child mounts, to keep a hand on the seat to stabilize the bicycle for the first few metres, and to coach and encourage. Gradually, these supports are withdrawn as the rider becomes more competent. Eventually, the process becomes automatic, and the rider is no longer aware of the skills being performed.

Providing this sort of support in teaching is called “scaffolding,” based on the work of Wood, Bruner, and Ross (1976). Teachers scaffold by

- structuring tasks so that learners begin with something they can do
- reducing the complexity of tasks
- calling students’ attention to critical features of the tasks
- modeling steps
- providing sufficient guided and independent practice

In a sense, each learning strategy is an external support or scaffold. At first, working with a new strategy may be challenging and the main focus of students’ attention. Eventually, students use the strategy automatically and rely on it as a learning tool. Students gradually internalize the process of the strategy. They begin to adjust and personalize the process and to apply the thinking behind the strategy automatically.

In strategic instruction, teachers observe and monitor students’ use of a strategy for a time, intervening where necessary. Students vary in the length of time they require scaffolding. In this respect, strategic instruction is also a useful tool for differentiation*. Struggling learners may work with simplified versions of a strategy, and they may continue to use the supports of a strategy (e.g., a graphic organizer for laboratory reports) after other students have internalized the process.

Strategic instruction works best when teachers pace the instruction of new strategies carefully (so that students have time to practise each one), and when they teach a strategy in the context of a specific task.

* Ideas and strategies for differentiating instruction are provided in *Success for All Learners* (Winnipeg, MB: Manitoba Education and Training, 1996) and in the *Senior Years Science Teachers’ Handbook* (Winnipeg, MB: Manitoba Education and Training, 1997).

Differentiating Instruction*

How can Senior Years science teachers meet each student's learning requirements and still make learning experiences challenging and meaningful for all? One way to help all students achieve the prescribed student learning outcomes is to differentiate the instructional strategies (see *Success for All Learners*, Manitoba Education and Training, 1996). Through differentiating instruction, teachers can

- activate students' prior knowledge
- accommodate multiple intelligences and the variety of learning and thinking approaches
- help students interpret, apply, and integrate information
- facilitate the transfer of knowledge, skills, and attitudes to students' daily lives
- challenge students to realize academic and personal progress and achievement

Differentiating instruction does not mean offering a different program to each student. Classroom experiences can be differentiated by offering students choices and by varying instructional and assessment strategies to provide challenging and effective learning experiences for all.

Learning Phases

Differentiated instructional strategies can be used in relation to the three learning phases:

- activating (preparing for learning)
- acquiring (integrating and processing learning)
- applying (consolidating learning)

These phases of learning are not entirely linear, nor are they discrete; rather, they provide teachers with a useful way of thinking and planning.

- The activating phase helps identify students' prior knowledge.
- The acquiring phase helps students to integrate new information with what they already know, adding or revising their previous knowledge as needed. Teachers help students make meaning of new information.
- The applying phase allows students to reflect on what they have learned, apply their learning to new situations, and extend their learning by drawing connections to other subject areas.

For a discussion of these three learning phases, see Chapter 6 of *Success for All Learners*.

Senior 2 Science: A Foundation for Implementation includes cross-references to *Success for All Learners* and *Senior Years Science Teachers' Handbook (SYSTH)*. Teachers can refer to these documents for further information. Strategies that can be used effectively in the Senior Years science classroom include graphic organizers (such as mind maps), knowledge charts that use students' prior knowledge, collaborative activities in brainstorming for solutions to design problems, information-processing strategies, science learning logs, and many others. The following list outlines instructional strategies that can be used with this *Senior 2 Science: A Foundation for Implementation*.

* Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998).

Instruction**• Entry-Level Knowledge**

— Entry-level knowledge summarizes prior content knowledge that students may have obtained in earlier grades, other courses, or through personal experiences. Activating this knowledge can be a powerful tool, as students organize and make meaning of new ideas, experiences, and information in connection with their prior knowledge.

• Notes for Instruction

— Notes for instruction outlines the depth and breadth to which learning outcomes are to be addressed. Definitions, safety concerns, and teaching/learning suggestions may also be included.

• Student Learning Activities

— A number of instructional strategies involving student engagement with learning materials are available for each learning outcome. Deciding which learning activities to use is an important part of a teacher's initial planning process. To successfully address each learning outcome of the curriculum, teachers need to make deliberate, informed decisions about the best tools to use for each learning task, given the particular needs and characteristics of their students.

• Journal Writing

— Science journal writing allows students to explore and record all aspects of their science class experiences. By sorting out their thoughts on paper or thinking about their learning (metacognition), students process more deeply what they are learning.

• Class Discussion

— Discussions can be used in a variety of ways. They can spark interest in a topic or learning outcome, activate prior knowledge by inviting speculation on why certain events occur, or generate ideas for solutions to problems.

• Prior Knowledge Activities

— Students learn best when they can relate new knowledge to what they already know. Brainstorming, KWL charts, and Listen-Think-Pair-Share are just a few of the strategies that can be used to activate and assess students' prior knowledge.

• Student Research/Reports

— Learning projects that involve student research are one of the most effective ways to individualize instruction in a diverse classroom. These learning activities provide students with the opportunity to develop their research skills as they gather, process, and evaluate information.

• Teacher Demonstration

— Demonstrations can arouse student interest and allow for visualization of phenomena. For instance, demonstrating discrepant events can be a powerful tool. Demonstrations can activate prior knowledge and generate discussion about learning outcomes.

• Visual Displays

— When students create visual displays, they make their thinking visible. Generating diagrams, posters, or models provides students with the opportunity to represent abstract information in a more concrete form.

- **Collaborative Teamwork**
 - Instructional strategies, such as the Jigsaw or Roundtable, encourage students to learn from one another and develop teamwork skills. The use of cooperative learning activities can lead to increased understanding of content and improved thinking skills.
- **Laboratory Activities**
 - Laboratory activities, whether student- or teacher-designed, provide students with the opportunity to apply their scientific knowledge and skills related to a group of learning outcomes. Students appreciate the hands-on experience of doing science.
- **Debates**
 - Debates draw upon students' own positions on STSE issues. When carefully structured, debates can encourage students' consideration of societal concerns and the opinions of others, and improve their communication and research skills.
- **Community/Career Connection**
 - Field trips and guest speakers can provide students with the opportunity to see science applied in their community and local natural environments.

CLASSROOM ASSESSMENT IN SCIENCE

Classroom assessment is an integral part of science instruction. Assessment is the “systematic process of gathering information about what a student knows, is able to do, and is learning to do” (Manitoba Education and Training, *Reporting on Student Progress and Achievement*, 1997). The primary purpose of classroom assessment is not to evaluate and classify student performance, but to inform teaching and improve learning, and to monitor student progress in achieving learning outcomes at the end of a grade or course of study.

Classroom assessment is broadly defined as any activity or experience that provides information about student learning. Teachers learn about student progress not only through formal tests, examinations, and projects, but also through moment-by-moment observation of students in action. They often conduct assessment through instructional activities.

Much of students’ learning is internal. To assess students’ science knowledge, skills and strategies, and attitudes, teachers require a variety of tools and approaches. They ask questions, observe students engaged in a variety of learning activities and processes, and examine student work in progress. They also engage students in peer-assessment and self-assessment activities. The information that teachers and students gain from assessment activities informs and shapes what happens in the classroom; assessment always implies that some action will follow.

Planning for Assessment

Since assessment is an integral part of instruction, teachers should plan it at the beginning of a unit of study. They select assessment purposes, approaches, and tools in conjunction with their choice of instructional strategies.

In developing assessment tasks and methods, teachers determine

- what they are assessing
- why they are assessing
- how the assessment information will be used
- who will receive the assessment information
- what assessment activities or tasks will allow students to demonstrate their learning in authentic ways

Characteristics of Effective Assessment*

Effective assessment assists learning. It helps focus effort on implementing strategies to facilitate learning both inside and outside the classroom. In Senior Years science, as in other subject areas, effective assessment is

- congruent with instruction, and integral to it
- based on authentic tasks and meaningful science-learning processes and contexts
- multi-dimensional, and uses a wide range of tools and methods
- based on criteria that students know and understand, appealing to their strengths
- a collaborative process involving students
- focused on what students have learned and can do
- ongoing and continuous

These seven characteristics of effective assessment are discussed in the following section.

Effective Assessment Is Congruent with Instruction and Integral to It

Assessment requires teachers to always be aware of the questions: “What do I want my students to learn?” and “What can they do to show they have learned it?”

How teachers assess depends on what they are assessing—whether they are assessing declarative knowledge, procedural knowledge, or attitudes and habits of mind.

- **Declarative knowledge:** Declarative knowledge is the most straightforward dimension of learning to measure using traditional tools—if teachers wish to measure fact-based recall. The purpose of fostering scientific literacy, however, is not met if students simply memorize the declarative knowledge related to science; what is more important is whether students understand and are able to apply this knowledge. For example, it is more important that they understand the purposes and effects of biodiversity, that they respond to and interpret what biodiversity means for them personally and environmentally, and that they use terminology with ease to enrich their own writing, and represent—rather than reproduce—a definition of biodiversity. The challenge teachers face is to design tools that test the application of declarative knowledge.
- **Procedural knowledge:** Tools that are designed to test declarative knowledge cannot effectively assess skills, strategies, and processes. For example, rather than trying to infer student processes by looking at final products, teachers assess procedural knowledge by observing students in action, by discussing their strategies with them in conferences and interviews, and by gathering data from student reflections such as journals.
- **Attitudes and habits of mind:** Attitudes and habits of mind cannot be assessed directly. They are implicit in what students do and say. Assessment tools typically describe the behaviours that reflect the attitudes and habits of literate individuals. They identify the attitudes and habits of mind that enhance science-related language learning and use, and provide students with the means to reflect on their own internal processes. For example, rather than assigning global marks for class participation, teachers assess learning outcomes related to students’ effective contributions to large and small groups.

* Adapted from Manitoba Education and Training, *Senior 1 English Language Arts: Manitoba Curriculum Framework of Outcomes and Senior 1 Standards* (Winnipeg, MB: Manitoba Education and Training, 1996) 53.

Assessment is intended to inform students of the programming emphases and to help them focus on important aspects of learning. If teachers assess only the elements that are easiest to measure, students may focus only on those things. For example, if science courses place a high value on collaboration, creativity, and divergent thinking (learning outcomes that may be more difficult to measure), then assessment tools and processes must reflect those values. The ways teachers assess (what and how) inform students of what is considered important in learning.

Effective Assessment Is Based on Authentic Tasks and Meaningful Science Learning Processes and Contexts

Assessment tasks in science should be authentic and meaningful—tasks worth mastering for their own sake rather than tasks designed simply to demonstrate student proficiency for teachers and others. Through assessment, teachers discover whether students can use knowledge, processes, and resources effectively to achieve worthwhile purposes. Therefore, teachers design tasks that replicate the context in which knowledge will be applied in the world beyond the classroom.

For example, authentic science writing tasks employ the forms used by a wide range of people (e.g., journalists, filmmakers, poets, novelists, publicists, speakers, technical writers, engineers, and academics). As often as possible, students write, speak, or represent their ideas for real audiences and for real purposes. In developing assessment tasks, teachers may consider providing students with the resources people use when performing the same tasks in real-life situations related to issues in science.

Authentic assessment tasks are not only tests of the information students possess, but also of the way their understanding of a subject has deepened, and of their ability to apply learning. They demonstrate to students the relevance and importance of learning. Performance-based tests are also a way of consolidating student learning. The perennial problem teachers have with “teaching to the test” is of less concern if tests are authentic assessments of student knowledge, skills and strategies, and attitudes.

Effective Assessment Is Multi-dimensional and Uses a Wide Range of Tools and Methods

Assessment in science must recognize the complexity and holistic nature of learning for scientific literacy. To compile a complete profile of each student’s progress, teachers gather data using many different means over numerous occasions.

Student profiles may involve both students and teachers in data gathering and assessment. The following chart identifies areas for assessment and some suggested assessment instruments, tools, and methods.

Data-Gathering Profile			
Observation of Processes		Observation of Products and Performances	
Teacher:	Students:	Teacher:	Students:
<ul style="list-style-type: none"> • checklists • conferences and interviews • anecdotal comments and records • reviews of drafts and revisions • oral presentations • rubrics and marking scales 	<ul style="list-style-type: none"> • journals • self-assessment instruments and tools (e.g., checklists, rating scales, progress charts) • peer-assessment instruments and tools (e.g., peer conference records, rating scales) 	<ul style="list-style-type: none"> • written assignments • demonstrations • presentations • seminars • projects • portfolios • student journals and notebooks • checklists • rubrics and marking scales 	<ul style="list-style-type: none"> • journals • self-assessment instruments and tools • peer-assessment instruments and tools • portfolio analysis
Classroom Tests		Divisional and Provincial Standards Tests	
Teacher:	Students:	Teacher marker:	
<ul style="list-style-type: none"> • paper-and-pencil tests (e.g., teacher-made tests, unit tests, essay-style tests) • performance tests and simulations • rubrics and marking scales 	<ul style="list-style-type: none"> • journals • self-assessment instruments and tools 	<ul style="list-style-type: none"> • rubrics and marking scales 	

Effective Assessment Is Based on Criteria That Students Know and Understand, Appealing to Their Strengths

Assessment criteria must be clearly established and made explicit to students before an assignment or test so students can focus their efforts. In addition, whenever possible, students need to be involved in developing assessment criteria. Appendix 5 describes a process for creating assessment rubrics in collaboration with students.

Students should also understand clearly what successful accomplishment of each proposed task looks like. Models of student work from previous years and other exemplars assist students in developing personal learning goals.

Each assessment task should test only those learning outcomes that have been identified to students. This means, for example, that laboratory skills tests need to be devised and marked to gather information about students’ laboratory skills, not their ability to express ideas effectively in writing a laboratory report.

Effective Assessment Is a Collaborative Process Involving Students

The ultimate purpose of assessment is to enable students to assess *themselves*. The gradual increase of student responsibility for assessment is aimed at developing students' autonomy as lifelong learners. Assessment should decrease, rather than foster, students' dependence on teachers' comments for direction in learning and on marks for validation of their accomplishments.

Assessment enhances students' metacognition. It helps them make judgments about their own learning, and provides them with information for goal setting and self-monitoring.

Teachers increase students' responsibility for assessment by

- requiring students to select the products and performances to demonstrate their learning
- involving students in developing assessment criteria whenever possible (see Appendix 5) (This clarifies the goals of a particular assignment and provides students with the vocabulary to discuss their own work.)
- involving students in peer assessment, informally through peer conferences and formally through using checklists
- having students use tools for reflection and self-assessment at every opportunity (e.g., self-assessment checklists, journals, identification and selection of goals, and self-assessment of portfolio items)
- establishing a protocol for students who wish to challenge a teacher-assigned mark (Formal appeals are valuable exercises in persuasive writing, and provide opportunities for students to examine their performance in light of the assessment criteria.)

Effective Assessment Focuses on What Students Have Learned and Can Do

Assessment must be equitable; it must offer opportunities for success to every student. Effective assessment demonstrates the knowledge, skills and attitudes, and strategies of each student and the progress the student is making, rather than simply identifying deficits in learning.

To assess what students have learned and can do, teachers need to use a variety of strategies and approaches, such as the following:

- Use a wide range of instruments to assess the multi-dimensional expressions of each student's learning, avoiding reliance upon rote recall.
- Provide students with opportunities to learn from feedback and to refine their work, recognizing that not every assignment will be successful nor will it become part of a summative evaluation.
- Examine several pieces of student work in assessing any particular learning outcome to ensure that data collected are valid bases for making generalizations about student learning.

- Develop complete student profiles by using information from both learning outcome-referenced assessment, which compares a student's performance to predetermined criteria, and self-referenced assessment, which compares a student's performance to her or his prior performance.
- Avoid using assessment for purposes of discipline or classroom control. Ryan, Connell, and Deci (1985) found that assessment that is perceived as a tool for controlling student behaviour, meting out rewards and punishments rather than providing feedback on student learning, reduces student motivation.

Students are sometimes assigned a mark of zero for incomplete work. Averaging a zero into the student's mark, however, means the mark no longer communicates accurate information about the student's achievement of science learning outcomes. Unfinished assignments signal personal or motivational problems that need to be addressed in appropriate and alternative ways.

- Allow students, when appropriate and possible, to choose how they will demonstrate their competence.
- Use assessment tools appropriate for assessing individual and unique products, processes, and performances.

Effective Assessment Is Ongoing and Continuous

Assessment that is woven into daily instruction offers students frequent opportunities to gain feedback, to modify their learning approaches and methods, and to observe their progress. Teachers provide informal assessment by questioning students and offering comments. They also conduct formal assessments at various stages of a project or unit of study.

Continuous assessment provides ongoing opportunities for teachers to review and revise instruction, content, process emphases, and learning resources.

Managing Classroom Assessment

Assessment is one of the greatest challenges science teachers face. The practices that make science classrooms vital and effective—promoting student choice, assessing processes, and assessing the subjective aspect of learning—make assessment a complex matter.

Systems and supports that may assist teachers in managing assessment include

- dispensing with ineffectual means of assessment
- using time savers
- sharing the load
- taking advantage of technology
- establishing systems of recording assessment information

These suggestions are discussed in the following section.

Dispensing with Ineffectual Means of Assessment

Teachers need to question the efficacy, for example, of writing lengthy commentaries on summative assessment of student projects. Detailed comments are best

- provided as formative assessment, when students can make immediate use of the feedback
- shared orally in conferences, which provide opportunities for student-teacher discussion

The time spent in assessment needs to be learning time, both for teacher and student.

Using Time Savers

Many effective assessment tools are time savers. Developing checklists and rubrics is time-consuming; however, well-written rubrics may eliminate the need to write extensive comments, and may mean that student performances can be assessed largely during class time. Some of the assessment tools in the professional literature related to science assessment may also be useful.

Sharing the Load

While the ultimate responsibility for assessment rests with the teacher, student self-assessment also provides a wealth of information. Collaborating with students to generate assessment criteria is part of effective instruction (see Appendix 5). Senior 2 students may develop checklists and keep copies of their own learning goals in an assessment binder for periodic conferences. Students may be willing to contribute work samples to be used as models with other classes.

Collaborating with other teachers in creating assessment tools saves time and provides opportunities to discuss assessment criteria.

Taking Advantage of Technology

Electronic tools (e.g., audiotapes, videotapes, and computer software) can assist teachers in making and recording observations. Word processors allow teachers to save, modify, and reuse task-specific checklists and rubrics.

Establishing Systems for Recording Assessment Information

Collecting data from student observations is especially challenging for Senior Years teachers, who may teach several classes of students in a given semester or term. Teachers may want to identify a group of students in each class for observation each week. Binders, card files, and electronic databases are useful for record keeping, as are self-stick notes recording brief observations on student files, which can later be transformed into anecdotal reports.

Teachers may also want to develop comprehensive forms for listing the prescribed learning outcomes, and for recording data. Online opportunities for the creation of lesson or unit packages based on the Manitoba learning outcomes for Senior 2 Science can be accessed at <http://www2.edu.gov.mb.ca/ks4/cur/science/>. Access the “Curriculum Documents” link in the navigation column.

This view of effective assessment in science for Manitoba is reflective of changes in emphases in science education at the national level and is congruent with international changes in science education. The following chart summarizes some of the changes in the area of assessment.

Changing Emphases in Assessment of Student Learning*

The *National Science Education Standards* envision change throughout the system. The assessment standards encompass the following changes in emphases:

LESS EMPHASIS ON	MORE EMPHASIS ON
Assessing what is easily measured	Assessing what is most highly valued
Assessing discrete knowledge	Assessing rich, well-structured knowledge
Assessing scientific knowledge	Assessing scientific understanding and reasoning
Assessing to learn what students do not know	Assessing to learn what students do understand
Assessing only achievement	Assessing achievement and opportunity to learn
End of unit or term assessments by teachers	Students engaged in ongoing assessment of their work and that of others
Development of external assessments by measurement experts alone	Teachers involved in the development of external assessments

Formative and Summative Assessment

Assessment can be formative or summative.

- **Formative assessment** is based on data collected before an instructional sequence is completed. Its purpose is to improve instruction and learning by
 - providing students and teachers with information about students' progress in accomplishing prescribed learning outcomes
 - evaluating the effectiveness of instructional programming content, methods, sequence, and pace
- **Summative assessment** (evaluation) is based on an interpretation of the assessment information collected. It helps determine the extent of each student's achievement of prescribed learning outcomes. Evaluation should be based on a variety of assessment information. Summative assessment is used primarily to
 - measure student achievement
 - report to parent(s) or guardian(s), students, and other stakeholders
 - measure the effectiveness of instructional programming

* Reproduced from National Research Council, *National Science Education Standards* (Washington, DC: National Academy Press, 1996) 100. Reproduced by permission.

Senior 2 Science: A Foundation for Implementation suggests a range of assessment strategies. The same strategy can be used both for formative and summative assessment, depending on the purpose of the assessment.

Suggested assessment strategies that can be used in the science classroom are discussed in detail in the following section:

- **Observation**

- Observation of students is an integral part of the assessment process. It is most effective when focused on skills, concepts, and attitudes. Without record keeping, however, observations and conversations can easily be forgotten. Making brief notes on index cards, self-stick notes, or grids, as well as keeping checklists, helps teachers maintain records of continuous progress and achievement.

- **Interviews**

- Interviews allow teachers to assess an individual's understanding and achievement of the prescribed student learning outcome(s). Interviews provide students with opportunities to model and explain their understandings.

Interviews may be both formal and informal. Posing science-related questions during planned interviews enables teachers to focus on individual student skills and attitudes. Students reveal their thinking processes and use of skills when they are questioned about how they solved problems or answered science questions. Using a prepared set of questions ensures that all interviews follow a similar structure. It is important to keep a record of student responses and/or understandings.

- **Group/Peer Assessment**

- Group assessment gives students opportunities to assess how well they work within a group. Peer assessment gives them opportunities to reflect on one another's work, according to clearly established criteria. During the peer assessment process, students reflect on their own understanding in order to assess the performance of another student.

- **Self-Assessment**

- Self-assessment is vital to all learning and, therefore, integral to the assessment process. Each student should be encouraged to assess her or his own work. Students apply known criteria and expectations to their work and reflect on results to determine their progress toward the mastery of a prescribed learning outcome. Participation in setting self-assessment criteria and expectations helps students to see themselves as scientists and problem solvers. It is important that teachers model the self-assessment process before expecting students to assess themselves.

- **Performance Assessment/Student Demonstration**

- Performance tasks provide students with opportunities to demonstrate their knowledge, thinking processes, and skill development. The tasks require the application of knowledge and skills related to a group of student learning outcomes. Performance-based tests do not test the information that students possess, but the way their understanding of a subject has been deepened, and their ability to apply their learning in a simulated performance. A scoring rubric that includes a scale for the performance of the task helps organize and interpret evidence. Rubrics allow for a continuum of performance levels associated with the task being assessed.

- **Science Journal Entries**
 - Science journal writing provides opportunities for students to reflect on their learning and to demonstrate their understanding using pictures, labeled drawings, and words. They can be powerful tools of formative assessment, allowing teachers to gauge a student's depth of understanding. In this document, direct questions/scenarios frame the science journal suggestions.
- **Rubrics/Checklists**
 - Rubrics and checklists are tools that identify the criteria upon which student processes, performances, or products will be assessed. They also describe the qualities of work at various levels of proficiency for each criterion. Rubrics and checklists may be developed in collaboration with students.
- **Visual Displays**
 - When students or student groups prepare visual displays, they are involved in processing information and producing a knowledge framework. The completed poster, concept map, diagram, model, etc., is the product with which teachers can determine what their students are thinking.
- **Laboratory Report**
 - Laboratory reports allow teachers to gauge the ability of students to observe, record, and interpret experimental results. These tools can aid teachers in determining how well students understand the content.
- **Pencil-and-Paper Tasks**
 - Quizzes can be used as discrete assessment tools, and tests can be larger assessment experiences. These written tasks may include items such as multiple choice questions, completion of a drawing or labeled diagram, problem solving, or long-answer questions. Ensure that both restricted and extended, expository responses are included in these assessment devices.
- **Research Report/Presentation**
 - Research projects allow students to achieve the learning outcomes in individual ways. Assessment should be built into the project at every stage, from planning, to researching, to presenting the finished product.

The foregoing assessment suggestions are not meant to be limiting. Teachers are strongly encouraged to develop their own assessment for Senior Years science based on their students' learning requirements and the prescribed student learning outcomes. *Reporting on Student Progress and Achievement: A Policy Handbook for Teachers, Administrators, and Parents* (Manitoba Education and Training, 1997) contains further information related to reporting on student progress.

DOCUMENT ORGANIZATION

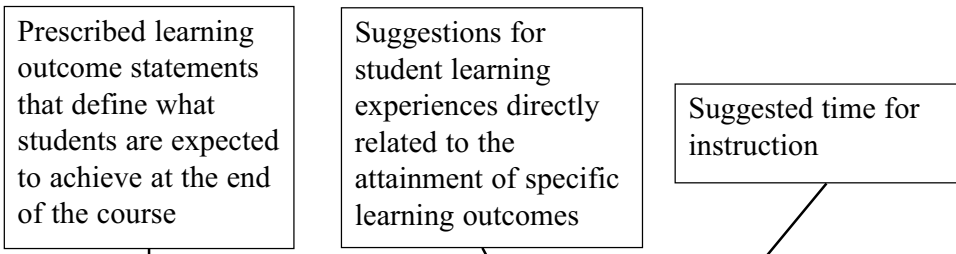
The prescribed learning outcomes and the suggestions for instruction, assessment, and learning resources contained within *Senior 2 Science: A Foundation for Implementation* provide teachers with a plan for helping students achieve the learning outcomes identified in *Senior 2 Science: Manitoba Curriculum Framework of Outcomes* (2001). The document is organized by clusters; Cluster 0: Overall Skills and Attitudes is followed by the four “thematic” clusters. In addition, the appendices comprise Student Learning Activities, Teacher Support Materials, and Blackline Masters. These complementary materials are designed to support, facilitate, and enhance student learning and assessment by being closely linked to the learning outcomes and the skills and attitudes.

Guide to Reading the Specific Learning Outcomes and the Four-Column Format

- The **Prescribed Learning Outcomes** identified in Column 1 outline the intended learning to be achieved by the student by the end of the course. They include the specific learning outcomes related to the thematic cluster in addition to the learning outcomes related to Cluster 0: Overall Skills and Attitudes, selected to correspond to the **Suggestions for Instruction**.
- Column 2 contains **Suggestions for Instruction** directly related to the achievement of the specific learning outcomes contained in the first column.
- Column 3 assists teachers with **Suggestions for Assessment** of the specific learning outcomes.
- Column 4 cites **Suggested Learning Resources** recommended to guide and support instruction, the learning process, and student assessment.
- **Teacher Background** information provides planning hints, special interest material, and depth of treatment on certain issues related to the learning outcomes. These are incorporated as text boxes in column two or three.

The pages that follow provide detailed clarification on reading the four-column format.

The Four-Column Format



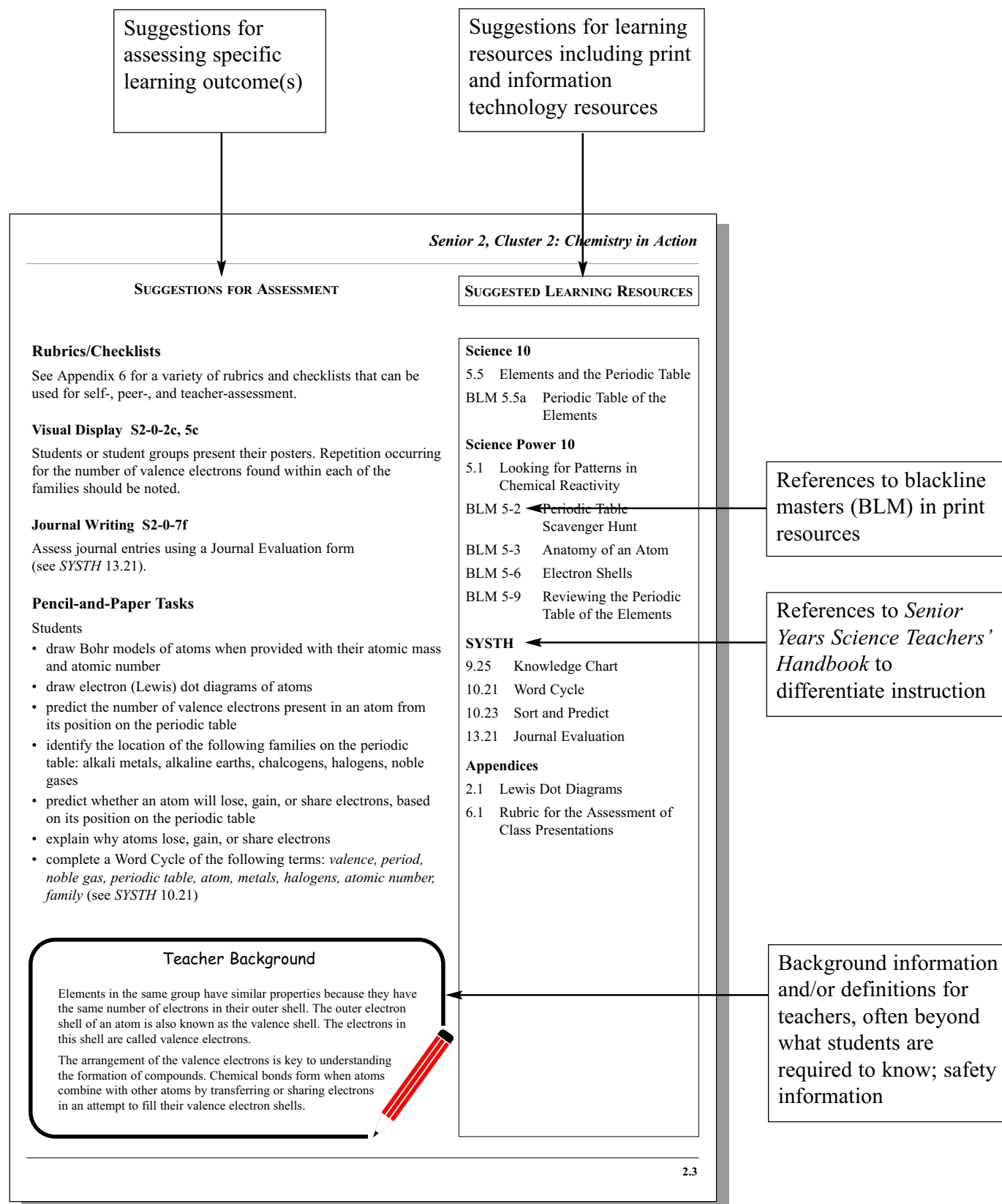
Learning outcomes related to thematic clusters; includes connections to General Learning Outcomes

Learning outcomes related to Cluster 0, Overall Skills and Attitudes, selected to correspond to Suggestions for Instruction (see next section for detailed specific learning outcomes)

Senior 2 Science: A Foundation for Implementation

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (1 HOUR)
<p><i>Students will...</i></p> <p>S2-2-01 Relate an element's position on the periodic table to its combining capacity (valence). Include: alkali metals, alkaline earth metals, chalcogens, halogens, noble gases GLO: D3, D4, E1</p>	<p>➤ Notes for Instruction</p> <p>A review of atomic structure and Bohr models, as well as the design of the periodic table from Senior 1, may be a starting point for this cluster. A Knowledge chart or Sort and Predict activity may be used (see <i>SYSTH</i> 9.25, 10.23). Bohr diagrams are useful to illustrate the number of electrons found within the valence shells, and to help students visualize how atoms lose, gain, or share electrons to fill their valence shells and become stable. Introduce electron (Lewis) dot diagrams as an alternative means of representing atoms and their valence electrons. They are valuable tools for describing, predicting, and explaining compound formation. Have students draw electron dot diagrams for the first 20 elements on the periodic table. It is strongly recommended that details of the periodic table not be memorized. However, the characteristics of the periodic table do provide a powerful conceptual and organizational tool.</p> <p>➤ Student Learning Activities</p> <p>Class Discussion</p> <p>Examine how the periodic table and Bohr models are used to determine the combining capacity of selected element groups. Have students brainstorm answers to questions such as "Why do elements of the same group have similar properties?" and "What is it about the properties of metals and non-metals that allow one to predict the types of compounds they are likely to form?" Knowing the number of valence electrons will help students predict the formation of compounds.</p> <p>Visual Displays/Collaborative Teamwork S2-0-2c, 5c</p> <p>Students or student groups create posters illustrating Bohr models and electron (Lewis) dot diagrams for the first three elements found within the alkali metal, alkaline earth metal, chalcogen, halogen, and noble gas families. The displays can be exhibited in the room for future reference. See Appendix 2.1 for Lewis dot diagrams.</p> <p>Journal Entry S2-0-7f</p> <p>Students complete a Word Cycle of terms related to this topic (see <i>SYSTH</i> 10.21).</p>

2.2



Guide to Reading Specific Learning Outcomes

Senior 2 Science: A Foundation for Implementation

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (3 hours)
<p><i>Students will...</i></p> <p>S2-4-05 Collect, interpret, and analyze meteorological data related to a severe weather event. Include: meteorological maps, satellite imagery, conditions prior to and following the event GLO: C2, C6, C8, D5</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 3, students observed and measured local weather conditions and analyzed the data collected. Students may have had exposure to meteorological maps through television and newspaper articles, as well as discussion on personal experiences with conditions prior to and following severe storms in the previous learning outcome.</p> <p>➤ Notes for Instruction</p> <p>This specific learning outcome can be significantly linked to SLO S2-4-04, which deals with the dynamics of severe weather events. A more “integrative” approach would have students use the context of a particular weather event to foster motivation to gather the relevant synoptic data, such as temperature, precipitation, and cloud cover records. In addition, the readily available satellite imagery databases allow for the observational information to be correlated to space platform images (i.e., visible, infrared, water vapour wavelengths satellite images). It may be important to introduce the fundamentals of remote sensing (e.g., Doppler radar) prior to their use in analyzing particular events. See Appendices 4.17, 4.18, and 4.19 for detailed student learning activities in these areas. Activate prior knowledge of this learning outcome with a “refresher” examination of weather maps and symbols. A Knowledge Chart could be used (see <i>SYSTH</i> 9.25).</p> <p>Discuss the types of data collected by meteorologists, and the technologies used. Take advantage of current and/or local weather events available in print and electronic media. The Environment Canada website has current weather data and maps, as well as satellite and radar images for all regions of Canada (see <http://weatheroffice.ec.gc.ca/canada_e.html> or <www.mb.ec.gc.ca>).</p>

First digit indicates grade; second digit indicates cluster number; third digit(s) indicates specific learning outcome number

Examples: Provides ideas of what could be included (non-mandatory)
None given in this outcome.

Include: Indicates a mandatory component of the specific learning outcome

Cross-reference to general learning outcomes (See Appendix 6.11)

Senior 2 Science: A Foundation for Implementation

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (3 hours)
<p><i>Students will...</i></p> <p>S2-4-05 Collect, interpret, and analyze meteorological data related to a severe weather event. Include: meteorological maps, satellite imagery, conditions prior to and following the event GLO: C2, C6, C8, D5</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 3, students observed and measured local weather conditions and analyzed the data collected. Students may have had exposure to meteorological maps through television and newspaper articles, as well as discussion on personal experiences with conditions prior to and following severe storms in the previous learning outcome.</p> <p>➤ Notes for Instruction</p> <p>This specific learning outcome can be significantly linked to SLO S2-4-04, which deals with the dynamics of severe weather events. A more “integrative” approach would have students use the context of a particular weather event to foster motivation to gather the relevant synoptic data, such as temperature, precipitation, and cloud cover records. In addition, the readily available satellite imagery databases allow for the observational information to be correlated to space platform images (i.e., visible, infrared, water vapour wavelengths satellite images). It may be important to introduce the fundamentals of remote sensing (e.g., Doppler radar) prior to their use in analyzing particular events. See Appendices 4.17, 4.18, and 4.19 for detailed student learning activities in these areas. Activate prior knowledge of this learning outcome with a “refresher” examination of weather maps and symbols. A Knowledge Chart could be used (see <i>SYSTH</i> 9.25).</p> <p>Discuss the types of data collected by meteorologists, and the technologies used. Take advantage of current and/or local weather events available in print and electronic media. The Environment Canada website has current weather data and maps, as well as satellite and radar images for all regions of Canada (see <http://weatheroffice.ec.gc.ca/canada_e.html> or <www.mb.ec.gc.ca>).</p>

Senior 2

Cluster 0: Overall Skills and Attitudes

Overview

Cluster 0 comprises nine categories of specific learning outcomes that describe the skills and attitudes* involved in scientific inquiry and the decision-making process for STSE issues. In Grade 5 to Senior 1, students develop scientific inquiry through the development of an hypothesis/prediction, the identification and treatment of variables, and the formation of conclusions. Students begin to make decisions based on scientific facts and refine their decision-making skills as they progress through the grades, gradually becoming more independent. Students also acquire key attitudes, an initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning.

In Senior 2, students continue to use scientific inquiry as an important process in their science learning, but also recognize that STSE issues require a more sophisticated treatment through the decision-making process. This process has been delineated in Cluster 0 specific learning outcomes.

Teachers should select appropriate contexts to introduce and reinforce scientific inquiry, the decision-making process, and positive attitudes within the thematic clusters (Clusters 1 to 4) throughout the school year. For example, students will use the decision-making process as they examine an STSE issue related to safe driving conditions in Cluster 3. To assist in planning and to facilitate curricular integration, many specific learning outcomes within this cluster are accompanied by links to specific learning outcomes in other subject areas, specifically English Language Arts (ELA) and Mathematics (Math). There are also links to *Technology As a Foundation Skill Area* (TFS).

Students will...

	Scientific Inquiry	STSE Issues
Initiating	<p>S2-0-1a Propose questions that could be tested experimentally. GLO: C2 (ELA: S2: 3.1.2)</p> <p>S2-0-1b Select and justify various methods for finding the answers to specific questions. GLO: C2 (Math: S2: A-1)</p>	<p>S2-0-1c Identify STSE issues that could be addressed. GLO: C4</p> <p>S2-0-1d Identify stakeholders and initiate research related to an STSE issue. GLO: C4 (ELA: S2: 3.1.2)</p>

* Cluster 0: Overall Skills and Attitudes—specific learning outcomes for this grade/course are presented as a chart (separate attachment). The purpose of this chart is to provide a full grade/course overview of skills and attitudes that need to be achieved.

	Scientific Inquiry	STSE Issues
Researching	<p>S2-0-2a Select and integrate information obtained from a variety of sources. Include: print and electronic sources, specialists, and other resource people. GLO: C2, C4, C6 TFS: 1.3.2, 4.3.4 (ELA: S2: 3.1.4, 3.2.4; Math: S2-B-1, 2)</p> <p>S2-0-2b Evaluate the reliability, bias, and usefulness of information. GLO: C2, C4, C5, C8 TFS: 2.2.2, 4.3.4 (ELA: S2: 3.2.3, 3.3.3)</p> <p>S2-0-2c Summarize and record information in a variety of forms. Include: paraphrasing, quoting relevant facts and opinions, proper referencing of sources. GLO: C2, C4, C6 TFS: 2.3.1, 4.3.4 (ELA: S2: 3.3.2; MATH: S2-AMA C-1)</p>	
		<p>S2-0-2d Review effects of past decisions and various perspectives related to an STSE issue. <i>Examples: environmentalist and industry group positions on fossil fuel emissions...</i> GLO: B1, C4 TFS: 1.3.2, 4.3.4 (ELA: S2: 3.2.2)</p>

	Scientific Inquiry	STSE Issues
Planning	<p>S2-0-3a State a testable hypothesis or prediction based on background data or on observed events. GLO: C2</p>	<p>S2-0-3d Summarize relevant data and consolidate existing arguments and positions related to an STSE issue. GLO: C4 TFS: 2.3.1, 4.3.4 (ELA: S2: 1.2.1, 3.3.1, 3.3.2)</p>
	<p>S2-0-3b Identify probable mathematical relationships between and among variables. <i>Examples: relationship among braking distance, velocity, and friction...</i> GLO: C2 (MATH: S2-AMA H-3, CMA F-3[11], PCA H-1,2)</p>	<p>S2-0-3e Determine criteria for the evaluation of an STSE decision. <i>Examples: scientific merit; technological feasibility; social, cultural, economic, and political factors; safety; cost; sustainability...</i> GLO: B5, C1, C3, C4</p>
	<p>S2-0-3c Plan an experiment to answer a specific scientific question. Include: materials, variables, controls, methods, safety considerations. GLO: C1, C2</p>	<p>S2-0-3f Formulate and develop options, which could lead to an STSE decision. GLO: C4</p>

	Scientific Inquiry	STSE Issues
Implementing a Plan	<p>S2-0-4a Carry out procedures that comprise a fair test. Include: controlling variables, repeating experiments to increase accuracy and reliability of results. GLO: C1, C2 TFS: 1.3.1 (MATH: S2-AMA H-1, 2, CMA F3[11])</p> <p>S2-0-4b Demonstrate work habits that ensure personal safety, the safety of others, as well as consideration for the environment. Include: knowledge and use of relevant safety precautions, WHMIS regulations, emergency equipment. GLO: B3, B5, C1, C2</p> <p>S2-0-4c Discuss safety procedures to follow in given situations. Examples: acid or base spill in a lab, use of cleaning products... GLO: C1, C2</p> <p>S2-0-4d Interpret relevant WHMIS regulations. Include: symbols, labels, Material Safety Data Sheets (MSDS). GLO: C1, C2</p>	<p>S2-0-4e Use various methods for anticipating the impacts of different options. Examples: test run, partial implementation, simulation, debate... GLO: C4, C5, C6, C7</p>
	<p>S2-0-4f Work cooperatively with group members to carry out a plan, and troubleshoot problems as they arise. GLO: C2, C4, C7 (ELA: S2: 3.1.3, 5.2.2)</p> <p>S2-0-4g Assume the responsibilities of various roles within a group and evaluate which roles are most appropriate for given tasks. GLO: C2, C4, C7 (ELA: S2: 5.2.2)</p>	

	Scientific Inquiry	STSE Issues
Observing, Measuring, Recording	<p>S2-0-5a Select and use appropriate methods and tools for collecting data or information. GLO: C2 TFS: 1.3.1 (MATH: S2-AMA: H-1, CMA: F-3,1, PCA: H-3)</p> <p>S2-0-5b Estimate and measure accurately using Système International (SI) and other standard units. Include: SI conversions. GLO: C2 (MATH: S2-AMA: H-2, CMA: D-1)</p> <p>S2-0-5c Record, organize, and display data using an appropriate format. Include: labeled diagrams, graphs, information technology. GLO: C2, C5 TFS: 1.3.1, 3.2.2 (ELA: S2: 4.4.1; MATH: S2-AMA B-5, 6, D-1, 2, F-1, A-1)</p>	<p>S2-0-5d Evaluate, using pre-determined criteria, different STSE options leading to a possible decision. Include: scientific merit; technological feasibility; social, cultural, economic, and political factors; safety; cost; sustainability. GLO: B5, C1, C3, C4 TFS: 1.3.2, 3.2.3 (ELA: S2: 3.3.3)</p>

	Scientific Inquiry	STSE Issues
Analyzing and Interpreting	<p>S2-0-6a Interpret patterns and trends in data, and infer and explain relationships. GLO: C2, C5 TFS: 1.3.1, 3.3.1 (ELA: S2: 3.3.1; MATH: S2: AMA J-2, CMA D-5, F-2, H-4)</p> <p>S2-0-6b Identify and suggest explanations for discrepancies in data. Include: sources of error GLO: C2 (ELA: S2: 3.3.4)</p> <p>S2-0-6c Evaluate the original plan for an investigation and suggest improvements. Examples: identify strengths and weaknesses of data-collection methods used... GLO: C2, C5</p>	<p>S2-0-6d Adjust STSE options as required once their potential effects become evident. GLO: C3, C4, C5, C8</p>

	Scientific Inquiry	STSE Issues
Concluding and Applying	<p>S2-0-7a Draw a conclusion that explains the results of an investigation. Include: cause-and-effect relationships, alternative explanations, supporting or rejecting the hypothesis or prediction. GLO: C2, C5, C8 (ELA: S2: 3.3.4; MATH: S2: AMA J-3, CMA F-2, PCA H-4)</p> <p>S2-0-7b Identify further questions and problems arising from an investigation. GLO: C4, C8</p>	<p>S2-0-7c Select the best option and determine a course of action to implement an STSE decision. GLO: B5, C4 (ELA: S2: 3.3.4)</p> <p>S2-0-7d Implement an STSE decision and evaluate its effects. GLO: B5, C4, C5, C8</p> <p>S2-0-7e Reflect on the process used to arrive at or to implement an STSE decision, and suggest improvements. GLO: C4, C5 (ELA: S2: 5.2.4)</p>
	<p>S2-0-7f Reflect on prior knowledge and experiences to develop new understanding. GLO: C2, C3, C4 (ELA: S2: 4.2.2)</p>	

	Scientific Inquiry
Reflecting on Science and Technology	<p>S2-0-8a Distinguish between science and technology. Include: purpose, procedures, products. GLO: A3</p> <p>S2-0-8b Explain the importance of using precise language in science and technology. GLO: A2, A3, C2, C3 (ELA: S2: 4.3.1)</p> <p>S2-0-8c Describe examples of how scientific knowledge has evolved in light of new evidence, and the role of technology in this evolution. GLO: A2, A5</p> <p>S2-0-8d Describe examples of how technologies have evolved in response to changing needs and scientific advances. GLO: A5</p> <p>S2-0-8e Discuss how peoples of various cultures have contributed to the development of science and technology. GLO: A4, A5</p> <p>S2-0-8f Relate personal activities and possible career choices to specific science disciplines. GLO: B4</p> <p>S2-0-8g Discuss social and environmental effects of past scientific and technological endeavours. Include: major shifts in scientific world views, unintended consequences. GLO: B1</p>

Demonstrating Scientific and Technological Attitudes and Habits of Mind	Scientific Inquiry
	<p>S2-0-9a Appreciate and respect that science and technology have evolved from different views held by women and men from a variety of societies and cultural backgrounds. GLO: A4</p> <p>S2-0-9b Express interest in a broad scope of science- and technology-related fields and issues. GLO: B4</p> <p>S2-0-9c Demonstrate confidence in their ability to carry out investigations in science and to address STSE issues. GLO: C2, C4, C5</p> <p>S2-0-9d Value skepticism, honesty, accuracy, precision, perseverance, and open-mindedness as scientific and technological habits of mind. GLO: C2, C3, C4, C5</p> <p>S2-0-9e Be sensitive and responsible in maintaining a balance between the needs of humans and a sustainable environment. GLO: B5, C4</p> <p>S2-0-9f Demonstrate personal involvement and be proactive with respect to STSE issues. GLO: B5, C4</p>

Senior 2

Cluster 1: Dynamics of Ecosystems

Overview

In this cluster, students examine the complex relationships present in ecosystems in order to further investigate issues of sustainability. The large-scale cycling of elements in biogeochemical cycles and the bioaccumulation of toxins in food chains are studied. Population dynamics are examined in the context of the carrying capacity and limiting factors of ecosystems. The concepts and implications of species biodiversity are explored as well. With the knowledge they have gained, students investigate how human activities affect an ecosystem and use the decision-making model to propose a course of action to enhance its sustainability.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-1-01 Illustrate and explain how carbon, nitrogen, and oxygen are cycled through an ecosystem. GLO: D2, D3, D5, E2

SUGGESTIONS FOR INSTRUCTION
(1-1/2 HOURS)

- **Entry-Level Knowledge**

In Grade 7, students were exposed to the idea of cycling in ecosystems, where they studied the cycling of matter in photosynthesis and respiration, energy flow through trophic levels, and examined the role of producers, consumers, scavengers and decomposers. In Grade 8, the concept was further developed with the hydrological cycle.

- **Notes for Instruction**

A brief review of photosynthesis, respiration, trophic levels, and energy flow in ecosystems studied previously in Grade 7 may be a starting point for this unit. A Knowledge Chart could be used (see *Senior Years Science Teachers' Handbook*, Manitoba Education and Training, 1997 [hereinafter referred to as *SYSTH*] 9.25).

Prior knowledge can be activated with a group discussion of the ways in which nutrients are cycled through ecosystems. The following questions may be used to spark discussion: “What happens to the bodies of dead organisms?” “How are the bodies of dead organisms reused and recycled in the environment?” and “What is fertilizer?” Diagrams and flowcharts should be used to illustrate the cycling of matter in an ecosystem.

- **Student Learning Activities**
 - Visual Display S2-0-2a, 5c**

Students or student groups construct visual displays of the three cycles being studied. Displays may include posters, dioramas, bulletin boards, and concept maps. These can be exhibited in the room for future reference.

 - Laboratory Activity S2-0-4a, 4b, 5b, 5c**

Students investigate the cycling of carbon and oxygen in an ecosystem. See Appendix 1.2: Creating a Closed Ecosystem.

 - Journal Writing S2-0-2a, 8b**

Students prepare a glossary of new words for quick reference. A Three-Point Approach could be used (see *SYSTH* 10.22).

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2a, 5c

Students or student groups prepare visual displays of the three cycles. The displays may include posters, dioramas, bulletin boards, and concept maps. Students should be provided with the rubric in advance of assessment. For review prior to a test or quiz, have students generate questions and answers based on the information contained in their display. The displays, questions, and answers can be shared among different groups.

Laboratory Report S2-0-6a, 6c, 7b, 9c

Students prepare a laboratory report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Journal Writing S2-0-2a, 8b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- draw and label diagrams of the three cycles
- describe what happens when sunlight strikes a wheat field or a forest
- explain how photosynthesis and cellular respiration affect the carbon cycle
- summarize the process of nitrogen fixation
- discuss the importance of the cycling of nutrients in ecosystems
- explain why some farmers alternate legumes (such as alfalfa) with their regular crops
- describe the relationship between the carbon cycle and the oxygen cycle

SUGGESTED LEARNING RESOURCES

Science 10

- 2.4 Case Study: The Interaction of Living Things
- 2.5 The Carbon Cycle
- 2.6 The Nitrogen Cycle
- 2.7 Agriculture and Nutrient Cycles
- BLM 2.4 Photosynthesis and Respiration Compared
- BLM 2.5 The Carbon Cycle
- BLM 2.6a The Nitrogen Cycle

Science Power 10

- 2.2 The Carbon Cycle
- Investigation 2-B: The Carbon Cycle and Climate
- 2.3 The Nitrogen Cycle
- Investigation 2-C: Fertilizers and Plant Growth
- BLM 2-2 Equation for Respiration
- BLM 2-3 Equation for Photosynthesis
- BLM 2-6 The Carbon Cycle
- BLM 2-10 The Nitrogen Cycle

SYSTH

- 9.25 Knowledge Chart
- 10.22 Three-Point Approach
- 13.21 Journal Evaluation
- 14.12 Lab Report

Appendices

- 1.2 Creating a Closed Ecosystem
- 6.1 Rubric for the Assessment of Class Presentations
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-1-02 Discuss factors that may disturb biogeochemical cycles. Include: natural events, human activities GLO: D2, D3, D5, E2</p>

SUGGESTIONS FOR INSTRUCTION

(1-1/2 HOURS)

➤ **Entry-Level Knowledge**

In Grade 7, students were introduced to the concept of positive and negative human interventions in ecosystems. Fossil fuel formation and human use of it as a source of energy were also discussed. In Grade 8, students examined factors that cause flooding, as well as the management of water resources. The media and other sources will have familiarized students with the enhancement of the greenhouse effect and global warming.

➤ **Notes for Instruction**

Take advantage of current and local issues in print and electronic media.

In Cluster 4: Weather Dynamics, students investigate and evaluate evidence that would indicate climate change occurs naturally and could be influenced by human activities. In addition, students discuss the potential consequences of climate change.

➤ **Student Learning Activities**

Laboratory Activity S2-0-1a, 3a, 3c, 4a

Students investigate the effect(s) of varying amounts of fertilizer on plant growth. They can also suggest additional variables to be tested, and perform these tests as an extension of their learning.

Student Research S2-0-2a, 2d, 8c, 8g

Students or student groups research factors that may disturb the biogeochemical cycles. Topics can include

- overuse of fertilizers or herbicides
- combustion of fossil fuels
- deforestation
- human and animal waste mismanagement
- volcanic activity
- fire

Case studies, newspaper articles, and Internet sources may be used.

Journal Writing S2-0-4e, 6a, 7f

Students create a Chain Concept Map to outline the sequence of events when a biogeochemical cycle is disturbed (see *SYSTH* 11.14).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5b, 6a, 6b, 7b

Students prepare a lab report based on their findings of the effects of fertilizers on plant growth. If students are encouraged to pursue further avenues of experimentation, their results and analysis can also be included in the assessment (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Research Report/Presentation S2-0-2a, 2c, 2d, 9c

Students or student groups research factors that disturb biogeochemical cycles and present

- written reports
- oral presentations
- newspaper articles
- multimedia presentations
- posters
- diagrams
- bulletin board displays
- concept maps
- charts

Journal Writing S2-0-4e, 6a, 7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- explain how deforestation, fire, and combustion of fossil fuels disrupt the balance between photosynthesis and cellular respiration
- describe how excess fertilizer or herbicide runoff affects bodies of water
- predict how a change in the cycling of carbon may affect the cycling of oxygen
- discuss how human and animal waste mismanagement may affect bodies of water
- predict how the carbon cycle would be disrupted by a reduction in the intensity of sunlight due to smoke and ash from a massive volcanic eruption

Science 10

- 2.5 The Carbon Cycle
- 2.6 The Nitrogen Cycle
- 2.7 Agriculture and Nutrient Cycles
- 2.8 Case Study: Effects of Deforestation on Cycling
- 3.11 Acid Deposition and Forest Ecosystems
- 4.2 Sources of Water Pollution
- 4.3 Investigation: Phosphate Identification
- BLM 2.6c Setting the Stage for the Survival of the Fishes
- BLM 4.3 That's a Lot of Hamburger

Science Power 10

- 2.2 The Carbon Cycle
- Investigation 2-B: The Carbon Cycle and Climate
- 2.3 The Nitrogen Cycle
- Investigation 2-C: Fertilizers and Plant Growth
- BLM 2-5 Charting Carbon Changes
- BLM 2-7 The Greenhouse Effect
- BLM G-29 Scientific Research Planner
- BLM G-30 Research Worksheet
- BLM G-31 Internet Research Tips

SYSTH

- 11.14 Chain Concept Map
- 13.21 Journal Evaluation
- 14.12 Lab Report Format

Appendices

- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-1-03 Describe bioaccumulation and explain its potential impact on consumers. <i>Examples: DDT, lead, dioxin, PCBs, mercury...</i> GLO: B1, D2

SUGGESTIONS FOR INSTRUCTION
(2 HOURS)

➤ **Entry-Level Knowledge**

In Grade 7, students examined food chains and food webs, and used the concept of ecological pyramids to analyze the potential for bioaccumulation within an ecosystem.

➤ **Notes for Instruction**

Activate prior knowledge of food chains and webs, using strategies such as Listen-Draw-Pair-Share or LINK (see *SYSTH* 9.15, 9.18) and note any misconceptions students have. A Sort and Predict activity could be used as a vocabulary warm-up/review (see *SYSTH* 10.13).

Emphasize that bioaccumulation is the result of the non-cycling of matter in ecosystems. Bioaccumulation is also known as biological magnification or bioamplification. It occurs when non-biodegradable substances are concentrated and stored in organisms. There are several instances of bioaccumulation in Manitoba and in Canada; where possible, use local or regional examples (e.g., PCBs in beluga whales, mercury poisoning in the Grassy Narrows First Nations community of northern Ontario, methyl-mercury in northern Manitoba lakes).

➤ **Student Learning Activities**

Visual Display S2-0-2a, 5c

Students or student groups create diagrams, posters, charts, concept maps, or bulletin boards to illustrate the mechanism of bioaccumulation.

Collaborative Teamwork/Student Research

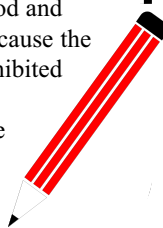
S2-0-2d, 8c, 8g, 9e

Student groups examine case studies, or research and prepare reports describing examples of the bioaccumulation of toxins and their effects on consumers.

A major focus could be that of the long-term implications of bioaccumulation on the environment. Take advantage of current and local issues in print and electronic media.

Teacher Background

The fashionable men's hats of the 18th and 19th centuries were made in a process that used mercury to convert Canadian beaver fur into felt. Exposure to high levels of mercury vapour can result in human nervous system damage, including tremors and mood and personality alterations. Because the hat makers (or hatters) exhibited symptoms of mercury poisoning, they came to be known as "mad hatters."



SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2a, 5c

Students or student groups present

- bulletin board displays
- posters
- diagrams
- charts
- concept maps

Research Report/Presentation S2-0-2c, 3d, 5c, 9c

Students or student groups examine case studies, or research and report examples of the bioaccumulation of toxins and their effects on consumers, and present

- written reports
- oral presentations
- dramatic presentations
- newspaper articles
- multimedia presentations
- pamphlets
- brochures

Pencil-and-Paper Tasks

Students

- describe the mechanism of bioaccumulation
- draw and label a diagram to illustrate how bioaccumulation occurs
- provide examples of environmental pollutants known to have accumulated in food chains, and discuss the consequences of their effects for consumers
- compare and contrast the bioaccumulation of mercury with the cycling of nitrogen
- suggest a reason why the continuing use of DDT in tropical nations is a concern in Canada

Science 10

- 2.2 Case Study: Pesticides
- BLM 1.11a Relationships in Ecosystems
- BLM 1.11b Constructing Ecological Pyramids
- BLM 4.2 Drinking Water: How Safe Is It?
- BLM 3.9 Self-Assessment Teamwork Skills
- TSM-3 Cooperative Learning

Science Power 10

- Investigation 1-C: DDT in a Food Chain
- BLM 1-1 You and Food Chains
- BLM 1-2 Flowchart of Connecting Links
- BLM 1-4 Getting to the Top
- BLM 1-10 Chains and Webs
- BLM 1-21 Biological Magnification in Nature

SYSTH

- 9.15 Listen-Draw-Pair-Share
- 9.18 LINK (List-Inquire-Note-Know)
- 10.13 Sort and Predict
- 10.24 Compare and Contrast

Appendices

- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-1-04 Describe the carrying capacity of an ecosystem. GLO: D2, E2, E3

SUGGESTIONS FOR INSTRUCTION
(1 HOUR)

- **Entry-Level Knowledge**

In Grade 7, students identified abiotic and biotic components of ecosystems that allow particular organisms to survive. They also examined the transfer of energy in ecological pyramids.

- **Notes for Instruction**

A review of the biotic and abiotic components of ecosystems could be used to activate prior knowledge for this outcome. A KWL or Knowledge chart could be used (see *SYSTH* 9.24, 9.25). Introduce the concept of *carrying capacity* as the optimum number of organisms of a particular species that can be supported by a particular environment. Provide students with the meaning of population in ecology and discuss important properties of a population such as density and age structure. Have students brainstorm to identify the conditions necessary for a population in an ecosystem to be stable and self-sustaining.

- **Student Learning Activities**

Class Discussion S2-0-6a, 7f

Students brainstorm to predict what would happen to the population of a species if abiotic or biotic components changed. For example: Would the population of algae increase or decrease if fertilizer was added to a lake? Would the deer population change if a wolf pack moved into the area? Ask students to explain the rationale for their predictions. Case studies may be used. This discussion can act as a springboard into a further exploration of the concepts of wildlife and habitat conservation, and sustainability (see Appendix 1.3: Carrying Capacity).

Journal Writing S2-0-2c

Students complete a Three-Point Approach frame of words and concepts related to this topic (see *SYSTH* 10.22).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- define *population* and discuss properties such as density and age structure
- describe the conditions necessary for a population in an ecosystem to be stable and self-sustaining
- define *carrying capacity* and use it to explain the importance of conservation
- predict the effects of changing biotic and abiotic components on a population (e.g., effects of a cold, snowy winter on the deer population, introduction of toxic waste into a lake)
- explain the relationship between the carrying capacity and the population equilibrium in an ecosystem
- provide examples of how technological advances in agriculture have affected the carrying capacity of humans in many ecosystems

Journal Writing S2-0-2c

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Science 10

1.12 Roles in Ecosystems

2.10 Limits on Populations

BLM 1.5 Ecological Reach for the Top

ABLM 1.5 Concepts in Ecology

ABLM 2.9a Setting a Moose Licence Quota

Science Power 10

1.3 Populations

4.2 Ecological Footprints

BLM 1-13 Animal Crackers

BLM 4-2 Charting Our World

SYSTH

9.24 KWL Plus

9.25 Knowledge Chart

10.22 Three-Point Approach

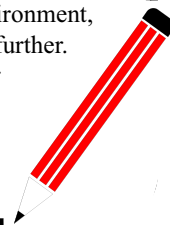
13.21 Journal Evaluation

Appendix

1.3 Carrying Capacity

Teacher Background

When a population reaches the carrying capacity of its environment, certain factors prevent the population from increasing any further. At this point, the population has reached the steady state or dynamic equilibrium. While the average growth rate of a population in the steady state is zero, fluctuations in the population size do occur.



PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-1-05 Investigate and discuss various limiting factors that influence population dynamics.</p> <p>Include: density-dependent and density-independent factors</p> <p>GLO: C2, D2, E2, E3</p>

SUGGESTIONS FOR INSTRUCTION

(5 HOURS)

➤ **Entry-Level Knowledge**

In Grade 7, students identified the biotic and abiotic components of ecosystems that allow organisms to survive, described succession, and identified the signs of succession in a variety of ecosystems.

➤ **Notes for Instruction**

Activate prior knowledge, and discuss misconceptions. A Sort and Predict activity could be used as a vocabulary warm-up/review. (See *SYSTH* 10.13.)

Use local examples where possible in the discussion of this topic (e.g., the impact of extremely cold winters on the deer and moose populations, or mange in the coyote populations of southwestern Manitoba). Take advantage of current and local issues in print and electronic media.

Suggestions for reading and writing strategies can be found in *SYSTH* Chapter 12: Reading Scientific Information and Chapter 14: Technical Writing in Science.

➤ **Student Learning Activities**

**Student Research/Collaborative Teamwork/Visual Display
S2-0-2a, 2b, 2c, 5c**

Students or student groups research the various ways in which natural populations are kept in dynamic equilibrium. Examples include

- predator-prey relationships
- succession
- resource limits
- competition
- disease
- overcrowding and stress
- drought
- flood
- extreme weather
- fire

Case studies may be used. See Appendix 1.1: Environmental Factors and Population Size.

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- differentiate between density-dependent and density-independent limiting factors (see *SYSTH* 11.21)
- use examples to describe ways in which natural populations are kept in equilibrium
- use the concept of carrying capacity to explain how the growth of predator and prey populations are interrelated
- describe the effect that humans can have on predator-prey relationships
- complete a Word Cycle of terms related to this topic (see *SYSTH* 10.21)
- evaluate the need for using pesticides to control pests such as mosquitoes or forest tent caterpillars
- predict the impact of a major flood on the deer population in the Red River valley
- discuss the effects overcrowding may have on an animal population

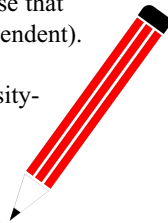
**Research Report/Presentation/Visual Display
S2-0-2a, 2b, 2c, 5c**

Students or student groups present research findings with

- | | |
|----------------------------|--------------------------|
| • written reports | • diagrams |
| • oral presentations | • charts |
| • multimedia presentations | • concept maps |
| • bulletin board displays | • dramatic presentations |
| • posters | |

Teacher Background

Once a population reaches the carrying capacity of its environment, a variety of factors keep the population in equilibrium and prevent it from growing any further. These include limiting factors that depend on the density of the population (density-dependent) and those that operate independent of the population density (density-independent). Examples of density-dependent limiting factors include competition, predation, crowding, and parasitism. Some density-independent limiting factors are fire, flood, drought, and extreme heat or cold.



(continued)

Science 10

- 1.5 Ecology
- 2.9 Monitoring Changes in Populations
- 2.10 Limits on Populations
- 2.11 Explore an Issue: Should We Use Pesticides to Control Pests?
- BLM 2.2 Confusing Insects to Prevent Reproduction
- BLM 2.11a Assessment Rubric for Debate Participation
- BLM 2.11b Decision Sheet for Debate Results
- AT-11 Assessment Rubric 6: Research Skills
- AT-15 Self-Assessment Checklist 2: Research Skills

Science Power 10

- 1.3 Populations Managing Resources
- 1.4 Investigation 4-A: Balancing Populations and the Environment
- BLM 1-17 Population Terms
- BLM 4-8 Balancing Populations
- BLM 4-9 Developing a Wildlife Policy
- BLM 4-10 Studying a Deer Population
- BLM G-34 Debating Procedures
- TSM-9 Debating

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-1-05 Investigate and discuss various limiting factors that influence population dynamics.</p> <p>Include: density-dependent and density-independent factors</p> <p>GLO: C2, D2, E2, E3</p>

SUGGESTIONS FOR INSTRUCTION

(5 HOURS)

Community Connection S2-0-8e, 8f, 9a

Invite a local conservation/parks officer, elder, trapper, or hunter to share her or his knowledge of this topic with the class. Students could also interview community members in their homes or workplaces.

Class Debate S2-0-1c, 3d, 5d, 7c

Students research and then debate the pros and cons of using pesticides to control forest tent caterpillar, spruce budworm, or mosquito populations.

Journal Writing S2-0-7f

Students pretend they are wise old organisms (e.g., an elm tree or a moose) passing on their knowledge of past hardships and necessary survival skills to a younger generation. A RAFTS format could be used (see *SYSTH* 13.23).

Class Discussion S2-0-7f

Students brainstorm a list of ways in which natural populations are kept in dynamic equilibrium. A Roundtable or Rotational Graffiti format may be used (see *SYSTH* 3.15). See Appendix 1.4: Limiting Factors.

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Journal Writing S2-0-2b, 3d, 7f

Encourage reflection on the debate. The following questions may be posed:

- What surprising points were raised during the debate?
- Do you think there is a right or wrong answer? Explain.
- What valid facts were used to support the arguments?
- Can you summarize the arguments given by each team, including potential environmental effects of pesticide use, insect control program costs, and benefits/risks of long-term use?

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

SYSTH

- 3.15 Rotational Cooperative Graffiti
- 10.13 Sort and Predict
- 10.21 Word Cycle
- 11.21 Concept Relationship Frame
- 13.21 Journal Evaluation
- 13.23 RAFTS

Appendices

- 1.1 Environmental Factors and Population Size
- 1.4 Limiting Factors
- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-1-06 Construct and interpret graphs of population dynamics. GLO: C6, D2, E2

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Notes for Instruction**

Have students analyze different tables, charts, and graphs of growing, stable, and declining populations. Students should be able to interpret growth curves and histograms and predict if the population is growing, declining, or stable. Students should also be able to account for changes in the shape of growth curves and histograms.

➤ **Student Learning Activities**

Collaborative Teamwork S2-0-3a, 5c, 6a

Students work in groups and construct population histograms, given sample data. Provide the groups with histograms of growing, stable, and declining populations. Ask students to analyze the shape of the histograms in order to predict future changes in populations. For example, the age distribution of Canadians indicates our population will begin to decline in the absence of immigration.

Students work in groups and construct growth curves of the relationship between populations of predator and prey (e.g., the lynx and snowshoe hare). Ask students what they can infer from the growth curves of each organism. Case studies may be used. See Appendix 1.5: Predator-Prey Interactions.

Laboratory Activity S2-0-4b, 5c, 6a, 7a

Students culture a yeast, bacterial, or paramecium population and calculate the size and growth rate over time. Spreadsheet software can be used to tabulate and graph data.

Students can use interactive population ecology software programs. These programs allow the user to manipulate variables affecting population size, and predict subsequent changes in the population.

Students can play a predator-prey simulation or game.

Journal Writing S2-0-2a

Students prepare a glossary of new words for quick reference. A Three-Point Approach could be used (see *SYSTH* 10.22).

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-3b, 4a, 5a, 7a

Students graph the results, interpret the growth patterns of their yeast, bacterial, or paramecium culture, and prepare a report of their findings.

Students prepare reports based on their use of interactive population ecology software programs or predator-prey simulations or games (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Journal Writing S2-0-2a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

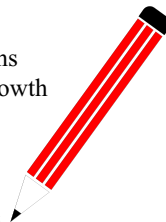
Pencil-and-Paper Tasks

Students

- construct a histogram, given population data
- analyze the histogram to determine if the population is growing, stable, or in decline
- use the histogram to predict future changes in the size of the population
- construct a growth curve, given population data
- analyze the phases of the growth curve to determine where the population is growing, stable, or declining
- account for changes in the shape of the growth curve over time
- interpret growth curves that represent the relationship between populations of predators and their prey

Teacher Background

Histograms (bar graphs) are used to illustrate age distributions within a population. Line graphs are used to represent the growth curve of a population.



SUGGESTED LEARNING RESOURCES

Science 10

2.9 Monitoring Changes in Populations

2.10 Limits on Populations

BLM 1 Assessment Template for the Microscope

BLM 1.9 Studying Decay Using Artificial Logs

BLM 2.9a Yeast Population Study

BLM 2.9b Case Study: Yeast Population

BLM 2.9c Population Graphs

ABLM 2.9 Understanding Exponential Population Growth

Science Power 10

Investigation 1-B: Regulating Population Size

BLM 1-15 Growing Bacteria

BLM 1-16 Predator-Prey Patterns

BLM 1-19 Geometric Population Growth

BLM 1-20 Population Growth Curves

SYSTH

10.22 Three-Point Approach for Words and Concepts

13.21 Journal Evaluation

14.12 Lab Report Format

Appendices

1.5 Predator-Prey Interactions

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-1-07 Discuss the potential consequences of introducing new species and of species extinction to an ecosystem.</p> <p>GLO: E1, E2</p>

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

➤ **Entry-Level Knowledge**

In Grade 6, students gained familiarity with the diversity of living things (five kingdoms). In Grade 7, they analyzed food webs and ecological pyramids, and identified and described positive and negative examples of human interventions that affect ecological succession, or the makeup of ecosystems.

➤ **Notes for Instruction**

Activate student knowledge by reviewing the diversity of living things, food webs, and ecological pyramids. A KWL frame or Anticipation Guide could be used (see *SYSTH* 9.24, 9.26). Students must first comprehend the concepts of ecological niche and competition in order to understand why the introduction of a new species or species extinction can effect devastating results on an ecosystem.

➤ **Student Learning Activities**

Class Discussion S2-0-7f

Examine a food chain in an ecosystem. Students brainstorm to predict the consequences of removing one species from the chain. Expand the discussion to the effects of species extinction on a food web.

Student Research S2-0-2a, 2c, 2d, 9e

Students or student groups research one example of how the introduction of a new species has affected an ecosystem.

Some examples may include

- zebra mussels in the Great Lakes
- purple loosestrife in Manitoba waterways
- lampreys in the Great Lakes
- carp in Manitoba lakes and rivers

Journal Writing S2-0-7f

Students speculate on reasons why large carnivores (such as bears and eagles) are in greater danger of extinction than small herbivores (such as mice and rabbits).

Collaborative Teamwork S2-0-2a, 2c, 2d, 4f

Various student groups investigate one example of the effect of introducing a new species or of species extinction into an ecosystem, and then share their findings with their classmates in a Jigsaw format (see *SYSTH* 3.20).

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-2a, 2c, 2d, 9e

Students or student groups present research findings with

- written reports
- oral presentations
- multimedia presentations
- bulletin board displays
- dramatic presentations
- posters
- debates
- newspaper articles

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- complete a Compare and Contrast or Concept Relationship frame comparing species extinction with species introduction (see *SYSTH* 10.24, 11.35)
- draw a food web diagram of 10 organisms in a local ecosystem, including at least one producer, one primary consumer, one secondary consumer, one tertiary consumer, and one decomposer
- use the diagram to predict how the introduction of a new species or the extinction of one of the 10 organisms would affect the food web
- describe, with the use of examples, the problems created when a new species is introduced into an ecosystem

SUGGESTED LEARNING RESOURCES

Science 10

- 1.1 The Silence of the Frogs
- 1.2 Canada's Endangered Species
- 1.3 Extinction in the Modern World
- 1.4 Explore an Issue: What is the Value of Wolves?

1.12 Roles in Ecosystems

BLM 1.4 Pleistocene Park?

AT-5 Assessment Rubric 2: Communication

Science Power 10

BLM G-10 Group Roles

BLM G-11 Say It with Style!

SYSTH

3.20 Jigsaw

9.24 KWL Plus

9.26 Anticipation Guide

10.24 Compare and Contrast

11.35 Concept Relationship Frame

13.21 Journal Evaluation

Appendices

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

Teacher Background

The introduction of rabbits in Australia and New Zealand is a well-documented example of how a new species can have an impact upon an ecosystem. Originally imported for hunting, the wild rabbits multiplied at an incredible rate in the absence of any predators. They have been one of the main causes of habitat destruction, native plant and animal extinction, land degradation, and crop damage. A variety of methods to control the rabbit population has been attempted, including chemical and biological means.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-1-08 Observe and document a range of organisms that illustrate the biodiversity within a local or regional ecosystem.</p> <p>GLO: D2, E1</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

In Grade 6, students studied the five kingdom classification system, identified organisms with classification keys, and observed and described the diversity of living things within a local environment. In Grade 7, students studied the role of producers, consumers, and decomposers, and analyzed food webs.

➤ **Notes for Instruction**

A field trip is a necessity for this learning outcome; however, the outing need not be to a distant location. A class in an urban school may visit a local park, while a class in a rural or northern school may be close to a wilderness area, such as a marsh or swamp.

➤ **Student Learning Activities**

Community Connection S2-0-2c, 4b, 5a, 8e

Visit a local park or wilderness area. Students observe and document the range of organisms present.

Students collect water samples and later examine them in the lab for the presence of freshwater invertebrates. Simple biological keys or field guides can be used to identify tree and shrub species, or leaf collections can be taken back to the lab for analysis. Invite a local birdwatcher to accompany the class and assist in the identification of bird species. Students can make sketches of plant, animal, and fungi species.

Laboratory Activity S2-0-2c, 5a, 5c, 6a

Students examine the water samples collected on the field trip and identify the freshwater invertebrates present in the samples.

Students can examine their leaf collections in the lab in order to identify the tree and shrub species present in the area.

Classification keys or field guides can be used for identifications of plants, animals, and fungi.

Collaborative Teamwork/Student Research S2-0-4f, 4g

Student groups prepare illustrated field guides or walking tours for the local or regional ecosystem visited on the field trip. The guides/tours should demonstrate the biodiversity of the area and include both animal and plant species, and possibly fungi and protists as well. The guides/tours can take the form of brochures, pamphlets, maps, or booklets.

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-2c, 5a, 5c, 9c

Students sketch and identify the freshwater invertebrates present in their water samples. Using their pressed leaves, students identify the tree and shrub species in the area. Classification keys or field guides could also be used for the identification of plants, animals, and fungi (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Visual Display/Research Report/Presentation S2-0-2c, 4f, 5c, 9b

Students or student groups present research findings of their field trip observations, field guides, or walking tours with

- bulletin board displays
- posters
- diagrams
- charts
- multimedia presentations
- brochures
- pamphlets
- booklets
- maps

Journal Writing S2-0-7b, 7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- define the term *biodiversity*
- identify organisms using a simple biological key
- provide examples of plant, animal, and fungi species found in their local/regional ecosystem
- identify organisms observed on the field trip as producers, consumers, or decomposers
- draw and label a food chain or web, based on the organisms observed on the field trip

Science 10

3.6 Investigation: The Animal Community in Soils

BLM 4.6a Indicator Organisms

BLM 4.6b Collecting Stream Organisms for the Lab

ABLM 3.9 Self-Assessment Teamwork Skills

ABLM 4.6a Aquatic Insect Larvae and Invertebrates

Science Power 10

Investigation 1-A: Seeing Patterns in Nature

SYSTH

13.21 Journal Evaluation

14.12 Lab Report Format

Appendices

6.1 Rubric for the Assessment of Class Presentations

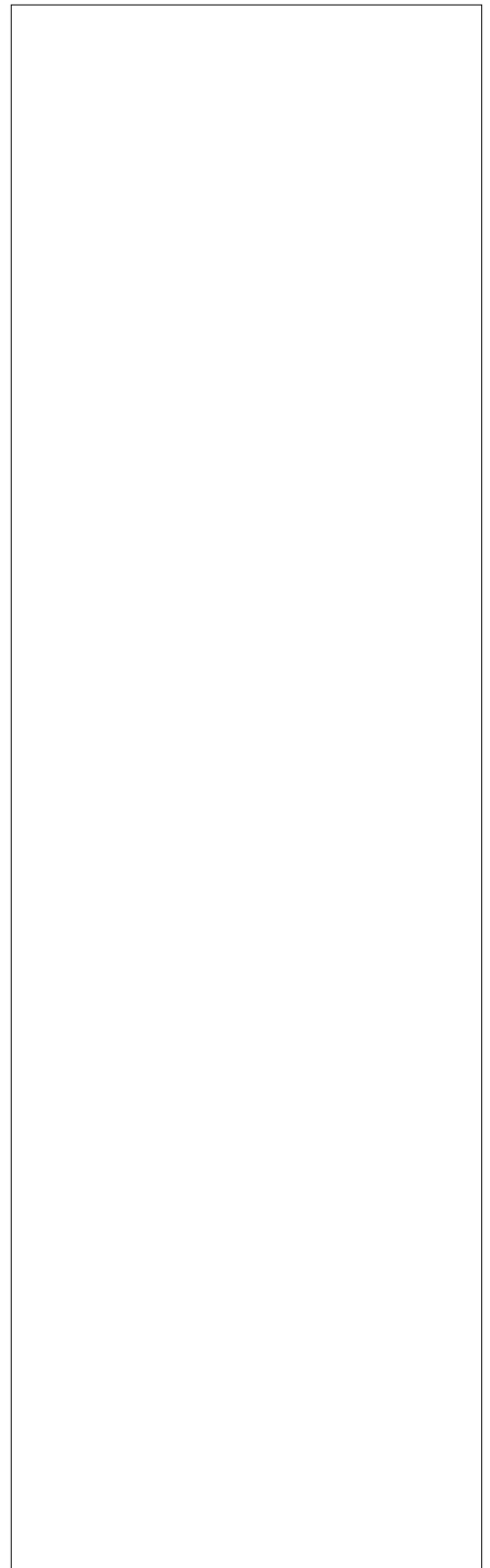
6.2 Rubric for the Assessment of a Research Project

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(3 HOURS)
<i>(continued)</i> S2-1-08 Observe and document a range of organisms that illustrate the biodiversity within a local or regional ecosystem. GLO: D2, E1	Visual Display S2-0-2c, 5c Students draw diagrams or prepare posters, bulletin board displays, charts, or multimedia presentations illustrating the range of organisms observed on their field trip. Journal Entry S2-0-7b, 7f, 9e Students reflect on their field trip observations and respond to the following questions: <ul style="list-style-type: none">• How has your understanding of biodiversity changed?• What new questions do you have about biodiversity?

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

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PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(1 HOUR)
<p>S2-1-09 Explain how the biodiversity of an ecosystem contributes to its sustainability. GLO: B5, E1</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 6, students gained familiarity with the diversity of living things, and in Grade 7, they analyzed food webs and ecological pyramids.</p> <p>➤ Notes for Instruction</p> <p>Activate prior knowledge by reviewing diversity of living things, food webs, and ecological pyramids. A KWL frame or Anticipation Guide could be used (see <i>SYSTH</i> 9.24, 9.26). An examination of the classification system for at-risk species in Canada or Manitoba can be used to introduce the topic. Some local examples of at-risk species include the burrowing owl and the small, white lady’s slipper orchid.</p> <p>The Manitoba Conservation Wildlife Branch website at www.gov.mb.ca/conservation/wildlife/index can provide additional information about <i>The Endangered Species Act</i>, biodiversity conservation, hunting and trapping guides, and problem wildlife.</p> <p>➤ Student Learning Activities</p> <p>Class Discussion S2-0-8g</p> <p>Guide the students through a discussion of the possible effects of introducing a new species or of species extinction to an ecosystem, by first examining a food chain and then a food web. Relate this discussion to how biodiversity contributes to the sustainability of an ecosystem. A case study could be used.</p> <p>Journal Writing S2-0-7f, 9e</p> <p>Students reflect on the sustainability of a monoculture ecosystem such as a canola field or a lawn and compare it to a natural grassland ecosystem.</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- complete a Word Cycle of the following terms: *ecosystem, population, biodiversity, extinction, species, predation, equilibrium, sustainability, competition* (see SYSTH 10.21)
- differentiate among extinct, endangered, extirpated, threatened, and vulnerable species
- list some examples of Canadian at-risk species
- suggest ways in which at-risk species could be protected
- discuss possible causes of species extinction
- with the use of examples, explain how the biodiversity of an ecosystem contributes to its sustainability

Journal Writing S2-0-7f, 9e

Assess journal entries using a Journal Evaluation form (see SYSTH 13.21).

Science 10

- 1.1 The Silence of the Frogs
- 1.2 Canada’s Endangered Species
- 1.3 Extinction in the Modern World
- 1.4 Explore an Issue: What Is the Value of Wolves?
- 3.7 Agriculture and Food Production
- 3.9 Explore an Issue: How Many Potatoes are Enough?
- BLM 1.2 Classification System for At-Risk Species
- BLM 1.8 Whose Neighborhood Is It?
- ABLM 1.8 Looking at a Meadow and a Park

SYSTH

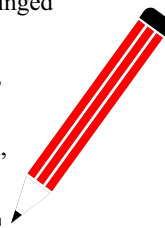
- 9.24 KWL Plus
- 9.26 Anticipation Guide
- 10.21 Word Cycle
- 13.21 Journal Evaluation

Teacher Background

Examples of **endangered** Manitoba species include the whooping crane, peregrine falcon, piping plover, and western prairie fringed orchid.

Threatened Manitoba species include the ferruginous hawk, western silvery aster, and western spiderwort.

Extirpated Manitoba species include the swift fox, musk ox, pronghorn antelope, and trumpeter swan.



PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-1-10 Investigate how human activities affect an ecosystem and use the decision-making model to propose a course of action to enhance its sustainability.</p> <p>Include: impact on biogeochemical cycling, population dynamics, and biodiversity</p> <p>GLO: B5, C4, C5, C8</p>

SUGGESTIONS FOR INSTRUCTION

(5 HOURS)

➤ **Entry-Level Knowledge**

In Grade 7, students identified environmental, social, and economic factors that should be considered in the management and preservation of ecosystems. They also proposed a course of action to protect the habitat of a particular organism in an ecosystem. In Senior 1, the formal decision-making model was introduced.

➤ **Notes for Instruction**

Guide students through the steps of the Decision-Making Model (see *Senior 2 Science: Manitoba Curriculum Framework of Outcomes* and Manitoba Foundations for Scientific Literacy section at the front of this document). Model the process, guide students, and provide opportunities for practice. Other Senior 2 clusters will provide more opportunities for decision making. See Appendix 1.6: Educating for Sustainability: Decision-Making Skills. Suggestions for reading and writing can be found in *SYSTH* Chapter 12: Reading Scientific Information and Chapter 14: Technical Writing in Science. Environment Canada’s Science and the Environment Bulletin <www.ec.gc.ca/science/splash.htm> and Envirozine <www.ec.gc.ca/envirozine/english/home_e.cfm> contain up-to-date information.

➤ **Student Learning Activities**

Student Research/Collaborative Teamwork
S2-0-1d, 2b, 3e, 6d

Students hold mock public hearings on the use of land and resources in provincial parks. The class first identifies the various stakeholders and their proposals. Next, students break into groups that represent the various stakeholders, and research the issue from their (stakeholders’) perspective. Each group then prepares a brief summary outlining their proposal for land and resource use, and presents it publicly. Class discussions are held after all the stakeholders’ briefs have been presented, and recommendations for a course of action are developed using the decision-making model. Case studies, newspaper articles, and Internet sources can be used.

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-5d, 7c, 7e, 9c

Students present their research findings with

- written reports
- oral presentations
- multimedia presentations
- bulletin board displays
- dramatic presentations
- newspaper articles
- public hearings

Visual Display S2-0-9c, 9e, 9f

Student groups present visual displays that depict ways human activities affect an ecosystem. Displays may take the form of

- posters
- bulletin board presentations
- charts
- cartoons
- dioramas

Teacher Background

See *SYSTH*, Chapter 5: Science and Sustainable Development for principles, fundamental guidelines, and approaches for teaching about sustainable development.

See *Education for a Sustainable Future* for additional information and instructional strategies (Manitoba Education and Training, 2000).

(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 3.10 Logging Forests
- 4.5 Case Study: The Great Lakes
- 4.9 Case Study: Managing Fish Populations
- 4.10 Explore an Issue: Can We Create a Sustainable Fishery?
- Unit 1 Challenge: Assessing the Environmental Effects of Human Communities
- BLM 2.3a When Is a Farm Not a Farm?
- BLM 3.7 What's the Alternative?
- BLM 3.10 The Forests of the Temagami Region

Science Power 10

- Investigation 3-C: Modeling an Environmental Impact Assessment
- 4.1 Managing Resources
- Investigation 4-B: Alternatives to Growth
- 4.3 Sustainable Future
- Unit 1 Issues Analysis: Clear-cutting Versus Selective Cutting of Forests
- BLM 3-10 Urban Use of Rural Lands
- BLM 4-11 Sustainable Metaphors
- BLM 4-12 Conserving Resources
- BLM G-33 Procedure for a Public Hearing
- BLM G-37 Decision-Making Organizer

(continued)

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(5 HOURS)
<p><i>(continued)</i></p> <p>S2-1-10 Investigate how human activities affect an ecosystem and use the decision-making model to propose a course of action to enhance its sustainability.</p> <p>Include: impact on biogeochemical cycling, population dynamics, and biodiversity</p> <p>GLO: B5, C4, C5, C8</p>	<p>Visual Display S2-0-1c, 3f, 7c, 7d</p> <p>Students or student groups create visual displays illustrating how human activities affect an ecosystem and propose a course of action to enhance its sustainability. Some examples can include</p> <ul style="list-style-type: none">• regulating the water levels in Lake Winnipeg and Lake Manitoba• building a shopping mall/housing development on prime agricultural land• draining wetlands for agriculture/housing developments <p>Case studies, newspaper articles, and Internet sources can be used.</p> <p>Class Debate S2-0-2d, 3e, 3f, 5d</p> <p>Students research and debate the pros and cons of local/regional issues such as</p> <ul style="list-style-type: none">• building a new hydro dam on the Nelson River• clear-cutting versus selective cutting of forests• allowing the expansion of hog barn operations• changing the creel limits for recreational fishers• permitting hunting in provincial/national parks <p>Student Research S2-0-2d, 9b, 9f</p> <p>Students complete a fact- or issue-based article analysis of a current newspaper, Internet, or magazine article related to these learning outcomes (see <i>SYSTH</i> 11.40, 11.41).</p>

SUGGESTIONS FOR ASSESSMENT

Journal Writing S2-0-2b, 3d, 7e, 9e

Encourage reflection on the debate. The following may be posed:

- What surprising points were raised during the debate?
- Do you think there is a right or wrong answer? Explain.
- What valid facts were used to support the arguments?
- Summarize the arguments given by each team according to agreed-upon criteria negotiated prior to the debate.

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- identify local/regional STSE issues
- summarize the arguments of the stakeholders in an issue related to this learning outcome
- evaluate the stakeholders' arguments
- formulate their own opinion on the issue
- defend their opinion
- complete a fact- or issue-based article analysis of a current newspaper or magazine article related to the topic (see *SYSTH* 11.40, 11.41)
- suggest ways in which they can be personally involved and proactive with respect to STSE issues

SUGGESTED LEARNING RESOURCES

SYSTH

Chapter 5: Science and Sustainable Development

Chapter 12: Reading Scientific Information

Chapter 14: Technical Writing in Science

11.40 Issue-Based Article Analysis

11.41 Fact-Based Article Analysis

13.21 Journal Evaluation

Appendices

1.6 Educating for Sustainability: Decision-Making Skills

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

6.3 Rubric for the Assessment of a Decision-Making Process Activity

NOTES

Senior 2

Cluster 2: Chemistry in Action

Overview

This cluster provides students with the opportunity to examine the interactions among elements as they form compounds through chemical reactions. Students become familiar with the formulas and naming of binary compounds, and investigate the Law of Conservation of Mass. The recognition that mass is conserved in chemical reactions allows students to balance equations with both words and symbols, and classify them by type. The principles of acid-base chemistry are studied and extended to large-scale environmental interactions. Students investigate the use of chemistry in biological, industrial, and domestic settings, recognizing that chemical use is pervasive in modern society.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-2-01 Relate an element's position on the periodic table to its combining capacity (valence). Include: alkali metals, alkaline earth metals, chalcogens, halogens, noble gases GLO: D3, D4, E1

SUGGESTIONS FOR INSTRUCTION

(1 HOUR)

➤ **Notes for Instruction**

A review of atomic structure and Bohr models, as well as the design of the periodic table from Senior 1, may be a starting point for this cluster. A Knowledge chart or Sort and Predict activity may be used (see *SYSTH* 9.25, 10.23).

Bohr diagrams are useful to illustrate the number of electrons found within the valence shells, and to help students visualize how atoms lose, gain, or share electrons to fill their valence shells and become stable.

Introduce electron (Lewis) dot diagrams as an alternative means of representing atoms and their valence electrons. They are valuable tools for describing, predicting, and explaining compound formation. Have students draw electron dot diagrams for the first 20 elements on the periodic table. It is strongly recommended that details of the periodic table not be memorized. However, the characteristics of the periodic table do provide a powerful conceptual and organizational tool.

➤ **Student Learning Activities**

Class Discussion

Examine how the periodic table and Bohr models are used to determine the combining capacity of selected element groups. Have students brainstorm answers to questions such as “Why do elements of the same group have similar properties?” and “What is it about the properties of metals and non-metals that allow one to predict the types of compounds they are likely to form?” Knowing the number of valence electrons will help students predict the formation of compounds.

Visual Displays/Collaborative Teamwork S2-0-2c, 5c

Students or student groups create posters illustrating Bohr models and electron (Lewis) dot diagrams for the first three elements found within the alkali metal, alkaline earth metal, chalcogen, halogen, and noble gas families. The displays can be exhibited in the room for future reference. See Appendix 2.1 for Lewis dot diagrams.

Journal Entry S2-0-7f

Students complete a Word Cycle of terms related to this topic (see *SYSTH* 10.21).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2c, 5c

Students or student groups present their posters. Repetition occurring for the number of valence electrons found within each of the families should be noted.

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- draw Bohr models of atoms when provided with their atomic mass and atomic number
- draw electron (Lewis) dot diagrams of atoms
- predict the number of valence electrons present in an atom from its position on the periodic table
- identify the location of the following families on the periodic table: alkali metals, alkaline earths, chalcogens, halogens, noble gases
- predict whether an atom will lose, gain, or share electrons, based on its position on the periodic table
- explain why atoms lose, gain, or share electrons
- complete a Word Cycle of the following terms: *valence, period, noble gas, periodic table, atom, metals, halogens, atomic number, family* (see *SYSTH* 10.21)

Science 10

5.5 Elements and the Periodic Table

BLM 5.5a Periodic Table of the Elements

Science Power 10

5.1 Looking for Patterns in Chemical Reactivity

BLM 5-2 Periodic Table Scavenger Hunt

BLM 5-3 Anatomy of an Atom

BLM 5-6 Electron Shells

BLM 5-9 Reviewing the Periodic Table of the Elements

SYSTH

9.25 Knowledge Chart

10.21 Word Cycle

10.23 Sort and Predict

13.21 Journal Evaluation

Appendices

2.1 Lewis Dot Diagrams

6.1 Rubric for the Assessment of Class Presentations

Teacher Background

Elements in the same group have similar properties because they have the same number of electrons in their outer shell. The outer electron shell of an atom is also known as the valence shell. The electrons in this shell are called valence electrons.

The arrangement of the valence electrons is key to understanding the formation of compounds. Chemical bonds form when atoms combine with other atoms by transferring or sharing electrons in an attempt to fill their valence electron shells.



PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-2-02 Explain, using the periodic table, how and why elements combine in specific ratios to form compounds. Include: ionic bonds, covalent bonds GLO: D3, E2

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

➤ Entry-Level Knowledge

In Senior 1, students differentiated between elements and compounds, and interpreted chemical formulas of elements and compounds in terms of the number of atoms of each element present.

➤ Notes for Instruction

When discussing the formations of compounds with students, it is important to focus on the “why” before the “how.” Students must have a firm understanding of the reasons why atoms lose/gain/share electrons to obtain a full valence electron arrangement.

Use electron (Lewis) dot diagrams to demonstrate why and how atoms lose or gain electrons to form ions.

Use electron (Lewis) dot diagrams to demonstrate why and how non-metal atoms share electrons.

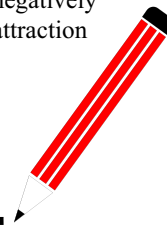
Teacher Background

Only electrons are involved in bond formation, as protons are tightly held in the nuclei of atoms.

Noble gases do not form chemical bonds with other elements due to their full valence shells. They are chemically stable. An atom may acquire a valence shell like that of its closest noble gas in one of three ways: gaining, losing, or sharing electrons.

When a neutral metal atom loses an electron, a positively charged ion forms. When a neutral non-metal atom gains an electron, a negatively charged ion forms. Ionic bonds are a result of the forces of attraction between positive and negative ions.

When electrons are shared between two non-metal atoms, a covalent bond forms. The resulting particle is called a molecule.



(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2a, 5c

Students or student groups present

- posters
- charts
- bulletin board displays
- concept maps
- models

Journal Writing S2-0-2a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- explain why atoms combine in specific ratios to form compounds
- predict whether a compound contains ionic or covalent bonds, given its chemical formula
- explain why the noble gases do not form chemical bonds
- compare and contrast ionic and covalent bonds
- draw Bohr models or electron (Lewis) dot diagrams of compounds with ionic bonds
- give examples of compounds that contain ionic bonds
- draw Bohr models or electron (Lewis) dot diagrams of compounds with covalent bonds
- give examples of compounds that contain covalent bonds
- list the elements found as diatomic molecules
- explain why diatomic molecules are classified as elements and not compounds, even though they contain chemical bonds

Science 10

5.6 How Elements Form Compounds

5.7 Activity: Ionic Charges and Chemical Families

BLM 2.1 Atoms, Elements, and Compounds

BLM 5.7a Ionic Charges and Chemical Families, A

BLM 5.7b Ionic Charges and Chemical Families, B

BLM 5.7c Ionic Charges and Chemical Families, C

Science Power 10

5.1 Looking for Patterns in Chemical Reactivity

5.2 Forming Compounds

Investigation 5-A: Ionic or Covalent—Track Those Electrons

BLM 5-4 Anatomy of an Ion

BLM 5-5 Keeping an ION That Electron

BLM 5-11 Ionic and Covalent Bonding

SYSTH

10.24 Compare and Contrast

13.21 Journal Evaluation

Appendix

Rubric for the Assessment of a Class Presentation

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-2-02 Explain, using the periodic table, how and why elements combine in specific ratios to form compounds.</p> <p>Include: ionic bonds, covalent bonds</p> <p>GLO: D3, E2</p>

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

➤ **Student Learning Activities**

Class Discussion

Illustrate the process by which a neutral sodium atom loses an electron to achieve the same electron arrangement as the noble gas neon.

Illustrate the process by which a neutral chlorine atom gains an electron to achieve the same electron arrangement as the noble gas argon.

Illustrate the process by which a neutral non-metal atom such as carbon shares electrons with another neutral non-metal atom to obtain a full valence shell.

Collaborative Teamwork S2-0-4f

Student groups construct Bohr or electron (Lewis) dot models of a variety of compounds containing ionic and covalent bonds. Examples may include NH_3 (ammonia), CH_4 (methane), H_2O (water), NaCl (sodium chloride), CaF_2 (calcium fluoride), MgS (magnesium sulfide), and Li_2O (lithium oxide). Diatomic molecules such as F_2 , H_2 , and Cl_2 can also be used.

Visual Display S2-0-2a, 5c

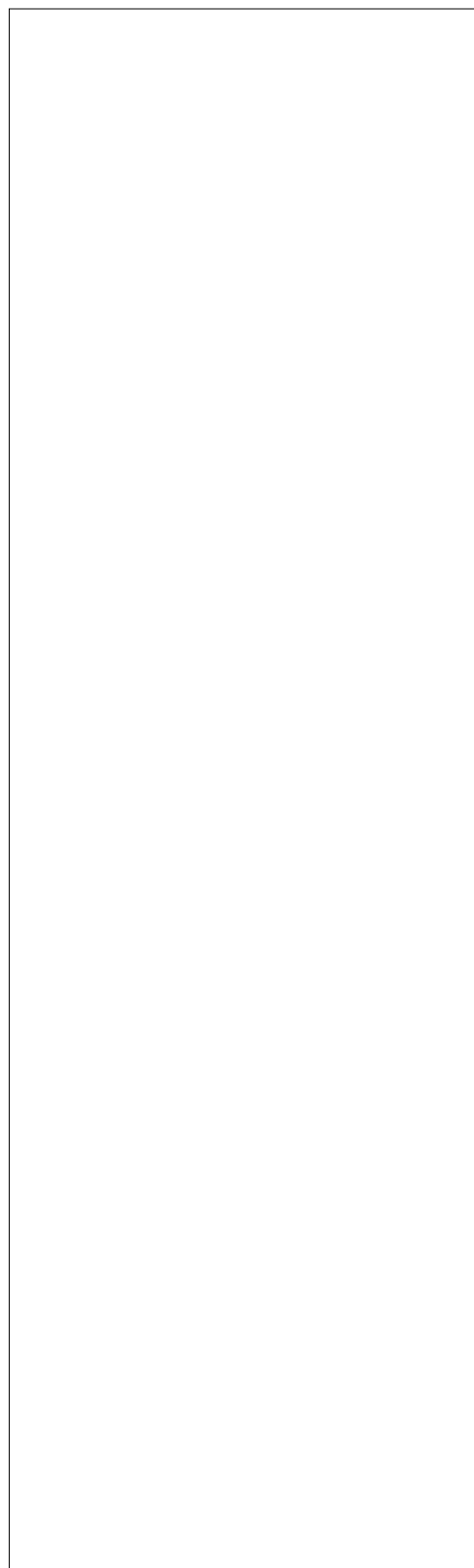
Students or student groups construct visual displays of compounds containing ionic and covalent bonds. Displays may include posters, charts, bulletin boards, concept maps, and models, and can be exhibited in the room for future reference.

Journal Writing S2-0-2a

Students compare and contrast ionic and covalent bonds (see *SYSTH* 10.24).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

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PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (2 HOURS)
<i>Students will...</i>	
<p>S2-2-03 Write formulas and names of binary ionic compounds. Include: IUPAC guidelines and rationale for their use GLO: A2, C2, D3, E1</p>	<p>➤ Entry-Level Knowledge</p> <p>In Senior 1, students examined the relationship among atoms, elements, and compounds. In addition, they interpreted chemical formulas of elements and compounds in terms of the number of atoms of each element.</p> <p>➤ Notes for Instruction</p> <p>Discuss only binary ionic compounds. Students may ask about compounds that contain polyatomic ions (e.g., sodium nitrate, NaNO_3), but these will be examined in Senior 3 Chemistry.</p> <p>Where circumstances are appropriate, treatment of polyatomic ions is encouraged as an extension for interested students. Avoid formal assessment of working with polyatomic ions in formulas. Emphasize the need for a global naming system. Compounds named using IUPAC guidelines name the positive ion first by writing the full name of the metallic element. The non-metal ion is then named by changing the last syllable to “ide.”</p> <p>Use the Stock (Roman numeral) system to name compounds in which the metal ion can have more than one charge. Students may have difficulty determining the Stock system name from a chemical formula. Provide students with plenty of opportunities for practice. See Appendix 2.7: Ionic Compounds (Teacher Support Material).</p> <p>➤ Student Learning Activities</p> <p>Collaborative Teamwork S2-0-4f, 8b</p> <p>Students work in pairs and practise naming binary ionic compounds. Examples: MgO = magnesium oxide, NiCl_3 = nickel (III) chloride, CaBr_2 = calcium bromide</p> <p>Students work in pairs and practise writing chemical formulas for binary ionic compounds. Examples: potassium nitride = K_3N, aluminum fluoride = AlF_3, tin (IV) sulfide = SnS_2</p>

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2a, 5c

Students or student groups present

- posters
- charts
- bulletin board displays
- concept maps

Journal Writing S2-0-2c

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- differentiate between elements and compounds
- interpret chemical formulas in terms of the number of atoms of each element present
- write the name of an ionic compound, given its formula
- write the formula of an ionic compound, given its name
- discuss the importance of the IUPAC system in naming compounds
- explain why the Stock (Roman numeral) system is needed for naming some compounds
- identify metals that, when found in compounds, are likely to require the use of the Stock system in naming

Science 10

5.8 Ionic Compounds

BLM 5.8 Ionic Compounds:
Names and Formulas

Science Power 10

5.3 Chemical Names and Formulas

Investigation 5-C: Writing Names and Formulas of Binary Ionic Compounds

BLM 5-14 Writing Names and Formulas

SYSTH

11.14 Chain Concept Map

13.21 Journal Evaluation

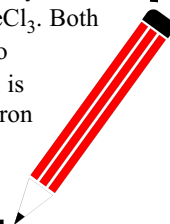
Appendices

2.7 Ionic Compounds

6.1 Rubric for the Assessment of Class Presentations

Teacher Background

The Stock (Roman numeral) system is used only if the metal ion in the compound can have more than one charge. Many transition metals form ions with a variety of charges. For example, iron ions may have a charge of 2+ or 3+, and form the compounds FeCl_2 and FeCl_3 . Both compounds would therefore be named iron oxide. In order to differentiate between the two compounds, a Roman numeral is used to indicate the charge of the metal ion. Thus, FeCl_2 is iron II chloride and FeCl_3 is iron III chloride.



PRESCRIBED LEARNING OUTCOMES

Students will...

(continued)

S2-2-03 Write formulas and names of binary ionic compounds.

Include: IUPAC guidelines and rationale for their use

GLO: A2, C2, D3, E1

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

Visual Display S2-0-2a, 5c

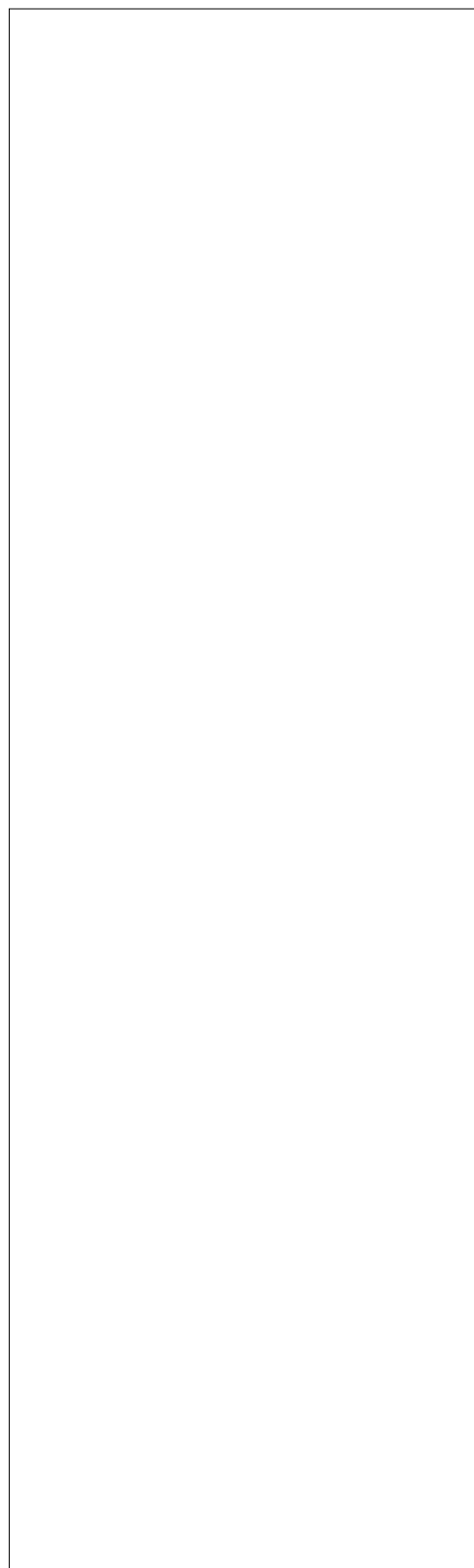
Students or student groups construct visual displays of the names and formulas of ionic compounds. Displays may include posters, charts, bulletin boards, or concept maps, and can be exhibited in the room for future reference.

Journal Writing S2-0-2c

Students prepare Chain Concept Maps outlining the steps used in naming and determining the formulas of ionic compounds (see *SYSTH* 11.14).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

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PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (2 HOURS)
<i>Students will...</i>	
<p>S2-2-04 Write formulas and names of molecular compounds using prefixes.</p> <p>Include: mono, di, tri, tetra</p> <p>GLO: C2, D3, E1</p>	<p>➤ Entry-Level Knowledge</p> <p>In Senior 1, students examined the relationship among atoms, elements, and compounds. In addition, they interpreted chemical formulas of elements and compounds in terms of the number of atoms of each element.</p> <p>➤ Notes for Instruction</p> <p>Binary molecular compounds contain atoms of two non-metals, bonded covalently by sharing electrons.</p> <p>Following IUPAC guidelines, the molecular compounds are named using a prefix system. A Greek prefix is used to indicate the number of each kind of covalently bonded atom in the molecule. Prefixes should be memorized for instant recall. See Appendix 2.8: Molecular Compounds (Teacher Support Material). Encourage the use of prefixes such as “penta” and “hexa” where circumstances permit. Students, however, should not be expected to go beyond hexavalent species.</p> <p>The naming system used for organic compounds such as methane (CH₄) and ethanol (CH₃-CH₂-OH) will be studied in Senior 3 Chemistry.</p> <p>➤ Student Learning Activities</p> <p>Collaborative Teamwork S2-0-4f, 8b</p> <p>Students work in pairs and practise naming binary molecular compounds. Examples: CO = carbon monoxide, SO₂ = sulfur dioxide, PCl₅ = phosphorous pentachloride</p> <p>Students work in pairs and practise writing chemical formulas for binary molecular compounds.</p> <p>Examples: sulfur hexafluoride = SF₆, dinitrogen tetroxide = N₂O₄, nitrogen tribromide = NBr₃</p> <p>Visual Display S2-0-2a, 5c</p> <p>Students or student groups construct visual displays of the names and formulas of ionic compounds. Displays may include posters, charts, bulletin boards, or concept maps, and can be exhibited in the room for future reference.</p> <p>Journal Writing S2-0-2c</p> <p>Students prepare Chain Concept Maps outlining the steps used in naming and determining the formulas of molecular compounds (see <i>SYSTH</i> 11.14).</p>

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2a, 5c

Students or student groups present

- posters
- charts
- bulletin board displays
- concept maps

Journal Writing S2-0-2c

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- differentiate between elements and compounds
- interpret chemical formulas in terms of the number of atoms of each element present
- write the name of a molecular compound, given its formula
- write the formula of a molecular compound, given its name
- discuss the importance of the IUPAC system in naming compounds
- explain why Greek prefixes are needed in naming molecular compounds
- distinguish among the various Greek prefixes used in naming molecular compounds
- predict why diatomic molecules are considered to be elements and not compounds, even though they contain covalent bonds

SUGGESTED LEARNING RESOURCES

Science 10

5.11 Molecular Compounds

BLM 5.11 Molecular Compounds:
Names and Formulas

Science Power 10

5.3 Chemical Names and Formulas

BLM 5-14 Writing Names and
Formulas

SYSTH

11.14 Chain Concept Map

13.21 Journal Evaluation

Appendices

6.1 Rubric for the Assessment of
Class Presentations

2.8 Molecular Compounds

Teacher Background

The Greek prefixes used in naming molecular compounds are:

mono = 1

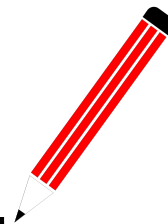
di = 2

tri = 3

tetra = 4

penta = 5

hexa = 6



PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (2 HOURS)
<i>Students will...</i>	
<p>S2-2-05 Investigate the Law of Conservation of Mass and recognize that mass is conserved in chemical reactions.</p> <p>GLO: A2, D3, D4, E3</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 5, students were first introduced to physical and chemical changes and examined them again in Senior 1 Science, along with the indicators of chemical change.</p> <p>➤ Notes for Instruction</p> <p>Activate student knowledge of chemical and physical changes, as well as the indicators of chemical change, with a KWL or Knowledge chart (see <i>SYSTH</i> 9.24, 9.25).</p> <p>A review of science safety procedures and WHMIS is appropriate at this time. Demonstration and laboratory activities may involve dangerous chemicals. Ensure everyone is aware of laboratory safety and chemical disposal procedures, household and workplace hazard symbols, and WHMIS regulations (see <i>Science Safety</i>, Manitoba Education and Training, 1997).</p> <p>Because the Law of Conservation of Mass states that matter is neither created nor destroyed, matter cannot simply appear or disappear. This gives stability to our world. Ask students to speculate how their world would be different if the Law of Conservation of Mass did not exist.</p> <p>➤ Student Learning Activities</p> <p>Laboratory Activity S2-0-3c, 4b, 4c, 4d</p> <p>Students perform a laboratory activity investigating the Law of Conservation of Mass by comparing the mass of reactants to the mass of products. See Appendix 2.5: Law of Conservation of Mass.</p> <p>Visual Display S2-0-4b, 4c, 4d</p> <p>Students or student groups create visual displays of laboratory safety equipment, techniques, and procedures. Examples may include</p> <ul style="list-style-type: none"> • demonstrating correct use of safety goggles • demonstrating correct handling and disposal of broken glass • demonstrating correct and safe operation of a Bunsen burner

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5b, 5c, 6a, 6b

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Visual Display S2-0-4b, 4c, 4d

Students or student groups present their findings of laboratory safety equipment, techniques, and procedures with

- posters
- cartoons
- charts
- multimedia presentations
- brochures
- pamphlets
- dramatic presentations

Journal Writing S2-0-8c, 8e, 9a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Science 10

- 5.1 Chemicals and Chemical Change
- 5.2 Case Study: Hazardous Household Chemicals
- 6.2 Investigation: Measuring Masses in Chemical Changes
- 6.3 Conserving Mass
- 6.4 Finding the Missing Mass
- BLM 5.1c Safety Symbols
- BLM 5.1d Lab Safety Concept Map
- BLM 6.2 Measuring Masses in Chemical Changes

Science Power 10

Investigation 5-E: Comparing the Masses of Reactants and Products

- BLM G-3 Using a Balance
- BLM G-6 Safety Scavenger Hunt
- BLM G-7 Safety Contract
- BLM G-8 Safety Checklist
- BLM G-9 WHMIS Symbols and Hazardous Household Products Symbols

SYSTH

- 9.24 KWL Plus Knowledge Chart
- 13.21 Journal Evaluation
- 13.23 RAFTS
- 14.12 Lab Report Format

Science Safety

(continued)

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-2-05 Investigate the Law of Conservation of Mass and recognize that mass is conserved in chemical reactions.</p> <p>GLO: A2, D3, D4, E3</p>

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

Journal Writing S2-0-8c, 8e, 9a

Have students imagine they are Antoine or Marie-Anne Lavoisier. They have discovered the Law of Conservation of Mass, but one of them has been imprisoned during the French Revolution. They write an appeal to a judge requesting their release. A RAFTS format could be used (see *SYSTH* 13.23).

Collaborative Teamwork S2-0-4c, 4d, 4f

Students design and evaluate a game that teaches WHMIS or consumer labeling. Games should include all necessary playing pieces, instructions, and scoring.

Students play and evaluate each other's games.

Class Discussion S2-0-7f, 9b

The Law of Conservation of Mass has implications far beyond the lab. For example, when a car burns gasoline, the energy produced in the chemical reaction is used to move the car. However, since mass is conserved, the mass of the fuel and oxygen consumed is still present in another form. (The balanced equation is $2 \text{C}_8\text{H}_{18} + 9 \text{O}_2 \rightarrow 16 \text{CO}_2 + 18 \text{H}_2\text{O}$.) Ask students to speculate on the implications of the Law of Conservation of Mass in their daily lives.

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- state the Law of Conservation of Mass
- recognize that mass is conserved in a chemical reaction
- relate the Law of Conservation of Mass to events in their daily lives
- identify WHMIS symbols
- interpret a WHMIS label
- identify and suggest corrections for potentially unsafe laboratory situations

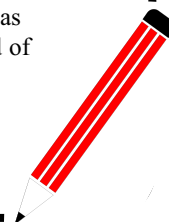
Appendices

- 2.5 Student Learning Activity: Law of Conservation of Mass
- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.4 Lab Report Assessment

Teacher Background

French chemists (and spouses) Antoine and Marie-Anne Lavoisier, conducted many experiments with chemical reactions in the late 18th century. They demonstrated that oxygen is required for combustion to occur. Their belief in the need to make exact measurements during experiments led them to recognize that mass is conserved in chemical reactions.

The Lavoisiers saw the need for change in pre-revolutionary France. Antoine was actively involved in committees proposing legislative, social, economic, and tax reform. Because he was a moderate, Marat and other radicals held him in contempt. He was arrested during the Reign of Terror and imprisoned. When Antoine requested time to complete some scientific work, the judge at his trial is said to have replied, “The Republic has no need of scientists.” Antoine was guillotined in May of 1794. Marie-Anne survived this period of hostility, and later married the American scientist Benjamin Thompson. Thompson endeared himself to the Bavarian scientific establishment, and was awarded the title “Count Rumford.”



PRESCRIBED LEARNING OUTCOMES

Students will...

S2-2-06 Balance chemical equations.

Include: translation of word equations to balanced chemical reactions, and balanced chemical equations to word equations

GLO: C2, D3

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Notes for Instruction**

Introduce the learning outcome by first modeling the balancing of skeleton equations. The terms *reactant*, *product*, *subscript*, and *coefficient* should be clarified. Provide students with opportunities for practice and feedback. As students progress, discuss physical state symbols and translation of word and chemical equations.

The translation of chemical equations into word equations (and vice versa) requires students to use their prior knowledge from learning outcomes S2-2-03 and S2-2-04. Remind students of this, and provide them with opportunities for practice and feedback. Ensure that physical state symbols (i.e., (s), (aq), (g)) are adequately explained to students.

➤ **Student Learning Activities**

Collaborative Teamwork S2-0-4f, 6a 6b

Students work in groups to balance skeleton equations. They should verify that chemical equations have been correctly balanced and, if not, identify where errors were made.

Students work in groups to translate equations and balance reactions. They should verify that chemical equations have been correctly translated and balanced and, if not, identify where errors were made. See Appendix 2.4: Balancing Chemical Equations.

Visual Display S2-0-2c, 4e

Students prepare models representing the process of balancing chemical equations. Bingo chips or candies of different colours could be used to represent the different atoms. Students should also write the balanced chemical reactions on their display.

Journal Writing S2-0-2c, 8b

Students create a glossary of new words for quick reference. A Three-Point Approach could be used (see *SYSTH* 10.22).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display/Performance Assessment S2-0-2c, 4e

Students present their models of chemical reactions, including the balanced chemical equation.

Journal Writing S2-0-2c, 8b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- explain the relationship between balancing equations and the Law of Conservation of Mass
- differentiate between subscripts and coefficients
- balance skeleton equations by adding coefficients
- identify the physical state symbols used in chemical equations
- verify that chemical equations have been correctly balanced and, if not, identify where errors were made
- differentiate between reactants and products
- relate the conservation of mass to the conservation of atoms in chemical reactions
- translate word equations into balanced chemical reactions
- translate balanced chemical reactions into word equations
- verify that chemical equations and reactions have been correctly balanced and translated and, if not, identify where errors have been made

Science 10

- 6.1 Word Equations
- 6.5 Balancing Chemical Equations
 - BLM 6.5a How to Count Atoms Review
 - BLM 6.5b Counting Atoms
 - BLM 6.5c Balancing Equations

Science Power 10

- 5.4 Chemical Equations And Chemical Reactions
 - BLM 5-18 Chemical Equations and Their Parts
 - BLM 5-19 Balancing Chemical Equations
 - BLM 5-20 Chemical Equations

SYSTH

- 10.22 Three-Point Approach
- 13.21 Journal Evaluation

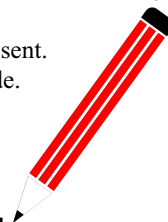
Appendices

- 2.4 Student Learning Activity: Balancing Chemical Equations
- 6.1 Rubric for the Assessment of Class Presentations

Teacher Background

Equations are balanced using four basic steps:

1. Count the number of atoms of each element on each side of the arrow.
2. Never change subscripts. This changes the substances present. For example, H_2O is water and H_2O_2 is hydrogen peroxide.
3. Change only the coefficients.
4. Use trial and error.



PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (3 HOURS)
<i>Students will...</i>	
<p>S2-2-07 Investigate and classify chemical reactions as synthesis, decomposition, single displacement, double displacement, or combustion. GLO: D3, D4, E3</p>	<p>➤ Entry-Level Knowledge</p> <p>In Senior 1, students experimented to determine the indicators of chemical change, such as colour change, production or absorption of heat and/or light, and production of gas or precipitate.</p> <p>➤ Notes for Instruction</p> <p>Include demonstrations and/or lab activities to address this learning outcome. Students can only classify reactions when provided with both the reactants and the products. For example, given $\text{Mg} + \text{O}_2 \rightarrow \text{MgO}$, a student should identify this as a synthesis reaction.</p> <p>Demonstration and laboratory activities may involve dangerous chemicals. Ensure everyone is aware of laboratory safety and chemical disposal procedures, household and workplace hazard symbols, and WHMIS regulations (see <i>Science Safety</i>, Manitoba Education and Training, 1997).</p> <p>➤ Student Learning Activities</p> <p>Laboratory Activity/Teacher Demonstration S2-0-3a, 4b, 4c, 4d</p> <p>Perform experiments that demonstrate the five types of chemical reactions. Some examples are</p> <ul style="list-style-type: none"> • Synthesis <ul style="list-style-type: none"> — Add powdered zinc to powdered sulfur in equal amounts (in fume hood). Burn magnesium in the blue flame of a Bunsen burner. • Decomposition <ul style="list-style-type: none"> — Break water down into oxygen and hydrogen with electrolysis. Heat copper sulfate pentahydrate. • Single displacement <ul style="list-style-type: none"> — Place aluminum foil in a solution of iron (III) nitrate, or place a copper wire in a silver nitrate solution. • Double displacement <ul style="list-style-type: none"> — Add potassium iodide solution to lead (II) nitrate solution. Add sodium hydroxide solution to copper sulfate or copper chloride solution. • Combustion <ul style="list-style-type: none"> — Burn a candle or light a Bunsen burner. Strike a match. <p>See Appendix 2.6: Experiment: Reaction Types.</p>

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5c, 6a, 6b, 7a

Students interpret their laboratory results, and prepare a report of their findings (see *SYSTH* 14.12 for report format). Word-processing software and spreadsheets can be used for report writing.

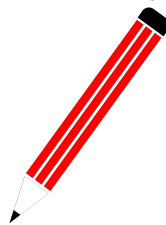
Performance Assessment S2-0-4b, 4c

Students demonstrate their ability to follow science safety procedures or interpret a WHMIS label.

Teacher Background

There are many methods for classifying chemical reactions, and some reactions may be a combination of more than one type. The five types to be examined in this learning outcome are

1. Synthesis (combination)
two or more elements or compounds \rightarrow compound
(i.e., $A + B \rightarrow AB$)
2. Decomposition
compound \rightarrow two or more elements or compounds
(i.e., $AB \rightarrow A + B$)
3. Single displacement (replacement)
element + compound \rightarrow element + compound
(i.e., $A + BC \rightarrow B + AC$)
4. Double displacement (replacement)
compound + compound \rightarrow compound + compound
(i.e., $AC + BD \rightarrow AD + BC$)
5. Combustion
hydrocarbon + oxygen \rightarrow carbon dioxide + water



(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 6.6 Combustion
- 6.7 Types of Chemical Reactions: Synthesis and Decomposition
- 6.8 Investigation: Putting Things Together
- 6.9 Investigation: Taking Things Apart
- 6.10 Types of Chemical Reactions: Single and Double Displacement
- 6.11 Investigation: Single Displacement Reactions
- 6.12 Investigation: Double Displacement Reactions
- 6.13 Activity: Putting It All Together
- BLM 6.8 Putting Things Together
- BLM 6.9 Taking Things Apart
- BLM 6.11 Single Displacement Reactions
- BLM 6.12 Double Displacement Reactions
- BLM 6.13 Types of Chemical Reactions

Science Power 10

- 6.2 Synthesis and Decomposition Reactions
- 6.3 Single Displacement and Double Displacement Reactions
- Investigation 6-C: Putting It Together: Classifying Chemical Reactions
- 6.4 Reaction Involving Carbon Compounds
- BLM 6-8 Single and Double Displacement Reactions

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<i>(continued)</i>
S2-2-07 Investigate and classify chemical reactions as synthesis, decomposition, single displacement, double displacement, or combustion. GLO: D3, D4, E3

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

Visual Display/Collaborative Teamwork S2-0-2a, 2c, 4f, 4g

Student groups construct visual displays to illustrate the five types of chemical reactions.

Class Discussion S2-0-7f

Discuss the five types of chemical reactions. Students should brainstorm examples from daily life, such as burning gasoline (combustion), digesting food (decomposition), iron rusting (synthesis), water softeners (double displacement), and copper bracelets that turn skin green (single displacement).

Journal Writing S2-0-2c, 8b

Students complete a Three-Point Approach to summarize the different types of chemical reactions (see *SYSTH* 10.22).

SUGGESTIONS FOR ASSESSMENT

Visual Display S2-0-5c, 8b, 9b

Student groups present their findings of the various types of chemical reactions with

- posters
- diagrams
- bulletin boards
- charts
- concept maps

Journal Writing S2-0-2c, 8b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- list the indicators of chemical change
- classify chemical reactions as synthesis, decomposition, single displacement, double displacement, or combustion
- list examples of the five types of chemical reactions
- discuss everyday uses of the five types of chemical reactions
- identify WHMIS symbols
- interpret a WHMIS label
- identify and suggest corrections for potentially unsafe laboratory situations

SUGGESTED LEARNING RESOURCES

BLM 6-11 Putting It Together:
Classifying Chemical
Reactions

SYSTH

10.22 Three-Point Approach

13.21 Journal Evaluation

14.12 Lab Report

Science Safety**Appendices**

2.4 Balancing Chemical Equations

2.6 Experiment: Reaction Types

6.1 Rubric for the Assessment of
Class Presentations

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-2-08 Experiment to classify acids and bases using their characteristic properties.</p> <p>Include: indicators, pH, reactivity with metals</p> <p>GLO: D3, E1</p>

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

➤ **Notes for Instruction**

Activate student knowledge about the topic and note any misconceptions; focus on the correct use of terminology in science. Introduce the pH scale as a method of representing the acidity or alkalinity of a solution. Students have not been introduced to ions, so avoid a discussion of hydrogen and hydroxide ions, or $\text{pH} = -\log[\text{H}_3\text{O}^2]$.

Introduce students to the names and formulas of common acids and bases, such as

- Hydrochloric acid: HCl
- Sulfuric acid: H_2SO_4
- Nitric acid: HNO_3
- Sodium hydroxide: NaOH
- Calcium hydroxide: $\text{Ca}(\text{OH})_2$
- Ammonium hydroxide: NH_4OH

Include demonstrations and/or lab activities to address this learning outcome. Take appropriate safety precautions when handling acids and bases, and reinforce WHMIS regulations.

➤ **Student Learning Activities**

Class Discussion S2-0-7f, 8b, 9b

Write the term “ACID” on the chalkboard, ask students to brainstorm, and write down what comes to mind when they see the word. A Rotational Cooperative Graffiti format could be used (see *SYSTH* 3.15).

Teacher Background

Indicators are substances whose colour varies, depending on the pH of a solution. For example, phenolphthalein is colourless in solutions with a pH below 8, and pink in solutions with a pH of above 10. Bromthymol Blue is yellow when the pH of a solution is below 6, green at a pH of 7, and blue above a pH of 8. Universal Indicator is a solution containing several indicators and can also be found in pH test strips.

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Performance Assessment S2-0-4a, 4b, 4d, 5a

Students test unknown solutions and identify them as acids or bases, based on their characteristic properties.

Students demonstrate safe handling and disposal of acids and bases in the lab.

Laboratory Report S2-0-6a, 6b, 7a, 7b

Students interpret their laboratory results and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Journal Writing S2-0-2c

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

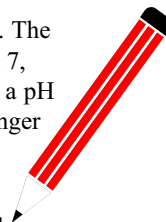
Pencil-and-Paper Tasks

Students

- identify the names and formulas of common acids and bases
- describe the pH scale
- predict if a substance is an acid or base, based on characteristic properties
- compare and contrast the properties of acids and bases (see *SYSTH* 10.24, 11.21)
- identify the acid/base colours of common indicators
- describe safe handling and disposal of acids and bases in the lab
- differentiate between strong acids and weak acids, and strong bases and weak bases, in terms of their pH

Teacher Background

The pH scale measures the acidity or alkalinity of a solution. The scale ranges between 0 and 14. Acids have a pH of less than 7, bases have a pH of greater than 7, and a neutral solution has a pH equal to 7. The stronger the acid, the lower the pH. The stronger the base, the higher the pH.



SUGGESTED LEARNING RESOURCES

Science 10

- 8.1 Investigation: Recognizing Acids and Bases
- 8.2 Properties of Acids and Bases
- 8.3 The pH Scale
- BLM 2.7a The pH Scale
- BLM 8.1 Natural Acid/Base Indicators: How They Work
- BLM 8.2 Different Kinds of Acids and Bases
- BLM 8.5 Making Acids and Bases

Science Power 10

- 7.1 Common Acids and Bases
Investigation 7-A: Acid or Base?
- 7.2 pH: A Powerful Scale
- 7.3 The Properties of Acids and Bases
Investigation 7-D: Chemical Properties of Acids
- BLM 7-1 Making a “Chemystery” Message
- BLM 7-2 A Matter of Taste
- BLM 7-3 Acid or Base Pre-Test
- BLM 7-6 Identifying Acids and Bases in Chemical Equations
- BLM 7-7 Know Your Indicators
- BLM 7-8 Identifying Acids and Bases
- BLM 7-9 pH Scale
- BLM 7-10 The pH of Common Acids and Bases
- BLM 7-18 Measuring the pH of Water Samples

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-2-08 Experiment to classify acids and bases using their characteristic properties.</p> <p>Include: indicators, pH, reactivity with metals</p> <p>GLO: D3, E1</p>

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

Laboratory Activity S2-0-3a, 4a, 4b, 9c

Students experiment to identify substances as acids or bases using their characteristic physical and chemical properties. See Appendix 2.3: Experiment: Properties of Acids and Bases.

Journal Writing S2-0-2c

Students compare and contrast the characteristic properties of acids and bases. A Compare and Contrast or Concept Relationship frame may be used (see *SYSTH* 10.24, 11.21).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

SYSTH

- 3.15 Rotational Cooperative
Graffiti
- 10.24 Compare and Contrast
- 11.21 Concept Relationship
- 13.21 Journal Evaluation
- 14.12 Lab Report

Appendices

- 2.3 Experiment: Acids and Bases
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-2-09 Discuss the occurrence of acids and bases in biological systems, industrial processes, and domestic applications. Include: safety and health considerations GLO: B2, B3, C1, C8

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Notes for Instruction**

There are many examples that can be used to illustrate systems, processes, and applications of acid/base chemistry, but the reactions are often quite complex. Limit the discussion to the occurrence and role of acids and bases in various settings.

➤ **Student Learning Activities**

Laboratory Activity S2-0-1a, 3c, 4b, 4d

Students investigate the occurrence and role of acids and bases. Possible laboratory activities may include

- testing the effectiveness of antacids
- preparing soap
- determining the pH of household products

Student Research S2-0-1b, 2b, 4d, 8g

Students or student groups research the occurrence of acids and bases in biological systems, industrial processes, and domestic applications. Examples may include

- antacids
- detergents
- citrus fruits
- household cleaning products
- industrial catalysts
- digestion of food
- fertilizers
- baking powder
- construction (mortar, plaster)

Safety and health considerations should be included.

Case studies, current newspaper articles, and Internet sources can be used.

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5c, 6a, 7a, 7b

Students interpret their laboratory results and prepare a report of their investigation findings (see *SYSTH* for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Research Report/Presentation S2-0-2c, 4c, 8e, 9a

Students or student groups prepare and present their research of the occurrence of acids and bases with

- written reports
- oral presentations
- multimedia presentations
- newspaper articles
- dramatic presentations
- brochures
- pamphlets

Teacher Background

Examples of acids and bases in biological systems include

- stomach acid (hydrochloric acid)
- bee and wasp stings (formic acid)
- pancreatic fluid (includes sodium bicarbonate)
- citrus fruit (citric acid)

Examples of acids and bases in industrial processes include

- explosives (nitric acid)
- fertilizers (ammonia)
- glass etching (hydrofluoric acid)
- speeding up industrial chemical reactions (sulfuric acid)

Examples of acids and bases in domestic applications include:

- window cleaner (ammonia)
- drain cleaner (sodium hydroxide)
- antacids (calcium hydroxide)
- pickles (acetic acid)



(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 8.4 Investigation: Household Products and pH
- 8.11 Investigation: Testing Antacids
- 8.12 Case Study: Putting It All Together: Acids and Bases in Industry
- BLM 8.4a pH of Household Products
- ABLM 8.2 WHMIS Symbols for Acids and Bases
- ABLM 8.4 Investigating Household Products and pH

Science Power 10

- 8.2 Chemicals for Consumers
- Investigation 8-C: Testing the Effectiveness of Antacids
- BLM 7-15 Daily Applications of Acids, Bases, and Salts
- BLM 7-17 Swimming-Pool Chemistry
- BLM 8-6 Analyzing Antacids
- BLM 8-7 Testing the Effectiveness of Antacids
- BLM 8-8 Antacid Calculations
- BLM 8-9 Water, Soaps, and Detergents
- BLM 8-10 Comparing Soaps and Detergents
- BLM 8-20 Uses of Sulfuric Acid in Industry

SYSTH

- 3.20 Jigsaw
- 13.21 Journal Evaluation
- 14.12 Lab Report Format

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-2-09 Discuss the occurrence of acids and bases in biological systems, industrial processes, and domestic applications.</p> <p>Include: safety and health considerations</p> <p>GLO: B2, B3, C1, C8</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

Visual Display S2-0-1d, 2c, 4c, 4f

Student groups construct visual displays of acids and bases in their homes. Health and safety considerations should be included. Examples may include

- baking soda
- soap
- vinegar
- window cleaner
- pickles
- swimming pool chemicals (muriatic acid)

Collaborative Teamwork S2-0-1c, 2a, 9b, 9c

Various student groups investigate examples of the occurrence of acids and bases, and share their findings with their classmates in a Jigsaw format (see *SYSTH* 3.20).

Journal Writing S2-0-7f

Students reflect on and respond to the following questions:

- How has your understanding of acids and bases changed since the start of the cluster?
- What new questions do you have about acids and bases?
- What new information in this cluster surprised you?

SUGGESTIONS FOR ASSESSMENT**Visual Display S2-0-5c, 8f, 9b, 9f**

Student groups present visual displays of acids and bases used in their homes. Displays may take the form of

- posters
- bulletin board presentations
- dioramas
- charts

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- identify WHMIS symbols for acids and bases
- explain why antacids are used to treat heartburn
- differentiate between soap and detergent
- discuss the role of sulfuric acid as a catalyst in industry
- explain why citrus fruits and pickles taste sour
- discuss why acids are always added to water when preparing solutions as a safety precaution
- describe the function of baking soda in baking
- identify basic cleaning products used in the home
- suggest safe storage tips for household cleaning products
- explain why one should always wash one's hands after using products such as drain cleaner or bleach
- describe first-aid treatment for accidental ingestion of cleaning products

SUGGESTED LEARNING RESOURCES**Appendices**

- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-2-10 Explain how acids and bases interact to form a salt and water in the process of neutralization.</p> <p>GLO: D3, E2</p>

SUGGESTIONS FOR INSTRUCTION

(1 HOUR)

➤ **Notes for Instruction**

Activate student knowledge and note misconceptions. Students will have heard the terms *neutralize*, *salt*, and *neutralization*, but may not be aware of the scientific use of the terms.

Discuss neutralization as a double displacement reaction producing a salt and water. Use halogen acids (e.g., hydrochloric acid) and alkali metal bases (e.g., sodium hydroxide) as examples.

For example, $\text{HCl} + \text{NaOH} \rightarrow \text{H}_2\text{O} + \text{NaCl}$.

Bronsted-Lowry and related advanced definitions of acid-base relationships should be expressly avoided in Senior 2. These aspects will be addressed in detail in Senior Years chemistry courses.

➤ **Student Learning Activities**

Laboratory Activity/Teacher Demonstration

S2-0-1a, 3a, 4a, 4d

Pose the question, “What happens when an acid and a base are mixed together?”

Add a few drops of universal indicator to an acid solution and to a base solution. Students observe the different indicator colours and therefore different pHs of the two solutions.

Add acid solution drop by drop to the base solution until the neutral point is reached. Students observe colour changes the base solution undergoes as it approaches the neutral point.

Repeat the procedure adding base solution drop by drop to the acid solution. Ask students to suggest an explanation for the observed colour changes. CBLs or MBLs equipped with pH metre and real-time graphing software can also be used.

Journal Writing S2-0-2c, 8b

Students complete a Word Cycle of the following acid-base related terms: *salt*, *pH*, *acid*, *neutralization*, *indicator*, *base*, *water*, *neutral*, and *reaction* (see SYSTH 10.21).

Collaborative Teamwork S2-0-4f

Student groups balance acid-base neutralization reactions.

Complex reactions such as $\text{H}_2\text{SO}_4 + \text{Al}(\text{OH})_3 \rightarrow \text{H}_2\text{O} + \text{Al}_2(\text{SO}_4)_3$ should be avoided.

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-4b, 6a, 7a,

Students interpret their laboratory results and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Journal Writing S2-0-2c, 8b

Assess journal entries with a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- define the terms *neutralization* and *salt*
- write balanced chemical equations for neutralization reactions
- explain why a salt and water form in a neutralization reaction
- discuss why a neutralization reaction is classified as a double displacement reaction
- complete a Word Cycle of the following terms: *salt*, *pH*, *acid*, *neutralization*, *indicator*, *base*, *water*, *neutral*, and *reaction* (see *SYSTH* 10.21)
- explain the importance of using precise language in science

SUGGESTED LEARNING RESOURCES

Science 10

8.9 Investigation: Reacting Acids and Bases

8.10 Neutralization Reactions

Science Power 10

7.4 Neutralization Reactions

Investigation 7-E: Drop-by-Drop Neutralization

BLM 7-5 Cracking the Chemistry Code

SYSTH

10.21 Word Cycle

13.21 Journal Evaluation

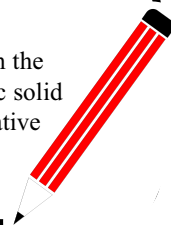
14.12 Lab Report

Appendix

6.4 Lab Report Assessment

Teacher Background

Salt is commonly thought of as sodium chloride or NaCl. In the language of chemistry, however, a salt is defined as an ionic solid consisting of a positive ion other than hydrogen, and a negative ion other than hydroxide.



PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-2-11 Describe the formation and environmental impact of various forms of air pollution.</p> <p><i>Examples: acid precipitation, ground-level ozone, air-borne particulates, smog, ozone depletion, respiratory ailments, and acidified lakes...</i></p> <p>GLO: B5, C6, D2, D5</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students explained how human health may be affected by natural- and human-caused environmental factors. In Grade 7, students examined the potential harmful effects of some substances on the environment. In Grade 8, the hydrological cycle and water pollution were studied. Students will have heard the terms *acid rain*, *smog*, and *ozone*.

➤ **Notes for Instruction**

A Listen-Draw-Pair-Share or KWL activity can be used to activate prior knowledge of the learning outcome (see *SYSTH* 9.15, 9.25). Take advantage of current information available in print and electronic media. Environment Canada’s Science and the Environment Bulletin <www.ec.gc.ca/science/splash.htm>, Envirozine <www.ec.gc.ca/envirozine/english/home_e.cfm>, and Meteorological Services, <www.msc-smc.ec.gc.ca/contents_e.html> contain up-to-date information.

While the term acid rain is most frequently used, acidic precipitation can also occur in the form of snow or sleet. Use chemical equations to illustrate the formation of acid rain. Distinguish between normal rain (pH of 5.5–6.2) and acid rain (pH < 5.0).

Distinguish between harmful ground-level ozone, which damages plants, lungs, and materials such as rubber and paint, and beneficial upper-level (stratosphere) ozone, which provides protection from ultraviolet radiation.

Describe how smog is produced, and explain why it tends to be a problem in summer, rather than in the winter. Explain that air-borne particulates can come from a variety of sources such as dust, pollen, smoke, and industrial and automobile emissions.

➤ **Student Learning Activities**

Visual Display/Collaborative Teamwork S2-0-1c, 2a, 4f, 4g

Student groups create displays illustrating the formation of various forms of air pollution. Some examples may include

- acid precipitation
- ground-level ozone
- smog

Case studies, newspaper articles, and Internet sources can be used.

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2b, 8a, 9b, 9c

Student groups present visual displays of various forms of air pollution with

- posters
- bulletin board presentations
- charts
- cartoons
- dioramas

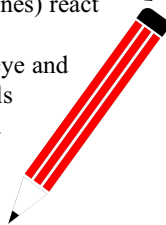
Laboratory Report S2-0-5a, 6a, 7a, 7b

Students interpret their results and prepare reports of their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Teacher Background

The burning of coal in electric power plants is a major source of sulfur oxide emissions. The sulfur oxides combine with water in the atmosphere and form sulfuric and sulfurous acid. Automobile engines are a major source of nitrogen oxide emissions. The nitrogen oxides combine with water in the atmosphere and form nitric and nitrous acids.

Photochemical smog continues to be a growing problem in both developed and developing nations. Smog forms when nitrogen oxides and unburned hydrocarbons (primarily from automobile engines) react in the presence of UV light to form ozone and toxic organic compounds (including PAN). The brownish haze can cause eye and lung irritation, damage or kill plants, and deteriorate materials such as rubber, paint, and nylon. The term “smog” is derived from the words *smoke* and *fog*.



(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 3.11 Acid Deposition and Forest Ecosystems
- 3.12 Investigation: Assessing the Effects of Acid Rain
- 6.14 Explore an Issue: Is Pollution Necessary?
- 7.8 Debate: The Sale and Use of Cars Should Be Restricted
- 8.7 Case Study: Air Pollution and Acid Precipitation
- 8.8 Investigation: Acid Precipitation and Buildings

Unit 2 Challenge: Chemical Processes and Society

- 16.2 The Greenhouse Effect and Ozone Depletion
- 16.4 Observing Pollution
- BLM 3.11 Formation of Acid Rain
- ABLM 3.11 KWL-Acid Precipitation
- ABLM 3.12 The Effects of Acid Rain
- ABLM 7.8 Restricting the Production of New Cars
- ABLM 16.5 Smog Alert!

Science Power 10

- Investigation 2-D: An Acid Test
- 8.3 Chemicals and our Environment
- Unit 2 Issue Analysis: Not in My Backyard Acid Precipitation Resource
- 16.5 Past, Present, and Future
- BLM 2-14 An Acid Test
- BLM 4-3 Environments in Distress
- BLM 8-11 Acid Rain and Its Effects

(continued)

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (3 HOURS)
<p><i>Students will...</i></p> <p><i>(continued)</i></p> <p>S2-2-11 Describe the formation and environmental impact of various forms of air pollution.</p> <p><i>Examples: acid precipitation, ground-level ozone, air-borne particulates, smog, ozone depletion, respiratory ailments, and acidified lakes...</i></p> <p>GLO: B5, C6, D2, D5</p>	<p>Laboratory Activity S2-0-1b, 3c, 4a, 4b</p> <p>Students experiment to determine the impact(s) of acid precipitation on</p> <ul style="list-style-type: none">• germinating seedlings• marble monuments• limestone buildings• growth of yeast populations <p>Student Research S2-0-1d, 2b, 8g, 9e</p> <p>Students or student groups research ways various forms of air pollution affect the environment, explaining the impact of</p> <ul style="list-style-type: none">• acid rain on stone buildings and monuments• air-borne particulates on the human respiratory system (e.g., asthma)• ground-level ozone on plants• ultraviolet radiation on human skin <p>Case studies, newspaper articles, and Internet sources can be used.</p> <p>Journal Writing S2-0-2d, 3d, 6d, 7d</p> <p>Students complete a creative writing assignment using a RAFTS format. They may be presented with scenarios such as the following:</p> <ul style="list-style-type: none">• As a fish, write an editorial in <i>The Aquatic Times</i>, complaining about acid rain to the other lake residents.• As a tree, write a letter to the editor of a newspaper, raising your concerns about air quality.

SUGGESTIONS FOR ASSESSMENT

Research Report/Presentation S2-0-8a, 8c, 8g, 9e

Students or student groups prepare and present their research findings with

- written reports
- oral presentations
- brochures
- pamphlets
- newspaper articles
- multimedia presentations

Journal Writing S2-0-7e, 9d, 9e, 9f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- write balanced chemical equations for the formation of acid rain
- distinguish normal rain from acid rain in terms of pH
- identify sources of sulfur oxide and nitrogen oxide emissions
- describe the effects of acid rain on lakes
- predict the economic impact of acid rain on the tourism industry
- describe the formation of smog
- suggest reasons why vigorous outdoor exercise is not advisable during a smog alert
- differentiate between ground-level ozone and upper-level ozone
- discuss the impact of CFCs on upper-level ozone
- describe the UV Index
- explain how sunscreens protect skin against UV radiation
- identify sources of air-borne particulates
- explain why people with respiratory ailments may be especially sensitive to air-borne particulates
- write balanced chemical equations for the combustion of fossil fuels such as methane (CH_4), gasoline (C_8H_{18}), and alcohols such as ethanol ($\text{CH}_3\text{CH}_2\text{OH}$)

SUGGESTED LEARNING RESOURCES

BLM 8-12 The Effects of Sulfur and Nitrogen Oxides

BLM 16-9 The Ozone Layer

BLM 16-10 CFCs: For or Against?

SYSTH

9.15 Listen-Draw-Pair-Share

9.17 KWL Plus

13.21 Journal Evaluation

13.22 RAFTS

14.12 Lab Report Format

Appendices

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

6.4 Lab Report Assessment

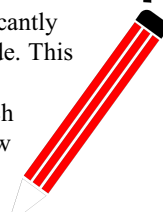
PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-2-12 Investigate technologies that are used to reduce emissions of potential air pollutants.</p> <p><i>Examples: catalytic converters in automobiles, regulation of vehicle emissions, elimination of CFCs from refrigerants and aerosol propellants...</i></p> <p>GLO: A5, B5, C8, E2</p>

SUGGESTIONS FOR INSTRUCTION
(3 HOURS)

- **Entry-Level Knowledge**
In Grade 8, students identified ways of reducing or eliminating the effects of water pollution.
- **Notes for Instruction**
A Listen-Draw-Pair-Share or KWL activity can be used to activate prior knowledge of the learning outcome (see *SYSTH* 9.15, 9.25). Take advantage of current information in print and electronic publications. Be sure to include the perspectives of various stakeholders in an exploration of the issues.
- **Student Learning Activities**
 - Student Research S2-0-1c, 2d, 8d, 9e**
Students or student groups investigate technologies that could be used to reduce emissions of potential air pollutants. Examples include
 - using catalytic converters in automobiles
 - burning low-sulfur coal in power plants
 - mandatory emissions testing of all cars and trucks
 - alternatives to using CFCs in refrigerators and air conditioners
 Case studies, newspaper articles, and Internet sources may be used.
 - Debate S2-0-1c, 2d, 3d, 3e**
Older models of cars and trucks are responsible for the greatest per capita amount of automobile exhaust pollutants being released into the atmosphere. Students debate whether older vehicles should undergo emissions testing, and whether those that fail should be removed from the road.
 - Visual Display/Collaborative Teamwork S2-0-1b, 4g, 8c, 8d**
Student groups create visual displays illustrating technologies that could be used to reduce emissions of potential air pollutants. Examples include
 - scrubbing of waste gases in smokestacks
 - alternatives to using CFCs in aerosol propellants
 - using gasohol as fuel in automobile engines

Teacher Background

Tougher standards in North America have reduced emissions of acid-rain-forming compounds. As a result, acid rain has significantly decreased in the past decade. This is not the case in many developing nations in which emissions standards are low or non-existent.



SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Journal Writing S2-0-2d, 3f, 7d, 7e,

Discuss the outcome of the debate. Ask students to summarize the arguments presented by both teams and to reflect on any new information they gained from the debate in their journals. Assess journal entries with a Journal Evaluation form (see *SYSTH* 13.21).

Visual Display S2-0-9b, 9c, 9d

Student groups present visual displays illustrating technologies that could be used to reduce emissions of potential air pollutants with

- posters
- bulletin board presentations
- dioramas
- models
- charts

Pencil-and-Paper Tasks

Students

- suggest ways they can change their transportation habits to reduce automobile emissions
- discuss technologies that could be used to reduce oxides of sulfur emissions
- describe the purpose and structure of a catalytic converter
- explain the significance of the Montreal Protocol
- formulate a rationale for the removal of sulfur from hydrocarbon fuels
- differentiate between gasoline and gasohol

Research Report/Presentation S2-0-7a, 7b, 8g, 9e

Students and student groups present

- written reports
- oral presentations
- brochures
- pamphlets
- multimedia presentations

SUGGESTED LEARNING RESOURCES

Science 10

6.14 Explore an Issue: Is Pollution Necessary?

7.8 Rates and Automobiles

8.7 Case Study: Air Pollution and Acid Precipitation

Unit 2 Challenge: Chemical Processes and Society

16.2 The Greenhouse Effect and Ozone Depletion

BLM 3.12b Sudbury: A Reclamation Success Story

BLM 7.8 Catalytic Converters—Reduce Automobile Pollution, But...

Science Power 10

8.3 Chemicals and our Environment

Unit 2 Issue Analysis: Not in My Backyard Acid Precipitation Resource

16.4 Past, Present, and Future

BLM G-29 Scientific Research Planner

BLM G-30 Research Worksheet

BLM G-31 Internet Research Tips

SYSTH

9.15 Listen-Draw-Pair-Share

9.17 KWL Plus

13.21 Journal Evaluation

Appendices

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

NOTES

Senior 2

Cluster 3: In Motion

Overview

In order to develop an understanding of the physics of motion, the outcomes of this cluster are examined within the context of the automobile. The relationships among displacement, velocity, acceleration, and time are analyzed in conceptual, numerical, graphical, and symbolic modes. Students investigate the qualitative aspects of inertia, force, impulse, and momentum as they relate to automobile safety. The conservation of energy in car collisions and braking distance is explored. Using the knowledge they have gained, students use the decision-making process to address an STSE issue related to safe driving conditions.

In order to assist students in achieving the specific learning outcomes of this cluster, references to *In Motion: A Learning Resource for Students* are included in the Suggested Learning Resources column for this cluster. In addition, important teacher background information, helpful suggestions for implementation, and complete solutions to problem sets are found in Appendix 7—In Motion: Teacher Resource Guide. This resource material is also available online at the Curriculum Documents links of Manitoba Education and Youth's website at <http://www2.edu.gov.mb.ca/ks4/cur/science/default.asp>.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-01 Analyze the relationship among displacement, time, and velocity for an object in uniform motion.</p> <p>Include: visual, numeric, graphical, symbolic (velocity = Dd/Dt)</p> <p>GLO: C5, C8, D4, E3</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Notes for Instruction**

Encourage the discussion of everyday language relating to acts of motion, such as speeding up, getting faster, bashing, and cushioning. Use this as an opportunity to bridge words used in everyday language with scientific terms like *acceleration*, *momentum*, et cetera. A formal mathematical approach is not required in the course. However, there are many opportunities for teachers to make math connections with students' prior experiences in Senior 1 and Senior 2 mathematics, particularly, Applied Mathematics (20S). Equations derived from a graphical analysis should be modeled in terms of their behaviour with respect to their proportions (i.e., increasing and decreasing at constant or exponential rates).

Students will often mix up Position-Time graphs with Velocity-Time graphs, and velocity with acceleration. Care must be taken when interpreting graphs to differentiate between these terms.

➤ **Student Learning Activities**

Laboratory Activity S2-0-31, 3b, 4a, 4e

Students or student groups investigate position and velocity for uniform motion. Activities may include the use of

- a ticker-tape apparatus and an object such as a motorized toy that moves with a constant velocity. By attaching a ticker tape to the back of the vehicle, a series of dots can be recorded on a tape. The spacing of the dots is a visual representation of the motion and should be emphasized. The spacing of the dots can be referred to as a "picture" of the motion. See Appendix 3.1: A Visual Representation of Motion.
- a videotape to analyze motion. A toy car that is released down an inclined plane and then allowed to move across a horizontal surface can be videotaped and used to investigate constant motion. Play back the videotape on a VCR with frame-by-frame advance. Place an acetate sheet over the TV screen and mark the position of the car on the sheet every frame (or every few frames). Normally, the tape will be played back at 30 frames per second. Students can measure the distance between the dots and calculate the time by the number of frames advanced. For uniform motion, the dots will be evenly spaced.

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

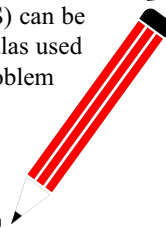
Students

- sketch a Position-Time graph from a description of motion (e.g., a walker and a runner leave the front door of the school at the same time; both move in the same direction at different constant velocities)
- differentiate between Position-Time graphs and Velocity-Time graphs
- describe how a record of motion is produced by a ticker-tape timer
- construct Distance-Time graphs, given data
- construct Velocity-Time graphs, given data
- discuss whether an odometer measures distance or displacement
- solve problems involving displacement, time, and velocity for an object in uniform motion
- calculate velocity, given data
- explain the difference between displacement and distance; velocity and speed

Teacher Background

It is important to note that only straight-line motion is examined and, in terms of defining vector quantities, it is only necessary to consider forward and backward motion. At this time, it is only necessary to examine situations where positive acceleration represents speeding up and negative acceleration represents slowing down. A more detailed analysis of motion in terms of vectors and direction in general will be left for Physics 30S/40S.

An understanding of *position*, *velocity*, and *acceleration* is developed conceptually (in this case visually), numerically (by measuring and collecting data), graphically, and symbolically (formula). The emphasis is intended to be on the conceptual understanding of the terms. Connections with Senior 2 Applied Mathematics (20S) can be made in the numerical and graphical modes. The only formulas used in this cluster will be to define velocity and acceleration. Problem solving using mathematical relationships is not emphasized; however, teachers could develop mathematical solutions to problems as an extension for advanced students.



(continued)

In Motion

- Ch. 1 Introduction
- Ch. 2 Analyzing Motion—Position and Displacement
 Instants and Intervals of Time
 Investigation 1—Vehicles in Motion
 Uniform Motion—Slope
 Instantaneous Velocity

Science 10

- 9.4 Investigation: Your Speed
- 9.5 Relating Speed to Distance and Time
- 9.6 Distance-Time Graphs
- 9.9 Activity: Simulation: Average Speed on an Air Table
- 9.10 Investigation: Determining an Average Speed
- 11.7 Velocity
- 12.1 Position-Time Graphs
- 12.2 Velocity-Time Graphs
- BLM 12.1a Position-Time Graphs
- ABLM 9.7a Distance-Time Graphs
- ABLM 12.1 Position-Time Graphs I
- ABLM 12.1a Position-Time Graphs II
- ABLM 12.2 Velocity-Time Graphs I

Science Power 10

- 9.1 Getting Into Motion
- 9.2 The Language of Motion
- 9.3 Measuring Motion
- Investigation 9-D: Slow but Sure
- 10.1 Position, Time, and Velocity
- 10.3 Velocity-Time Graphs

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-3-01 Analyze the relationship among displacement, time, and velocity for an object in uniform motion.</p> <p>Include: visual, numeric, graphical, symbolic (velocity = Dd/Dt)</p> <p>GLO: C5, C8, D4, E3</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

- a motion detector with a microcomputer or a graphing calculator to investigate uniform and accelerated motion. Students stand in front of the detector and try to make graphs that correspond to different types of motion. See Appendix 3.1 for more information on this activity.

Collaborative Teamwork S2-0-3b, 4e, 4f, 4g

Student groups solve problems involving displacement, time, and velocity for an object in uniform motion.

Journal Writing S2-0-8b

Students “tell a story,” given a Position-Time graph. Students can exchange stories, draw the corresponding Position-Time graph, and compare to the original. A RAFTS format could be used (see *SYSTH* 13.23). For sample graphs, see Appendix 3.2: Graphical Analysis.

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5b, 5c, 6a, 6b

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Journal Writing S2-0-8b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

BLM 10-1 Describing Position-Time Graphs

BLM 10-2 The Helicopter Challenge

BLM 10-7 Once Upon a Time

BLM 10-12 Car in Motion

SYSTH

13.21 Journal Evaluation

13.23 RAFTS

14.12 Lab Report Format
Concept Map

Appendices

3.1 A Visual Representation of Motion

3.2 Graphical Analysis

6.4 Lab Report Assessment

Teacher Background

Erratum: Page 5, In Motion Collision Scenario.

Figure 3 Legend:
 Car B (blue rectangle)
 Car A (yellow rectangle)
 Skateboarder (red circle)
 Motorcycle (orange rectangle)
 Motorcyclist (black square)
 Helmet (green triangle)

Figure 4 Legend:
 Car B (blue rectangle)
 Car A (yellow rectangle)
 Skateboarder (red circle)
 Motorcycle (orange rectangle)
 Motorcyclist (black square)
 Helmet (green triangle)
 Oil Drops (black dots)
 Skid Marks (grey squiggly lines)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-3-02 Collect displacement data to calculate and graph velocity versus time for an object that is accelerating at a constant rate. GLO: C5, C8, D4, E3
S2-3-03 Analyze the relationships among velocity, time, and acceleration for an object that is accelerating at a constant rate. Include: visual, numeric, graphical, symbolic GLO: C5, C8, D4, E3

SUGGESTIONS FOR INSTRUCTION

(1 HOUR) & (2 HOURS)

➤ **Notes for Instruction**

Learning outcomes S2-3-02 and S2-3-03 can be addressed together. Students should first collect displacement data (S2-3-02) through experimentation, and then analyze their data (S2-3-03). Students often confuse velocity and acceleration. Reinforce the point that these are related, but distinct, concepts. A ticker tape, video analysis, or motion detector can be used to collect data for an object that is accelerating at a constant rate. Calculate the average velocity for each interval and graph at the midpoint of the interval. (Note: The average velocity for an interval closely approximates the instantaneous velocity at the midpoint of the interval.) For a straight-line graph, the rate of change of velocity is proportional to the change of time, and acceleration is defined as Dv/Dt .

➤ **Student Learning Activities**

Laboratory Activity S2-0-3c, 4e, 5a, 5b

Students or student groups collect displacement data to calculate and graph velocity versus time for an object that is accelerating at a constant rate. For example:

- a toy car is released down an inclined plane surface and videotaped. For accelerated motion, the spaces between the dots will increase (or decrease if the acceleration is negative).
- a cart with a ticker-tape timer is released down a ramp. The tape is examined to calculate the distance traveled and the speed for each time interval.

Collaborative Teamwork S2-0-4f, 4g, 9b, 9c

Student groups analyze their data collected during the laboratory activity to determine the relationships among velocity, time, and acceleration for an object that is accelerating at a constant rate.

Student groups solve problems involving velocity, time, and acceleration for an object that is accelerating at a constant rate.

Journal Writing S2-0-2c, 8b

Students prepare a glossary of new words for quick reference. A Three-Point Approach could be used (see *SYSTH* 10.22).

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5c, 6c, 7a, 7b

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Journal Writing S2-0-2c, 8b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- construct graphs of velocity versus time when provided with data
- contrast velocity with acceleration
- match written descriptions of objects in motion with their graphical representations
- predict which has the greater acceleration: a bike that increases its speed from 0–10 km/h, or a car that goes from 50–60 km/h in the same time
- explain what is meant by *negative acceleration*
- solve problems involving velocity, time, and acceleration for an object that is accelerating at a constant rate

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 2 Analyzing Motion
Accelerated Motion
Real-life Motion

Science 10

10.2 Activity: Speed Comparisons
10.3 Defining Acceleration
10.4 Speed-Time Graphs for Acceleration
10.5 Investigation: Graphing Distances During Acceleration
10.9 Investigation: Constant Acceleration
10.10 Investigation: Acceleration of Different Vehicles
12.2 Velocity-Time Graphs
12.4 Investigation: Speeding Up and Slowing Down

ABLM 10.2 Speed Comparisons
ABLM 10.4 Speed-Time Graphs for Acceleration
ABLM 10.5 Graphing Distances During Acceleration
ABLM 10.9 Constant Acceleration

Science Power 10

9.1 Getting Into Motion
9.2 The Language of Motion
9.3 Measuring Motion
Investigation 10-C: Pick Up the Pace
11.1 Describing and Measuring Acceleration
11.2 Using and Picturing Acceleration
Investigation 11-A: The Definite Difference
BLM 9-11 The Bug Race
BLM 10-13 Pick Up the Pace
BLM 11-2 Recognizing Accelerated Motion
BLM 11-20 Stunt Driving

SYSTH

10.22 Three-Point Approach
13.21 Journal Evaluation
14.12 Lab Report Format

Appendix

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-04 Outline the historical development of the concepts of force and “natural” motion.</p> <p>Include: Aristotle, Galileo, Newton’s First Law</p> <p>GLO: A2, A4, B1</p>

SUGGESTIONS FOR INSTRUCTION

(1 HOUR)

➤ **Entry-Level Knowledge**

In Grades 5 and Senior 1, students gained some familiarity with the work of Aristotle, Galileo, and Newton. The stories of Newton’s apple and Galileo’s Tower of Pisa experiment are well known.

➤ **Notes for Instruction**

Develop the principles of Newton’s laws qualitatively with the intention of using these principles of force and motion in later discussion about car collisions. A historical discussion can introduce the idea of inertia.

Use a KWL frame to activate students’ prior knowledge of concepts related to this learning outcome (see *SYSTH* 9.24). Discuss student misconceptions, such as the idea that heavier objects fall faster than lighter ones. The use of demonstrations and hands-on activities will aid in student understanding of this learning outcome.

➤ **Student Learning Activities**

Class Discussion S2-0-8e, 8d, 8g, 9a

Galileo’s Thought Experiment can be imitated using toy cars. See Appendix 3.3: Force and Natural Motion. Relate Galileo’s story while demonstrating that the toy car will rise to almost the same height from where it was released. Discuss the limitations of the demonstration (friction) and tell students that Galileo’s contribution to the way we practise science was his ability to idealize a situation.

Teacher Demonstration S2-0-9b

There are several demonstrations of inertia, the most popular of which is pulling a tablecloth rapidly from under a set table. The dishes should stay behind. Other examples:

- Place a penny on a card that is resting on your finger. Using your other hand, flick the card quickly, leaving the penny on your finger.
- Cut a ring from a large PVC pipe and place the ring on top of a pop bottle or an open-mouthed flask. On top of the ring, place a peanut or small marble. If you pull the ring rapidly, the peanut will fall into the bottle.

These demonstrations can also be attempted by students.

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- explain why the dishes stay behind when a tablecloth is rapidly pulled from under a set table
- contrast Aristotle’s view of motion with that of Galileo’s
- define *inertia*
- predict which of two objects of similar size but different masses, dropped from the same height, will reach the ground first
- draw a timeline outlining the historical development of the concepts of force and “natural” motion
- summarize Galileo’s contribution to our knowledge of motion
- state, in their own words, Newton’s First Law of Motion
- explain why a person has to push harder on the pedals of a single-speed bicycle to start it moving than to keep it moving at a constant velocity
- predict what will happen to the passengers in a car as it moves along a curve
- describe how Newton’s First Law applies when a billiard ball rolls toward and collides with an unmoving ball

Journal Writing S2-0-8c, 8e, 8g, 9a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Teacher Background

Initially, Aristotle proposed that every terrestrial object had a natural motion toward the centre of the universe (Earth). To move otherwise, an object would be in violent motion under the influence of an external force. Two thousand years later, Galileo challenged Aristotle’s views in his *Two New Sciences*. Students can read Galileo’s words and draw their own conclusions about Galileo’s view of inertia.

It is not well understood whether Galileo thought that inertial motion was circular (i.e., an object free to move on the surface of the Earth would circumnavigate the Earth). See Appendix 3.4 for a discussion of Galileo’s Thought Experiment.

In Motion

Ch. 3 Inertia

Natural Motion—Aristotle
 Natural Motion—Galileo
 Newton’s First Law and the
 “Second Collision”

Science 10

12.7 Acceleration Due to Gravity

12.10 Explore an Issue: “Nothing by Authority”

Unit 3 Challenge: Scientific
 Perspectives on Motion: Testing of
 Motion

Science Power 10

Investigation 9-A: Be Specific

BLM 9-2 Arguing with Aristotle

BLM 9-3 Be Specific

BLM 9-4 The Parachute Drop

BLM 9-5 Galileo’s Experiments

SYSTH

3.20 Jigsaw

9.24 KWL Plus

11.14 Chain Concept Map

13.21 Journal Evaluation

Galileo

Galileo, trans. Stillman Drake
 (Berkeley and Los Angeles:
 University of California Press, 1967)
 145–149. A Galileo dialogue
 concerning the two chief world
 systems.

Appendices

3.3 Force and Natural Motion

3.4 Galileo’s Thought Experiment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-3-04 Outline the historical development of the concepts of force and “natural” motion.</p> <p>Include: Aristotle, Galileo, Newton’s First Law</p> <p>GLO: A2, A4, B1</p>

SUGGESTIONS FOR INSTRUCTION

(1 HOUR)

Collaborative Teamwork S2-0-4f, 4g 8c, 8e

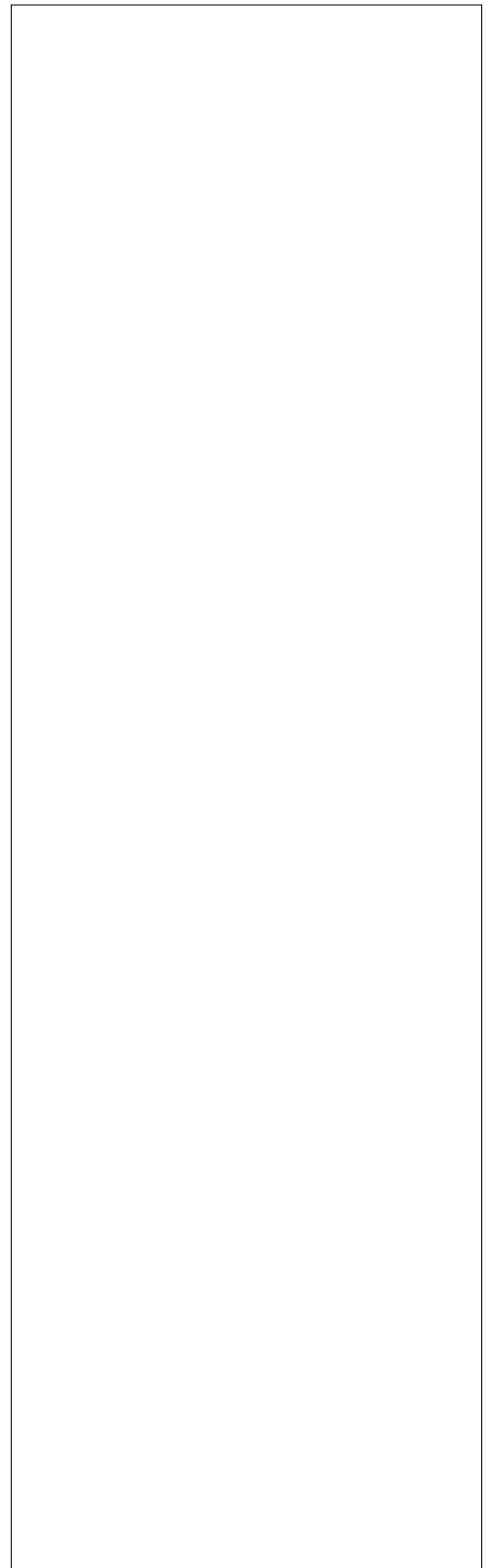
Student groups summarize the work of different scientists with respect to the historical development of the concepts of force and “natural” motion, and then share their work with their classmates in a Jigsaw format (see *SYSTH* 3.20).

Journal Writing S2-0-8c, 8e, 8g, 9c

Students develop a timeline or Chain Concept Map outlining the historical development of the concepts of force and “natural” motion (see *SYSTH* 11.14).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

A large, empty rectangular box with a thin black border, intended for listing suggested learning resources. It occupies the right half of the page below the header.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-05 Experiment to illustrate the effects of inertia in car collisions. Include: distance traveled (of an unrestrained passenger) is proportional to velocity squared GLO: C2, C6, C7, E3</p>

SUGGESTIONS FOR INSTRUCTION

(2 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students were introduced to balanced and unbalanced forces, and Newton’s Laws. Students will also have personal experience with inertia from accelerating and decelerating in automobiles, planes, bikes, skateboards, et cetera.

➤ **Notes for Instruction**

Activate prior knowledge of this learning outcome with a discussion of the effects of inertia in car collisions. A Knowledge Chart could be used (see *SYSTH 9.25*). Hands-on activities and laboratory experiments will aid in student understanding of the concept.

➤ **Student Learning Activities**

Laboratory Activity S2-0-3a, 3b, 4b, 5a

See Appendix 3.5: Newton’s First Law, for a student learning activity to investigate the inertia of an unrestrained passenger in a car collision. The distance is proportional to the velocity squared. Note that it is not necessary to “straighten the curve” to determine the relationship; the relationship can simply be modeled as exponential since the graph curves upward. The important idea for students to understand is that if the velocity doubles, the distance the passenger travels more than doubles.

Debate S2-0-1d, 2b, 2d, 3e

Students debate the statement, “It is better to be thrown out of the car and clear of the crash than to be trapped in the car by a seat belt.”

Journal Writing S2-0-2c, 7e, 9d

Encourage reflection on the debate. Have students summarize the arguments given by each team and ask the following:

- What surprising points were raised during the debate?
- What is your opinion, based on the evidence presented in the debate?

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5c, 6a, 7a, 7b

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Journal Writing S2-0-2c, 7e, 9d

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- define *inertia*
- discuss how seat belts acting with air bags help protect passengers in a car accident
- explain why a person standing on a bus falls backward when the bus moves forward, and falls forward when the bus stops
- discuss whether it is better to be thrown out of the car and clear of the crash, than to be trapped in the car by a seat belt
- describe the relationship between the speed of a car and the distance traveled by an unrestrained passenger in a car crash
- explain why a transport truck (e.g., grain truck) has a sturdy wall behind the driver's cab

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 3 Inertia

The Velocity of a Car on an Inclined Plane

Investigation #2—Inertia and the Unrestrained Occupant

SYSTH

9.25 Knowledge Chart

13.21 Journal Evaluation

14.12 Lab Report Format

Appendices

3.6 Inertia and the Unrestrained Passenger

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<p><i>Students will...</i></p>	<p>(3 HOURS)</p>
<p>S2-3-06 Describe qualitatively how force is related to motion. Include: no force; constant force; the relationship among force, mass, and acceleration (Newton’s Second Law) GLO: D4, E3</p>	<p>➤ Entry-Level Knowledge In Grade 5, students were introduced to balanced and unbalanced forces, and Newton’s Laws.</p> <p>➤ Notes for Instruction Newton’s Second Law is $F = ma$ (i.e., force equals mass times acceleration). It is not the intention to derive this relationship experimentally, or to use a mathematical problem-solving approach. In order to examine car collisions, students need only be familiar with the basic principles of applying the law. These principles include the following:</p> <ol style="list-style-type: none"> 1. Force is proportional to acceleration. If we apply a greater force, we will have a greater acceleration (remember that this includes speeding up and slowing down). 2. Force is proportional to mass. More massive objects require more force to accelerate (change speed). 3. Force can change the direction of motion. <p>➤ Student Learning Activities Laboratory Activity S2-0-1a, 1b, 3c, 4a Students or student groups investigate qualitatively how force is related to motion. Activities can include the following:</p> <ul style="list-style-type: none"> • Attach a ticker tape to the rear of a toy car and release the car down a ramp. Increase the angle of the plane and repeat several times. Examine the dots on the ticker tape. As the force increases, the acceleration increases. • Place a mass on the plane attached to a spring scale and raise the ramp. The spring scale will reach a maximum when the plane is vertical. This shows that the force increases as the angle of the plane increases. • Place a small mass (like a block of wood) at the bottom of an inclined plane and release a cart down the plane. Record how far the mass moves. Double the mass and repeat. In order to move the heavier mass the same distance, the force must be increased. • Use a pulley system to accelerate a cart on a table. <p>Journal Writing S2-0-2a Students complete a Word Cycle of the following terms: <i>velocity, Galileo, inertia, acceleration, force, Newton, motion, and mass</i> (see SYSTH 10.21).</p>

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-6a, 6b, 7a, 7b

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Journal Writing S2-0-2a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- explain why a person wearing a cast on one leg becomes more tired than usual by the end of the day
- suggest reasons why large automobiles such as vans and sport-utility vehicles tend to have larger engines and higher rates of fuel consumption than compact and sub-compact cars
- use Newton's Laws to explain why people in cars often get neck injuries (e.g., whiplash) when struck from behind
- explain why small gazelles often escape bigger and faster cheetahs in pursuit by zigzagging as they run
- predict when serious injuries are more likely to occur—when a car crashes into a large tree or into a wooden fence
- complete a Word Cycle of the following terms: *velocity*, *Galileo*, *inertia*, *acceleration*, *force*, *Newton*, *motion*, and *mass* (see *SYSTH* 10.21)

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 4 Forces and Motion

Investigation #3—Force and Acceleration

Investigation #4—Mass and Acceleration

Investigation #5—Force and Mass

Force and Direction

SYSTH

10.21 Word Cycle

13.21 Journal Evaluation

14.12 Lab Report Format

Appendix

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (1 HOUR)
<p><i>Students will...</i></p>	
<p>S2-3-07 Investigate and describe qualitatively Newton’s Third Law. <i>Examples: balloon-powered car, model rockets, head-on collision...</i> GLO: C2, C6, C7, E3</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 5, students were introduced to balanced and unbalanced forces, and Newton’s Laws. In Grade 6, gravity, thrust, drag, and the use of unbalanced forces to steer air and spacecraft were examined.</p> <p>➤ Notes for Instruction</p> <p>Newton’s Third Law is commonly known as the action-reaction law. It is often misunderstood that forces always occur in pairs. The head-on collision should also be examined in this context. It is a common misconception that in a collision between a large vehicle and a small vehicle, the large vehicle exerts a larger force. According to Newton’s Third Law, each vehicle experiences the same force. Of course, the smaller vehicle will probably experience the most damage.</p> <p>➤ Student Learning Activities</p> <p>Teacher Demonstration</p> <p>Newton’s Third Law can be demonstrated using a model rocket or a go-cart powered by a fire extinguisher. Ensure safety precautions are observed.</p> <p>Laboratory Activity S2-0-3c, 3e, 4a, 4e</p> <p>Students design and build a balloon-powered car. Plastic bottle caps can be used for wheels and a contest can be organized.</p> <p>Student Research S2-0-2a, 2b, 2c, 3d</p> <p>Students research and describe everyday applications of Newton’s Third Law. Topics can include</p> <ul style="list-style-type: none"> • slingshots • swimming • rockets • skateboarding • rollerblading <p>Case studies and Internet sources can be used.</p> <p>Visual Display/Collaborative Teamwork S2-0-4f, 4g, 5c</p> <p>Student groups research and prepare visual displays illustrating everyday applications of Newton’s Third Law.</p> <p style="text-align: right;"><i>(continued)</i></p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5d, 6c, 6d, 7d

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Research Report/Presentation S2-0-8a, 8d, 9b, 9c

Students present research findings with

- written reports
- oral presentations
- newspaper articles
- demonstrations
- dramatic presentations

Visual Display S2-0-8a, 8d, 9b, 9c

Student groups present their visual displays of everyday applications of Newton's Third Law with

- posters
- dioramas
- bulletin board presentations
- multimedia presentations
- diagrams

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

In Motion

Ch. 4 Forces and Motion
Action-Reaction Forces
Design Challenge: The
"Rocket" Car Race

Science 10

9.6 Investigation: Balloon Car Contest

ABLM 9.6 Balloon Car Contest

ABLM 9.6a Balloon Car Contest-
Evaluation Table

Science Power 10

Investigation 9-B Air Power

SYSTH

13.21 Journal Evaluation

14.12 Lab Report Format

Appendices

6.1 Rubric for the Assessment of
Class Presentations

6.2 Rubric for the Assessment of a
Research Project

6.4 Lab Report Assessment

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-3-07 Investigate and describe qualitatively Newton’s Third Law. <i>Examples: balloon-powered car, model rockets, head-on collision...</i></p> <p>GLO: C2, C6, C7, E3</p>

SUGGESTIONS FOR INSTRUCTION

(1-1/2 HOURS)

Journal Writing S2-0-7f

Students reflect on and respond to the following questions:

- How has your understanding of motion changed since the start of the cluster?
- What new questions do you have about motion?
- What new information in this cluster surprises you?

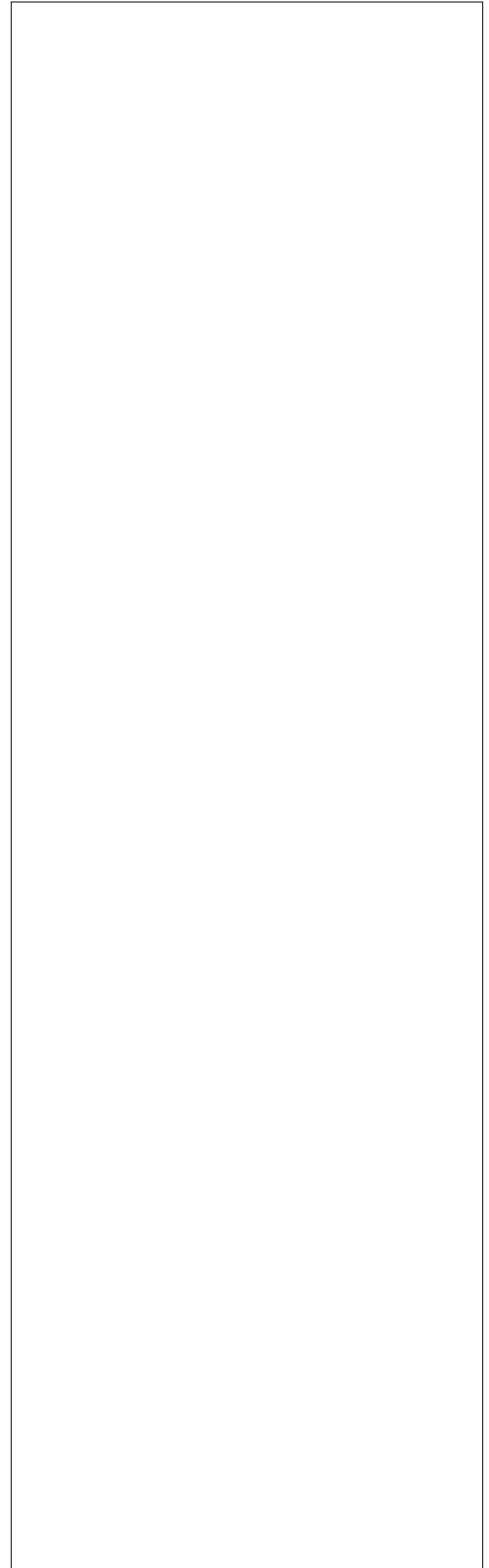
SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- summarize, in their own words, Newton’s Third Law of Motion
- describe how the reaction engine of a rocket is an application of the Third Law of Motion
- predict and explain, with the use of diagrams that include force vectors, what would happen if a person stepped out of a boat onto a dock without first securing the boat to the dock
- discuss Newton’s Third Law of Motion in the context of a head-on car collision
- explain how walking is an example of Newton’s Third Law of Motion
- explain whether astronauts in a space station should choose pencils with a hard lead or a soft lead for taking notes



PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-08 Define <i>momentum</i> and <i>impulse</i> and qualitatively relate impulse to change in momentum for everyday situations.</p> <p>Include: car collisions, bumpers, restraints, air bags</p> <p>GLO: A5, B1, B2, D4</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

In Grade 7, forces and structures were examined. Students determined the effect of a force on a structure, and described how common structural shapes and components can increase the strength and stability of a structure. Students may also have personal experience with car collisions.

➤ **Notes for Instruction**

Newton actually formulated his law in terms of the change of velocity.

That is, $F = ma$ is the same as $F = mDv/Dt$.

If we multiply each side by Dt , then we have $F Dt = m Dv$.

Once again, the mathematical application of this relationship is NOT necessary. The basic principles to be discussed are as follows:

1. The product of force and time (left-hand side) is called *impulse*. To increase impulse, we must increase the force applied or the time over which we apply the force.
2. The product of mass and velocity is called *momentum*. Momentum is known as a quantity of motion. A 100 000-kg train moving at 5.0 m/s has more momentum than a 10-g toy car moving at 5.0 m/s (and consequently is more difficult to stop).
3. In order to change momentum (i.e., change an object's velocity) we must apply an impulse. For example, to kick or hit a ball we apply a force on the ball for a period of time. To kick or hit the ball further we must have a greater change in velocity (and therefore momentum). To do this, we can increase our force by kicking or hitting harder (build up your muscles!) or we can apply the force for a greater length of time (or, as the coach says, "follow through"). This principle applies to many everyday types of activities like kicking, throwing, or hitting a ball, puck, or other object.

Manitoba Public Insurance's website <www.mpi.mb.ca> offers information on road safety and other topics. Visit <www.hwysafety.org> for highway and vehicle safety statistics. Automaker websites provide information on automobiles and their safety features.

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-6c, 6d, 7c, 7d

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

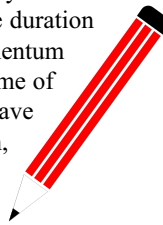
Research Report/Presentation S2-0-7e, 8c, 8d

Students present their investigation findings of the various technologies that cushion the impact of the second collision in a car accident with

- written reports
- oral presentations
- dioramas
- dramatic presentations
- newspaper articles
- multimedia presentations

Teacher Background

In a car collision, the impulse that is most threatening to drivers and passengers is called the second collision. The second collision occurs when an individual hits the steering wheel, windshield, tree, or any other rigid object. To bring a moving object, such as a passenger thrown from a car, to rest, an impulse is required to reduce the momentum to zero. Since impulse is the product of $F \cdot t$, when a person collides with a fixed object, the duration of time is very small and the force is very large. This causes damage and severe personal injury. To protect passengers in moving vehicles, engineers try to “cushion” the blow. That is, a cushioning effect increases the duration of time during which the force is applied, to reduce the momentum to zero. Since the same impulse is required, increasing the time of impact reduces the force of the impact. Many technologies have been developed to cushion the impact of the second collision, including seat belts and air bags.



(continued)

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 5 Momentum and Energy
Momentum
Impulse and Momentum
Cushioning Devices
The Great Egg Drop Competition

Science 10

10.6 Case Study: Buying a Car?

Science Power 10

Unit 3: Ask an Expert

SYSTH

13.21 Journal Evaluation

13.23 RAFTS

14.12 Lab Report Format

Appendices

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-3-08 Define <i>momentum</i> and <i>impulse</i> and qualitatively relate impulse to change in momentum for everyday situations.</p> <p>Include: car collisions, bumpers, restraints, air bags</p> <p>GLO: A5, B1, B2, D4</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

Teacher Demonstration

An effective demonstration of momentum and impulse is the egg toss. Throw or drop an egg onto a hard surface. The egg will splatter easily, as a larger force is applied for a short period of time to stop the egg. Get a blanket and hold it vertically. Throw the egg into the blanket (you can actually throw the egg quite fast, but make sure you do not squeeze the egg!). The impulse necessary to stop the egg is the same but the cushioning of the blanket spreads the impulse over a longer period of time and the force is considerably less.

➤ **Student Learning Activities**

Laboratory Activity S2-0-1a, 1b, 3e, 3f

Suggested ways to approach an egg-drop activity:

- Given a set of materials, students can build a landing pad and drop an egg from a height onto the landing pad.
- Using a vehicle analogy, students can build a restraint system to protect a passenger (the egg) in a collision. The restraint system could be used to investigate the effects of seat belts, air bags, dashboards, and bumpers.

Student Research S2-0-1c, 1d, 2b, 3e

Students research the benefits of various technologies that cushion the impact of the second collision in a car accident.

Technologies include

- seat belts
- air bags
- dashboards
- side panels
- bumpers

Visual Display/Collaborative Teamwork S2-0-2d, 3d, 3f, 5d

Student groups develop advertising campaigns to increase community awareness of how various technologies cushion the impact of the second collision in a car accident.

Journal Writing S2-0-7f

As a crash-test dummy, students write a diary entry describing their day at work. A RAFTS format could be used (see *SYSTH* 13.23).

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Visual Display S2-0-7c, 7d, 8d, 9f

Student groups present their advertising campaigns. Displays may take the form of

- radio commercials
- posters
- bulletin board displays
- television commercials
- pamphlets
- brochures
- newspaper/magazine advertisements

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- define *impulse* and *momentum*
- predict what a smaller football player's velocity must be if his momentum is enough to stop a larger player
- describe how seat belts help reduce injury to passengers
- explain why long jumpers sprint up the approach before jumping
- discuss the importance of follow-through on a golf swing, swimming stroke, or soccer kick
- predict what will happen to the momentum of a person who falls off a roof, upon landing on the ground
- suggest why headrests help the driver and passenger of a car that has been rear-ended
- explain why the engines of supertankers must be shut off several kilometres before they need to stop
- describe how air bags cushion the impact of the second collision in a car accident
- discuss how a bullet can have the same momentum as a truck

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<p><i>Students will...</i></p>	<p>(1 HOUR)</p>
<p>S2-3-09 Investigate the conservation of energy in a motor vehicle collision.</p> <p>Include: kinetic energy, heat energy, sound</p> <p>GLO: B2, D4, E4</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 6, students were introduced to the Law of Conservation of Energy, where they recognized that energy can neither be created nor destroyed but changed from one form to another.</p> <p>➤ Notes for Instruction</p> <p>Activate prior knowledge of the conservation of energy in motor vehicle collisions. A Listen-Draw-Pair-Share strategy could be used (see <i>SYSTH</i> 9.15). The Law of Conservation of Energy is not derived from any of the dynamic laws of motion. It is an independent statement about order in nature. In a car crash, energy is dissipated through the transfer of energy to other forms and other systems (like the pavement, the crumpling of fenders, breaking of bones). <i>Kinetic energy</i> can be defined as the energy of motion; <i>potential energy</i> as the energy of position (with respect to the surface of the Earth), heat energy as the energy of molecules in motion; and <i>sound energy</i> as the disturbance of a medium. In a car collision, huge amounts of kinetic energy are transferred to other systems. As the kinetic energy reduces to zero, other forms of energy increase.</p> <p>➤ Student Learning Activities</p> <p>Class Discussion S2-0-7f</p> <p>Challenge students with the statement, “What would our world be like if energy was not conserved?” Examine a picture of a car collision and summarize the energy changes.</p> <p>Student Research/Collaborative Teamwork S2-0-1b, 2c, 4f, 4g</p> <p>Student groups investigate the conservation of energy in a motor vehicle collision. Groups should be assigned to</p> <ul style="list-style-type: none"> • kinetic energy • heat • sound <p>Case studies, newspaper articles, and Internet sources may be used. Groups then share their findings with their classmates in a Jigsaw format (see <i>SYSTH</i> 3.20).</p> <p>Journal Writing S2-0-2a</p> <p>Students complete a Concept Frame or Concept Overview of the conservation of energy in motor vehicle collisions (see <i>SYSTH</i> 11.24, 11.25).</p>

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-9b, 9c, 9d

Student groups prepare and present their research findings with

- written reports
- oral presentations
- posters
- dioramas
- models
- multimedia presentations
- newspaper articles
- bulletin board displays

Journal Writing S2-0-2a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- state how the Law of Conservation of Energy applies to car crashes
- compare and contrast kinetic and potential energy (see *SYSTH* 10.24)
- explain, from the standpoint of kinetic energy, why a loaded semi-trailer is more dangerous than a sub-compact car in a collision, even though they are both traveling at the same speed.
- describe how bouncing on a trampoline illustrates both potential and kinetic energy
- identify various energy conversions involved in a car collision
- explain, in terms of energy transfers, how air bags greatly reduce the chance of injury in a car accident

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 5 Momentum and Energy in a Collision

SYSTH

- 3.20 Jigsaw
- 9.15 Listen-Draw-Pair-Share
- 11.24 Concept Frame
- 11.25 Concept Overview
- 13.21 Journal Evaluation

Appendices

- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (1 HOUR)
<i>Students will...</i>	
<p>S2-3-10 Investigate conditions that illustrate the effects of friction on motion.</p> <p>Include: weather conditions</p> <p>GLO: C2, C5, D4, E2</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 5, students were introduced to the effects of friction on motion. Students may have personal knowledge of conditions that illustrate the effects of friction on motion.</p> <p>➤ Notes for Instruction</p> <p>There are many conditions that illustrate the effects of friction on motion. Activate students’ knowledge of this learning outcome. A Sort and Predict activity can be used (see <i>SYSTH</i> 10.23).</p> <p>➤ Student Learning Activities</p> <p>Visual Display/Collaborative Teamwork S2-0-2d, 3e, 3f, 5d</p> <p>Student groups research and prepare visual displays of technologies used to increase or reduce friction. Examples may include</p> <ul style="list-style-type: none"> • how and why cyclists reduce friction • how and why drag racers increase tire friction • how and why snowboarders reduce friction <p>Case studies, newspaper articles, and Internet sources can be used.</p> <p>Student Research S2-0-1b, 1d, 2a, 2c</p> <p>Students investigate conditions that illustrate the effects of friction on motion. These may include</p> <ul style="list-style-type: none"> • road conditions (icy, wet, snow-covered, dry, gravel, dirt) • type of vehicle (sub-compact car, sport-utility vehicle, pickup truck) • type of tire (snow tire, studded tire, racing slick, all-season radial) <p>Case studies, newspaper articles, and Internet sources can be used.</p> <p>Journal Writing S2-0-7f</p> <p>Students complete a fact- or issue-based article analysis of a current newspaper, Internet, or magazine article related to this learning outcome (see <i>SYSTH</i> 11.40, 11.41).</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-8a, 8b, 8d, 8g

Student groups present visual displays such as

- posters
- models
- dioramas
- bulletin board displays
- cartoons

Research Report/Presentation S2-0-9b, 9c, 9d

Students present investigation findings with

- written reports
- oral presentations
- demonstrations
- newspaper articles
- multimedia presentations

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- explain why sand is sprinkled on icy roads and sidewalks
- suggest ways to reduce friction between a bicycle and the road
- describe why studded tires or chains are used in icy winter driving conditions
- discuss why skiers and snowboarders use wax

In Motion

Ch. 6 Braking

Challenge—The Effects of Friction on Braking

Science 10

11.6 Explore an Issue: Athletes on the Edge

12.3 Case Study: Technology and Skiing

Science Power 10

Investigation 10-B: The Better Bicycle

SYSTH

10.23 Sort and Predict

11.40 Issue-Based Article Analysis

11.41 Fact-Based Article Analysis

13.21 Journal Evaluation

Appendices

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-11 Investigate the factors that influence braking distance. Include: reaction time, friction, condition of driver, speed GLO: C2, C3, C6, D4</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

From personal experience, as well as radio and television advertising, students will have knowledge of the factors that influence braking distance.

➤ **Notes for Instruction**

There are many factors that influence the braking distance of a car. Activate prior knowledge using a brainstorming activity such as Rotational Graffiti (see *SYSTH* 3.15).

It is not necessary to complete a graphical analysis. Students should realize that we can model a curve that bends upward using a power of 2, in this case, $d \propto v^2$. If the velocity doubles, the distance the car takes to stop will increase four times. Hands-on activities and laboratory experiments will aid in student understanding of this topic.

➤ **Student Learning Activities**

Laboratory Activity S2-0-3a, 4a, 4e, 5b

Another toy car activity (see Appendix 3.7: Braking Distance) can be used to investigate the relationship between speed and braking distance. Release the car down an incline from various heights. At the bottom of the incline, place a “braking sled” made of paper. The braking sled simulates a locked braking system on a vehicle. Record the distance that the sled slides to a stop. Students can graph distance versus velocity to observe that the distance increases exponentially with the velocity.

Student Research S2-0-1d, 2a, 2c, 3d

Students research factors that influence braking distance. These factors can include

- alcohol
- wet road surfaces
- hallucinogenic drugs
- age of the driver
- icy road surfaces
- depressant drugs
- driver fatigue

Case studies, newspaper articles, and Internet sources can be used.

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-6a, 6b, 7a, 7b

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Research Report/Presentation S2-0-8d, 8g, 9c, 9f

Students or student groups prepare and present their research findings with

- written reports
- oral presentations
- newspaper articles
- dramatic presentations
- posters
- bulletin board displays
- multimedia presentations

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

SUGGESTED LEARNING RESOURCES

In Motion

- Ch. 6 Braking
 Investigation #6—Braking Distance
 Challenge—The Effects of Friction on Braking

Science 10

- 9.11 Career Profile: Marilyn Reynolds, Police Constable

Science Power 10

- Investigation 11-D: Hit the Brakes!

SYSTH

- 3.15 Rotational Cooperative Graffiti
 10.24 Compare and Contrast
 11.11 Category Concept Map
 13.21 Journal Evaluation
 14.12 Lab Report Format

Appendices

- 6.1 Rubric for the Assessment of Class Presentations
 6.2 Rubric for the Assessment of a Research Project
 6.4 Lab Report Assessment

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<i>(continued)</i> S2-3-11 Investigate the factors that influence braking distance. Include: reaction time, friction, condition of driver, speed GLO: C2, C3, C6, D4

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

Journal Writing S2-0-7f

Students create a Category Concept Map of the factors that influence braking distance (see *SYSTH* 11.11).

Collaborative Teamwork S2-0-4a, 4f, 4g

Students work in teams to test each other's reaction time. Give the following instructions. Students hold a ruler vertically above their partner's outstretched hand between the thumb and forefinger. They drop the ruler and record the centimetre mark where the ruler is caught. The reaction time will be the square root of the distance divided by five (see Appendix 3.3: Force and Natural Motion).

Community Connection S2-0-8f

Law enforcement agencies and insurance companies are good sources of information about accident reconstruction and factors that influence braking distance. Invite a community member such as a law enforcement officer, driving instructor, or claims adjuster to come into the classroom and answer student-generated questions. Students could also visit the community members in the workplace. The questions could be prepared in advance so that appropriate topics are covered.

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- describe the relationship between reaction time and braking distance
- discuss the accuracy of the advertising slogan “Speed Kills”
- compare and contrast disc brakes with anti-lock brakes (see *SYSTH* 10.24)
- explain why drinking and driving don’t mix
- identify substances that, when ingested, will adversely affect reaction time
- predict the effect of increased speed on braking distance
- describe how an escape ramp on a mountain road could be designed to help trucks with failed brakes stop
- discuss why braking distance on a gravel road is greater than that on a paved road
- suggest why fast-moving airplanes use air brakes, rather than disc brakes, to stop more quickly

Appendix

3.3 Force and Natural Motion

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-12 Using the relationship among displacement, velocity, and friction ($d=kv^2$), calculate the braking distance of a motor vehicle.</p> <p>GLO: C2, C3, C5, C8</p>

SUGGESTIONS FOR INSTRUCTION

(1 HOUR)

➤ **Notes for Instruction**

The characteristics of friction for different surfaces are represented as a coefficient of friction. Students can calculate braking distances using the equation $d = kv^2$. A table of common coefficients is included in the Appendix. The equation should only be modeled in terms of the relationship with velocity and friction. That is, as the coefficient of friction decreases, the surface becomes more slippery and the vehicle takes longer to stop. A detailed discussion, including a mathematical analysis, is included in Appendix 7, Chapter 6 for the teacher. Hands-on activities and laboratory experiments will aid in student understanding of this concept.

➤ **Student Learning Activities**

Laboratory Activity S2-0-3b, 4b, 4e, 5a

The braking distance lab can also be used to investigate the effects of friction. Students repeat the experiment but cover the surface of the table beneath the braking sled with body oil. Students compare the resulting graphs of the braking distance. The time it takes to assess a dangerous situation and then apply appropriate actions is called the *reaction time*. During the reaction time, a vehicle will cover a distance calculated by velocity x time. This distance must be added to the previously calculated braking distance to arrive at a true braking distance.

Collaborative Teamwork S2-0-4f, 4g

Student groups solve problems using the relationship among displacement, velocity, and friction ($d = kv^2$).

Journal Writing S2-0-7f

Students complete a fact- or issue-based article analysis of a current newspaper, Internet, or magazine article related to this learning outcome (see *SYSTH* 11.40, 11.41).

SUGGESTIONS FOR ASSESSMENT
Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-5b, 5c, 6a, 7a

Students interpret their laboratory results, and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing, graphing, and spreadsheet software can be used for report writing.

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- solve problems using $d = kv^2$ to calculate the braking distance of a motor vehicle
- suggest why dragsters “boil” or “smoke” their tires on the track before a race
- use coefficients of friction to predict changes in braking distance as a car moves from dry to wet pavement
- explain how brakes use friction to stop a moving vehicle
- predict which has the lower coefficient of friction: an icy road or dry pavement

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 6	Braking
	Math Connection
	Total Stopping Distance
	Reaction Time
	The Final Challenge

SYSTH

11.40	Issue-Based Article Analysis
11.41	Fact-Based Article Analysis
13.21	Journal Evaluation
14.12	Lab Report Format

Appendix

6.4	Lab Report Assessment
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PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-3-13 Use the decision-making process to address an STSE issue related to safe driving conditions.</p> <p><i>Examples: adverse driving conditions, reaction time, narcotic influences such as blood alcohol level, excessive vehicle speed...</i></p> <p>GLO: B3, C4, C5, C8</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

Students will have knowledge of STSE issues related to safe driving conditions from personal experience, as well as from the media.

➤ **Notes for Instruction**

Guide students through the steps of the Decision-Making Model (see the *Senior 2 Science Framework* and the Manitoba Foundations for Scientific Literacy section at the front of this document). Model the process, guide students, and provide opportunities for practice. Other Senior 2 clusters will provide more opportunities for decision making.

There are many websites that are devoted to driver/road safety including <www.mpi.mb.ca> and <www.hwysafety.org>. See Chapter 4 of *SYSTH* for strategies to use when exploring STSE issues. An activity such as an Anticipation Guide can be used to probe controversial STSE issues (see *SYSTH* 9.20).

➤ **Student Learning Activities**

Student Research/Collaborative Teamwork

S2-0-1c, 3e, 3f, 4e

Student groups develop public awareness campaigns to address STSE issues related to safe driving conditions. Topics can include

- drinking and driving
- speeding
- adjusting to icy road conditions
- driver fatigue
- cellphone use
- defensive driving

Case studies, newspaper articles, and Internet sources can be used.

Debate S2-0-3d, 7c, 7d, 7e

Students research and debate statements such as

- speed limits on Manitoba highways should be raised
- cellphone use by drivers should not be permitted
- all new drivers must take a Driver’s Education course

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-6d, 9c, 9e, 9f

Student groups present their public awareness campaigns using

- television/radio commercials
- cartoons
- posters
- pamphlets
- brochures
- bulletin board displays
- newspaper/magazine advertisements

Journal Writing S2-0-7f

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- describe the effect alcohol has on the human body and discuss implications for safe driving
- outline Manitoba's legislation regarding graduated driver licensing and discuss whether they support this approach
- suggest specific driving behaviours that can reduce the risk of accident when driving on gravel, wet, or icy roads
- explain how prescription drugs can affect a driver
- discuss the pros and cons of prohibiting cellphone use by drivers
- explain whether drinking coffee will sober a drunk driver
- outline Manitoba's legislation with respect to child car seats
- explain why tailgating is a dangerous driving practice
- describe what is meant by the "No-Zone"

SUGGESTED LEARNING RESOURCES

In Motion

Ch. 7 Driving Responsibility

Case Study #1

Case Study #2

Science 10

9.1 Explore an Issue: Progress and Speed on our Highways

9.8 Case Study: Smart Highways

9.11 Career Profile: Marilyn Reynolds, Police Constable

10.1 Explore an Issue: Traveling Off-Road

Unit 3 Challenge: Scientific Perspectives on Motion-Driver Training

Science Power 10

Investigation 12-C: Speeding, Safety, and Modern Life

Unit 3 Project: High-Tech Highway

Unit 3 Issue Analysis: Who's in the Driving Seat?

SYSTH

Chapter 4: Science-Technology-Society-Environment Connections

9.20 Anticipation Guide

13.21 Journal Evaluation

Appendices

6.1 Rubric for the Assessment of Class Presentations

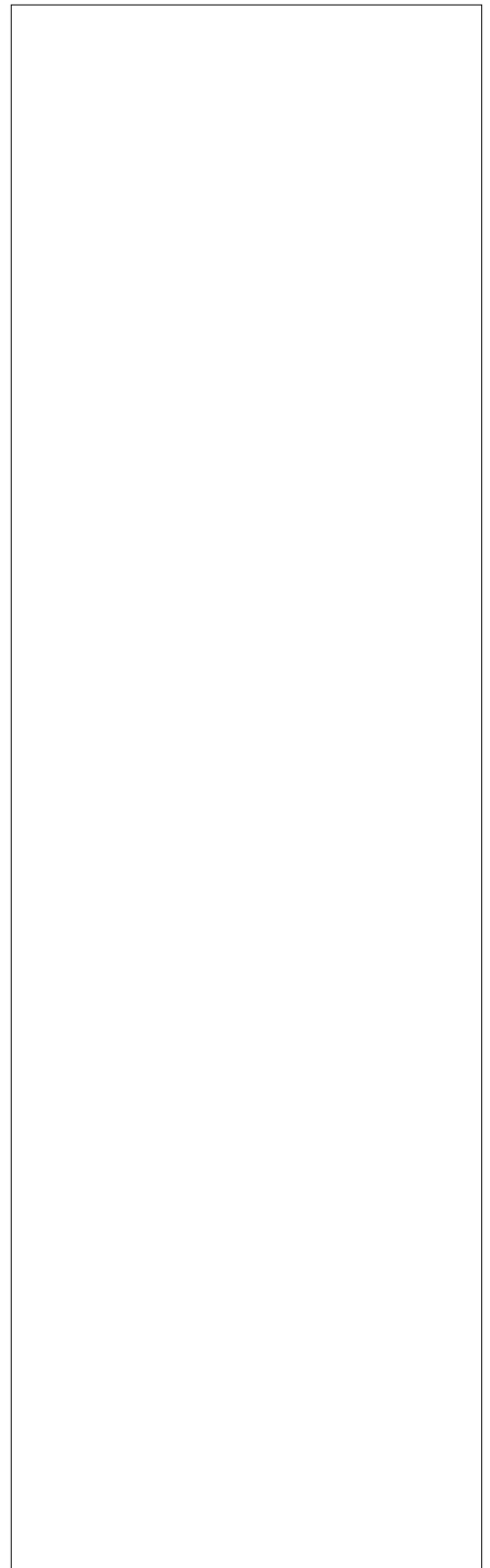
6.2 Rubric for the Assessment of a Research Project

6.3 Rubric for the Assessment of a Decision-Making Process Activity

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(3 HOURS)
<p><i>(continued)</i></p> <p>S2-3-13 Use the decision-making process to address an STSE issue related to safe driving conditions.</p> <p><i>Examples: adverse driving conditions, reaction time, narcotic influences such as blood alcohol level, excessive vehicle speed...</i></p> <p>GLO: B3, C4, C5, C8</p>	<p>Community Connection S2-0-8f</p> <p>Invite a law enforcement officer to give a presentation to the class addressing an STSE issue related to safe driving conditions.</p> <p>Journal Writing S2-0-7f</p> <p>Students reflect on how their driving habits can affect their safety and the safety of others.</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

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NOTES

Senior 2

Cluster 4: Weather Dynamics

Overview

This cluster develops an understanding of the sometimes complex relationships that influence weather and climate. An examination of the global energy budget of Earth, through water and heat transfer, provides the basis for discussion of global winds, ocean currents, and ultimately severe weather phenomena. Students gain understanding of sophisticated meteorological information, gather and analyze meteorological data related to a severe weather event, and explore the social, economic, and environmental impact of the event. Evidence that climate change occurs due to natural events and human activities is investigated and evaluated. Students apply their understanding of weather and climate in a discussion of the potential consequences of climate change.

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(2 HOURS)
<p>S2-4-01 Illustrate the composition and organization of the hydrosphere and the atmosphere.</p> <p>Include: salt water, fresh water, polar ice caps/glaciers, troposphere, stratosphere</p> <p>GLO: D5, E2</p>	<p>➤ Entry-Level Knowledge</p> <p>In Grade 5, the study of weather was first introduced.</p> <p>In Grade 8, the hydrological cycle, global distribution, and relative amounts of salt and fresh water were discussed.</p> <p>➤ Notes for Instruction</p> <p>A review of the hydrological cycle may be a starting point for this cluster. A Knowledge Chart or Sort and Predict activity could be used to activate prior knowledge (see <i>SYSTH</i> 9.25, 10.23).</p> <p>The use of maps, diagrams, graphs, charts, and analogies will aid in student understanding of the composition and organization of the hydrosphere and atmosphere.</p> <p>➤ Student Learning Activities</p> <p>Visual Display/Collaborative Teamwork S2-0-1b, 4f, 4g</p> <p>Student groups construct visual displays of the composition and organization of the hydrosphere and the atmosphere. Displays may include</p> <ul style="list-style-type: none">• world maps with the oceans and continents labeled• pie charts or graphs illustrating the distribution of water in the hydrosphere• labeled diagrams of the layers of the Earth’s atmosphere <p>Displays can be exhibited in the room and used for future reference.</p> <p>Journal Writing S2-0-2a</p> <p>Provide students with a blank world map with several latitude and longitude lines and the outlines of all the continents and oceans. Students label the oceans, continents, and major lines of latitude (Equator, Tropic of Cancer and Tropic of Capricorn, Arctic Circle and Antarctic Circle).</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-5c, 6a

Student groups present

- maps
- diagrams
- posters
- charts
- graphs

Journal Writing S2-0-2a

Students label the oceans, continents, and major lines of latitude on a world map. Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- compare and contrast the hydrosphere and the atmosphere (see *SYSTH* 10.24)
- label the oceans, continents, and major lines of latitude on a map of the world
- create a pie chart to illustrate the distribution of water in the hydrosphere
- draw a diagram of the Earth's atmosphere and label the troposphere and stratosphere
- discuss the implications of the unequal distribution of fresh water on the planet
- predict why so few clouds are found in the stratosphere

Science 10

13.4 The Atmosphere

13.8 The Hydrosphere

BLM 13.4 The Layers of the Atmosphere

ABLM 13.4 Looking at the Atmosphere

Science Power 10

13.3 Interactions of Solar Energy with Land and Air

BLM 13-12 Levels of the Atmosphere

BLM 13-13 Atmospheric Composition

BLM 13-14 The Atmosphere

SYSTH

9.25 Knowledge Chart

10.23 Sort and Predict

10.24 Compare and Contrast

13.21 Journal Evaluation

Appendix

6.1 Rubric for the Assessment of Class Presentations

Teacher Background

While there are several layers of the atmosphere above the Earth's surface, the troposphere and stratosphere are responsible for our weather systems. The gases present in the air near the Earth's surface are nitrogen (78%), oxygen (21%), and other gases such as water vapour, argon, carbon dioxide, and others (1%). The hydrosphere is composed of salt water, fresh water, and polar icecaps and glaciers—the largest component being salt water.

Canada has an abundance of fresh water in its lakes, rivers, and glaciers. We have almost 10% of the world's freshwater supply.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-4-02 Outline factors influencing the Earth’s radiation budget. Include: solar radiation, cloud cover, surface and atmospheric reflectance (albedo), absorption, latitude GLO: D4, D5, E2, E3

SUGGESTIONS FOR INSTRUCTION
(2 HOURS)

- **Entry-Level Knowledge**
In Grade 5, the transfer of energy from the Sun was first introduced. In Grade 6, students examined how the Earth’s tilt of axis and revolution cause the yearly cycle of seasons. In Grade 7, heat transfer by conduction, convection, and radiation was discussed. In Grade 8, the various types of electromagnetic radiation (e.g., ultraviolet, infrared) were compared.

- **Notes for Instruction**
Students have familiarity with many of the concepts related to this learning outcome. Activate students’ knowledge of these concepts and discuss misconceptions. A KWL frame could be used (see *SYSTH* 9.24). A common misconception often held by students is that the seasons change because the Earth moves closer to or further away from the Sun. In fact, seasons change due to a combination of the Earth’s revolution around the Sun and the tilt of the Earth’s axis. The use of maps, diagrams, graphs, and analogies will aid in student understanding of the factors influencing the Earth’s radiation budget.

- **Student Learning Activities**
Laboratory Activity S2-0-1a, 3c, 4a, 5b
Students or student groups conduct a laboratory activity. Investigations may include
 - determining the relationship between the angle of sunlight and the seasons on the Earth
 - comparing rates of heating and cooling of soil and water
 - calculating the hours of daylight in a community on the longest and shortest days of the year
 - determining the characteristics of an object that cause it to absorb or reflect solar energy

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Laboratory Report S2-0-6b, 6c, 7a, 7b

Students interpret their laboratory results and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Student Research S2-0-2a, 9b, 9c

Students present research findings with

- written reports
- oral presentations
- multimedia presentations
- newspaper articles

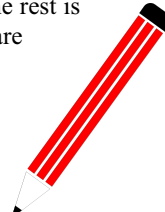
Visual Display S2-0-4f, 4g, 5c

Student groups present their visual displays of the factors influencing the Earth’s energy budget with

- posters
- diagrams
- charts
- bulletin board displays
- dioramas
- cartoons

Teacher Background

The Sun’s energy travels through space essentially with no interference until it reaches the Earth’s atmosphere. A number of interactions then occur. Much of the Sun’s energy is absorbed by gases, dust particles, clouds, and the Earth’s surface, while the rest is reflected. Of 100 units of incoming solar radiation, 19 units are absorbed by the atmosphere and clouds. Fifty-one units are absorbed by the Earth’s surface. The remaining 30 units are reflected and scattered by the atmosphere, clouds, and the Earth’s surface.



(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 13.1 A Closer Look at Earth
- 13.2 Earth’s Energy Balance
- 13.3 Investigation: Seasons and the Angle of Sunlight
- BLM 13.1a Map of the World
- BLM 13.1b What’s Your Angle?
- BLM 13.2 How Much Do I Know?
- BLM 13.3 Mysterious Planet
- BLM 16.6 Look at Frosty Go
- ABLM 13.3 The Intensity of Light and the Angle of Incidence
- ABLM 13.3a Changing Seasons for the Northern Hemisphere

Science Power 10

- 13.1 Earth’s Energy Budget
- 13.2 Energy and Water
- 13.3 Interactions of Solar Energy with Land and Air
- Investigation 13-A: Comparing the Properties of Soil and Water
- 14.1 Solar Energy and a Spherical Earth
- Investigation 14-A: Hours of Daylight
- BLM 13-2 Absorption or Reflection
- BLM 13-7 Moisture in the Air
- BLM 14-2 Hours of Daylight
- BLM 14-3 Solar Energy and a Spherical Earth

(continued)

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(2 HOURS)
<p><i>(continued)</i></p> <p>S2-4-02 Outline factors influencing the Earth’s radiation budget.</p> <p>Include: solar radiation, cloud cover, surface and atmospheric reflectance (albedo), absorption, latitude</p> <p>GLO: D4, D5, E2, E3</p>	<p>Student Research S2-0-2a, 9b, 9c</p> <p>Students research the factors influencing the Earth’s radiation budget. These factors include</p> <ul style="list-style-type: none">• solar radiation• cloud cover• albedo• absorption <p>Case studies, newspaper articles, and Internet sources may be used. See also Appendix 4.2: Sunlight and Seasonal Variations.</p> <p>Visual Display/Collaborative Teamwork S2-0-4f, 4g, 5c</p> <p>Student groups research and prepare visual displays of the factors influencing the Earth’s radiation budget, such as</p> <ul style="list-style-type: none">• cloud cover• latitude• atmospheric reflectance <p>Journal Writing S2-0-2c</p> <p>Students prepare a glossary of new words for quick reference. A Three-Point Approach could be used (see <i>SYSTH</i> 10.22).</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Journal Writing S2-0-2c

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- complete a Word Cycle of terms related to this learning outcome (see *SYSTH* 10.21)
- predict the effect of melting polar ice caps on the albedo of the Earth
- describe the effect of latitude on absorption of solar radiation
- differentiate between latitude and longitude
- draw and label a diagram showing how solar radiation is distributed when it reaches the Earth
- explain the relationship between the seasons and the angle of sunlight
- describe the effect of cloud cover on reflectance of solar radiation
- differentiate between absorption and reflection

SYSTH

- 9.24 KWL Plus
- 10.21 Word Cycle
- 10.22 Three-Point Approach
- 13.21 Journal Evaluation
- 14.12 Lab Report Format

Appendices

- 4.1 Earth's Energy Budget
- 4.2 Sunlight and Seasonal Variations
- 4.3 Exploring Albedo
- 4.4 Connecting Mathematics to the Atmosphere
- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-4-03 Explain effects of heat transfer within the atmosphere and hydrosphere on the development and movement of wind and ocean currents.</p> <p>Include: Coriolis effect and atmospheric convection, prevailing winds, jet streams, El Niño/La Niña</p> <p>GLO: A2, D5, E1, E4</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students learned how the transfer of energy from the sun affects weather conditions. In Grade 7, the concept of heat transfer was discussed. In Grade 8, the hydrological cycle, Coriolis effect, prevailing winds, ocean currents, and the heat capacity of water were introduced.

➤ **Notes for Instruction**

Students have familiarity with many of the concepts related to this learning outcome. Activate students’ prior knowledge using a Sort and Predict activity (see *SYSTH* 10.23). Discuss misconceptions, such as the Coriolis effect, causing water to swirl in a certain direction down a drain (see Teacher Background for this learning outcome in Appendix 4.5 and Appendix 4.6). The use of maps, diagrams, graphs, analogies, and demonstrations will aid in student understanding of the effects of heat transfer within the atmosphere and hydrosphere. In particular, java applets and simulations of the Coriolis effect can be very effective in developing student understanding of this phenomenon that is unique to spinning planets with atmospheres.

Teacher Demonstration S2-0-1a, 3a, 6a, 7a

See Appendix 4.9: Convection Currents for a demonstration illustrating the formation and movement of convection currents. This demonstration can be adapted for use as a laboratory activity.

Teacher Background

As the air above Earth’s surface warms, it becomes less dense and rises. Cooler and denser air tends to sink. These differences in air temperature and density initiate worldwide movements of air, and global wind patterns can develop. Having a spinning planet is also very important, with just the right rate of spin. Venus, for instance, has no wind belts because of its extremely slow rate of rotation (one rotation every 244 Earth days). Jupiter and Saturn (with rotation periods of 9h 55.5m and 10h 14m respectively) have very well-developed—and persistent—global wind belts. We observe these wind belts as coloured bands in the outer atmospheres of these large, gaseous planets).

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- label a world map and/or map of North America with major ocean currents and the direction in which they move
- explain why a direct flight from Winnipeg to Calgary usually takes longer than a direct flight from Calgary to Winnipeg
- label a world map and/or map of North America showing the direction of prevailing winds (see Appendix 4.11–4.12 for a world map template)
- describe how solar energy causes wind currents
- suggest reasons why winters in Iceland and Norway are warmer than in Manitoba with similar latitude among these places
- distinguish between El Niño and La Niña ocean currents
- explain how the Coriolis effect influences the movement of wind and ocean currents
- differentiate between prevailing winds and jet streams

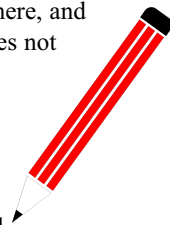
Laboratory Report S2-0-6a, 6b, 6c, 7b

Students interpret their laboratory results and prepare a report describing their investigation findings (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing.

Teacher Background

The influence of the Earth’s rotation on air, or on any object moving on the Earth’s surface, is called the Coriolis effect. As one moves away from the equator, each point on the Earth rotates at different speeds, depending on the latitude. For example, at the equator, the speed of rotation at the Earth’s surface is 1664 km/h. At 30 degrees north latitude, the speed is 1392 km/h, and at 45 degrees north latitude, the speed drops to 1168 km/h.

The Coriolis effect is responsible for the deflection of wind and ocean currents to the right from the equator in the northern hemisphere, and to the left from the equator in the southern hemisphere. It does not cause water to swirl down the drain in the counter-clockwise direction in the northern hemisphere, and in the clockwise direction in the southern hemisphere! This is a popular, and apparently incorrect, urban legend. Try it yourself...!



(continued)

Science 10

- 13.6 Prevailing Wind Patterns
- 13.7 Case Study: The First Round-the-World Balloon Flight
- 13.9 Major Ocean Currents
- 13.13 A Global Weather Model
- 15.12 El Niño and La Niña
- BLM 13.6b How Do You Hit a Moving Target?
- BLM 13.9 A Tale of Two Islands
- BLM 13.13 What’s the Weather Factor
- BLM 16GS Trapped in Ice
- ABLM 13.7 Making and Flying a Hot-Air Balloon
- ABLM 15.12 El Niño’s Effects on Air and Water Currents

Science Power 10

- Investigation 13-B: Blowing in the Wind
- 14.2 Worldwide Wind Currents
- Investigation 14-B: Determining the Direction of Prevailing Winds
- 14.3 Rivers in the Sea
- Investigation 14-C: Moving Mountains of Water
- BLM 14-4 The Coriolis Effect
- BLM 14-5 Determining the Direction of Prevailing Winds
- BLM 14-6 The Jet Stream
- BLM 14-8 Ocean Gyres
- BLM 14-10 Moving Mountains of Water
- BLM 14-11 El Niño
- BLM 14-12 El Niño

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-4-03 Explain effects of heat transfer within the atmosphere and hydrosphere on the development and movement of wind and ocean currents.</p> <p>Include: Coriolis effect and atmospheric convection, prevailing winds, jet streams, El Niño/La Niña</p> <p>GLO: A2, D5, E1, E4</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Student Learning Activities**

Laboratory Activity S2-0-1a, 3a, 3c, 4a

Students or student groups conduct a laboratory activity. Investigations may include determining

- what happens when water of one temperature comes in contact with water of a different temperature (use coloured dyes)
- how the concentration of salt affects the motion of water
- how interactions between ground, water, and air pressure gradients result in winds
- the direction of prevailing winds on certain continents (i.e., North America)

Student Research S2-0-1b, 2b, 2c

Students or student groups research the effects of wind and ocean currents. Topics may include

- the jet stream and the race to the first “round-the-world” balloon flight
- the use of the Gulf Stream by sailing ships
- how the Horse Latitudes got their name
- the link between the location of deserts and wind/ocean currents
- how, and by whom, the jet stream was discovered
- how the Gulf Stream affects the climate of Newfoundland and western Europe
- how the “Roaring Forties” got their name

Case studies, newspaper articles, and Internet sources may be used.

Journal Writing S2-0-2a

Students label maps (world and North America) indicating major ocean currents, and the prevailing winds. On a map of North America, the location of the west-east jet stream could be plotted over a succession of days. This would make an ideal “heads-up” for later work on the association of major pressure systems with jet streams.

SUGGESTIONS FOR ASSESSMENT

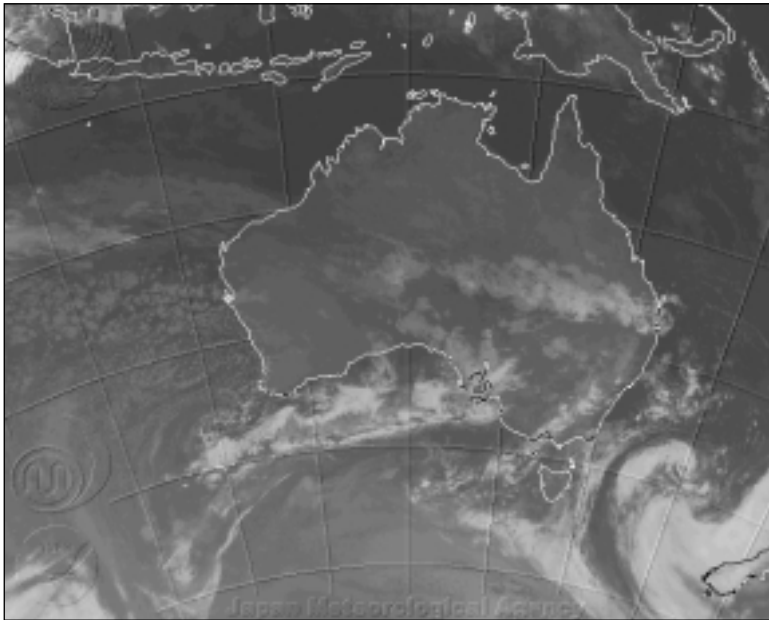
Research Report/Presentation S2-0-8c, 8e, 9a

Students or student groups present research findings with

- oral presentations
- written reports
- multimedia presentations
- posters
- bulletin board displays
- newspaper articles
- dramatic presentations

Journal Writing S2-0-2a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).



Satellite image showing clockwise rotation (lower right) around a low pressure centre. Coriolis effect induces the “bending” as seen here in the Southern Hemisphere.

Graphic courtesy of NOAA. All rights reserved.

SUGGESTED LEARNING RESOURCES

SYSTH

- 10.23 Sort and Predict
- 13.21 Journal Evaluation
- 14.12 Lab Report Format

Appendices

- 4.5 The Coriolis Effect
- 4.6 Understanding the Link Between Coriolis and Weather
- 4.7 It Bends Because the Earth Turns
- 4.9 Convection Currents
- 4.10 The Atmosphere-Ocean Connection—El Niño and La Niña
- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-4-04 Explain the formation and dynamics of severe weather phenomena.</p> <p><i>Examples: thunderstorms, tornadoes, blizzards, hurricanes, extreme temperature events, cyclonic storms...</i></p> <p>GLO: A2, D5, E1, E4</p>

SUGGESTIONS FOR INSTRUCTION

(5 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, the study of weather was first introduced. Topics examined included warm and cold air masses, fronts, high- and low-pressure systems, formation and types of clouds, transfer of energy from the sun, and examples of severe weather. Students will also have had real-life experiences related to severe weather, as well as exposure through the media (e.g., television, movies, newspaper).

Nevertheless, it will be important to insert an intervention related to these fundamentals of meteorology **before** consideration can be given to discussion and exploration of specific weather-related phenomena. That is, prior to addressing this student learning outcome, students will need to have in place some solid basis upon which to address the dynamics of severe weather. The following text box outlines some of the essentials of meteorology considered implicit in this specific learning outcome:

- Use the particle theory to predict how air masses will behave when placed in a **pressure gradient** (i.e., movement of air from region of high pressure to one of lower pressure)
- Be acquainted with basic meteorological symbols (weather station glyphs), the prevalent symbols used in media-type weather maps (e.g., warm and cold fronts, highs and lows, the position of the jet stream(s))
- Familiarity with terms such as air pressure, ambient temperature, dew point, isobars, surface analysis map
- The movement of frontal systems over time (accomplished through actively watching weather systems from a variety of media sources in “real-time” if possible)

➤ **Notes for Instruction**

This learning outcome could be introduced with a discussion and examination of warm, cold, stationary, and occluded fronts. High- and low-pressure systems should be included at this time. Diagrams, maps, and demonstrations should be used to illustrate the formation and dynamics of weather phenomena. Take advantage of current and/or local weather events to increase the level of immediate relevance to class activities. Excellent visual documentation of severe weather phenomena can be found on television, in software simulations, videotapes, and numerous websites devoted to instances of tornadoes, blizzards, and hurricanes, among others.

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-2a, 5c, 8b

Students or student groups prepare and present visual displays of the development of weather phenomena. Displays may take the form of

- posters
- diagrams
- charts
- bulletin board presentations
- dioramas
- cartoons
- demonstrations

Research Report/Presentation S2-0-9b, 9c

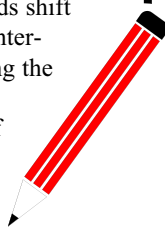
Students or student groups research the formation and dynamics of severe weather phenomena, and present

- written reports
- oral presentations
- brochures
- pamphlets
- multimedia presentations
- newspaper articles

Teacher Background

A Colorado Low is a counter-clockwise rotating, low-pressure system, that forms over the east side of the U.S. Rocky Mountains. If the low intensifies, air from the Gulf of Mexico is drawn into the Prairies and Central Plains regions of North America. When this warm, moist air meets the cold Arctic air from the north along a frontal boundary, a mid-latitude cyclonic storm develops. Precipitation falls as rain or snow, depending on the air temperature.

As the jet stream pushes the storm from west to east, the winds shift from the southeast to the northwest as the system rotates counter-clockwise, drawing colder Arctic air to the region, and causing the temperature to plunge. Some of Manitoba’s worst blizzards (March 1966, November 1986, April 1997) were the result of mid-latitude cyclonic storms. See the Appendix 4.30: The 1997 Manitoba Blizzard for a student activity.



(continued)

Science 10

- 14.2 North American Weather Systems
- 15.3 Thunderstorms and Tornadoes
- 15.4 Floods and Droughts
- 15.6 Hurricanes, Typhoons, and Tropical Cyclones
- 15.7 Blizzards
- 15.9 Extreme Heat and Cold
- BLM 14.2a The Life of a Storm
- BLM 14.2b The Life of a Storm
- BLM 15.6a The Formation of Hurricanes
- BLM 15.6b The Formation of Hurricanes

Science Power 10

- 15.1 Highs, Lows, and Fronts
- 15.3 Severe Weather
- BLM 15-5 Description of a Warm Front
- BLM 15-6 Description of a Cold Front
- BLM 15-7 Cold Front
- BLM 15-8 Warm Front
- BLM 15-9 Description of an Occluded Front
- BLM 15-10 Temperature Profile of a Frontal System
- BLM 15-11 High and Low Pressure Systems
- BLM 15-12 Fronts and Winds
- BLM 15-13 Highs, Lows, and Fronts
- BLM 15-14 Thunderstorms
- BLM 15-15 Tornado in a Bottle

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-4-04 Explain the formation and dynamics of selected severe weather phenomena.</p> <p><i>Examples: thunderstorms, tornadoes, blizzards, hurricanes, extreme temperature events, cyclonic storms...</i></p> <p>GLO: A2, D5, E1, E4</p>

SUGGESTIONS FOR INSTRUCTION

(5 HOURS)

Note: The Atlantic hurricane season runs from late August to early November, averaging five to eight tropical storms of note per season. The western Pacific typhoon season runs from about March through May, while the winter months often host a number of Southern Hemisphere tropical storms and cyclones in the Indian Ocean or offshore Australia. For teachers who would benefit from automatic notification of such events, there are listserves available on the Internet, and software packages that track storms and hurricanes (e.g., *Tracking the Eye* and *Global Tracks 6.0 2003*).

➤ **Student Learning Activities**

Teacher Demonstration S2-0-3a, 4a, 4e

Fill a clear glass tray or shallow bowl halfway with warm water. Add a few drops of food colouring to the warm water and mix. Slowly pour in cold milk. Observe the movement and shape of the milk.

The milk represents an approaching cold air mass. A cold air mass will displace a warm air mass by pushing the warm air upwards along a cold front.

Class Discussion S2-0-7f

Generate interest in the learning outcome by having students relate their experiences with severe weather phenomena to the class. A Listen-Think-Pair-Share structure could be used (see *SYSTH 3.10*).

Visual Display S2-0-2a, 5c, 8b

Students or student groups construct visual displays illustrating the development of weather phenomena such as

- thunderstorms
- tornadoes
- blizzards
- cyclonic storms
- hurricanes

Displays can be exhibited in the room and used for future reference.

(continued)

SUGGESTIONS FOR ASSESSMENT

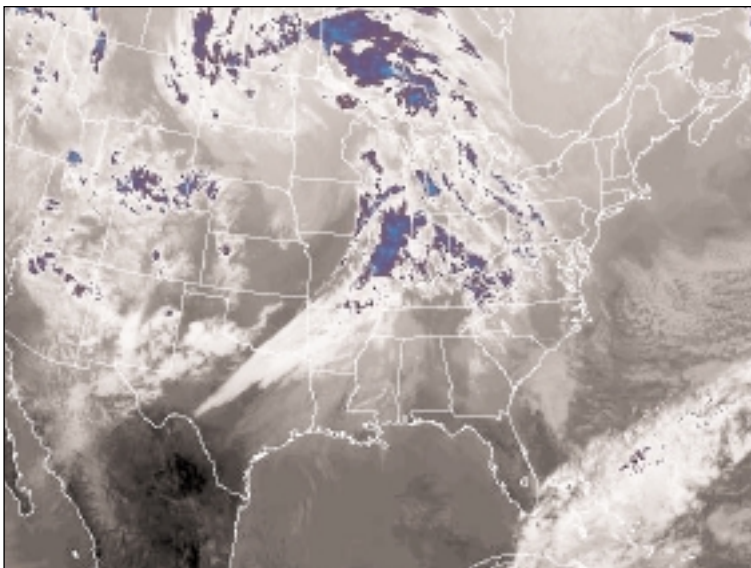
Journal Writing S2-0-2a

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- describe the role of the Coriolis effect in the development and movement of hurricanes
- draw and label diagrams illustrating the stages of a thunderstorm
- differentiate between cyclones and anticyclones
- explain why most tornadoes tend to occur in the Central Plains region of the United States
- list the characteristics of a blizzard
- summarize the stages of tornado formation
- predict why it is unlikely that hurricanes will form in the Arctic Ocean
- formulate a hypothesis to explain why thunderstorms seldom occur in the winter in Manitoba
- explain why a Colorado Low (a cyclonic storm) often brings severe weather (e.g., blizzards) to Manitoba



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SUGGESTED LEARNING RESOURCES

- BLM 15-16 Hurricanes
- BLM 15-18 Naming Hurricanes
- BLM 15-19 Storm Surges
- BLM 15-20 Severe Weather Quiz
- BLM 15-21 Weather Events

SYSTH

- 3.10 Listen-Think-Pair-Share
- 9.24 KWL Plus
- 10.22 Three-Point Approach
- 13.21 Journal Evaluation

Appendices

- 4.17 Understanding Highs and Lows
- 4.18 Introduction to Weather Maps and Symbols
- 4.20 The Fujita Scale of Tornado Intensity
- 4.21a Canadian Tornado Frequency Data—An Applied Mathematics (20S) Approach
- 4.21b Canadian Tornado Frequency Data—A Consumer Mathematics (20S) Approach
- 4.21c Canadian Tornado Frequency Data—A Pre-Calculus Mathematics (20S) Approach
- 4.22a Watch Out! There May Be a Tornado in Your Backyard
- 4.22b Tornado Plotting Map of Canada
- 4.23 Tornado-Related Statistics and Graphing
- 4.24 Location/Place—Where in the World Can Severe Storm Events Happen?
- 4.25 Tracking a Killer Hurricane

(continued)

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION (5 HOURS)
<p><i>Students will...</i></p> <p><i>(continued)</i></p> <p>S2-4-04 Explain the formation and dynamics of selected severe weather phenomena.</p> <p><i>Examples: thunderstorms, tornadoes, blizzards, hurricanes, extreme temperature events, cyclonic storms...</i></p> <p>GLO: A2, D5, E1, E4</p>	<p>Student Research S2-0-1b, 2c</p> <p>Students or student groups research the formation and dynamics of severe weather phenomena. Topics can include</p> <ul style="list-style-type: none">• thunderstorms• monsoons• extreme temperature events• ice storms <p>Case studies, newspaper articles, and Internet sources may be used.</p> <p>Journal Writing S2-0-2a</p> <p>Students prepare a glossary of new words for quick reference. A Three-Point Approach could be used (see <i>SYSTH</i> 10.22).</p> <p>Teacher Demonstration S2-0-3a, 4a, 4e</p> <p>Fill a tall beaker or jar with water. Place several non-floating objects such as paper clips and thumbtacks on the bottom of the beaker. Stir the top 5 cm of water with a spoon. Observe.</p> <p>The stirring simulates the wind shear that starts or intensifies the rotation of updrafts in thunderclouds, creating a vortex. As air continues to rise upward, the vortex spins faster and faster, and a funnel cloud forms. When a funnel cloud touches the ground, it is then considered to be a tornado.</p> <p>Alternatively, this can be simulated as a “tornado in a bottle” demonstration. Attach two empty 2-litre plastic bottles together by gluing their lids together back-to-back. Drill a 0.5-cm hole in the lids to allow the transfer of liquid. Fill one bottle with water, a little blue food colouring, and a small handful of confetti from the copy machine. After you have re-attached the two bottles, invert the assembly, give it a few strong swirls, then watch the “tornado” develop.</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.3 Rubric for the Assessment of a Decision-Making Process Activity
- 6.4 Lab Report Assessment

Hurricane/Severe Storm-Tracking Software

Global Tracks 6.0 (2003)

<<http://www.jincolutions.com/home.asp>>

Tracking the Eye

<<http://www.hurricanesoftware.com/>>

Eye of the Storm

<<http://www.starstonesoftware.com>>

McHurricane (for Mac) Version 5.2.2

<<http://www.mchurricane.com>>

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-4-05 Collect, interpret, and analyze meteorological data related to a severe weather event.</p> <p>Include: meteorological maps, satellite imagery, conditions prior to and following the event</p> <p>GLO: C2, C6, C8, D5</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students observed and measured local weather conditions and analyzed the data collected. Students may have had exposure to meteorological maps through television and newspaper articles, as well as discussion on personal experiences with conditions prior to and following severe storms in the previous learning outcome.

➤ **Notes for Instruction**

This specific learning outcome can be significantly linked to SLO S2-4-04, which deals with the dynamics of severe weather events. A more “integrative” approach would have students use the context of a particular weather event to motivate the gathering of the relevant synoptic data, such as temperature, precipitation, and cloud cover records. In addition, the readily available satellite imagery databases allow for the observational information to be correlated to space platform images (i.e., visible, infrared, water vapour wavelengths satellite images). It may be important to introduce the fundamentals of remote sensing (e.g., Doppler radar) prior to their use in analyzing particular events. See Appendices 4.17, 4.18, and 4.19 for student learning activities in these areas. Activate prior knowledge of this learning outcome with a “refresher” examination of weather maps and symbols. A Knowledge Chart could be used (see *SYSTH* 9.25).

Discuss the types of data collected by meteorologists, and the technologies used. Take advantage of current and/or local weather events available in print and electronic media. The Environment Canada website has current weather data and maps, as well as satellite and radar images for all regions of Canada (see <<http://weatheroffice.ec.gc.ca/>> or <www.mb.ec.gc.ca/>).

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Visual Display S2-0-5c, 6a, 9c

Student groups present meteorological data and weather maps as

- television/radio broadcasts
- multimedia presentations
- newspaper articles
- charts
- posters
- bulletin board displays

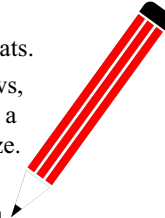
Laboratory Report S2-0-5a, 7b, 9c, 9d

Students prepare a lab or case study report including their collected weather data, satellite imagery, issued weather advisories, their analyses and interpretation of the data, and their weather forecast for a chosen community or region over time (see *SYSTH* 14.12 for a lab report format). Word-processing software and spreadsheets can be used for report writing. At some point, individual students (or small groups) could take responsibility for tracking a weather event in order to contribute to a whole-class archive of “storm-watching.”

Teacher Background

Many animals are sensitive to environmental changes that humans often cannot detect. Here are a few popularized examples:

- When air pressure drops, flying insects become more active and stay closer to the ground, so they seem to swarm before a rainstorm.
- The calls of some birds, including crows and geese, become more frequent with falling air pressure.
- Static electricity may increase the grooming activities of cats.
- Falling air pressure may affect the digestive system of cows, making them less willing to go to pasture. They then have a greater tendency to lie down and ruminate rather than graze.



(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 14.3 Case Study: Three Days of Canadian Weather
- 14.8 Weather Heritage
- 14.9 Weather Forecasting Technology
- 14.10 Investigation: The Weather Forecasting Business
- 14.13 Weather Records and Events
- 14.15 How Accurate Are Advanced Forecasts?

BLM 14.3 Map for Tracking Weather Patterns

BLM 14.8 Nature’s Weather Forecasts—or Not?

BLM 15.1a Looking at the Records

BLM 15.1b A Study in Contrasts

ABLM 13.1 Looking at Weather Maps

Science Power 10

- 16.1 Collecting Weather Data
- 16.2 Weather Maps and Forecasting
- 16.3 Past, Present, and Future
- Investigation 16-C: Forecast the Weather
- BLM 16-3 Interpreting Weather Maps
- BLM 16-4 Drawing Isobars
- BLM 16-5 Drawing Isotherms
- BLM 16-6 Forecasting the Weather
- BLM 16-7 Forecasting Quiz
- BLM 16-8 Thunderstorms: Myth, Folklore, and Science
- BLM 16-11 Weather and Chaos

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-4-05 Collect, interpret, and analyze meteorological data related to a severe weather event.</p> <p>Include: meteorological maps, satellite imagery, conditions prior to and following the event</p> <p>GLO: C2, C6, C8, D5</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Student Learning Activities**

Visual Display/Collaborative Teamwork S2-0-1b, 2a, 4f, 4g

Student groups track a storm as it moves across the country or a region, or the entire continent, and interpret and analyze the meteorological data. Students then prepare a weather map (or source the map information from available archives), using the collected data, and choose a method to showcase their results for peer review. It is recommended that this be done so that the seasonal variations in severe weather events can be highlighted. For instance, fall constitutes an excellent time to track Atlantic hurricanes; winter offers classic “Colorado Lows” that can bring blizzards to the Prairies; transition to spring often brings benevolent weather to Manitoba, but eastern Canada often has spectacular events such as ice storms (e.g., January 1998), early season thunderstorms and tornadoes (central US), and unanticipated spring snowstorms. For an archive of significant weather events, see: <<http://www.osei.noaa.gov/>>; for significant events as they happen, see <<http://Earthobservatory.nasa.gov/Newsroom/Headlines/>>. NASA operates an automatic updates page on important natural developments around the world, accessible at <<http://Earthobservatory.nasa.gov/>>.

Laboratory Activity S2-0-1b, 2b, 3a, 4e

Students or student groups collect North American weather data daily for several consecutive days. Prior to this activity, students could benefit from the mapping sequence activity found in Appendix 4.16: Introduction to Weather Maps. The data for a particular community are analyzed, and a weather forecast is prepared. Meteorological data should be collected from a variety of sources, such as the Internet, television, radio, or newspaper. Case studies may be used for this approach, and it may be useful to have groups of students work in different regions of the world, and then compare/contrast inter-hemisphere phenomena.

(continued)

SUGGESTIONS FOR ASSESSMENT

Research Report/Presentation S2-0-3e, 8e, 9a, 9d

Students or student groups present research findings with

- written reports
- oral presentations
- newspaper articles
- posters
- bulletin board displays
- brochures
- pamphlets
- multimedia presentations

Journal Writing S2-0-7f, 8d

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- discuss the importance of satellite imagery in weather forecasting, and make use of actual satellite image products as a component of this discussion
- describe how weather balloons are used to gather weather-related data
- discuss the advantages/difficulties of using Doppler radar in weather forecasting
- identify symbols used on weather maps (e.g., warm front, isobars, low pressure, et cetera)
- interpret and analyze meteorological data related to a severe weather event
- compare and contrast isotherms and isobars (all examples of *isopleths*) (see *SYSTH* 10.24)
- differentiate among a visible wavelengths satellite image, an infrared (IR) image, a water vapour image, and a radar image as these are used in weather forecasting and analysis of conditions

SUGGESTED LEARNING RESOURCES

SYSTH

- 9.25 Knowledge Chart
 10.24 Compare and Contrast
 13.21 Journal Evaluation
 14.12 Lab Report Format

Appendices

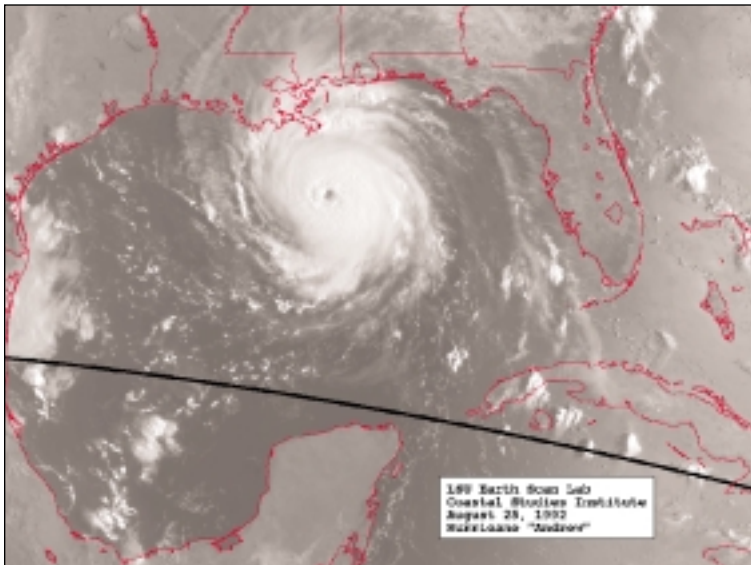
- 4.17 Understanding Highs and Lows
 4.18 Introduction to Weather Maps and Symbols
 4.19 Using Satellites to Track Weather
 4.20 The Fujita Scale of Tornado Intensity
 4.21a Canadian Tornado Frequency Data—An Applied Mathematics (20S) Approach
 4.21b Canadian Tornado Frequency Data—A Consumer Mathematics (20S) Approach
 4.21c Canadian Tornado Frequency Data—A Pre-Calculus (20S) Approach
 4.22a Watch Out! There May be a Tornado in Your Backyard!
 4.22b Tornado Plotting Map of Canada
 4.23 Tornado-Related Statistics and Graphing
 4.24 Location/Place—Where in the World Can Severe Storm Events Happen?
 4.25 Tracking a Killer Hurricane
 4.26a East Pacific Hurricane Tracking Chart
 4.26b Atlantic Hurricane Track Chart

(continued)

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(3 HOURS)
<p><i>(continued)</i></p> <p>S2-4-05 Collect, interpret, and analyze meteorological data related to a severe weather event.</p> <p>Include: meteorological maps, satellite imagery, conditions prior to and following the event</p> <p>GLO: C2, C6, C8, D5</p>	<p>Student Research S2-0-1b, 2b, 8e, 9a</p> <p>Students or student groups research the origin or veracity of folkloric sayings/observations with respect to weather. Examples include</p> <ul style="list-style-type: none">• “Red sky at night, sailor’s delight, Red sky in the morning, sailors take warning”• “The dog days of summer”• the number of stripes on a woolly bear caterpillar and the length/cold of the coming winter• the correlation between a groundhog’s seeing its shadow and the arrival of spring• arthritic joint pain foretelling a change in the weather• the thickness of the mud on a beaver lodge and the length/cold of the upcoming winter• “a three dog night” <p>Students may wish to interview or invite community elders to the class to share their knowledge.</p> <p>Journal Writing S2-0-7f, 8c</p> <p>Students reflect and respond to the following questions:</p> <ul style="list-style-type: none">• How has your understanding of weather changed since the start of the unit?• What new questions do you have about weather?• What new information in this cluster surprises you?• How has technology played a role in our understanding of weather? <p>Community/Career Connection S2-0-8c, 8d, 8f, 9b</p> <p>Invite a community member such as a pilot, weather announcer, or meteorologist to come into the classroom and answer students’ questions. The questions may be prepared in advance so that appropriate topics are covered. Questions may include:</p> <ul style="list-style-type: none">• What special training in weather forecasting have you received?• Where do you get your meteorological data?• What sciences are involved in meteorology, both academic and applied?• How does meteorological technology assist you in your job?

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES



Graphic courtesy of NOAA. All rights reserved.

- 4.27 The Saffir-Simpson Hurricane Scale and Fujita Tornado Scale
- 4.28 Weather Map Symbols
- 4.29 Weather Map Symbols—A Student's Guide
- 4.30 The 1997 Manitoba Blizzard
- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project
- 6.3 Rubric for Assessment of a Decision-Making Process Activity
- 6.4 Lab Report Assessment

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-4-06 Investigate the social, economic, and environmental impact of a recent severe weather event.</p> <p>Include: related consequences on personal and societal decision-making</p> <p>GLO: B2, B4, C6</p>

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students described how weather may affect the activities of humans and animals. Severe weather forecasts and preparations for ensuring personal safety were also discussed. Students may have personal experience with the impact of a severe weather event, or familiarity from the media and other sources.

➤ **Notes for Instruction**

Activate prior knowledge of this learning outcome by having students relate ways severe weather events have affected their lives. A Rotational Cooperative Graffiti structure could be used (see *SYSTH* 3.15).

Take advantage of current and/or local weather events. Excellent visual documentation of severe weather phenomena can be found on television or videotape footage, and numerous websites devoted to instances of tornadoes, blizzards, and hurricanes.

➤ **Student Learning Activities**

Student Research/Collaborative Teamwork

S2-0-1b, 1d, 4f, 4g

Student groups examine case studies, or research the effects of a severe weather event. Research may include interviewing

- survivors of a tornado
- homeowners affected by a flood
- trappers, elders, or conservation officers about the impact of extreme cold on wildlife populations
- motorists stranded by a snowstorm
- boaters caught by a windstorm

The social, economic, and/or environmental impact of a severe weather event should be included.

(continued)

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- discuss how severe weather phenomena can disrupt our everyday lives
- differentiate between a severe weather watch and a severe weather warning
- formulate a plan to ensure personal safety if a thunderstorm develops during a canoe trip or golf game
- calculate the distance between themselves and a lightning bolt, using the time between seeing the lightning and hearing the thunder
- describe survival techniques for stranded motorists or snowmobile operators
- predict the potential consequences of an extended hot and dry spell on Manitoba forests or farms
- compare and contrast the humidex scale with the wind chill factor or Environment Canada’s new “Chilldex/Froidex” at http://www.msc.ec.gc.ca/education/windchill/index_e.cfm (see *SYSTH* 10.24)

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-5a, 9b, 9c

Student groups present their research on the social, economic, and/or environmental impact of a severe weather event with

- oral presentations
- written reports
- dramatic presentations
- newspaper articles
- multimedia presentations

Science 10

- 15.1 Weather Records and Events
- 15.2 Weather in the News
- 15.8 Case Study: Surviving the 1998 Ice Storm
- 15.9 Extreme Heat and Cold
- 15.10 Explore an Issue: Winter Shelters for the Homeless
- 15.11 Reporting an Extreme Weather Event

BLM 13.10 Weather or Not!

BLM 14.11 How Vital Is It?

BLM 15.2 We Interrupt This Program...

BLM 15.3 Tornadoes in Canada

BLM 15.6c Hurricanes in Canada

Science Power 10

16.3 Past, Present, and Future

Unit 4 Project: Preparing for a Really Rainy Day

BLM 15-17 Hurricane Evacuation Game

BLM G-29 Scientific Research Planner

BLM G-30 Research Worksheet

BLM G-31 Internet Research Tips

SYSTH

3.15 Rotational Cooperative Graffiti

10.24 Compare and Contrast

11.40 Issue-Based Article Analysis

11.41 Fact-Based Article Analysis

13.21 Journal Evaluation

(continued)

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<i>(continued)</i>
S2-4-06 Investigate the social, economic, and environmental impact of a recent severe weather event. Include: related consequences on personal and societal decision making GLO: B2, B4, C6

SUGGESTIONS FOR INSTRUCTION

(3 HOURS)

Visual Display S2-0- 1c, 2a, 7c, 7d

Students or student groups develop an advertising campaign to increase knowledge of

- winter emergency kits for cars and trucks
- community flood preparation
- the role of EMO (Emergency Measures Organization)
- tornado safety
- thunderstorm safety
- recognizing and treating frostbite/hypothermia
- recognizing and treating heat exhaustion/stroke
- winter driving techniques
- emergency measures for boaters

Journal Writing S2-0-9b

Students complete a fact- or issue-based article analysis of a current newspaper or magazine article related to the impact of a severe weather event (see *SYSTH* 11.40, 11.41).

Collaborative Teamwork S2-0-4f, 8b, 9b

Student groups create severe weather haiku poetry, such as

Snowflakes fall and drift

as the north wind howls—blizzard

No school tomorrow!

Haiku poems typically contain 17 syllables in a 5-7-5 arrangement and a seasonal reference.

Community/Career Connection S2-0-8e, 8f, 9a

Invite guests such as construction workers, resort operators, hunters, fishers, trappers, or farmers to speak to the class about how the weather affects their work and/or how their knowledge of weather helps them in their jobs. Students could also interview community members in their homes or workplaces.

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Visual Display S2-0-3f, 7d, 7e, 9f

Students or student groups present visual displays of their advertising campaigns such as

- posters
- radio commercials
- bulletin board displays
- television commercials
- pamphlets
- brochures
- newspaper/magazine advertisements

Journal Writing S2-0-9b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Appendices

- 4.24 Location/Place—Where in the World Can Severe Storm Events Happen?
- 6.1 Rubric for the Assessment of Class Presentations
- 6.2 Rubric for the Assessment of a Research Project

Teacher Background

Significant Canadian Severe Weather Events**Tornadoes**

Regina — June 1912
 Portage la Prairie — June 1922
 Windsor — June 1946
 Barrie, Ontario — May 1985
 Edmonton — July 1987
 Pine Lake, Alberta — July 2000

Blizzards/Snowstorms

Southern Saskatchewan — February 1947
 St. John's — February 1959
 Southern Manitoba — March 1966, November 1968, April 1997
 Victoria — December 1996
 Toronto — December 1998 to January 1999

Hailstorms

Calgary — July 1981
 Southern Manitoba (Morden, Pilot Mound) — June 1992
 Winnipeg — July 1996
 Okanagan — July 1997

Floods

Fraser River — spring 1948
 Red River — spring 1950, spring 1997
 Saguenay River — July 1996

Hurricanes

Hazel — Southern Ontario, October 1954
 Freda — British Columbia, October 1962
 Beth — Nova Scotia, August 1971

Ice Storms

Quebec/Eastern Ontario — January 1998

Drought & Extreme Heat

Prairies — 1933–1937: “Dustbowl Era”
 Manitoba and Ontario — July 5–17, 1936: heat wave in which temperatures exceeded 44°C
 Midale and Yellowgrass, Saskatchewan — July 5, 1937: hottest temperature ever recorded in Canada (45°C)
 Prairies — 1961

Extreme Cold

Snag, Yukon — February 3, 1947: coldest temperature ever recorded in North America (–63°C)
 Pelly Bay, NWT — January 28, 1989: record wind chill made the –51°C temperature feel like it was –91°C

Adapted from The Green Line [Fact Sheet] Top Weather Events of the 20th Century at: <www.ec.gc.ca/press/vote20_f_e.htm>

Data Source: Environment Canada, 2001.

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
S2-4-07 Investigate and evaluate evidence that climate change occurs naturally and can be influenced by human activities. Include: the use of technology in gathering and interpreting data GLO: A1, A4, D5, E3

SUGGESTIONS FOR INSTRUCTION
(4 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students were introduced to the concept that climate can change. They also identified possible explanations for climate change such as the greenhouse effect and volcanic activity. In Grade 7, fossil fuel formation and use by humans as a source of energy was discussed. Students may have familiarity with the enhancement of the greenhouse effect and global warming from the media and other sources.

➤ **Notes for Instruction**

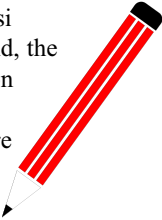
In Senior 2, Cluster 1: Dynamics of Ecosystems, the carbon cycle and factors that disturb the cycling of matter are examined. Explain the difference between weather and climate.

While students will have heard of the greenhouse effect, they may be unfamiliar with the process by which the Earth’s temperature is maintained. A discussion of the mechanism of the greenhouse effect, greenhouse gases, and the effects of human activities on greenhouse gases would be appropriate at this time. Take advantage of current information available in print and electronic media. The Natural Resources Canada website <<http://climatechange.gc.ca>> contains up-to-date information.

Teacher Background

Even though accurate records of precipitation, temperature, and other weather patterns have been kept for only about 150 years, humans in general tend to judge events in history on the same time scale as their lifespan. When a weather pattern exists for two or three years, it is seen as a trend. Meteorologists, however, generally accept that a 30-year period is the minimum required to assess what is termed “normal trends.”

The Little Ice Age (1550–1850) was a time of cooler global temperatures. Evidence of this colder than average period is illustrated in paintings by the Flemish artist, Pieter Bruegel, which show skaters on canals that do not freeze to this extent today. In China, warm weather crops, such as oranges, were abandoned in the Kiangsi Province, where they had been grown for centuries. In England, the Thames River froze over so regularly that it became a common sight to see people crossing by foot during winter. Permanent snow was found on mountain peaks in Ethiopia at levels where it does not occur today.



(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-8c, 8g, 9a, 9e

Students or student groups evaluate evidence that would indicate climate change occurs naturally, and/or can be influenced by human activities, and present

- written reports
- oral presentations
- newspaper articles
- multimedia presentations
- posters
- bulletin board displays
- dramatic presentations

Journal Writing S2-0-3d, 7f

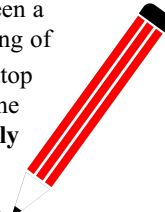
Encourage reflection on the debate (see following page). Have students summarize the arguments given by each team and ask the following questions:

- What surprising points were raised during the debate?
- What is your opinion, based on the evidence presented in the debate?

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Teacher Background

The natural greenhouse effect results from the presence of certain gases (particularly water vapour, H₂O(g), and including CO₂) in the atmosphere that absorb solar radiation and re-emit it in the infrared. As the concentration of these greenhouse gases increases, the average temperature of the Earth and its atmosphere could also increase, giving rise to global warming. The combustion of fossil fuels has been a primary source of increased CO₂ emissions since the beginning of the industrial age in the early 19th century. Record-keeping atop Hawaii’s Mauna Loa volcano has clearly demonstrated that the atmospheric concentration of CO₂ has increased **exponentially** since about 1950.



(continued)

SUGGESTED LEARNING RESOURCES

Science 10

- 7.8 Debate: The Sale and Use of Cars Should be Restricted
- 16.1 Evidence of Change
- 16.2 The Greenhouse Effect and Ozone Depletion
- 16.3 Investigation: Observing Pollution
- 16.4 Microclimates
- 16.7 Our Disappearing Forests
- BLM 15.12 El Niño Visits Canada
- BLM 16.1 The Trees Can Talk

Science Power 10

Investigation 2-B: Carbon Cycle and Climate

- 13.3 Interactions of Solar Energy with Land and Air
- 16.3 Past, Present, and Future

Unit 4 Issue Analysis: Cooling the Driving Habit

- BLM G-29 Scientific Research Planner
- BLM G-30 Research Worksheet
- BLM G-31 Internet Research Tips

SYSTH

- 13.21 Journal Evaluation

Appendices

- 4.1 Earth’s Energy Budget
- 4.4 Connecting Mathematics to the Atmosphere
- 4.31 Climates Do Change Naturally
- 4.32 Canadian Climatology Datasets
- 4.33 Annual Regional Temperature and Precipitation Datasets

(continued)

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p><i>(continued)</i></p> <p>S2-4-07 Investigate and evaluate evidence that climate change occurs naturally and can be influenced by human activities.</p> <p>Include: the use of technology in gathering and interpreting data</p> <p>GLO: A1, A4, D5, E3</p>

SUGGESTIONS FOR INSTRUCTION

(4 HOURS)

➤ **Student Learning Activities**

Student Research S2-0-1b, 2b, 3d, 8c

Students or student groups research evidence of climate change. Some projects may

- comment on human activities that may have an influence on greenhouse gases
- describe how dendrochronology (study of tree rings) can provide evidence of regional weather in the past
- discuss El Niño’s or La Niña’s effects on air and water currents and their impact on Canada’s economy, society, and environment
- assess evidence that civilizations have vanished due to climate change (e.g., Vikings in Greenland)
- investigate how ice core sampling is used to determine the climate of the past
- explore the evidence for the “Snowball Earth” hypothesis, which claims that our planet has completely frozen over as much as four times in Earth’s past, followed by rapid warming to tropical extremes
- describe how Manitoba’s landscape provides evidence of glaciation
- discuss how microclimates can be modified by humans
- compare Manitoba’s current climate with the climate of the past

Case studies, newspaper articles, and Internet sources may be used.

Class Debate S2-0-1d, 3d, 3e, 7c

Students research and then debate the pros and cons of a government-imposed carbon tax to reduce fossil fuel consumption. Environmental implications, cost of buying fuel, and issues of public health may be considered.

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Pencil-and-Paper Tasks

Students

- differentiate between weather and climate
- list the atmospheric gases that absorb electromagnetic radiation from the Sun and re-emit infrared radiation
- identify human activities that have an influence on greenhouse gases
- describe the mechanism of the greenhouse effect
- explain how tree rings can provide evidence of past weather
- describe the technique of ice core sampling and how it is used to determine the gas and aerosol chemistry of ancient atmospheres
- interpret graphs to determine average world temperatures in past centuries
- evaluate evidence that suggests climate change occurs naturally
- explain why deforestation may contribute to the enhancement of the greenhouse effect
- predict how a major volcanic eruption or meteorite impact may affect global temperatures
- discuss how urban microclimates differ from the climate in a city's outer suburbs
- evaluate the evidence for climate change as seen through traditional environment knowledge (TEK) of Canada's northern Aboriginal peoples

4.34 Greenhouse Gases and Climate Change

4.35 Plotting CO₂ and Temperature

4.36 Ozone—What Is It, and Why Do We Care About It?

4.37 Volcanoes and Global Cooling

6.1 Rubric for the Assessment of Class Presentations

6.2 Rubric for the Assessment of a Research Project

Multimedia

Sila Alangotok: Inuit Observations on Climate Change

PRESCRIBED LEARNING OUTCOMES
<i>Students will...</i>
<p>S2-4-08 Discuss potential consequences of climate change.</p> <p><i>Examples: changes in ocean temperature may affect aquatic populations, higher frequency of severe weather events influencing social and economic activities, scientific debate over nature and degree of change...</i></p> <p>GLO: A1, A2, C5, C8</p>

SUGGESTIONS FOR INSTRUCTION

(3-1/2 HOURS)

➤ **Entry-Level Knowledge**

In Grade 5, students were introduced to the concept that climate can change. They also identified possible explanations for climate change, such as the greenhouse effect and volcanic activity. Students may have familiarity with the potential consequences of climate change from the media and other sources.

➤ **Notes for Instruction**

The scientific debate over the nature and degree of global warming due to the enhanced greenhouse effect is ongoing. Some computer models forecast increased temperatures, while others predict global cooling. Take advantage of current information available in print and electronic media. The Natural Resources Canada website <<http://climatechange.gc.ca>> contains up-to-date information.

➤ **Student Learning Activities**

Class Discussion S2-0-1c, 4e, 4f, 9b

Generate interest in the learning outcome by having students predict the potential consequences of climate change (especially due to global warming perceptions). Since the science of climate change is in a state of flux, be cautious about the extremism on both sides of the debate (e.g., both global warming and cooling should be discussed in relation to a higher CO₂ future for the atmosphere). This situation is advantageous in that it highlights important considerations about the nature of scientific debate. A Rotational Cooperative Graffiti structure could be used (see *SYSTH 3.15*).

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 6 for a variety of rubrics and checklists that can be used for self-, peer-, and teacher-assessment.

Research Report/Presentation S2-0-8c, 8g, 9b, 9d

Students or student groups present research findings with

- written reports
- oral presentations
- posters
- bulletin board displays
- dramatic presentations
- newspaper articles
- multimedia presentations

Journal Writing S2-0-9b

Assess journal entries using a Journal Evaluation form (see *SYSTH* 13.21).

Pencil-and-Paper Tasks

Students

- describe the consequences of thin or absent sea ice for polar bear populations in the Arctic
- predict the effect of hotter and drier summers on agriculture in Manitoba
- discuss the effect of El Niño on the winter sport industry (e.g., ski hills, snowmobile trails, equipment sales)
- explain how an increase in greenhouse gases may affect extreme weather events
- assess the impact of the movement of the Gulf Stream to a more southerly course and its effect on the climate of northern Europe
- suggest reasons why there are more concerns about global warming today than in the past
- discuss potential economic, social, and environmental consequences of both the warming and cooling of Manitoba's climate
- discuss the effect of the 2003 European heat wave on the healthcare systems of affected countries

SUGGESTED LEARNING RESOURCES

Science 10

- 16.8 Canada's Fragile North
- 16.9 Case Study: Monsoons in Bangladesh
- 16.10 Weather of the Future
- 16.11 Explore an Issue: The Human Impact on Global Temperatures
- ABLM 16.2 A Model of the Greenhouse Effect
- ABLM 16.8 Building on Permafrost
- ABLM 16.10 Water Levels—Up or Down?

Science Power 10

Investigation 13-C: Weather After Global Warming

- 16.3 Past, Present, and Future
- BLM G-29 Scientific Research Planner
- BLM G-30 Research Worksheet
- BLM G-31 Internet Research Tips

SYSTH

- 3.15 Rotational Cooperative Graffiti
- 11.40 Issue-Based Article Analysis
- 11.41 Fact-Based Article Analysis
- 13.21 Journal Evaluation

Appendices

- 4.36 Ozone—What Is It, and Why Do We Care About It?
- 4.37 Volcanoes and Global Cooling
- 6.1 Rubric for the Assessment of Class Presentations

(continued)

PRESCRIBED LEARNING OUTCOMES	SUGGESTIONS FOR INSTRUCTION
<i>Students will...</i>	(3-1/2 HOURS)
<p><i>(continued)</i></p> <p>S2-4-08 Discuss potential consequences of climate change.</p> <p><i>Examples: changes in ocean temperature may affect aquatic populations, higher frequency of severe weather events influencing social and economic activities, scientific debate over nature and degree of change...</i></p> <p>GLO: A1, A2, C5, C8</p>	<p>Student Research S2-0-1d, 2b, 3d, 6d</p> <p>Students or student groups research the potential consequences of climate change. Topics may include</p> <ul style="list-style-type: none">• melting of permafrost in northern Manitoba• decreased rainfall and hotter summers in southwestern Manitoba• thin or absent sea ice in Hudson Bay and its effect on polar bear populations• increased number of thunderstorms and tornadoes in southern Manitoba• increased snowfall in the western Arctic• movement of the Gulf Stream to a more southerly course• flooding of low-lying coastal plains (e.g., Florida, Bangladesh, the Netherlands) <p>Case studies, newspaper articles, and Internet sources may be used.</p> <p>Journal Writing S2-0-2d, 8c</p> <p>Students complete a fact- or issue-based article analysis of a current newspaper or magazine article related to the potential consequences of climate change (see <i>SYSTH</i> 11.40, 11.41).</p> <p>Collaborative Teamwork S2-0-9d, 9e, 9f</p> <p>Students list the activities they do and the resources they use that produce CO₂. They then reflect on the question “How could I change my lifestyle to help reverse the increasing production of CO₂?”</p>

SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

- 6.2 Rubric for the Assessment of a Research Project
- 6.3 Rubric for the Assessment of a Decision-Making Process Activity

Teacher Background

Climate Change Websites:

Climate Change in Canada—Climate Change in the Prairie Provinces: <http://www.adaptation.nrcan.gc.ca/posters/reg_en.asp?Region=pr>

Climatology Links:

<<http://www.uwinnipeg.ca/~blair/climlink.htm>>

Apple Learning Interchange-Global Warming Activities:

<http://ali.apple.com/ali/uops_display.php?findunit=51>

Atmospheric Greenhouse Gases:

<<http://vathena.arc.nasa.gov/curric/land/global/greenhou.html>>

Canadian Climate and Water Information—Links and Downloads (Meteorological Service of Canada—The Green Lane): <http://www.msc-smc.ec.gc.ca/climate/links/climate_outlook_e.cfm>

Canadian Climate and Water Information:

<http://www.msc-smc.ec.gc.ca/climate/index_e.cfm>

Climate Change Connection—Manitoba:

<<http://www.web.ca/~climate/>>

Climate Change in Canada—Futures Wheel Teacher's Guide:

<http://www.adaptation.nrcan.gc.ca/posters/teachers/wheel_e.asp>

Climate Change in Canada—Home Page:

<http://adaptation.nrcan.gc.ca/posters/wel_en.asp?Language=en>

Climate Change in Canada—Le changement climatique au Canada: <<http://www.adaptation.nrcan.gc.ca/posters/>>

Climate Change in Canada Poster—Le changement climatique au Canada: <<http://www.adaptation.nrcan.gc.ca/posters/>>

Climate Timeline Tool: <<http://www.ngdc.noaa.gov/paleo/ctl/>>

Climate Trends and Variations Bulletin for Canada—Climate Trends and Variations Bulletin (Meteorological Service of Canada): <http://www.msc-smc.ec.gc.ca/ccrm/bulletin/annual98/page2_e.html>

CPC Products—Stratosphere SBUV-2 Total Ozone:

<<http://www.cpc.noaa.gov/products/stratosphere/sbuv2to/>>

Encyclopedia of the Atmospheric Environment:

<<http://www.doc.mmu.ac.uk/aric/eae/english.html>>

Global Climate Change Student Guide:

<<http://www.docm.mmu.ac.uk/aric/gccsg/>>

Ice Core Research Global Warming and Cooling Studying the Ice Sheet:

<<http://www.secretsoftheice.org/icecore/studies.html>>

Large-Scale Climate Change Linked to Simultaneous Population Fluctuations in Arctic Mammals:

<<http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2002/2002111410899.html>>

Manitoba Climate Change Task Force—Home:

<<http://www.iisd.org/taskforce/>>

Manitoba Conservation, Climate Change Branch Home

Page: <<http://www.gov.mb.ca/conservation/climatechange/>>

NASA Goddard Institute Datasets and Images:

<<http://www.giss.nasa.gov/data/>>

New Evidence that El Niño Influences Global Climate

Conditions on a 2,000-Year Cycle—November:

<<http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2002/2002111410898.html>>

New Scientist Environment Report Climate Change:

<<http://www.newscientist.com/hottopics/climate/>>

NOAA Paleoclimatology Global Warming—The Story:

<<http://www.ngdc.noaa.gov/paleo/globalwarming/what.html>>

NOAA Paleoclimatology Program—Vostok Ice Core:

<<http://www.ngdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok.html>>

NOVA Online Warnings from the Ice Stories in the Ice:

<<http://www.pbs.org/wgbh/nova/warnings/stories/nojs.html>>

Pacific Ocean Temperature Changes Point to Natural Climate Variability—November 13, 2002:

<<http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2002/2002111310900.html>>

Past Climate From Antarctic Ice Cores:

<http://www.agu.org/sci_soc/vostok.html>

Science of Ozone:

<<http://www.sprl.umich.edu/GCL/Notes-1999-Fall/Ozone.pdf>>

Skywatchers Environment Canada:

<http://weatheroffice.ec.gc.ca/skywatchers/national/information_e.html>

The Methane Budget (May 1992):

<<http://www.globalchange.org/gccd/gcc-digest/1992/d92may13.htm>>

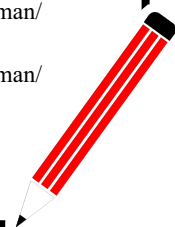
Twin Ice Cores From Greenland Reveal History of Climate Change, More U.S. Tornadoes 1953-2001:

<http://www.agu.org/sci_soc/eismayewski.html#stadial/interstadial%20oscillations>

The Snowball Earth Hypothesis—Earth Freezes Over from Pole to Pole in the Past:

<http://www-eps.harvard.edu/people/faculty/hoffman/snowball_paper.html>

<<http://www-eps.harvard.edu/people/faculty/hoffman/TerraNova.PDF>>



Senior 2

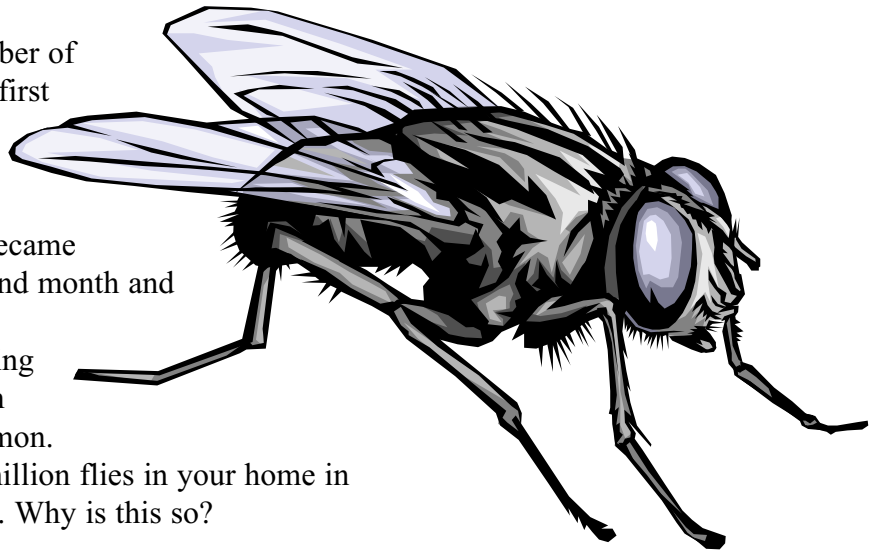
Appendix 1:
Dynamics of Ecosystems



Environmental Factors and Population Size

Imagine you notice a pair of houseflies in your warm house on a cold day in December. Assuming one of the flies is a female, and the other a male, you could expect them to reproduce. Houseflies lay up to 900 eggs at a time. If the house is warm (approximately 20°C), the eggs will hatch into larvae (a small worm-like stage of fly development) in about one day. The larvae go through several stages of development, and become mature houseflies in about a month. If the home remains warm, and the larvae find enough food to eat, there could be approximately 900 flies in the house by January (assuming that all the larvae survive until they become mature flies!). If all goes well, hundreds of pairs of these flies will lay hundreds of eggs each, producing approximately 400,000 new flies by late February. If this continues, you could have an additional 180,000,000 mature flies by the time you open your windows in late March (and maybe let some of the flies out).

As you can see, the number of flies increases slowly at first (in this example, 2 flies become 900 flies in the first month), then very rapidly (900 flies became 400,000 flies in the second month and 180,000,000 by the third month). Finding a breeding pair of flies in a house in December is not uncommon. Having a few hundred million flies in your home in March is highly unlikely. Why is this so?



What factors in the environment prevent a breeding pair of organisms from becoming a population numbering in the billions in a relatively short period of time? One reason is that resources are in limited supply. There may be enough food in a typical house for a few dozen flies, but there usually isn't enough for thousands of them. Also, there may be other insects in the house that compete with the flies for the little bits of food that humans leave behind. Many of the flies and their larvae starve to death. Some flies are eaten by other insects in the home (predators), while others die of "natural causes" (such as disease). If the home's heating system were to break down, and the temperature in the house were to drop to the freezing point, many flies and larvae would die due to lack of warmth. Although this doesn't usually happen in your home, it does happen outdoors where many organisms live. All these environmental factors help limit the population size of a particular organism.

Many environmental factors affect the population size of a particular organism. This is true in a “closed” environment such as a home, but also in an “open” environment such as the outdoors. Limiting factors may be categorized as density-dependent or density-independent. Density-dependent factors operate when a population is large and crowded, and density-independent factors operate regardless of the population density. Some limiting factors are

- availability of food and water
- availability of living space
- heat or cold
- predators
- disease
- overcrowding and stress

Questions

1. How many flies were in the house in December?
2. How many new flies were added in January?
3. How many new flies were added in February?
4. How many new flies were added in March?
5. Why does the population grow slowly at first (in December and January), and much more rapidly later (in February and March)?
6. Suggest two other organisms that houseflies compete with for food in a home.
7. Which factor(s) changed when the window was opened in March?
8. From the list of limiting factors, identify those that are density-dependent.
9. From the list of limiting factors, identify those that are density-independent.
10. Would you consider drought to be a density-dependent or density-independent limiting factor? Explain your answer.
11. Would you consider competition for resources a density-dependent or density-independent limiting factor? Explain your answer.

Adapted from *Locally Developed Grade 10 Science—Catholic* (Toronto, ON: Ministry of Education and Training, 2000), Appendix 2.5.9.



Creating a Closed Ecosystem

Purpose

To create and use a closed ecosystem to study the concepts of the cycling of matter and the flow of energy.

Introduction

A closed ecosystem is a good way to study the interactions between the abiotic and biotic components of the environment. In this system, the material parts of the environment will be contained within a jar. The energy for the system, in the form of light, will come from outside the system. This model is similar to our own planet where the Sun provides energy for the Earth and the Earth provides the materials.

Living things will be imported into the ecosystem. Micro-organisms such as bacteria and algae are important to an aquatic ecosystem. One way to introduce them into a closed ecosystem is to add water or a small amount of gravel from an established pond or aquarium. First, plants will be added to the ecosystem; then, animals will be added. After that, the ecosystem will be sealed to study the interactions.

Materials

For each day, groups will require the following:

Day 1

- clear glass jar with a lid (5–10 L) or a suitable alternative
- gravel
- tap water
- light source (a lamp or grow light)

Day 2

- 50 mL of water and/or a small handful of water from an established aquarium or pond

Day 3

- several sprigs of Elodea (or a suitable alternative)

Day 7 – 14

- two snails

The timing of this stage will vary in different environments. The snails should only be added after a green coating of algae is visible on the sides of the container.

Procedure

1. Rinse the jar, gravel, and lid with clean water. Do not use soap.
2. Place the clean gravel in the bottom of the jar. Add tap water to within 10 cm from the top of the jar. Do not put the lid on the jar.
3. Let the jar sit overnight to allow the gravel to settle, and any chlorine to escape from the tap water.
4. Add 50 mL of water and/or a handful of gravel from an established aquarium or pond. Seal the jar with the lid and place the jar under a light source. The light must be kept on at all times to maintain a constant environment.
5. On Day 3, add several sprigs of Elodea (or suitable alternative) to the jar. Reseal the jar and place it back under the light.
6. Once algae have formed on the sides of the jar, introduce the two snails. Reseal the jar, and place it under the light again.
7. Observe the system daily.

Observations

1. Maintain a daily log of observations. Date each entry, and list the materials, procedures, and/or observations made that day.
2. Make observations carefully. Be sure to note any changes, as well as anything that appears to remain the same.

Analysis

1. What role do the bacteria play in your ecosystem?
2. What role does the aquatic plant play in your ecosystem?
3. What role do the snails play in your ecosystem?
4. Why were you instructed to wait until the algae had formed on the sides of the jar before you added the snails?
5. Why does your ecosystem require a source of light?
6. Draw a diagram of your ecosystem and include the carbon and oxygen cycles present. Indicate where oxygen and carbon dioxide are made and consumed.
7. Suggest two ways in which the cycling of carbon and oxygen could be disturbed in your ecosystem. Predict the effects of each disturbance on the organisms present.

Adapted from *Locally Developed Grade 10 Science—Catholic* (Toronto, ON: Ministry of Education and Training, 2000), Appendix 2.5.9.



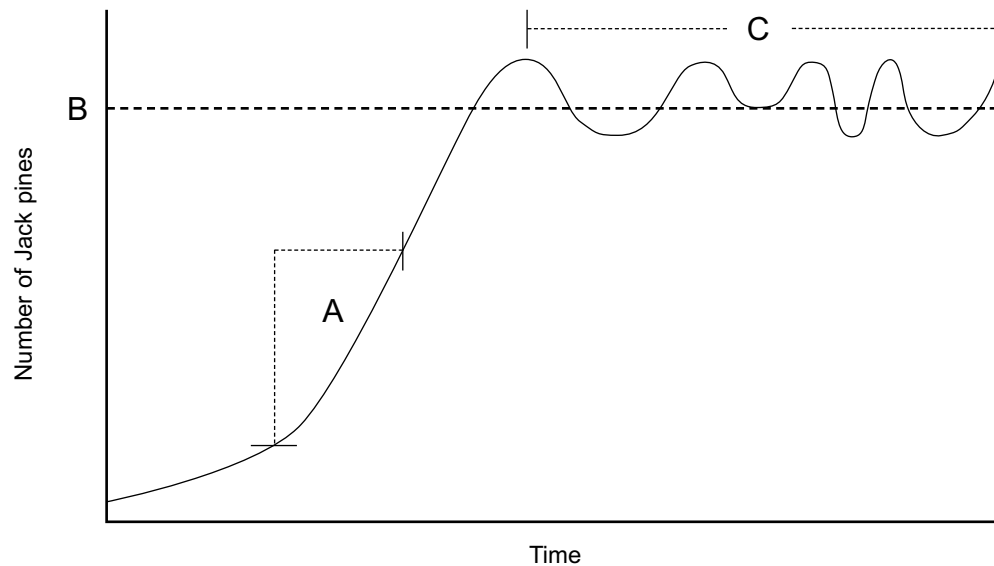
Creating a Closed Ecosystem

1. Remind students of electrical safety precautions when working with electricity near water.
2. Use a light source that promotes the growth of plants. Ensure jars are not placed too close to the light.
3. Remind students to wash their hands with soap and water after handling any live organisms.
4. A large pickle jar can be used as a container for the ecosystem.
5. Substitute a floating aquatic plant, such as hornwort or parrot feather, in place of Elodea.
6. An algae-eating fish can be added to larger (10 L) ecosystems.
7. When disposing of the ecosystems, pour the water down the drain first. Place plants, gravel, and snails in sealed plastic bags before disposal. If jars are to be reused, they must be cleaned with soap and rinsed several times.



Carrying Capacity

Many years ago, a fire swept through the boreal forest in an area of northern Manitoba. The trees, shrubs, and other plants perished in the fire. A team of wildlife biologists decided to study the regrowth of the forest over time. They chose to focus on the Jack pine population as these trees are some of the first to grow back after a fire. A graph of the results of their study is shown below.



Questions

1. Why is the number of Jack pines increasing so rapidly in area A of the graph?
2. How do you account for the fluctuations in area C of the graph?
3. What does B represent?
4. What is your estimate of the average growth rate in area C?
5. Describe, in your own words, what is happening to the Jack pine population in the graph.
6. Predict how the graph would change if another forest fire swept through the region.
7. Predict how the graph would change if a forestry company began to log the area.



Limiting Factors

1. Explain the difference between density-dependent and density-independent limiting factors.

2. Each of the statements below involves a situation that will affect the growth of a population. Classify each of the statements as DD (density-dependent) or DI (density-independent) and give a reason for your choice.

a. A lion and a cheetah attempt to occupy the same niche. The more aggressive lion survives; the cheetah does not.

b. Coyotes cross the winter pack ice and enter Newfoundland. The moose population starts to decline.

c. A severe frost wipes out 50 percent of the coffee crop in Brazil.

d. A forest fire destroys much of the wildlife in an area of northern Manitoba.

e. Due to severe overcrowding in an Asian village, many children do not survive to reach adulthood.

- f. Since lynx prey on hares, an increase in the hare population causes an increase in the lynx population.

- g. A severe flood in the Red River valley causes a decline in the deer population.

- h. Due to stress, large numbers of female lemmings miscarry their young and fail to reproduce.

- i. Travelers who visit a crowded African village become infected with a disease caused by parasites.

- j. Many fish die due to a change in the winds and the appearance of the El Niño ocean current off the coast of Peru and Chile.

- k. Because rabbits in Australia have no natural enemies, their population increases rapidly.

- l. Fish on a coral reef stake out their territory and chase away any younger fish that try to live there.

- m. An extensive drought on the Serengeti Plain threatens wildebeest, giraffe, zebra, and springbok populations.



Predator-Prey Interactions

In the 1980s, people became concerned about the wolf and deer populations in a Manitoba provincial park. A wildlife biologist was hired to monitor the populations over 10 years. The results of the study are found below.

Year	Wolf Population	Deer Population
1991	20	4000
1992	24	4600
1993	33	5000
1994	44	4800
1995	56	4500
1996	48	4200
1997	42	3900
1998	36	3850
1999	38	3900
2000	38	3950

Questions

- On a piece of graph paper, plot the fluctuations in the deer and wolf populations for the study period. Place the year along the horizontal axis. Create two vertical axes. Number the left vertical axis to accommodate the number of deer. Number the right vertical axis using a different scale for the size of the wolf population.
- Examine the completed graph. What factors could account for the large increase in the deer population between 1991 and 1992?

- What might have caused the decline in the deer population between 1993 and 1997?

* Reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.

4. Why was the wolf population so high in 1995?

5. How would you describe the relationship between the wolf population and the deer population?

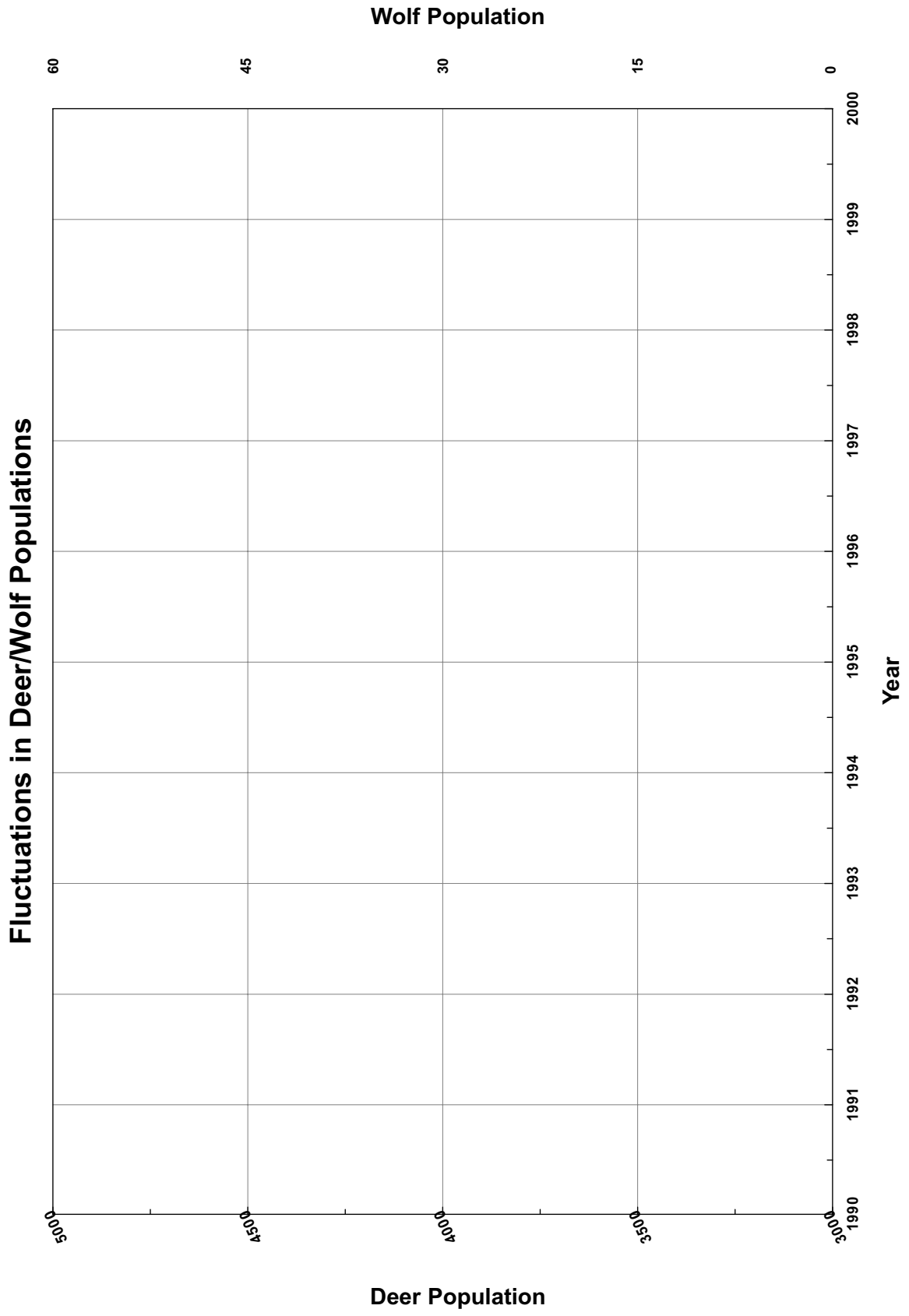
6. Make a prediction for the size of each of the populations for the year 2005.

7. Should there be a concern about the changes in the wolf and deer populations in the area studied? Explain your answer.

8. Predict the effect on the deer population if...

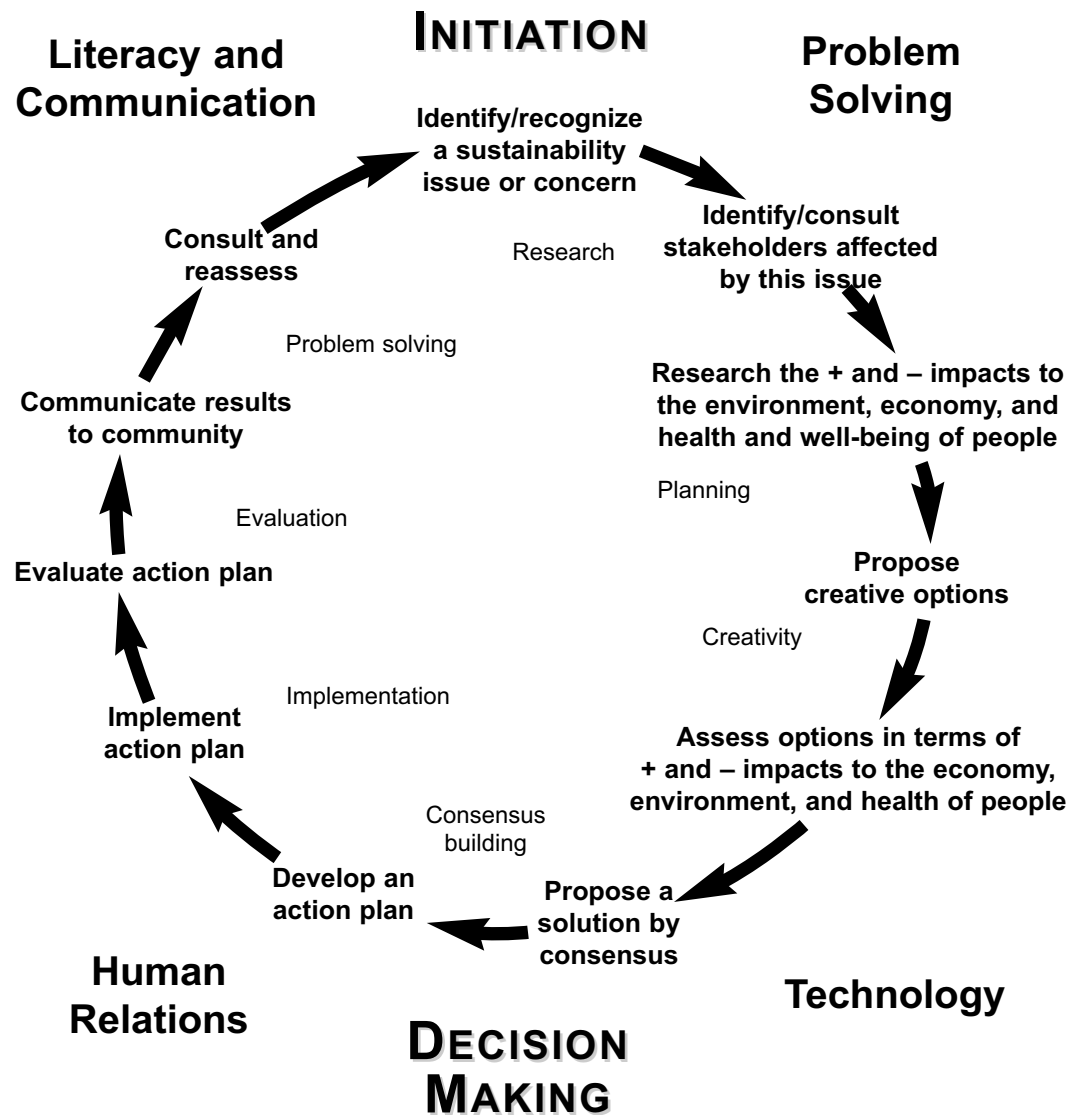
- a. a forest fire occurs _____
- b. the wolf population suffers from mange _____
- c. prolonged harsh winter weather conditions occur _____
- d. deer hunting quotas are increased _____
- e. wolf trapping quotas are increased _____

9. How can understanding the natural fluctuations of these populations aid conservation officers in setting trapping and hunting limits?





Educating for Sustainability: Decision-Making Skills



Reproduced from *Education for a Sustainable Future: A Resource for Curriculum Developers, Teachers, and Administrators* (Winnipeg, MB: Manitoba Education and Training, 2000) 16.

Senior 2

Appendix 2:
Chemistry in Action



Lewis Dot Diagrams (Electron Dot Diagrams)

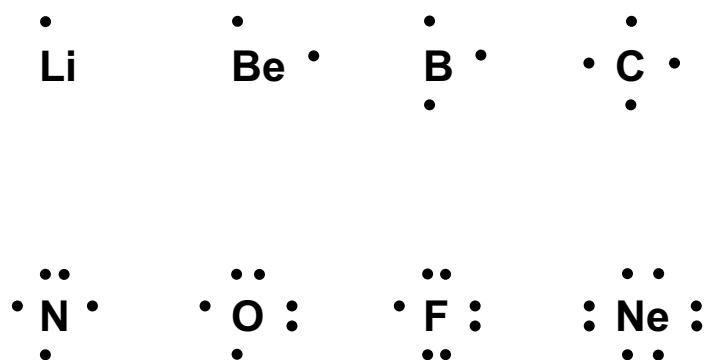
A Lewis dot diagram is a convenient, shorthand method to represent an element and its valence electrons. The arrangement of elements on the periodic table yields more information about the electronic structures of atoms, and how those structures can help predict the properties of many elements. The arrangement of valence electrons is key to understanding how atoms behave in chemical reactions.

Lewis dot diagrams are diagrams in which dots or other small symbols are placed around the chemical symbol of an element to illustrate the valence electrons.

Note:

- i. Each dot represents one valence electron.
- ii. In the dot diagram, the element's symbol represents the core of the atom (the nucleus plus all the inner electrons).
- iii. Atoms in the same family (column) will have similar Lewis dot diagrams, except for helium (He) which has only two valence electrons.

The Lewis dot diagrams for the elements in the second period are as follows:



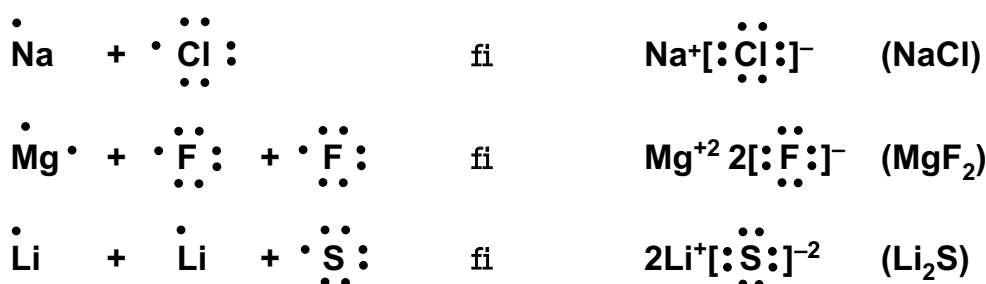


Chemical Bonds and Lewis Dot Diagrams

Atoms gain, lose, or share electrons to obtain full valence shells and become stable. The number of electrons present remains the same, but their arrangement changes when compounds form. Metal atoms tend to lose electrons, while non-metal atoms tend to gain or share electrons. Members of the noble gas family are chemically inert; they do not react.

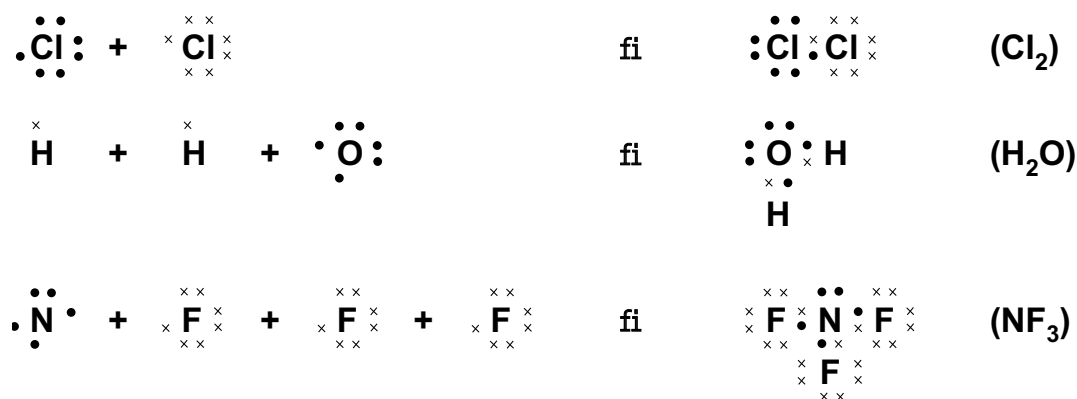
Ionic Bonds

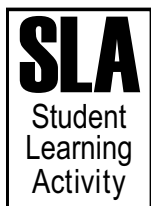
Ionic bonds result when electrons are transferred from metal atoms to non-metal atoms. The metal atoms lose electrons to become positive ions, while the non-metal atoms gain electrons to become negative ions. The ions are then held together by the attraction of opposite charges in an ionic bond.



Covalent Bonds

Covalent bonds result when non-metal atoms share electrons. By overlapping their valence electron shells, the atoms share pairs of electrons. This increases the number of electrons in each atom's valence shell, so that the atoms appear to have full shells.





Experiment: Properties of Acids and Bases

Purpose

1. To classify substances as acids or bases using their characteristic properties.
2. To determine the pH values of the acids and bases used.
3. To examine the reactivity of acids with metals.

Equipment/Materials

- Safety goggles
- Red and blue litmus paper
- Test tubes and test-tube racks
- Indicators (universal indicator, phenolphthalein, bromothymol blue)
- A pH meter or pH test paper
- Eyedroppers
- Microtray
- Samples of acids and bases (milk of magnesia, ammonia window cleaner, vinegar, lemon juice, tomato juice, drain cleaner, carbonated drinks, shampoo, black coffee, laundry detergent, milk, salt water, tap water, baking soda, apples)
- Samples of metals (copper, zinc, iron, magnesium)
- Hydrochloric acid (6M), acetic acid (6M), sodium hydroxide (0.5M), calcium hydroxide (0.5M)

Procedure

Part A: Effects of Acids and Bases on Indicators

1. Place five drops of each of the following into the wells of a microtray: 6M Hydrochloric acid, 6M acetic acid, 0.5M sodium hydroxide, and 0.5M calcium hydroxide.
2. Using a different piece of clean, dry, red litmus paper for each of the solutions, dip the end of a piece of red litmus paper into each solution. Record results in a data table.
3. Repeat step 2 using blue litmus paper. Record results in a data table.

Part B: Determine the pH Range of a Substance

1. Use the bromothymol, phenolphthalein, and universal indicators to measure the pH of the samples.
2. Add two drops of the bromothymol indicator to each sample from part A. Record your observations in a data table. Wash microtray and repeat for phenolphthalein and universal indicator.
3. Confirm your results by retesting each sample with a pH meter or pH test paper.

Part C: Determine the Reactivity of Acids with Metals

1. Place a small sample of each metal to be tested in the different wells of a clean, dry microtray.
2. Use an eyedropper to add five drops of the hydrochloric acid onto each sample of metal. Note any signs of chemical change and record your observations in a data table. Repeat using the acetic acid.

Part D: Determine the Acidity and Basicity of Household Substances

1. In different wells in your microtray, add five drops of any six of the following: vinegar, lemon juice, tomato juice, milk, household ammonia, cola, milk of magnesia, window cleaner, drain cleaner, shampoo, salt water, tap water.
2. Test each substance as you did in part A, using red and blue litmus paper.
3. Test each substance as you did in part B, using indicators and pH paper.
4. Record results in data table.

SAFETY

Many household cleaners and hydrochloric acid solution(s) are corrosive or caustic. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water. Report any spills to the teacher.

Data Collection**Part A**

Sample	Reaction with red litmus paper	Reaction with blue litmus paper
Hydrochloric acid		
Acetic acid		
Sodium hydroxide		
Calcium hydroxide		

Part B

Sample	Bromothymol Blue	Phenolphthalein	Universal indicator
Hydrochloric acid			
Acetic acid			
Sodium hydroxide			
Calcium hydroxide			

Part C

Metal	Reaction with hydrochloric acid	Reaction with acetic acid
Zinc		
Magnesium		
Iron		
Copper		

Part D

Household substance	Red litmus paper	Blue litmus paper	pH paper	Bromothymol Blue	Phenolphthalein	Universal indicator

Data Analysis

Tests	Acid properties	Base properties
Red litmus paper		
Blue litmus paper		
pH paper		
Bromothymol Blue		
Phenolphthalein		
Universal indicator		
Reaction with a metal		

Household sample	pH value	Acid or base?

Questions (respond on a separate sheet)

1. Can either red or blue litmus paper be used to identify acids? Explain.
2. How accurate are indicators for measuring pH?
3. What signs of chemical change were observed when acids were placed on metals?
4. Did all metals react similarly? Explain.
5. List the general properties of acids and bases.
6. Which of the household substances are acidic? Which are almost neutral? Which are basic?



Experiment: Acids and Bases (*Teacher Notes*)

1. Review appropriate safety precautions.
2. As only binary acids have been discussed in class, students will not be expected to write chemical formulas for complex acids and bases. However, a wide range of acids and bases such as H_2SO_4 , HNO_3 , CH_3COOH , HCl , $\text{Ca}(\text{OH})_2$, NaOH , NH_3 and $\text{Ba}(\text{OH})_2$ can be used. The samples could be placed in dropper bottles for safer handling.
3. Instead of 6M acids, 3M acids could be used.
4. Some indicators that may be used are phenolphthalein, bromothymol blue, universal indicator, and methyl orange. Indicators that provide definite pH values will work best.
5. The metals used may include Cu, Zn, Fe, Al, Mg. Clean pieces or strips will work best.

Data Collection

Part A

Sample	Reaction with red litmus paper	Reaction with blue litmus paper
Hydrochloric acid	No change	Turns red
Acetic acid	No change	Turns red
Sodium hydroxide	Turns blue	No change
Calcium hydroxide	Turns blue	No change

Part B

Sample	Bromothymol Blue	Phenolphthalein	Universal indicator
Hydrochloric acid	Turns yellow	No change	Turns red
Acetic acid	Turns yellow	No change	Turns orange-red
Sodium hydroxide	No change	Turns pink	Turns violet
Calcium hydroxide	No change	Turns pink	Turns blue-violet

Part C

Metal	Reaction with hydrochloric acid	Reaction with acetic acid
Zinc	Strong reaction	Weaker reaction
Magnesium	Strong reaction	Weaker reaction
Iron	Weak reaction	Very weak or no reaction
Copper	No reaction	No reaction

Part D

Household substance	Red litmus paper	Blue litmus paper	pH paper	Bromothymol Blue	Phenolphthlein	Universal indicator
Lemon juice			Red			
Apple			Red-orange			
Vinegar			Red-orange			
Carbonated drink			Orange			
Tomato juice			Orange			
Black coffee			Orange			
Milk			Yellow-green			
Water			Green			
Salt water			Green-blue			
Baking soda			Green-blue			
Laundry detergent			Turquoise			
Milk of magnesia			Blue			
Household ammonia			Blue			
Bleach			Blue			
Drain cleaner			Dark blue			

Note: pH paper colours may differ from the chart and should be tested ahead of time, as different brands can be more acidic or basic.

Data Analysis

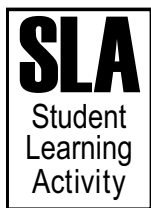
Tests	Acid properties	Base properties
Red litmus paper	No change	Turns blue
Blue litmus paper	Turns red	No change
pH paper	Red – Orange	Green – dark blue
Bromothymol Blue	Turns yellow	No change
Phenolphthalein	No change	Turns pink
Universal indicator	Red-orange	Blue-purple
Reaction with a metal	Reaction	No reaction

Household sample	pH value	Acid or base?
Lemon juice	2	
Apple	3	
Vinegar	2.5–3.5	
Carbonated drink	4	
Tomato juice	4	
Black coffee	5	
Milk	6.5	
Water	7	
Salt water	8	
Baking soda	8	
Laundry detergent	9	
Milk of magnesia	10	
Household ammonia	11–12	
Bleach	12.5	
Drain cleaner	13–14	

Note: pH paper colours may differ from the chart and should be tested ahead of time, as different brands can be more acidic or basic.

Answers to Questions

1. Either type of litmus paper can be used. Red litmus paper will not change. Blue litmus paper will turn red.
2. Indicators usually give a range of pH values, not a precise pH value.
3. When acids were placed on most metals, a reaction could be observed. The metal disappeared and a gas and heat were produced.
4. Not all metals reacted similarly. The iron reacted less than the magnesium or zinc, and the copper did not react at all.
5. Acids: pH value: less than 7. Stronger acids have lower pH values, react with metals, turn litmus paper red, turn bromothymol blue indicator to yellow, turn universal indicator solution from red to green, and do not react with a phenolphthalein solution. Bases: pH value: greater than 7, stronger bases have higher pH values, do not react with metals, turn litmus paper blue, do not react with bromothymol blue, turn universal indicator solution from green to purple, and turn phenolphthalein solution pink.
6. See data analysis table. Students should arrive at the following conclusions:
 1. Acids have a pH of less than 7.
 2. Bases have a pH greater than 7.
 3. Acids react with metals, but not all react with the same intensity. The strength of the reaction varies with each acid and each metal.



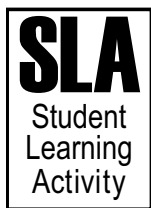
Balancing Chemical Equations

1. Translate the following word equations to balanced chemical equations. Identify the type of reaction. Write your responses on a separate sheet.
 - a. Sodium metal combines with chlorine gas to produce sodium chloride crystals.
 - b. Solid magnesium reacts with hydrogen chloride to produce a magnesium chloride solution and hydrogen gas.
 - c. Potassium iodide reacts with calcium sulfide to produce potassium sulfide and calcium iodide.
 - d. Silver oxide decomposes to produce silver metal and oxygen gas.
 - e. Dicarbon hexahydride (ethane) reacts with oxygen gas to produce carbon dioxide gas and water vapour.
2. Translate the following chemical equations to word equations. Identify the type of reaction.
 - a. $\text{Fe}_{(s)} + \text{CuS}_{(aq)} \rightarrow \text{FeS}_{(aq)} + \text{Cu}_{(s)}$
 - b. $4\text{Fe}_{(s)} + 3\text{O}_{2(g)} \rightarrow 2\text{Fe}_2\text{O}_{3(s)}$
 - c. $\text{BaF}_{2(aq)} + 2\text{LiBr}_{(aq)} \rightarrow \text{BaBr}_{2(aq)} + 2\text{LiF}_{(aq)}$
 - d. $\text{CH}_{4(g)} + 2\text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + 2\text{H}_2\text{O}_{(g)}$
 - e. $2\text{MgO}_{(s)} \rightarrow 2\text{Mg}_{(s)} + \text{O}_{2(g)}$
3. Complete and balance the following equations.
 - a. $\text{C}_8\text{H}_{18(l)} + \text{O}_{2(g)} \rightarrow$ (combustion)
 - b. $\text{Al}_{(s)} + \text{I}_{2(g)} \rightarrow$ (synthesis)
 - c. $\text{BeF}_{2(aq)} + \text{K}_2\text{O}_{(aq)} \rightarrow$ (double displacement)
 - d. $\text{Cl}_{2(g)} + \text{NaBr}_{(aq)} \rightarrow$ (single displacement)
 - e. $\text{NaCl}_{(l)} \rightarrow$ (decomposition)



Balancing Chemical Equations (*Teacher Notes*)

1. Translate the following word equations to balanced chemical equations. Identify the type of reaction.
 - a. $2\text{Na}_{(s)} + \text{Cl}_{2(g)} \rightarrow 2\text{NaCl}_{(s)}$ (synthesis)
 - b. $\text{Mg}_{(s)} + 2\text{HCl}_{(aq)} \rightarrow \text{MgCl}_{2(aq)} + \text{H}_{2(g)}$ (single displacement)
 - c. $2\text{KI}_{(aq)} + \text{CaS}_{(s)} \rightarrow \text{K}_2\text{S} + \text{CaI}_2$ (double displacement)
 - d. $2\text{Ag}_2\text{O}_{(s)} \rightarrow 4\text{Ag}_{(s)} + \text{O}_{2(g)}$ (decomposition)
 - e. $2\text{C}_2\text{H}_{6(g)} + 7\text{O}_{2(g)} \rightarrow 4\text{CO}_{2(g)} + 6\text{H}_2\text{O}_{(g)}$ (combustion)
2. Translate the following chemical equations to word equations. Identify the type of reaction.
 - a. Iron metal reacts in a solution of copper (II) sulfide to produce iron sulfide in solution and a solid copper precipitate (single displacement).
 - b. Iron metal reacts with oxygen gas in the air to produce iron (III) oxide as rust (synthesis).
 - c. Solutions of barium fluoride and lithium bromide combine to produce a new solution containing barium bromide and lithium fluoride (double displacement).
 - d. Carbon tetrahydride (methane gas) burns in the presence of oxygen gas to produce carbon dioxide gas and water vapour (combustion).
 - e. Solid magnesium oxide decomposes into pure magnesium metal and gives off oxygen gas (decomposition).
3. Complete and balance the following equations.
 - a. $2\text{C}_8\text{H}_{18(l)} + 25\text{O}_{2(g)} \rightarrow 16\text{CO}_{2(g)} + 18\text{H}_2\text{O}_{(g)}$
 - b. $6\text{Al}_{(s)} + 9\text{I}_{2(g)} \rightarrow 6\text{AlI}_{3(s)}$
 - c. $\text{BeF}_{2(aq)} + \text{K}_2\text{O}_{(aq)} \rightarrow \text{BeO}_{(s)} + 2\text{KF}_{(aq)}$
 - d. $\text{Cl}_{2(g)} + 2\text{NaBr}_{(aq)} \rightarrow 2\text{NaCl}_{(aq)} + \text{Br}_{2(g)}$
 - e. $2\text{NaCl}_{(l)} \rightarrow \text{Na}_{2(g)} + \text{Cl}_{2(g)}$



Experiment: Law of Conservation of Mass

Purpose

To determine experimentally whether mass is conserved during a chemical reaction.

Equipment/Materials

- Balance
- Erlenmeyer flask (125 mL)
- Antacid tablet
- Balloon
- Warm water (25 mL)

Procedure

Part A: Open Reaction

1. Before the reaction, find the combined mass of the Erlenmeyer flask with 25 mL of water and one whole antacid tablet. Record results.
2. Drop the antacid tablet into the water, and agitate gently until the reaction has stopped.
3. After the reaction, find the combined mass of the Erlenmeyer flask with water and antacid tablet. Record results.

Part B: Closed Reaction

1. Before the reaction, find the combined mass of the Erlenmeyer flask with 25 mL of water, one whole antacid tablet, and the balloon. Record results.
2. Drop the antacid tablet into the water and quickly place the balloon over the mouth of the Erlenmeyer Flask. Agitate gently until the balloon is inflated and the reaction has stopped.
3. After the reaction has stopped, find the combined mass of the Erlenmeyer flask with water, the antacid tablet, and balloon still attached. Record results.

Data Collection

	Mass before reaction	Mass after reaction
Open system		
Closed system		

Data Analysis

Interpret your data collection results and draw conclusions about whether mass is conserved during all chemical reactions. Construct your response in the space below.

Questions

1. In part A, how did the mass of the reactants and glassware before the reaction compare to the mass of the reactants and glassware after the reaction? Explain.

2. In part B, how did the mass of the reactants and glassware before the reaction compare to the mass of the reactants and glassware after the reaction? Explain.

3. Did your results support the Law of Conservation of Mass? Explain. If not, what sources of error might have affected your results?

4. A chemical reaction occurs when one or more substances react to produce one or more new substances. What happened to the reactants? Did they disappear? Were new atoms created when products were formed?

5. Can matter be created? Destroyed? Changed?

6. Do gases have a mass? If so, how can their mass be measured?



Experiment: Law of Conservation of Mass (Teacher Notes)

1. Caution should be exercised, as it is possible that enough gas will be produced from the reaction to propel the balloon off the mouth of the flask.
2. Avoid using hot water, as it will cause the reaction to happen too fast, and students may not have enough time to properly place the balloon on the mouth of the Erlenmeyer flask.
3. The amount of water or tablet size can be left up to the discretion of the teacher. Perform the lab ahead of time to ensure expected results.
4. Often student measurements may not be accurate or equipment may not be calibrated precisely. This can lead to incorrect assumptions about conservation of mass. Explain possible sources of error to students to avoid erroneous conclusions.

Data Collection

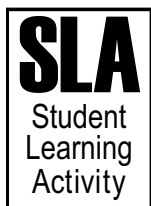
Answers may vary, depending upon the amount of water used, amount of antacid tablet, size of balloon, and size of flask. However, in the open system, the mass before the reaction should be higher than the mass after the reaction. In the closed system, both masses should be the same.

Data Analysis

Students should conclude that in the open system, masses differed due to lost gas. In the closed system, masses were the same, because the gas could not escape. However, students should recognize that in any chemical reaction, mass of reactants is always equal to mass of products and therefore conserved.

Answers to Questions

1. The mass before the reaction was greater than the mass after the reaction. Because the Erlenmeyer flask was open, a gas escaped.
2. The mass before the reaction was equal to the mass after the reaction. The balloon that was placed on the mouth of the Erlenmeyer prevented the gas from escaping.
3. Answers may vary. Possible sources of error could include an improperly calibrated balance, incorrect balance readings, poor seal with the balloon on the flask, too much time taken to place the balloon on the mouth of the flask, balloon propelled off the mouth of the flask.
4. The reactants were transformed into the products. They did not disappear, but atoms that made up the reactants were rearranged to form the new substances.
5. The Law of Conservation of Mass states that matter cannot be created or destroyed, only changed to form new substances with the original atoms.
6. Gases do have a mass, but their mass is very small and difficult to measure. Possible ways to answer this question include measuring the mass of an empty container (balloon), re-massing the container with the gas, and then subtracting the results. Using a gas collection tube is another method of obtaining the mass of gas.



Experiment: Reaction Types

Purpose

1. To investigate and identify five types of chemical reactions
2. Balance chemical reactions

Equipment/Materials

Bunsen burner	magnesium ribbon
crucible tongs	hydrochloric acid (6M)
test tubes	mossy zinc
test-tube holder	copper wire
test-tube rack	silver nitrate (0.5M)
wooden splints	cobalt chloride paper
safety goggles	limewater solution
candle	potassium iodide (0.1M)
Erlenmeyer flasks	lead (II) nitrate (0.1M)
500 mL beaker	sodium hydroxide (0.1M)
evaporating dish	copper (II) sulfate (0.1M)/copper (II) chloride (0.1M)

SAFETY

In this investigation you will be working with open flames, handling acids, heating chemicals, and producing gaseous products.

Wear safety goggles and review safety procedures before performing any experiments.

Do not look directly at the magnesium ribbon flame! Hold the burning magnesium away from you and over an evaporating dish.

Handle hydrochloric acid with care as it can cause painful burns. Do not inhale any of the HCl fumes.

Procedure**Part A: Synthesis**

1. Before heating the magnesium ribbon, examine its properties.
2. Using crucible tongs, hold the magnesium ribbon in the blue flame of a Bunsen burner for one to two minutes, or until the magnesium starts to burn.
3. When the ribbon stops burning, put the residue in an evaporating dish.
4. Examine the magnesium and note any changes in its appearance caused by heating.

Part B: Single Displacement

1. Place about 5 mL of 6M HCl in a test tube. Add a small piece of mossy zinc to the solution. Observe and record what happens.
2. Using a test-tube holder, invert a second test tube over the mouth of the first test tube where the reaction is occurring. Remove the inverted test tube after about 30 seconds and quickly insert a burning wooden splint. Note the appearance of the substance in the reaction test tube.

OR

1. Loosely coil a 10-cm piece of copper wire around a pen or pencil.
2. Place the coiled wire into a test tube that is two-thirds full of 0.5M silver nitrate solution. Allow solution to stand overnight.
3. Observe and record changes to both the copper wire and the silver nitrate solution.

Part C: Combustion

1. Observe the appearance of both a strip of cobalt chloride paper and a limewater solution. Describe and record their appearance.
2. Using beaker tongs, place a large beaker (500 mL) over a lit candle. Hold the beaker over the candle until the candle is extinguished.
3. When the flame goes out, turn the beaker over, examine, and record its contents.
4. Test for any moisture with a strip of cobalt chloride paper. Record any observable changes.
5. Relight the candle and place an Erlenmeyer flask over the candle until the candle goes out.
6. Quickly overturn the flask and add 25 mL of limewater solution. Record any observable changes.

Part D: Double Displacement

1. Add 5 mL of a 0.1M potassium iodide solution to a test tube. Next, add 5 mL of a 0.1M lead (II) nitrate solution. Observe what happens and note any changes in the mixture. Record results.

OR

1. Add 5 mL of a 0.1M sodium hydroxide solution to a test tube. Next, add 5 mL of 0.1M copper sulfate or 5 mL of 0.1M copper chloride solution. Observe what happens and note any changes in the mixture. Record results.

Part E: Decomposition

1. Place approximately 2g of copper (II) carbonate in a clean, dry test tube. Note the appearance of the sample.
2. Using a test-tube holder, heat the copper (II) carbonate strongly for about two minutes.
3. Extinguish the burner flame and insert a burning wooden splint into the test tube.
4. Note: If carbon dioxide gas is present, it will put the flame out.
5. Observe any changes in the appearance of the chemical remaining in the test tube. Record results.

Data Collection

Sample	Before reaction	After reaction
A. Synthesis		
B. Single displacement		
C. Combustion		
D. Double displacement		
E. Decomposition		

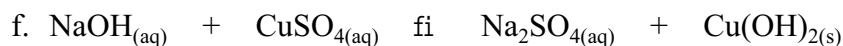
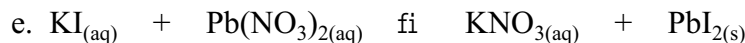
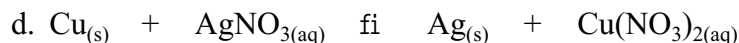
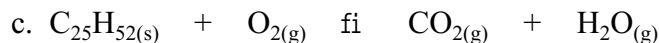
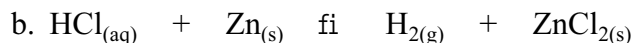
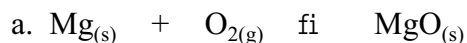
Data Analysis

In this section, students should interpret observations and explain reaction types by the products they form. Include chemical equations for each of the reactions. For example, combustion reactions always form carbon dioxide and water as their products.

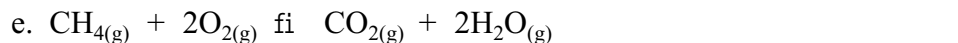
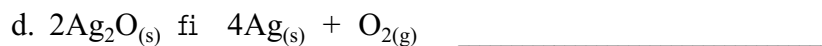
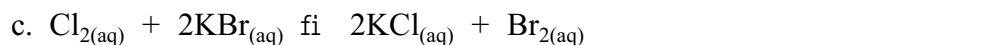
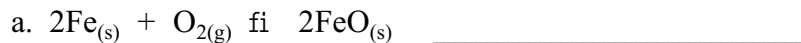
Questions

1. In this experiment, what method was used to test the presence of carbon dioxide gas? Hydrogen gas? Water?

2. Balance each of the following equations by inserting the proper coefficients where needed.



3. Classify each of the following reactions





Experiment: Reaction Types (Teacher Notes)

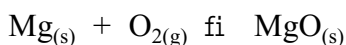
1. Review appropriate safety precautions.
2. As only binary compounds have been discussed in class, the formulas of any reactants or products that contain polyatomic ions must be provided.

Data Collection

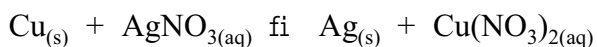
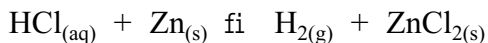
Sample	Before reaction	After reaction
A. Synthesis	Magnesium is shiny, malleable, and ductile.	The product is a white powder, called magnesium oxide.
B. Single displacement	HCl is a clear, colourless, room-temperature solution. Zinc is a dark gray malleable solid.	A combustible gas is produced. The solution is still clear and colourless, but its temperature has increased.
C. Combustion	The candle is an opaque solid composed of paraffin wax.	The candle reacts with oxygen to produce a colourless gas that extinguishes a wooden splint. Residue along the inside of the test tube turns cobalt chloride paper pink.
D. Double displacement	Both reactants (potassium iodide and lead [II] nitrate) are odourless, colourless solutions. The HCl solution is colourless. The copper chloride solution has a pale blue colour.	A yellow precipitate is formed that will settle out of the colourless solution. A bluish gel-like precipitate is formed and settles out of the colourless solution.
E. Decomposition	The copper carbonate is a granular blue powder.	After heating, the powder becomes white. A colourless gas is released, which will extinguish a burning splint.

Data Analysis

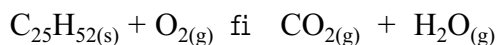
Synthesis reactions: element + element \rightarrow compound



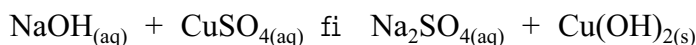
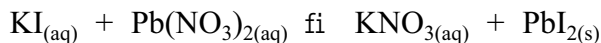
Single displacement: element + compound \rightarrow element + compound



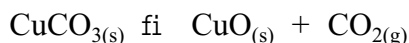
Combustion reactions: hydrocarbon + oxygen \rightarrow carbon dioxide + water vapour



Double displacement: compound + compound \rightarrow compound + compound



Decomposition reactions: compound \rightarrow compound + compound



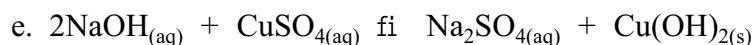
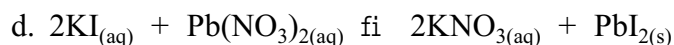
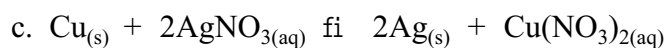
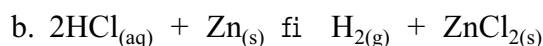
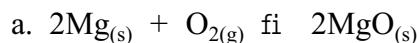
Note: In decomposition reactions, elements or compounds can be produced as products.

Answers to Questions

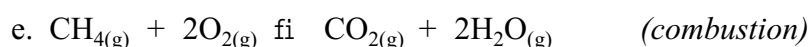
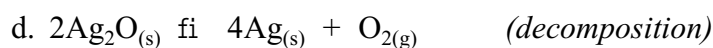
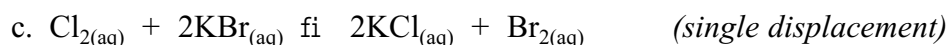
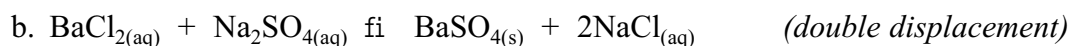
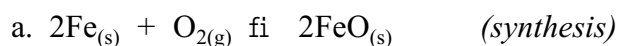
1. In this experiment, what method was used to test the presence of carbon dioxide gas? Hydrogen gas? Water?

If carbon dioxide gas is present, it will put the flame of a wooden splint out and turn limewater milky. If hydrogen gas is present, a popping sound will be heard as the hydrogen gas explodes. If water is present, the cobalt chloride paper will turn from blue to pink.

2. Balance each of the following equations by inserting the proper coefficients where needed.



3. Classify each of the following reactions





Ionic Compounds

Ionic compounds form when electrons are transferred from metal atoms to non-metal atoms so that the atoms obtain the stable electron arrangements of the nearest noble gases.

Rules for naming binary ionic compounds

1. Name the positive ion first by writing the full name of the metallic element.
2. Name the non-metal ion next by dropping the last syllable(s) of the name of the element and adding the suffix “ide.”

Example: reaction between sodium and chlorine forms sodium chloride

Example: given the chemical formula SrS is strontium sulfide

Rules for writing chemical formulas for binary ionic compounds

1. Using the name of the binary compound, write the symbols and charge for the ions involved. Write the ion charge as a superscript.

Example: aluminum oxide — $\text{Al}^{3+} \text{O}^{2-}$

2. Determine subscripts that will produce a balance of charge.

Example: $\text{Al}_2^{3+} \text{O}_3^{2-}$

3. As a check to ensure the formula is written correctly, multiply the charge for each ion by the subscript for the same ion. The total positive charge should equal the total negative charge and the net charge per ionic formula should be zero.

Example: $\text{Al}^{3+} \times 2 = 6^+$

$\text{O}^{2-} \times 3 = 6^-$

$6^+ + 6^- = 0$ (zero net charge)

4. Write the final chemical formula without the charges.

Final Answer: Al_2O_3

Note:

1. The subscript “1” is not used.

Example: lithium bromide — $\text{Li}^{1+} \text{Br}^{1-}$

$\text{Li}_1^{1+} \text{Br}_1^{1-}$

Final Answer: LiBr

2. Reduce and simplify the ratio.

Example: magnesium sulfide — $\text{Mg}^{2+} \text{S}^{2-}$

$\text{Mg}_2^{2+} \text{S}_2^{2-}$

Mg_2S_2

Final Answer: MgS

Stock System

The Stock System is used only if the metal element in the compound may have more than one charge. Example: Iron can form ions that have a charge of 2+ or 3+.

In this system, the valence of the metal element is indicated by using a Roman numeral in parenthesis following the name for the metal.

Example: Iron (II) for a valence of 2+ and Iron (III) for a valence of 3+.

Determining the Stock System name from a chemical formula may be more difficult for students. Knowing that the total charge on a compound is equal to zero, and using the known non-metal charge, students can determine the charge on the metal.

Example: Fe_2O_3

1. The non-metal ion, oxygen, has a charge of O^{2-} . As there are three oxide ions in the formula, the total negative charge in the compound is $2^- \times 3 = 6^-$.
2. The positive ions must have a charge equal to the charge of negative ions to give the compound a net charge of zero. The charge on the ion must be $6+$ ($? \times 2 = 6+$).
3. Since there are two iron ions shown, the valence on the lead is 3+. The name of the compound is lead (III) oxide.

Example: PbS_2

Total negative ion charge is $2^- \times 2 = 4^-$.

Therefore, total positive ions must equal $4+$ ($? \times 1 = 4+$).

Since there is only one lead ion, the valence on the lead is 4.

The name of the compound is lead (IV) sulfide.



Molecular Compounds

Binary molecular compounds contain atoms of two non-metal elements, covalently bonded by sharing electrons.

Following IUPAC guidelines, molecular compounds are named using a prefix system. A Greek prefix is used to indicate the number of each type of atom in the molecule. The prefixes are:

mono = 1

di = 2

tri = 3

tetra = 4

penta = 5

hexa = 6

Rules for naming binary molecular compounds

1. The first non-metal name is written in full.
2. The second non-metal element is named with the suffix “ide” ending.
3. Assign a prefix to each element expressing the number of atoms present in the molecule. The prefix mono is used only with the second element in the compound. When the second element is oxygen, the vowel “o” in mono is dropped and the name becomes monoxide rather than monooxide. Similarly, the “a” in tetra, penta, or hexa is also dropped.

Example: CO_2 is written as carbon dioxide

N_2O_5 is written as dinitrogen pentaoxide

Rules for writing binary molecular compounds

1. Both non-metal symbols are followed by a subscript indicating the number of atoms present. The number 1 is not written, as it is understood to be present.

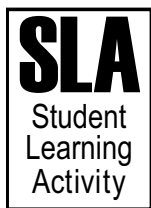
Example: carbon tetrachloride = CCl_4

silicon hexafluoride = SiF_6

2. When determining which non-metal element to place first in the compound, the general rule is to read across the periodic table from left to right. The element that appears first is usually written first. There are exceptions to this general rule.

Example: H_2S = hydrogen sulfide

NF_3 = nitrogen trifluoride



Experiment: Reaction Types

Purpose

1. To investigate and identify five types of chemical reactions.
2. Balance chemical reactions.

Materials

- test tube (25 mL)
- magnesium ribbon (~5–10 cm)
- thin copper wire (~10 cm piece)
- cobalt chloride paper
- limewater solution
- Erlenmeyer flask (250 mL)
- 3.00 M HCl
- Bunsen burner

Solutions

- silver nitrate
- potassium iodide
- lead (II) nitrate
- sodium hydroxide
- copper (II) sulfate
- copper (II) chloride

Procedure

- A. Burn magnesium in the blue flame of a Bunsen burner.
- B. Place about 3 mL of HCl in a test tube. Add a small piece of mossy zinc to the solution. Test for any gas with a burning splint.
- C. Loosely coil a 10-cm piece of copper wire around a pen or pencil. Place the coiled wire into a test tube that is two thirds full of .5M silver nitrate solution.
- D.
 1. Observe both a strip of cobalt chloride paper and 25 mL of limewater solution. Describe and record their appearance in your lab book or log.
 2. Light a candle. Place a large beaker (500 mL) over the candle. When the flame goes out, turn the beaker over, examine, and record its contents.
 3. Test for any moisture with a strip of cobalt chloride paper. Record any observable changes.
 4. Relight the candle and place an Erlenmeyer flask over the candle until the candle goes out.
 5. Quickly overturn the flask and add the 25 mL of limewater solution. Record any observable changes.
- E.
 1. Add 5 mL of a .1M potassium iodide solution to 5 mL of a .1M lead (II) nitrate solution. Observe and record results.
 2. Add 5 mL of a .1M sodium hydroxide solution to 5 mL of .1M copper sulfate or 5 mL of .1M copper chloride solution. Observe and record results.

Senior 2

**Appendix 3:
In Motion**



A Visual Representation of Motion Teacher Background

There are several ways to produce a visual representation of motion. To investigate position, velocity, and acceleration using a ticker-tape apparatus, attach a tape to an object that is in uniform or accelerated motion. For uniform motion, the dots will be evenly spaced; in accelerated motion, the spaces between the dots will increase. The same relationship can be seen with the measured data. The intervals for uniform motion are approximately the same and the intervals for accelerated motion become larger (or smaller if the acceleration is negative).

For Uniform Motion

1. Motorized toys will move across a table with a constant speed. By attaching a ticker tape to the back of the vehicle, a series of dots can be recorded on a tape. For uniform motion the dots will be evenly spaced.

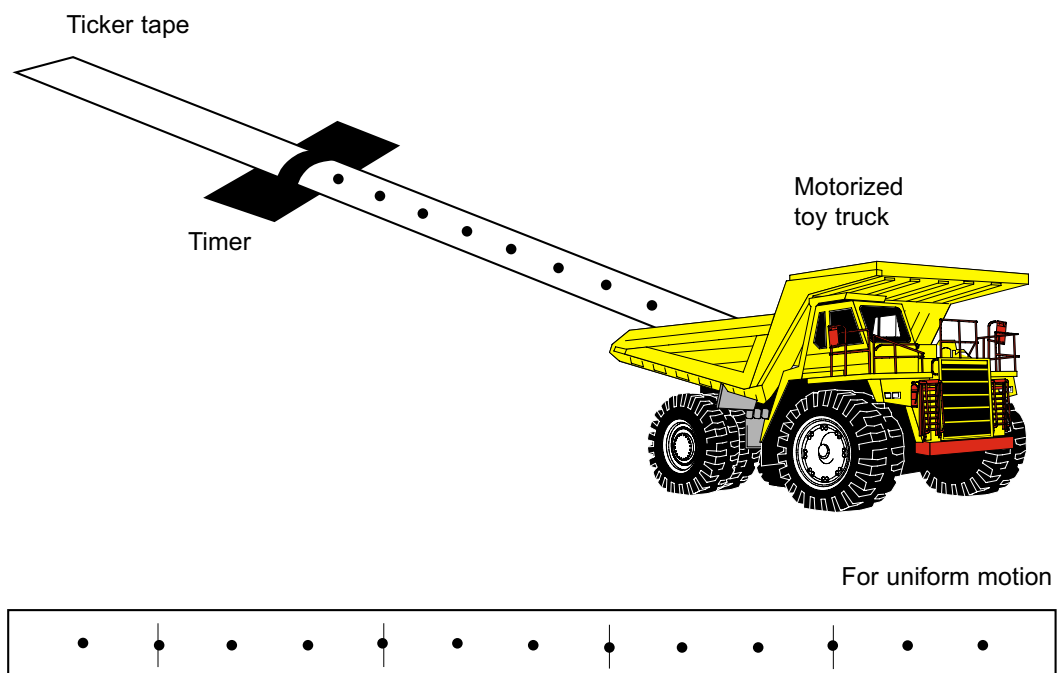
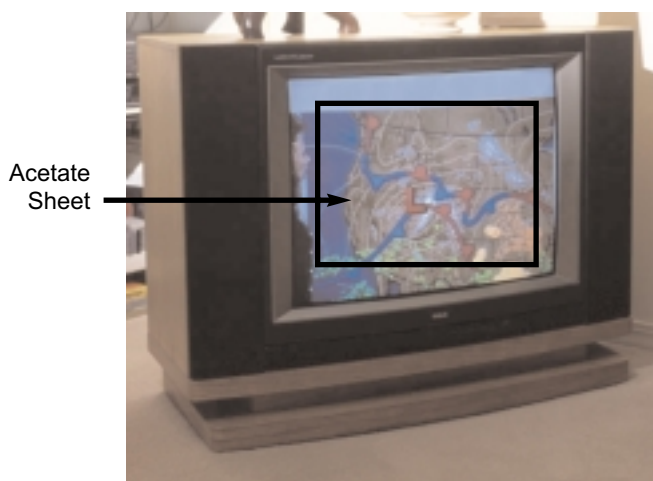


Figure 1

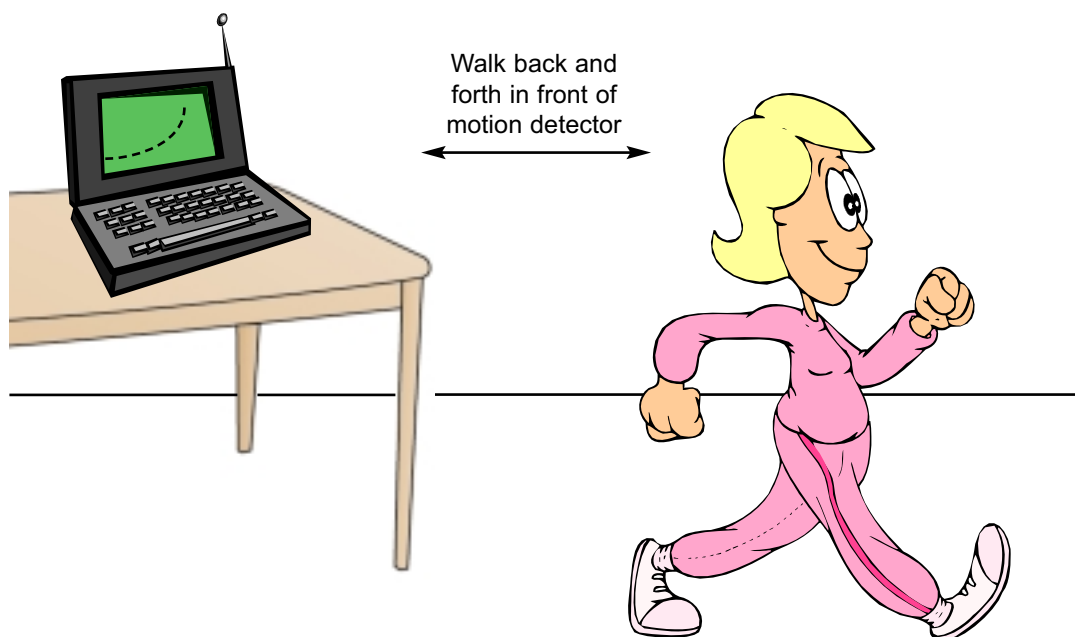
Students can measure the position from the origin and graph position versus time. It is usually convenient to group four to six dots together as one interval. Most timers will vibrate at 60 Hz which means that if you choose 6 intervals the interval of time is 0.1 seconds.

2. Video Analysis



Using a camcorder, videotape uniform and accelerated motion. For uniform motion you can use motorized toys or a ball rolling across a flat surface. A ball rolling down an inclined plane or an object in free fall will accelerate. Replay the videotape and place a mark on the acetate by advancing the tape frame by frame. The marks on the acetate can be interpreted exactly the same as the marks on the ticker tape. Using “canned” tapes of action scenes from movies and/or television, students can analyze “real world” types of motion.

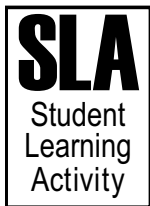
3. Motion Detector



The corresponding graphs also indicate the type of motion. Students should be familiar with the following interpretations:

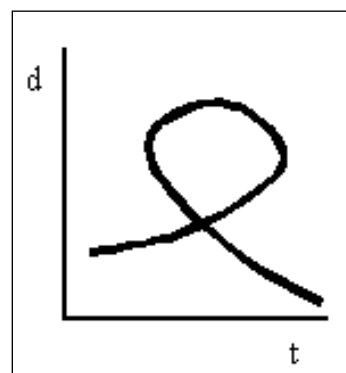
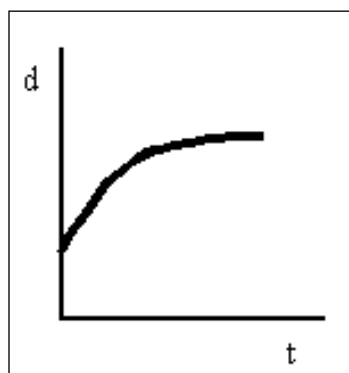
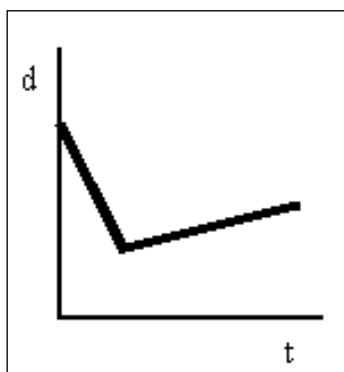
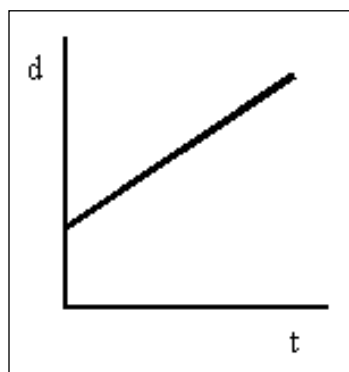
1. Horizontal line—no motion, the object is at rest
2. Oblique line rising up gently—constant velocity, “slow”
3. Oblique line rising up steeply—constant velocity, “fast”
4. Oblique line falling down—constant velocity in the opposite direction

Note: All interpretations are for graphs above the time axis.



Graphical Analysis

1. Using a motion detector, try to make the following graphs by moving in front of the detector.
2. Describe your motion in terms of position, velocity, and acceleration.
3. Tell a story about some “real world” motion that each graph might depict.
4. Are any graphs not possible in the “real world”? If so, explain.



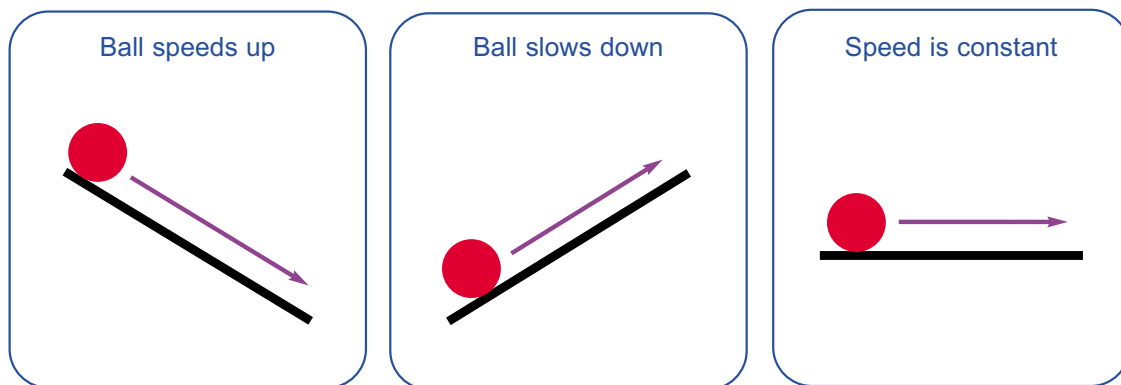


Force and Natural Motion (Historical Perspective) *Teacher Background*

Newton's laws are developed qualitatively with the intention of using these principles of force and motion in later discussions about vehicular motion and collisions. An historical discussion can introduce the idea of inertia. Initially, Aristotle proposed that every terrestrial object had a natural motion toward the centre of the universe (Earth). To move otherwise, an object would be in violent motion under the influence of an external force. In Aristotle's physics, it was necessary to continually apply a force to keep an object moving. This idea can be challenged with a discussion of the flight of an arrow. Aristotle believed that the arrow kept moving because the air swirled around behind the arrow, continuing to push it forward. Many critics of Aristotle pointed out that, if this was the case, the air was both the mover and the resistance at the same time!

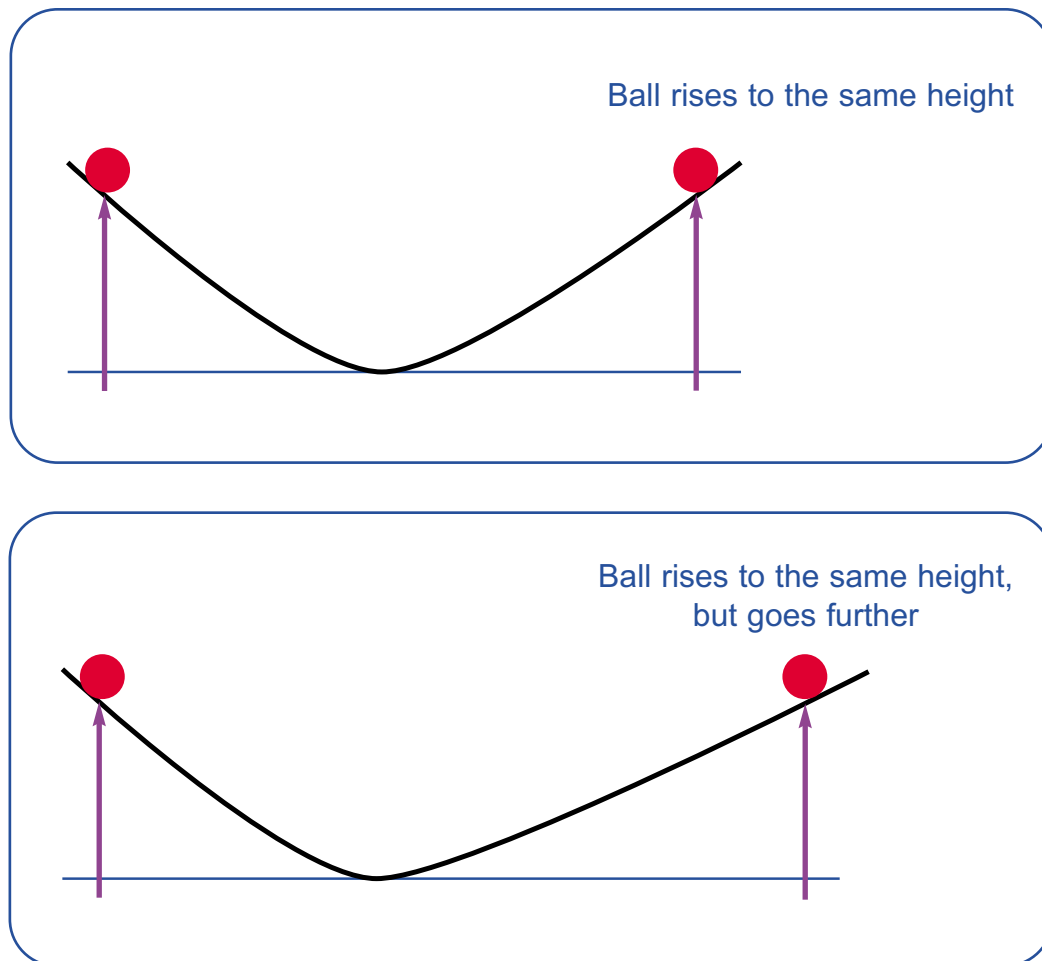
Two thousand years later, Galileo challenged Aristotle's views in his *Dialogues*. Students can read Galileo's words and draw their own conclusions about Galileo's view of inertia. Galileo thought that inertial motion was circular (i.e., an object free to move on the surface of the Earth would circumnavigate the Earth). Galileo proposed the following thought experiments using inclined planes. In A, if we release a mass down the plane, the mass speeds up. Then if we propel a mass up the plane it will slow down. Therefore, it follows that if the plane is neither up nor down (i.e., horizontal), the mass should neither slow down or speed up, but continue moving at a constant speed.

Figure A



In B, a mass released down the plane will rise up the plane on the other side to the same height. If we decrease the angle of the right plane, then the mass must travel further in order to achieve the same height from which it is dropped. If we continue to decrease the angle, it follows that if the second plane has an angle of zero (i.e., horizontal), the mass will continue forever as it tries to achieve the same height from where it was dropped.

Figure B



Descartes was the first to propose straight inertial motion and, later, Newton synthesized inertial motion in the *Principia*. We have since called inertial motion **Newton's First Law**.

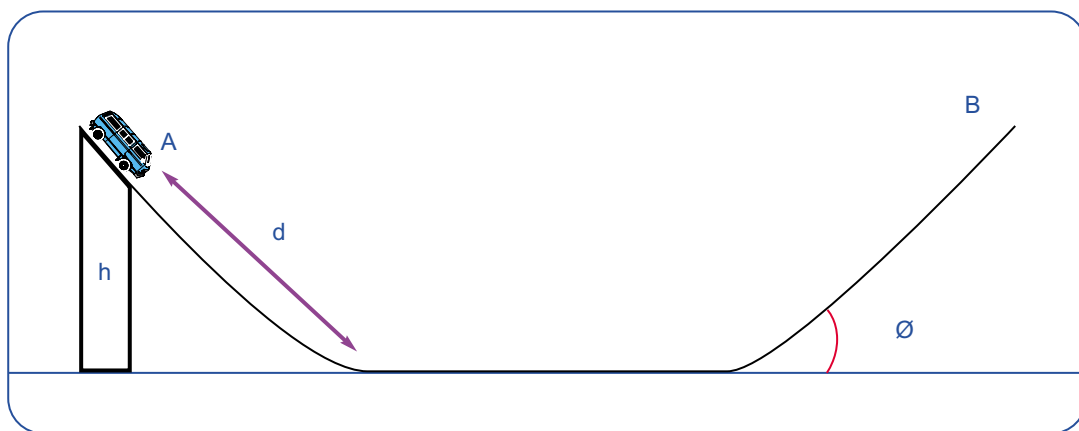


Galileo's Thought Experiment

We can imitate Galileo's thought experiment by using toy cars. Relate Galileo's story while demonstrating that the car will rise to almost the same height from which it was dropped. Discuss the limitations of the demonstration (friction) and relate to students that Galileo's great contribution to the way we practise science was his ability to idealize a situation.

To investigate the Law of Inertia:

1. Set up a track apparatus as shown and measure the angle of inclination of the ramp (2). Choose your best car for this activity.



2. Measure the height from which you release the car at point A and then measure the height the car rises up the other side of the ramp at point B. How do these heights compare?
3. Measure the distance down the ramp and the distance up the ramp. How do these compare?
4. Decrease the angle of the up ramp and release the car from the same height. Again, measure and compare the heights and distances.

Questions

1. As the angle decreases, what happens to the distance the car travels along the up ramp? Why does this distance increase?
2. If the angle of inclination is zero, how far would we expect the car to go?



Newton's First Law

Teacher Background

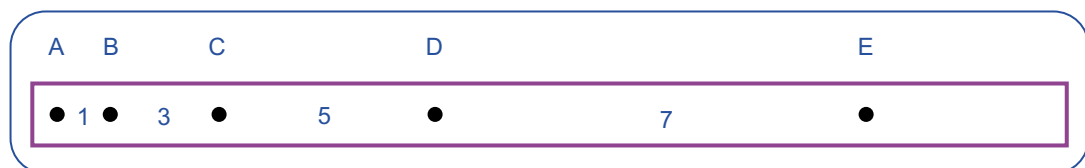
Newton's laws apply to all moving objects (and those that don't move too!). Motor vehicles are familiar moving objects that always obey the law—Newton's law, that is. According to Newton's First Law, a motor vehicle in motion will remain in motion, moving at the same speed and direction unless acted upon by an unbalanced force. When a moving vehicle suddenly stops in a collision, any unrestrained passengers in the car will continue to move with the same speed and in the same direction until they experience another force. This force is often called the *second collision*. Although we say the passengers have been “thrown” from the vehicle, they are really just continuing to move with the same inertia until they experience an unbalanced force in another collision. What are some of the factors that might influence how far an unrestrained passenger will be “thrown”?

Velocity of a Car on an Inclined Plane

For the following exercises, it is necessary to determine the velocity of a car on an inclined plane at regular intervals. Since the car accelerates down the plane, we must determine the distance up the plane from which the car is released in order to increase the velocity at a known rate. Several ways that this may be approached are included here, but it is not intended that all be introduced in the classroom.

1. Historical Context

Galileo showed that an object that was accelerating (either in free fall or down a plane) would cover a displacement according to the odd numbers (1, 3, 5, 7, and so on) for equal time intervals. In other words, Galileo's ticker tape (if he had one) would look like this:



Previously, we showed that velocity \propto time. Since the displacements in Galileo's example are across equal time intervals, the velocity must also increase proportionally for these intervals. That is, the velocity at C is twice the velocity at B, and the velocity at D is three times the velocity at B, and so on. Since the distance from the origin follows the pattern 1, 4, 9, 16 (add up the individual displacements), if we release a car from these positions on an inclined plane, we will know that the velocity increases proportionally. So we can choose convenient numbers (see example on the following page).

Ratio needed	Distance (from bottom of plane in cm)	Velocity (arbitrary units)
1	5	1
4	20	2
9	45	3
16	80	4
25	125	5

Students could be given the information in columns 2 and 3 with a brief explanation.

2. Energy Considerations

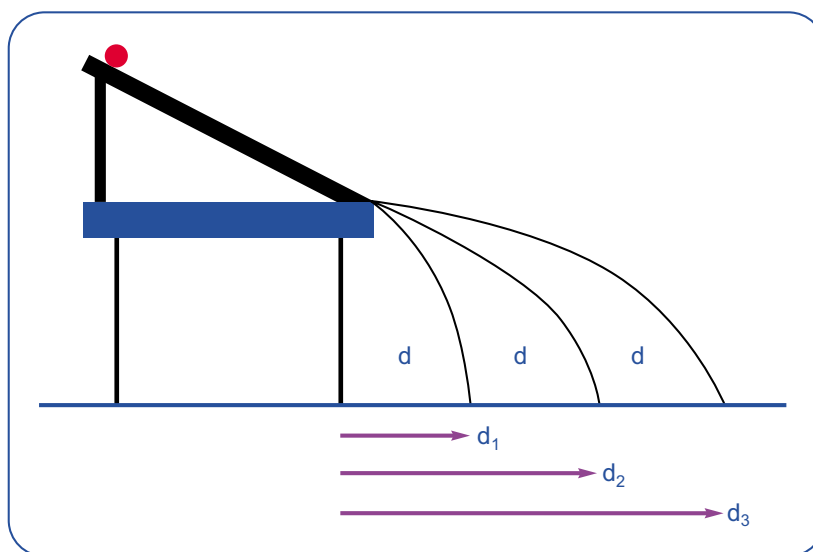
If we release an object from above the surface of the Earth, its potential energy is converted in kinetic energy. That is:

$$mgh = \frac{mv^2}{2}$$

and $v = \sqrt{2gh}$

So if we increase h by 4, v increases by 2; if we increase h by 9, v increases by 3. Note that we have the same ratio as before—1, 4, 9, 16, et cetera. Remember, in this case, h is measured as the distance above the surface. In any case, we get the same table as above.

3. Calibration of the Inclined Plane (recommended as a student activity)



If we release a ball from point A, it accelerates down the plane to some velocity (v_1) and we find that it will fall to the surface some distance (d_1) from the edge of the table. Once the ball leaves the inclined plane, there are no forces acting in the horizontal direction (ignoring air resistance), and the ball moves away from the table with a constant velocity. **Note:** Gravity accelerates the ball only in the vertical direction.

If we release the ball further up the plane it will accelerate down the plane to some velocity (v_2). If the ball lands in a way that d_2 is exactly twice d_1 then v_2 must be twice v_1 . We can repeat the process in a way that the ball lands at $3d_1$, $4d_1$, and so on to calibrate the plane.

- Example:**
1. We release the ball from 5 cm up the plane and measure that it lands 3 cm from the edge of the table.
 2. Make a mark 6 cm (2×3 cm) from the edge of the table.
 3. Release the ball further up the plane such that it lands 6 cm from the edge of the table. Record the point from which the ball is released.
 4. Repeat four or five times and your inclined plane is calibrated.

4. Calculation of Velocity

- A. Release the car from some distance up the plane. Using a stopwatch, record the time it takes the car to reach the bottom of the plane.

i. Calculate the velocity from $a = \frac{Dv}{Dt}$, that is:

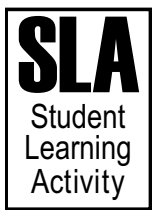
$$Dv = aDt \text{ and therefore, } v_2 - v_1 = aDt$$

$$\text{Since } v_1 = 0, v_2 = aDt \text{ where } a = g \sin \alpha$$

$$\text{So } v_2 = g \sin \alpha Dt$$

For example: if the angle of inclination is 15° , then $g = 10$ and $g \sin 15^\circ = 2.6$ and $v_2 = 2.6 \times \text{time}$.

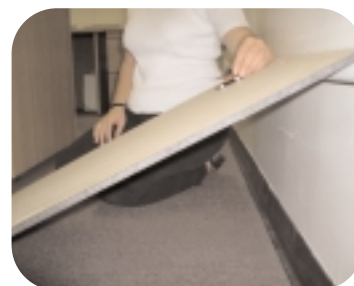
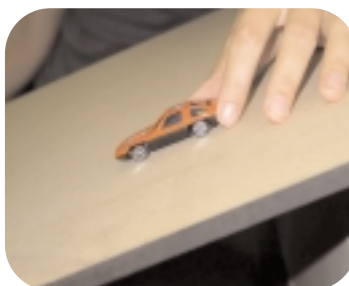
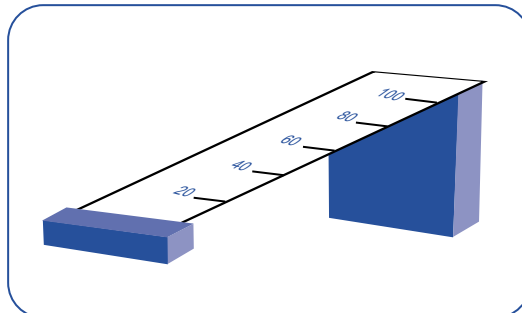
- B. If you allow the car to move a short distance across a flat surface, after it accelerates down the plane, the velocity will be constant. Use photogates to measure the time it takes the car to cover this distance and calculate velocity as distance over time.



Inertia and the Unrestrained Passenger

To investigate the relationship between speed and distance, demonstrate the activity of an unrestrained passenger traveling in a collision.

1. Set up an inclined plane and secure a barrier at the bottom of the plane. Mark the points on the plane from where you will release your car (see previous discussion: Velocity of a car on an incline).
2. Make a “passenger” using modeling clay and rest your passenger on the front of a flatbed cart (you can use a toy car).
3. Release your car down the plane so that the velocity increases at regular intervals, and record the distance the passenger is thrown after the collision with the barrier.

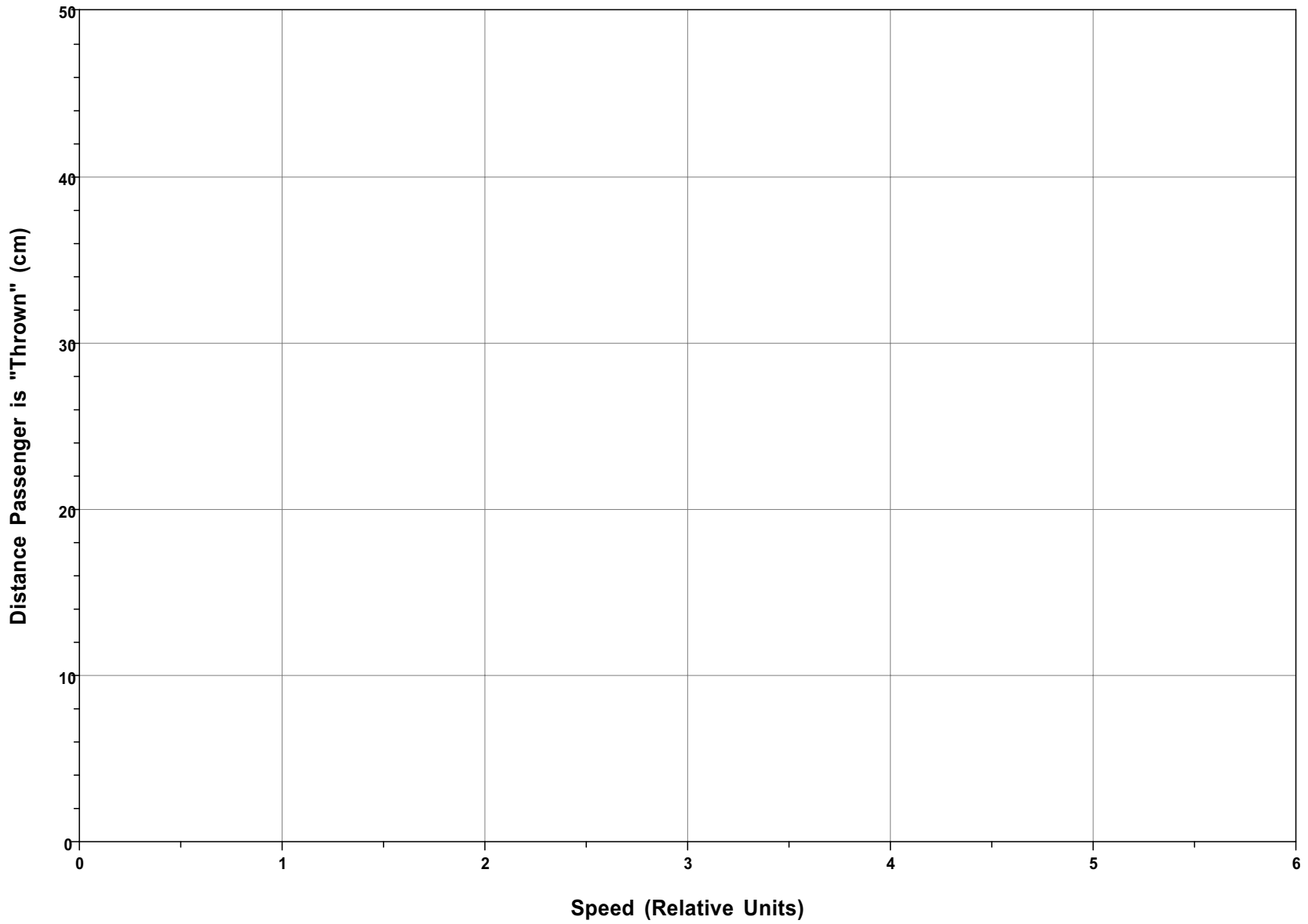


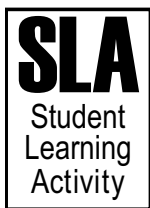
Speed	Trial #1	Trial #2	Trial #3	Average distance the passenger is “thrown” (cm)
1				
2				
3				
4				
5				
6				

Activity Follow-up Questions

1. Graph the speed of the cart versus the average distance the passenger is thrown.
2. What does your graph tell you about the relationship between the speed of a vehicle and the distance an unrestrained object is thrown?

Inertia and the Unrestrained Passenger





Braking Distance

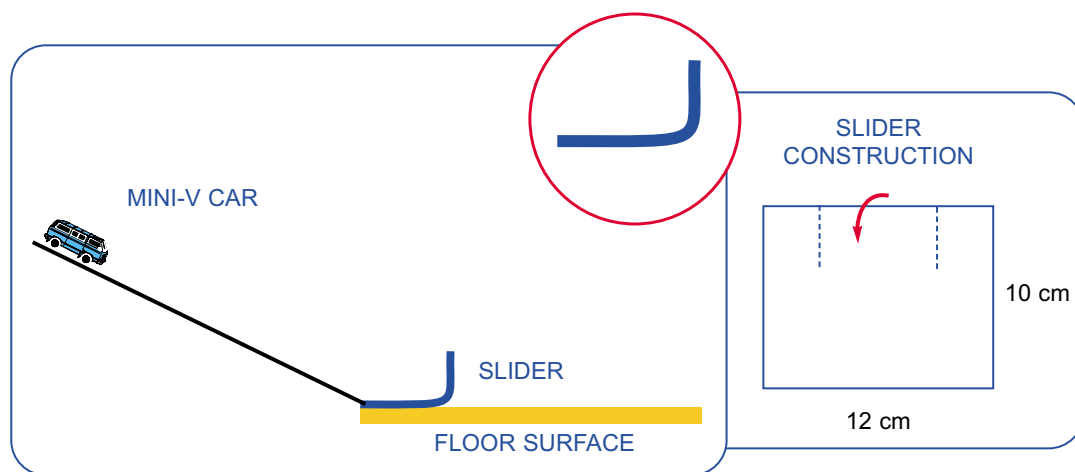
Purpose

To investigate the relationship between the velocity of a car and the distance it takes the car to brake.

When a car brakes, the brake pads press against part of the rotating wheel to apply a frictional force on the wheel. This frictional force causes the car to slow down and eventually stop. The distance the car travels while it is trying to stop is called the *braking* or *stopping distance*.

Procedure

1. Set up the track/ramp apparatus as shown. You can build a slider by cutting a 10-cm x 12-cm piece of paper along the dotted lines and folding it (see below).



2. Release the car from some distance up the plane (see earlier discussion: Velocity of a car on an inclined plane).
3. Measure the distance the car travels in the braking sled. Repeat three times and calculate the average stopping distance.
4. Repeat until you have five or six sets of data.
5. Graph braking distance versus speed.

Table A: Braking Distance

Distance "up the ramp" (cm)	Speed	Trial #1	Trial #2	Trial #3	Average braking distance (cm)
5	1				
20	2				
45	3				
80	4				
125	5				

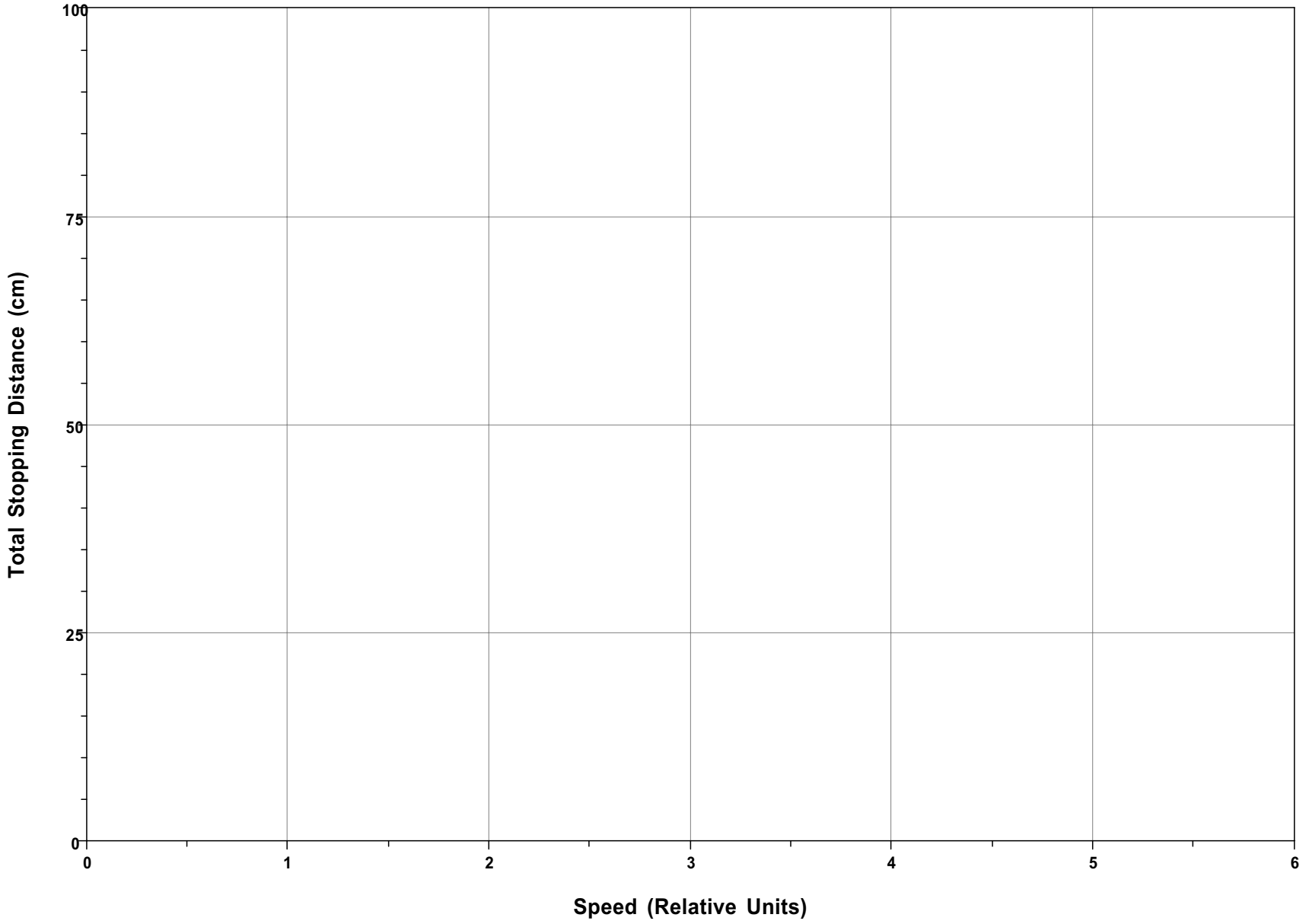
Questions

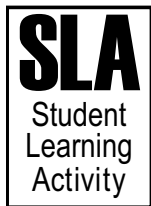
1. Describe in your own words the relationship between velocity and braking distance.

2. How does the stopping distance of different vehicles compare?

3. How does a slippery surface affect the stopping distance?

Braking Distance and Speed

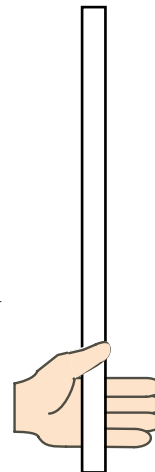




Reaction Time

In the previous activity, we assumed that the brakes were applied instantaneously. In reality, every driver has a reaction time between observing that he or she needs to apply the brakes and applying the brakes. Find your reaction time as follows:

1. Hold your thumb and forefinger about 5 cm apart. Have a partner hold a metre stick so that the 30-cm mark is level with your thumb (see diagram).
2. Without warning, your partner releases the metre stick and you catch it by closing your thumb and forefinger. Record the distance mark where you catch it.
3. Repeat three times and take the average.



4. To find your reaction time use the following formula: $\text{time} = \sqrt{\frac{d}{5}}$

Note: There are several computer programs that you can use to measure reaction time. Try the following URLs for java applets that can be used to measure reaction time.

- <http://www.phys.hawaii.edu/~teb/java/ntnujava/Reaction/reactionTime.html>
- <http://www.bigriver.net/~rasmith/rt/rt.html>
- http://members.tripod.com/fast_wheels/react.htm
- http://schoolsite.edex.net.uk/323/spreadsheet/html/reaction_time.html

Total Stopping Distance

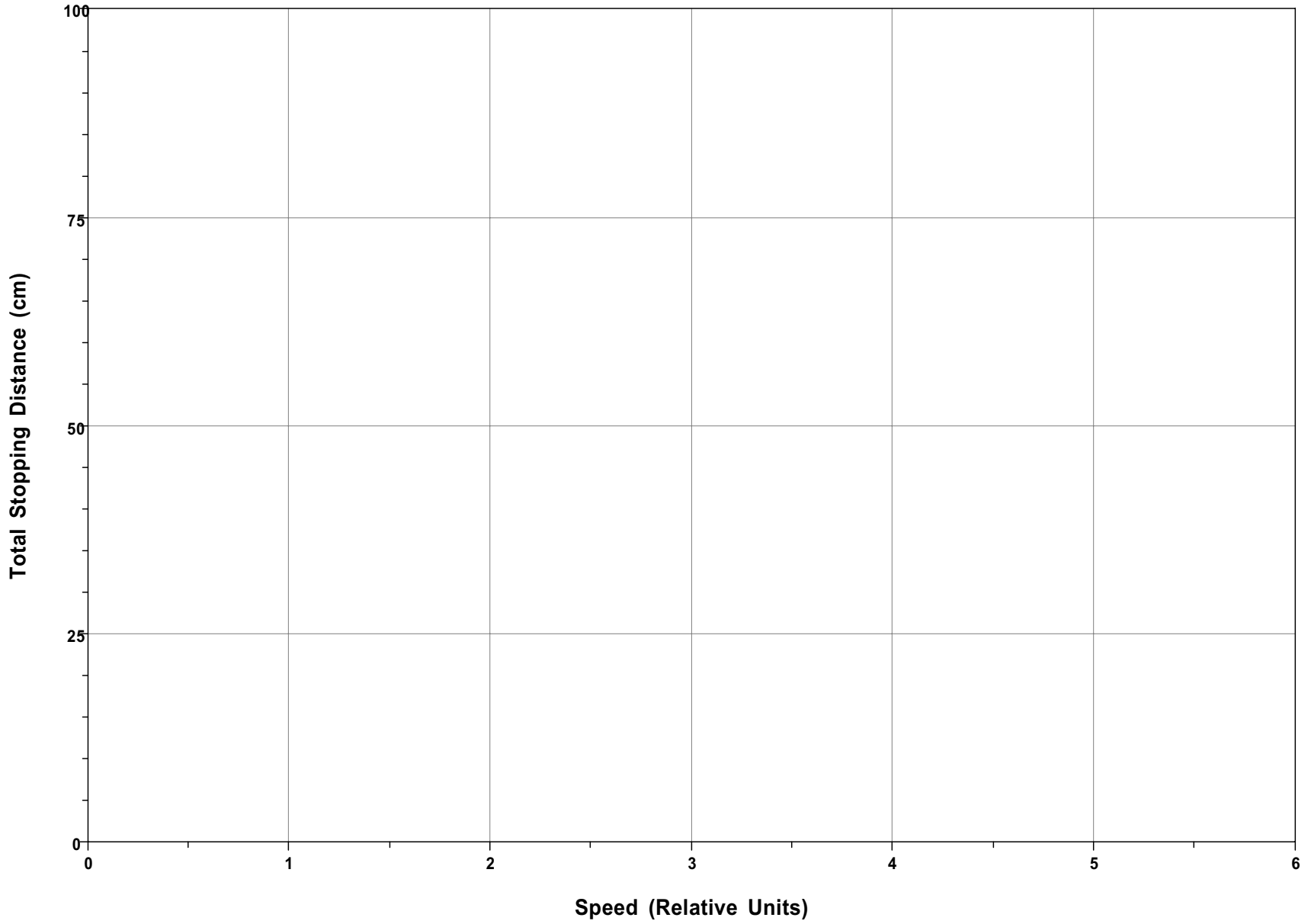
1. Calculate the distance the car travels during your reaction times as $d = v \times t$ and add this to the braking distance to get your total stopping distance.

Speed	Braking distance (cm)	Reaction time (s)	Distance traveled during reaction time (cm)	Total stopping distance (cm)
1				
2				
3				
4				
5				
6				

2. Graph Total Stopping Distance versus Speed, with speed on the x -axis. Make a sketch in this space, and reproduce your graph using the sheet provided by your instructor.

3. What conclusions can you draw by comparing the two graphs?

Reaction Time, Braking Distance, and Speed





Calculating Braking Distance

Student drivers are often given a table of braking distances for various speeds, without being given any indication of how these values are calculated. From the braking distance activity, we have determined that distance varies with the square of the velocity (v^2). Therefore, we can calculate braking distance from $d = kv^2$ where k is a constant of proportionality that represents the frictional conditions. The table shows the k values for different kinds of road conditions, using coefficients for kinetic friction (the coefficient of kinetic, or rolling friction, is generally slightly smaller than for static friction). The mathematical derivation is included for the interested teacher. Students can use known values to calculate braking distances for different speeds.

Proportionality constant (k) (velocity units are m/s)	Road conditions
0.06	rubber tires on dry concrete
0.1	rubber tires on wet concrete
0.25	rubber tires on ice

Derivation of the Mathematical (Symbolic) Relationship

Work done = change in kinetic energy

$$F D = \frac{mv^2}{2} \quad \text{where } F \text{ is the force of friction, (i.e., } F = \mu mg)$$

$$\mu mg D = \frac{mv^2}{2}, \quad \text{therefore } D = \frac{v^2}{2\mu g}$$

$$\text{or simply, } D = kv^2 \quad \text{where } k = \frac{1}{2\mu g}$$

Example:

The braking distance for a car that is traveling at 100 km/h...

Following the conversion of 100 km/h to 27.8 m/s,

$$d = 0.06(27.8^2)$$

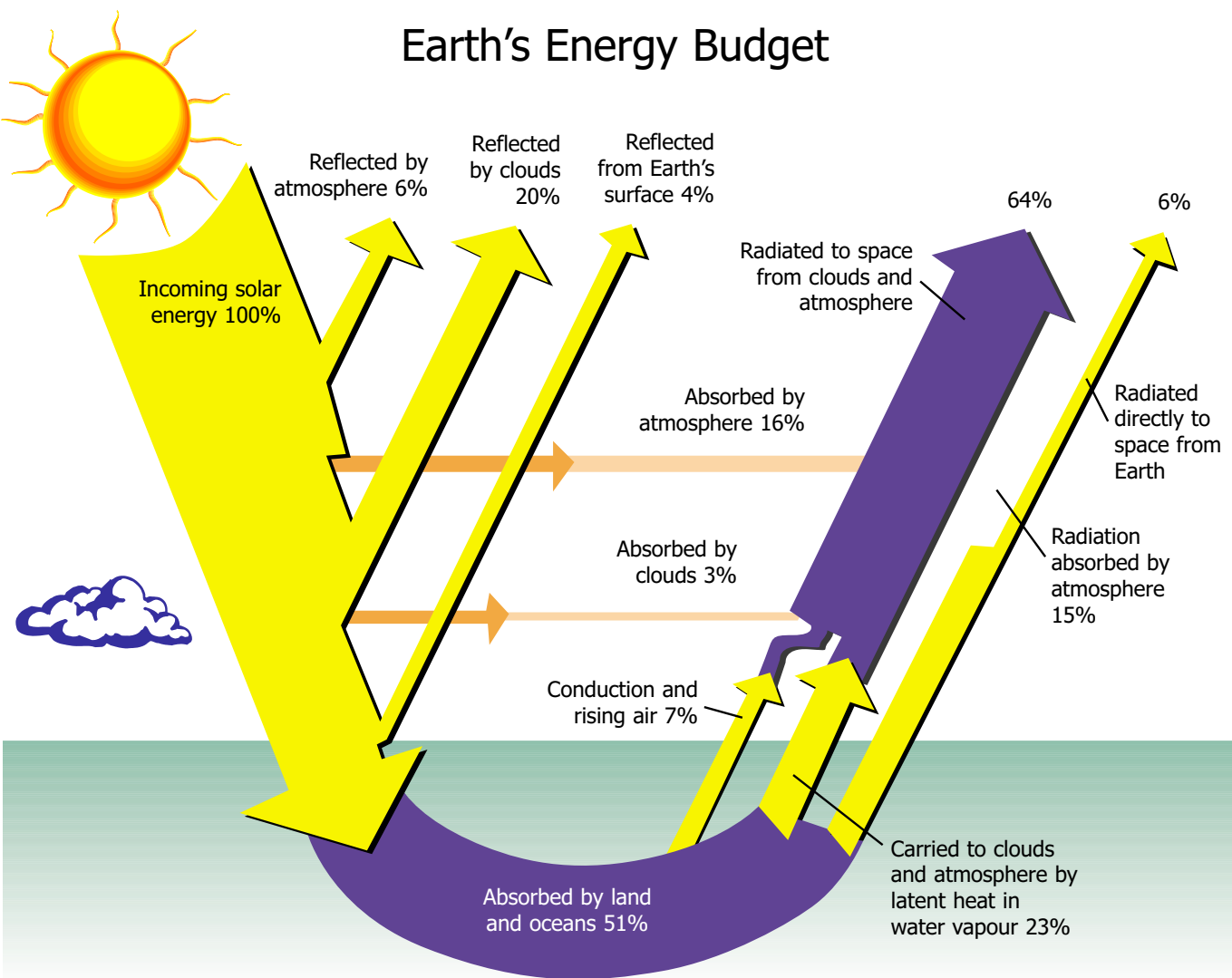
$$d = 46.3 \text{ m}$$

Senior 2

Appendix 4:
Weather Dynamics



Earth's Energy Budget*



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Sunlight and Seasonal Variations

Introduction

Weather, the current state of the atmosphere, generally varies from day to day, and more so over the seasons. Climate, the long-term summary of weather conditions, follows patterns that remain nearly constant from year to year. Astronomical factors that govern the amount of sunlight Earth receives play a major role in determining these weather and climate patterns.

Our solar system consists of the Sun and a series of planets orbiting at varying distances from the Sun. We can see other stars and we are fairly certain other planets exist, however, Earth is the only world on which we are sure life exists. It is the Sun's energy that makes all life on Earth possible. The variations in the amounts of solar energy received at different locations on Earth are also fundamental to the seasonal changes of weather and climate.

Essentially, all the energy received by the Earth originates from thermonuclear reactions within the Sun. Energy from the Sun travels outward through the near-vacuum of space. The concentration of the Sun's emissions decreases rapidly as they spread in all directions. By the time they reach the Earth, some 150 million kilometres (93 million miles) from the Sun, only about $1 / 2,000,000,000$ of the Sun's electromagnetic and particle emissions are intercepted by the Earth. This tiny fraction of solar energy is still significant with about 1,365 watts per square metre of solar power falling on a surface oriented perpendicular to the Sun's rays at the top of the Earth's atmosphere. To the Earth system, this important life-giving amount of energy is called the "solar constant," even though it does vary slightly with solar activity and the position of Earth in its elliptical orbit. For most purposes, the delivery of the Sun's energy can be considered essentially constant at the average distance of the Earth from the Sun. About 31 percent of the solar energy reaching the top of the Earth's atmosphere is scattered back into space.

Because of Earth's nearly spherical form, the incoming energy at any one instant strikes only one point on the Earth's surface at a 90-degree angle (called the sub-solar point). All other locations on the sunlit half of the Earth receive the Sun's rays at lower angles, causing the same energy to be spread over larger areas of horizontal surface. The lower the Sun in the sky, the less intense the sunlight received.

As shown in the accompanying **Sunlight and Seasons diagram, Fig. 1**, the Earth has two planetary motions that affect the receipt of solar energy at the surface: its once-per-day rotation and its once-per-year revolution about the Sun. These combined motions cause daily changes in the receipt of sunlight at individual locations. As the Earth rotates and revolves about the Sun, its axis of rotation always remains in the same alignment with respect to the distant "fixed stars." Because of this, throughout the year, the North Pole points toward Polaris, also called the North

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Star or, astronomically speaking, *alpha Ursae Minoris*. This axis orientation is a steady 23.5-degree inclination from the perpendicular to the plane of the orbit. While the inclination remains the same relative to the Earth's orbital plane, the Earth's axis is continuously changing position relative to the Sun's rays.

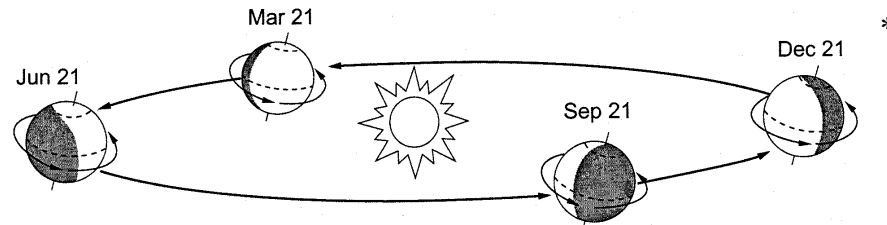


Figure 1

Figs. 2(a), 2(b), and 2(c) show the effects of rotation, revolution, and orientation of the Earth's axis on the path of the Sun through the sky at equatorial, mid-latitude, and polar locations at different times of the year.

SKY VIEWS OF THE SUN *

Daylight hours depicted for Brockport, NY (43.5°N)

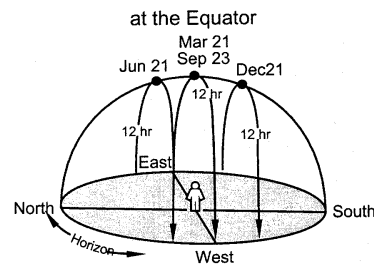


Figure 2a

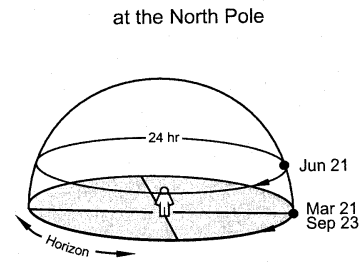


Figure 2b

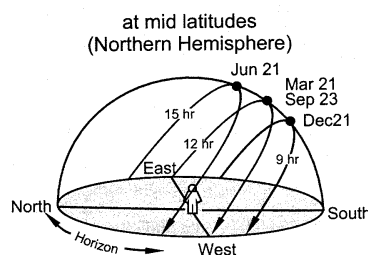


Figure 2c

Twice each year, as the Earth makes its journey around the centre of the solar system, the Earth's axis is oriented perpendicular to the Sun's rays. This happens on the Spring (or Vernal) Equinox—on or about March 21, and the Fall (or Autumnal) Equinox—on or about September 23 (terminology being a Northern Hemisphere bias!).

On these days (i.e., on or about March 21 and September 23), the sub-solar point is over the equator. Exactly one-half of both the Northern and Southern Hemispheres

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are illuminated and everywhere (except the pole itself) receives 12 hours of daylight in the absence of atmospheric effects. From the perspective of a surface observer located anywhere except at the poles, the Sun would rise in the due east position and set due west. At the equator, the Sun would be directly overhead at local noon.

At the North Pole, the Spring Equinox marks the beginning of the transition period from 24 hours of darkness to 24 hours of daylight and vice versa from 24 hours of daylight to 24 hours of darkness for the Fall Equinox. In the Northern Hemisphere, this transition to 24-hour daylight, which begins on the Spring Equinox at the North Pole, progresses southward to reach 66.5 degrees north latitude (the Arctic Circle) at the Summer Solstice on or about June 21.

There are two times when the Earth's axis is inclined the most from the perpendicular to the Sun's rays. These are the solstices, approximately midway between the equinoxes. For the Summer Solstice, on or about June 21, the North Pole is inclined 23.5-degrees from the perpendicular and tipped towards the Sun. The sub-solar point is at 23.5 degrees north latitude, which is also referred to as the Tropic of Cancer. At this time, more than half of the Northern Hemisphere is illuminated at any instant and, thus, has daylight lengths greater than 12 hours. The day length increases with increasing latitude until above 66.5 degrees north (the Arctic Circle) there is 24 hours of sunlight.

Conversely, for the Winter Solstice, on or about December 21, the Earth's axis is also inclined 23.5 degrees from the perpendicular to the Sun's rays. However, at this time of the year the sub-solar point is at 23.5 degrees south latitude, which is also referred to as the Tropic of Capricorn. The North Pole tips away from the Sun and no sunlight reaches above the Arctic Circle (66.5 degrees N). Less than half of the Northern Hemisphere is illuminated and experiences daylight periods shorter than 12 hours.

Sunlight variability due to astronomical factors in the Southern Hemisphere is the reverse of the Northern Hemisphere pattern. The seasons are also reversed.

Together, the path of the Sun through the local sky and the length of daylight combine to produce varying amounts of solar energy reaching Earth's surface. The energy received is one of the major factors in determining the character of weather conditions and, in total, the climate of a location. Generally, the higher the latitude, the greater the range (difference between maximum and minimum) in solar radiation received over the year, and the greater the difference from season to season.

Astronomical factors do not tell the whole story about sunlight and seasons. The daily changes of solar energy received at the Earth's surface within each season come primarily from the interaction of the radiation with the atmosphere through which it is passing. Gases within the atmosphere scatter, reflect, and absorb energy. Scattering of visible light produces the blue sky, white clouds, and hazy gray days. Ozone formation and dissociation absorb harmful ultraviolet radiation while water vapour absorbs infrared. Clouds strongly reflect and scatter solar energy as well as absorb light, depending on their thickness. Haze, dust, smoke, and other atmospheric pollutants also scatter solar radiation.

Basic Understandings for the Seasonal Variations

Solar Energy

Practically all the energy that makes the Earth hospitable to life and determines weather and climate comes from the Sun. The Sun, because of its high surface temperatures, emits radiant energy throughout the electromagnetic spectrum, most in the form of visible light and infrared (heat) radiation. The Earth, on average some 150 million kilometres away, intercepts a tiny fraction ($1 / 2,000,000,000$) of the Sun's radiation.

The rate at which solar energy is received outside the Earth's atmosphere on a flat surface placed perpendicular to the Sun's rays, and at the average distance of the Earth from the Sun, is called the solar constant. The value of the solar constant is about 2 calories per square centimetre per minute (1370 watts per square metre). Solar radiation is not received the same everywhere at the Earth's surface, due primarily to astronomical and atmospheric factors.

Astronomical Factors—The Spherical Earth

At any instant of time, one-half of the nearly spherical Earth is in sunlight and one-half is in darkness. The total amount of solar energy received by Earth is limited to the amount intercepted by a circular area with a radius equal to the radius of the Earth.

In the absence of atmospheric effects, sunlight is most intense at the place on Earth where the Sun is directly overhead (i.e., at the zenith for that location). As the Sun's position in the sky lowers, the sunlight received on a horizontal surface decreases. Due to our planet's rotation and revolution, the place on Earth where the Sun's position is directly overhead is constantly changing.

Astronomical Factors—The Inclination of the Earth's Axis

Throughout Earth's annual journey around the Sun, the planet's rotational axis remains in the same position relative to the background stars. Throughout the year, the North Pole points in the same direction towards Polaris, also called the North Star or *alpha Ursae Minoris*. The Earth's rotational axis is inclined 23.5 degrees from the perpendicular to the plane of the Earth's orbit. The orientation of the Earth's axis relative to the Sun and its rays changes continuously as our planet speeds along its orbital path.

Twice a year the Earth's axis is positioned perpendicular to the Sun's rays. In the absence of atmospheric effects, all places on Earth except the poles experience equal periods of daylight and darkness. These times are the equinoxes, the first days of spring and fall, and they occur on or about March 21 and September 23, respectively.

The Earth's rotational axis is positioned at the greatest angle from its perpendicular equinox orientation to the Sun's rays on the solstices. On or about June 21, our Northern Hemisphere is most tipped towards the Sun on its first day of summer. On or about December 21, the Northern Hemisphere is most tipped away from the Sun on its first day of winter.

As the Earth orbits the Sun, the inclined axis causes the Northern Hemisphere to tilt towards the Sun for half of the year (i.e., the spring and summer seasons in North America). During this time, more than half of the Northern Hemisphere is in sunlight at any instant of time. During the other half of the year (i.e., the fall and winter seasons in North America), the axis tilts away and less than half of the Northern Hemisphere is in sunlight.

The tilting of the Southern Hemisphere relative to the Sun's rays progresses in opposite fashion, reversing its seasons relative to those in the Northern Hemisphere. The changing orientation of the Earth's axis to the Sun's rays determines the length of daylight and the path of the Sun as it passes through the sky at every location on Earth. The continuous change in the angular relationship between the Earth's axis and the Sun's rays causes the daily length of daylight to vary throughout the year everywhere on Earth except at the equator.

From day to day in a perpetually repeating annual cycle, the path of the Sun through the sunlit sky changes everywhere on Earth, including at the equator. In the latitudes between 23.5 degrees north and 23.5 degrees south, the Sun passes directly overhead twice each year. At latitudes greater than 23.5 degrees, the maximum altitude the Sun ever reaches in the local sky during the year decreases as latitude increases. At either pole, the maximum altitude is 23.5 degrees above the horizon, occurring on the first day of that hemisphere's summer.

Solar Energy Received

In the absence of atmospheric effects, the length of the daylight period and the path of the Sun through the local sky determine the amount of solar radiation received at the Earth's surface. Ignoring atmospheric effects, the variation in the amount of sunlight received over the period of a year at the equator is determined by the path of the Sun. The Sun's path is highest in the sky on the equinoxes and lowest on the solstices. This results in two periods of maximum sunlight centring on the equinoxes and two periods of minimum sunlight at solstice times each year.

The Four Seasons

At the equator, the daily period of daylight is the same day after day. The changing path of the Sun through the sky over the year produces a cyclical variation in the amounts of solar radiation received that exhibit maxima near the equinoxes and minima near the solstices. The relatively little variation in the amounts of solar energy received over the year produces seasons quite different from those experienced at higher latitudes.

Away from the tropics, the variations in the amounts of solar radiation received over the year increase as latitude increases. The amounts of sunlight received exhibit one minimum and one maximum in their annual swings. The poles have the greatest range, since the Sun is in their skies continuously for six months and then below the horizon for the other half-year.

In general, the variations in solar radiation received at the surface over the year at higher latitudes create greater seasonal differences. While the receipt of solar energy is the major cause of seasonal swings of weather and climate at middle and high latitudes, other factors such as nearness to bodies of water, topographical features, and migrations of weather systems play significant roles as well.

Atmospheric Factors

The atmosphere reflects, scatters, and absorbs solar radiation, reducing the amount of sunlight that reaches the Earth's surface. Some atmospheric gases absorb specific wavelengths of solar radiation. Water vapour is a strong absorber of incoming infrared energy, causing a significant reduction in the amount of solar radiation reaching the ground during humid conditions. Ozone, during its formation and dissociation, absorbs harmful ultraviolet radiation that can lead to sunburn and skin cancer.

To some extent, haze, dust, smoke, and other general air pollutants block incoming solar energy wherever present. Clouds strongly reflect, scatter, and absorb incoming sunlight. High, thin cirrus absorbs some sunlight while dense clouds, if thick enough, can produce almost nighttime conditions.



Exploring Albedo

Guiding Question—What effect does albedo have on surface temperature?

Concepts

Albedo is the fraction of incoming sunlight that is reflected, rather than absorbed.

Principles

1. Albedo is represented as a percent of Earth's total incoming energy. Thus, an albedo of 50 percent would indicate that half of all incoming radiation is reflected. In general, the more radiation that is reflected, the lower the overall surface temperatures.
2. Albedo represents an important aspect of the radiation budget.
3. Earth's Radiation Budget is a model that depicts the amount of energy the Earth gets from the Sun and the amount of energy Earth sends back to space. If Earth receives more solar energy than it sends back to space, we expect it to warm up. If Earth sends more energy than it receives from the Sun, we expect Earth to cool down.
4. In general, more lightly coloured surfaces (e.g., snow and ice) have a higher albedo than dark-coloured ones (e.g., trees, blacktop, and so on).

Facts

1. The overall albedo of Earth is thought to be about 30 percent.
2. NASA satellite instruments collect data concerning Earth's albedo.
3. The concept of albedo explains, for example, why white robes are favoured in desert regions.

Skills

1. Experimenting and making measurements
2. Drawing conclusions

Preparation

Materials

1. Thermometers (three per lab team)
2. Black- and white-coloured paper (one sheet each per lab team)
3. One paper cup of water per lab team
4. Earth's Radiation Budget graphic from this or other learning resources or websites, such as: <http://asd-www.larc.nasa.gov/erbe/components2.gif>

Room Preparation

As most of the lesson will take place outside, no room preparation is necessary. In the absence of warm, sunny weather, the room can be set up with a number of high-intensity lamps as “suns.”

Note: The number of sun lamps will depend on how many students and how many groups are working on the activity. It is suggested that there should be one lamp per group.

Safety Precautions

1. Students should report broken thermometers immediately. Both broken glass and mercury have a high hazard potential.
2. If lamps are used, make sure students are careful not to let clothes or skin touch the bulb or metal shade (if any).

Procedures and Activity

Prelab discussions

1. Introduce the Earth’s Radiation Budget so students will understand the concept, and how their learning resources (such as the text) explain albedo.
2. Ask students if they would be hotter on a sunny day wearing black- or white-coloured clothes. Guide them into realizing that because white is “brighter” (it has a higher albedo), it is correspondingly cooler; black garments reflect little sunlight and thus are warmer.
3. Review variables—*independent* and *dependent*. Which variables are involved here?

Activity

1. Distribute materials among students. Each lab team should wrap one thermometer tightly in black paper. A second thermometer should be wrapped tightly in white paper, and the third thermometer should be submerged in the cup of water. All three thermometers should then be put in the Sun (or underneath the lamp).
2. The temperature readings for all three thermometers should be checked and recorded every five minutes, for a total of 10 minutes. At the end of the first five-minute waiting period, students should rank the three materials (white paper, black paper, and water) in order, from the highest to the lowest albedo, as a working hypothesis.
3. Each of the three materials (white paper, black paper, and water) should be rated for albedo again at the end of the final five-minute waiting period, this time using the idea that a higher albedo will yield a lower final temperature.

Discussion

1. Which final temperature was the highest? Which was the lowest? Did your results turn out the way you expected?
2. Just in case: If the final temperature for the water proves to exceed that for the black paper, help students to understand the fact that the black paper “shields” its thermometer and thus might have influenced the results. Ask for suggestions on how to redesign the experiment to account for this (an example of a more accurate method is given under “Extension Ideas” below).

Closing

Ask students “What effect does albedo have on surface temperature?”

Assessment

1. Completion of a lab activity sheet or formal lab report.
2. Did each student contribute equally to the group effort? You may wish to add a question to each activity sheet, along the lines of “How did you divide up the work?”

Extension Ideas to Challenge Students

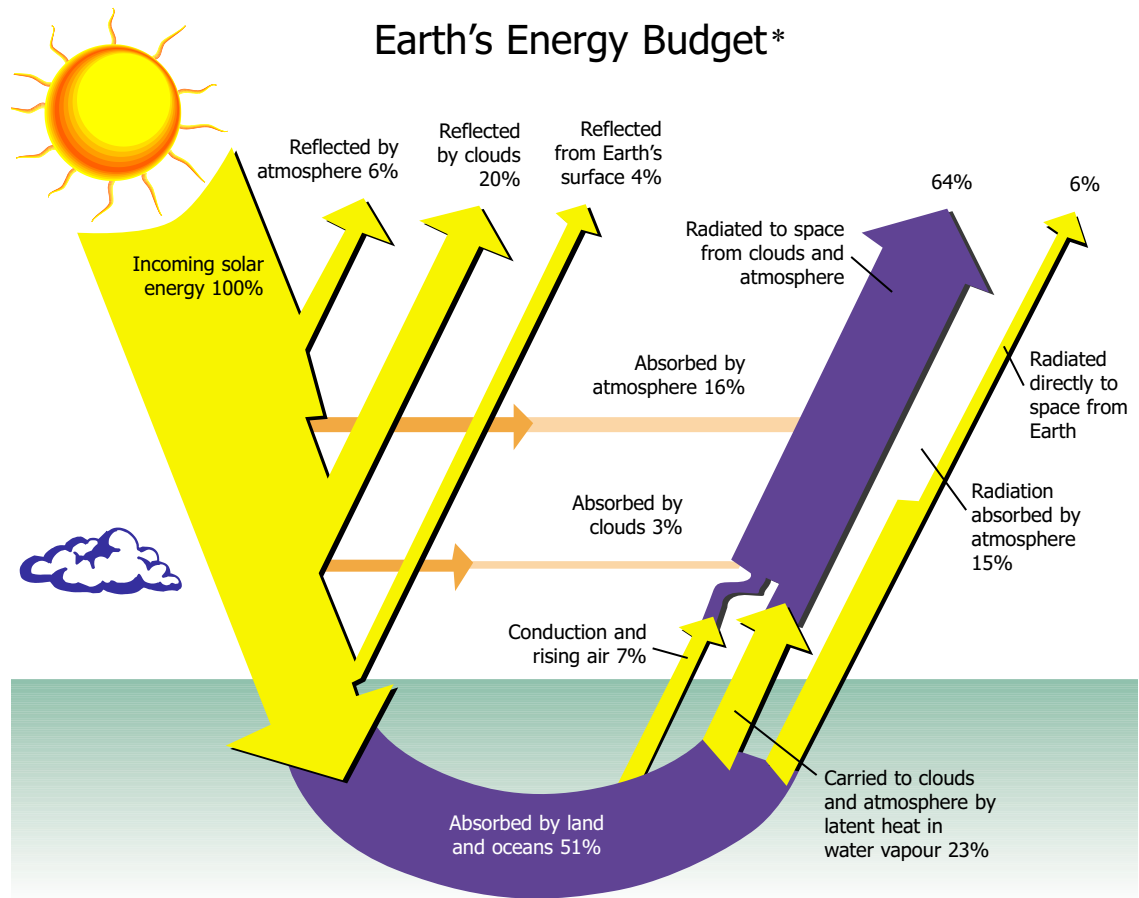
1. Have students graph temperature versus time for all three thermometers, and ask if all three warmed up at the same rate.
2. A more accurate method of determining albedo-temperature-colour relationships would be to put each thermometer in a cup filled with either cola, milk, or plain water. Make sure that the starting temperatures of all three liquids are identical, and that the volumes of the three are more or less equivalent. You might wish to run the experiment this way after completing it as described above, and allow students to compare results.
3. Assume (for the sake of this experiment) that the black paper (or cola) has an albedo of 0 percent. Further assume that the albedo of the white paper (or milk) is 100 percent. Have students interpolate the temperature for Earth in general (30 percent albedo) under similar light conditions, based on the two end-point temperatures.

$$\text{Interpolated Temperature (30\%)} = 100\% \text{ albedo temperature} + (0.3) \times (0\% \text{ temperature} - 100\% \text{ temperature})$$

Careers Related to the Lesson Topics

1. Atmospheric scientist
2. Land-use management
3. Climatologist
4. Optical physicist

Students could explore the above careers in some detail to see how their science can be directly connected to interesting career options.



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Connecting Mathematics to the Atmosphere (For Further Exploration)

Purpose

Develop and apply a variety of strategies to solve problems, with emphasis on multistep and nonroutine problems.

Instructional Delivery

Co-operative Groups/Flexible Groups/Independent

Materials

Appendix 4.1: Earth's Energy Budget

Activity

Students solve the suggested mathematical word problems by looking at the Earth's Energy Budget. Students use their Earth's Energy Budget graphic to assist with answering the questions. After answering the questions, use a self-assessment or peer-assessment strategy to have students follow up on the class responses.

Assessment

Have students (independently, or in co-operative or flexible groups) create and solve an original mathematical word problem by using the information on the Earth's Energy Budget handout.

Extension Ideas

When introducing the information to the class about the long and short waves, have the students estimate and predict wavelengths. Use a piece of yarn or a coil spring toy to represent and simulate wavelength. The students can manipulate the piece of yarn or spring toy after making their predictions. This activity may be altered to predict measurement in inches, centimetres, yards, feet, and so on. There are particular unit conversion skills involved here, and students of *Applied Mathematics (20S)* could use this as reinforcement.

Student Activity Questions

1. Determine the radiation budget by looking at the Earth's Energy Budget. (Subtract the amount of solar energy from the total amount of reflected energy from the Earth in order to determine the radiation budget.)

2. What is the total percentage of the incoming solar energy reflected from the Earth by the atmosphere, clouds, and Earth's surface?

Total Reflected: (% atmosphere + % clouds + % Earth's surface) = _____%

3. Is the total percentage of the incoming solar energy reflected from the atmosphere, clouds, and Earth's surface less than or greater than the incoming solar energy absorbed by the land and oceans?

(% atmosphere + % clouds + % Earth's surface) < or > (% land + % ocean)

4. If the amount of incoming solar energy reflected from the Earth's surface tripled, how much energy would be reflected?

(% incoming solar energy) x 3 = _____%



The Coriolis Effect*

The Coriolis effect (sometimes erroneously called a force) results from Earth's rotation and our perspective as residents who are more or less fixed to the surface. Because the Earth is big (relative to us), and everything around us (including us) is moving at the same speed as the Earth's surface, we don't really notice this constant rotation. The atmosphere, however, is not attached rigidly to the Earth's surface, and is therefore not constrained to move at the same speed or direction as the Earth's surface. Because of this, objects (such as air, ocean currents, airplanes) not rigidly attached to the Earth will appear to us to move along a curved path even though they may actually be traveling in a straight line.

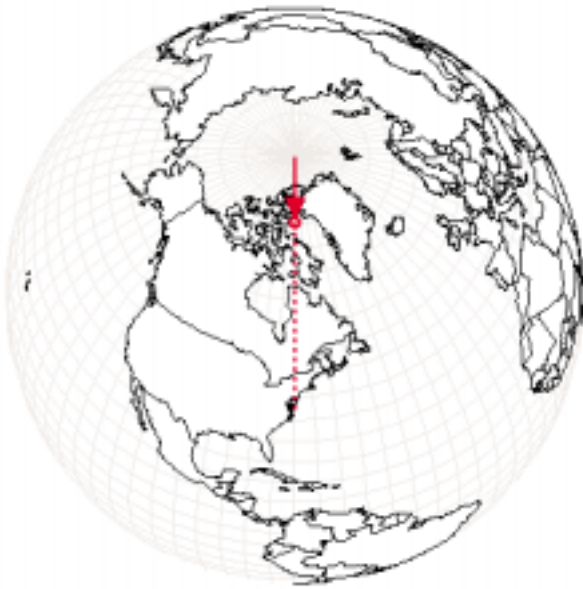
Consider the following example. Suppose that an airplane takes off from the North Pole (see sketches on the following page) and is traveling in a straight line due south (of course). After one hour of flying, the plane is headed straight toward Montreal and New York City. If the plane continues to fly in a perfectly straight line, after a second hour, the Earth will have rotated through an angle of about 15 degrees underneath the airplane, which is now somewhere over Hudson Bay. By hour three, another 15 degrees of Earth rotation puts the plane in the centre of the continent, at about the Canada-U.S. Border. After four hours of flight, the airplane is somewhere over northern California. Notice that the plane flew in a straight line while the apparent path on the ground is curved. Work through the sketches a few times until it starts to make sense. Where would the plane be after another hour of flight?

As viewed from the North Pole, the plane, which was headed directly toward New York City, has drifted severely off its course, curving to the right. In the Northern Hemisphere, the Coriolis effect makes objects appear to curve to the right. This would also be the case if the plane took off at the equator and headed toward the North Pole. In the Southern Hemisphere, the direction of the effect is reversed and there is an apparent deflection to the left (from the perspective of the starting point). For further information, see your textbook or visit some Coriolis effect websites that you may find on the Internet.

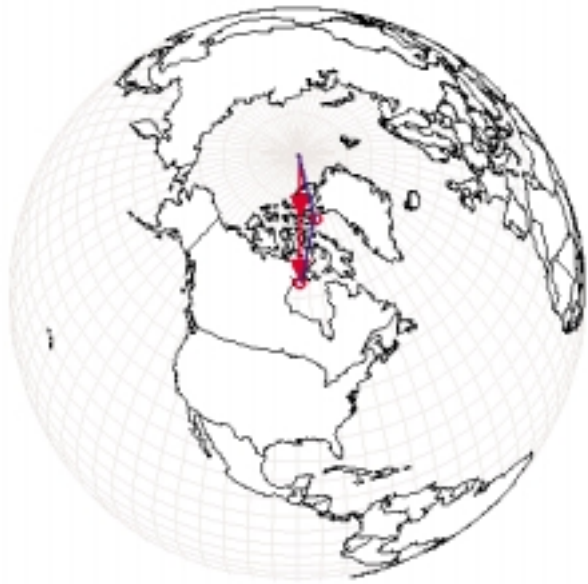
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Position of Aircraft (Looking North)*

After 1 hour:



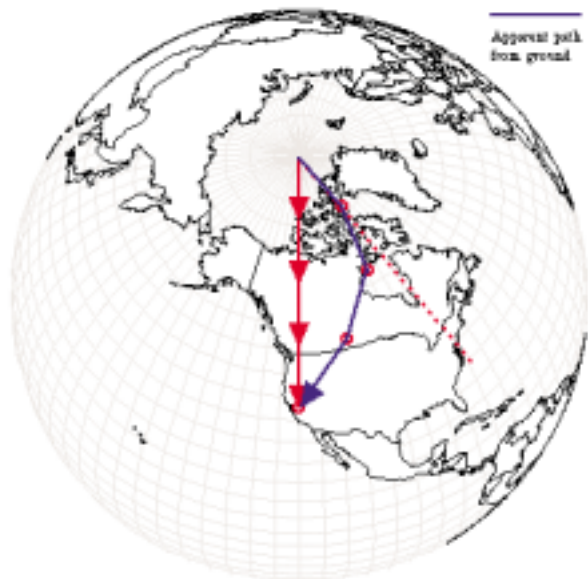
After 2 hours:



After 3 hours:



After 4 hours:



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Understanding the Link Between Coriolis and Weather

Why Do Objects Follow a Curved Path as Earth Rotates?

Most of us know that the Earth rotates in an easterly direction, but few appreciate that the surface of the Earth rotates at different speeds at different latitudes. This phenomenon is best illustrated at the extremes. Both the poles and the equator have to make a full rotation in 24 hours, but the circumference of Earth near the poles is much smaller than that of the equator; therefore, the equator has to spin much “faster” relative to regions near the poles. In fact, a point on the equator travels at ~1,640 kph, while a point 100 kilometres south of the North Pole travels at only ~6 kph. For a typical Manitoba student, the ground has a rotational velocity of ~1,000 kph in an easterly direction. This rotational speed decreases as one travels further north toward the pole, and is zero at the North Pole.

Earth’s atmosphere and ocean exhibit numerous instances of horizontal motions along curved paths. Near-surface winds spiral into low-pressure areas and out of high-pressure areas. Ocean currents flow in huge almost circular gyres thousands of kilometres across. Other objects, including planes and boats, freely moving horizontally almost everywhere on Earth (except at the equator) turn right or left. The turning of these moving object’s paths, as seen from our vantage point on Earth, is the **Coriolis effect**.

Why does this curved motion occur? Aren’t objects that are moving “freely” (not held down) in horizontal directions supposed to move in straight paths? As described by Sir Isaac Newton’s First Law of Motion, an object in motion should remain in motion in a straight line, unless acted upon by an external force. But, there is no horizontal force acting on an object moving freely across the Earth’s surface to cause it to turn right or left. Yet, except at the equator, the moving object is apparently deflected. If there is no horizontal force acting to make this happen, there must be another explanation. There is! The Earth is turning underneath the moving object; that is, the Earth rotates.

All motion must be measured with respect to something, and the Earth is our frame of reference. The Earth is so immense that we usually think of it as being unmoving. That is why objects that are moving horizontally and freely appear to turn to the right or left. Actually, it is the Earth that is turning underneath as the objects move forward.

The effect of the Earth’s rotation on horizontally moving objects is greatest at the poles. The Coriolis deflection decreases as latitude decreases, until it is zero at the equator. In the Northern Hemisphere, the sense of the Earth’s rotation is counterclockwise as seen from above the North Pole. Consequently, moving objects always appear to turn rightward in the Northern Hemisphere. The reverse happens in

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the Southern Hemisphere because of the clockwise sense of our planet's rotation when looking down from above the South Pole. There, horizontally moving objects appear to turn toward the left.

Scientists account for the Coriolis effect by inventing an imaginary force called the **Coriolis “force.”** This imaginary Coriolis “force” is applied in combination with real forces, such as the air pressure gradient force and friction, to explain motions of objects in terms of Newton's laws. The Coriolis “force” is defined as always acting perpendicular to the direction of motion: to the right in the Northern Hemisphere to explain rightward turning, and to the left in the Southern Hemisphere to describe leftward turning. It is all necessary because the Earth turns!

Basic Understandings About Earth to Appreciate the Coriolis Effect

Motion of Objects (Revisiting “In Motion” from Cluster 3)

1. Motion describes the continuous change of location of an object.
2. All motion is relative; that is, motion must be measured from a frame of reference. Most of the time we use the Earth as our frame of reference, such as when we measure the speed of a car. But persons walking in a traveling airliner, ship, or train car use the airliner, ship, or train as their frame of reference.
3. The term “speed” describes how fast an object is moving. Speed is the magnitude of motion. Motion can be described fully by indicating both speed and direction. Such fully described motion is called velocity, and was described as a **vector quantity** in Cluster 3, In Motion.
4. Motion results from forces (pushes or pulls) acting on an object. Sir Isaac Newton studied motion and devised basic laws to describe his findings. His First Law indicates that an object at rest tends to stay at rest and a moving object moves in a straight line at a constant speed, unless acted upon by an outside force. Another of his laws describes how an outside force can speed up or slow down the object, or it can change the direction of the object's motion.

Horizontal Motions Near Earth's Surface

5. Objects moving horizontally and freely (unconstrained and not being acted upon by an outside horizontal force) across the surface of the Earth at the equator follow paths that are straight relative to the Earth's surface, as described by Newton's First Law of Motion.
6. Objects moving horizontally and freely across the surface of the Earth everywhere except at the equator follow paths that are curved as measured from Earth. In the Northern Hemisphere, they turn towards the right of the direction of motion and in the Southern Hemisphere they turn left. This deflection is called the Coriolis effect, after Gustave-Gaspard de Coriolis.

7. The observed Coriolis effect arises because the Earth is rotating and, in locations not on the equator, is actually turning underneath as a horizontally and freely moving object travels forward. Because the motion is being measured relative to the Earth, the motion appears to be along a curved path.
8. Anywhere in the Northern Hemisphere, the sense of the Earth's rotation is counterclockwise as seen from above the North Pole. Consequently, the observed curved motion is always to the right of the direction of motion.
9. Anywhere in the Southern Hemisphere, the sense of the Earth's rotation is clockwise as seen from above the South Pole. Consequently, the observed curved motion is always to the left of the direction of motion.
10. Because there is no turning of the surface of the Earth (sense of rotation) underneath a horizontally and freely moving object at the equator, there is no curving of the object's path as measured relative to the Earth's surface. The object's path is straight; that is, there is no Coriolis effect.
11. The Earth's rotational effects on horizontally and freely moving objects are greatest at the poles; therefore, the Coriolis effect is greatest at the poles.
12. As the latitude at which horizontally and freely moving objects are located decreases, the twisting of the underlying Earth's surface due to the planet's rotation decreases. That is, the Coriolis effect decreases as the latitude decreases. It is maximum at the poles and absent at the equator.

The Coriolis “Force”

13. The Coriolis effect arises because motion is being measured from a rotating frame of reference. There are no outside forces acting on a horizontally moving object that causes the observed curved motion.
14. Scientists have invented an imaginary force, called the Coriolis force, to account for the Coriolis effect. This has been done so that Newton's Laws of Motion can be applied to movements measured relative to the Earth's surface.
15. The Coriolis force is defined as always acting perpendicular to the direction of motion. Because the sense of the Earth's rotation as seen from above in the Northern Hemisphere is opposite to that in the Southern Hemisphere, it is further defined as always acting to the right in the Northern Hemisphere and always to the left in the Southern Hemisphere.

Mathematics Connection

16. The Coriolis force is also defined as being directly proportional to the sine of the latitude to account for the increasing curvature of paths as latitude increases. The trigonometric function sine is zero at an angle of 0 degrees (equatorial latitude) and 1 (maximum) at an angle of 90 degrees (polar latitude).



It Bends Because the Earth Turns

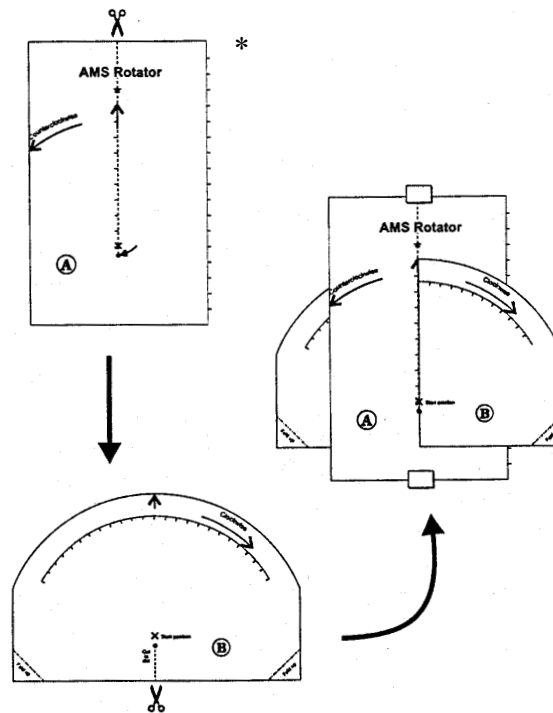
Introduction

Almost everywhere on Earth (except at the equator), objects moving horizontally and freely (unconstrained) across the Earth's surface travel in curved paths. Objects, such as planes, boats, bullets, air parcels, and water parcels, turn right or left as seen from our vantage point on Earth. This activity investigates the reason for this turning, a phenomenon known as the Coriolis effect.

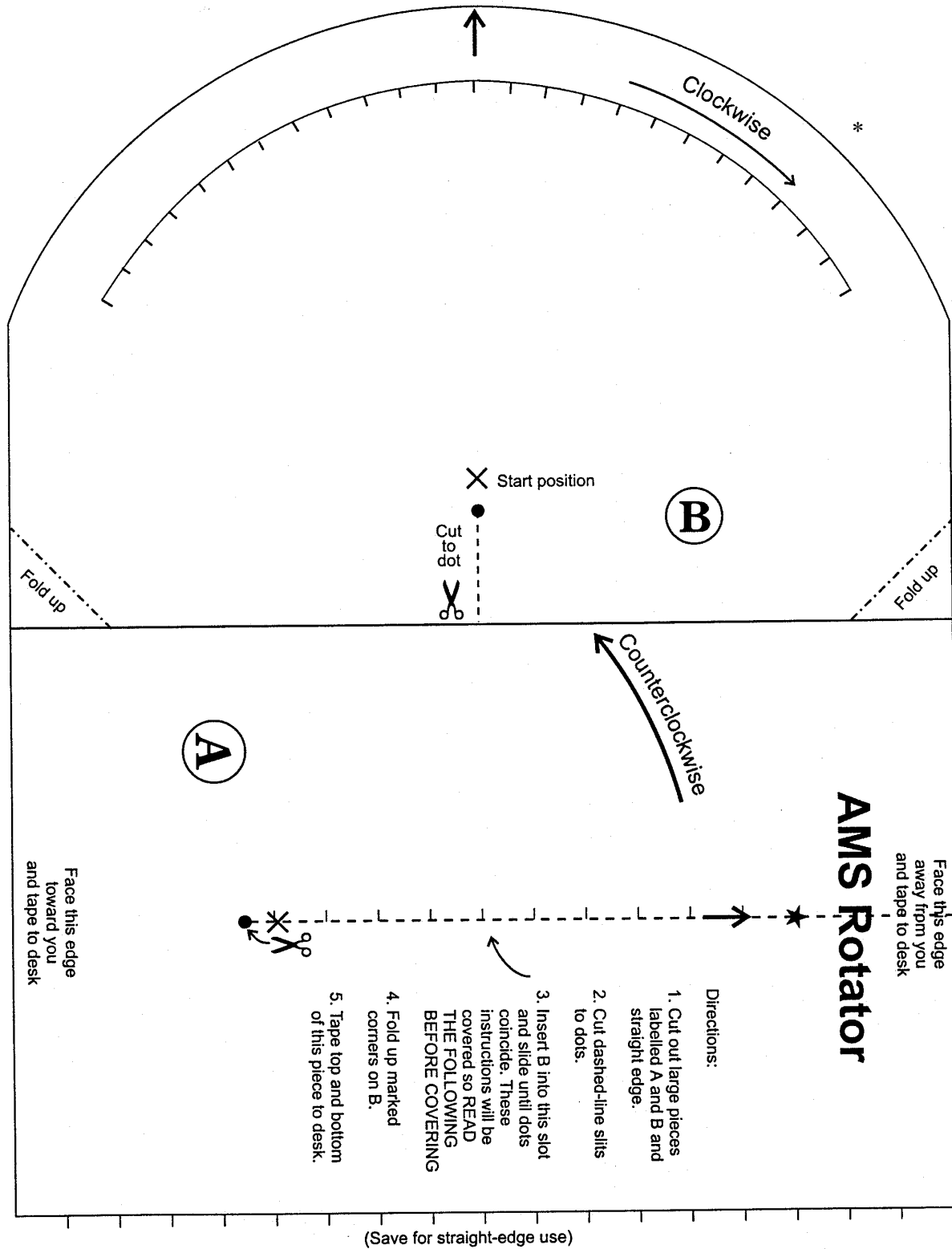
Directions

First construct the **AMS Rotator** device that appears on page A84. As outlined in the diagrams, cut out the two large pieces, labeled "A" and "B," plus the "straight-edge." Cut along the dashed lines on "A" and "B" only as far as the dots. Fit "A" and "B" together as shown in the drawing, making sure that the dot on "A" coincides with the dot on "B." Lay the device flat on the desk in front of you with the cut end of "A" positioned away from you. Now tape "A" to your desk at the two places indicated at the midpoints of the far and near edges of "A," making sure that "B" can rotate freely. Fold up the bottom two corners of "B" as shown. Gripping these tabs, practise rotating "B" so that the two dots always coincide. Note that a straight scale is drawn on "A" along the cut edge and a curved scale is drawn on "B."

The following diagrams should assist you in constructing the **AMS Rotator**....



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Student Investigations

Where options are contained in [brackets], students CIRCLE the response that they believe is the correct one

1. Orient B in the “cross” position as shown in the drawing. If positioned properly, a straight arrow should point towards the ★. Place your pencil point at the centre of the Start Position X. Carefully draw a line on B along the cut edge and directly towards the ★. The line you drew represents a path that is **[(straight) (curved)]**.
2. Now investigate how rotation affects the path of your pencil lines. Again, begin with B in the “cross” position with the direction arrow pointing towards the ★. Pulling the lower left tab towards you, rotate B counterclockwise through one division of the curved scale (on B). Make a pencil dot on B along the straight scale at one scale division above the Start Position X. Continue rotating B counterclockwise one division at a time along the curved scale, stopping each time to mark a pencil dot on B at each successive division along the straight scale. Repeat these steps until you reach the curved scale. Starting at X, connect the dots with a smooth curve. Place an arrowhead at the end of the line to show the direction of the motion. The line you drew on B is **[(straight) (curved)]**.
3. You actually moved the pencil point along a path that was both straight and curved at the same time! This is possible because motion is measured relative to a frame of reference. (A familiar frame of reference is east-west, north-south, up-down.) In this activity, you were using two different frames of reference: one fixed and the other rotating. When the pencil-point motion was observed relative to the fixed A and ★, its path was **[(straight) (curved)]**. When the pencil motion was measured relative to B, which was rotating, the path was **[(straight) (curved)]**.
4. Begin again with B in the “cross” position and the arrow pointing towards the ★. Pulling the lower right tab towards you, rotate B clockwise one division of the curved scale and make a pencil dot on B along the straight scale at one scale division above the Start Position X. Continue in similar fashion as you did in Item 2 to determine the path of the moving pencil point. The path was straight when the pencil-point motion was observed relative to **[(A) (B)]**. The path was curved when the pencil motion was measured relative to **[(A) (B)]**.
5. Imagine yourself shrunk down in size, located at X, and looking towards the ★. You observe all three situations described above (i.e., no motion of B, counterclockwise rotation, and clockwise rotation). From your perspective at the X starting position, in all three cases the pencil point moved towards the ★ along a **[(straight) (curved)]** path.
6. Watching the same motion on B, the pencil path was straight in the absence of any rotation. However, the pencil path curved to the **[(right) (left)]** when B rotated counterclockwise. When the rotation was clockwise, the pencil path curved to the **[(right) (left)]**.

This apparent deflection of motion from a straight line in a rotating co-ordinate system is called the Coriolis effect for Gustave-Gaspard de Coriolis (1792–1843) who first explained it mathematically. Because the Earth rotates, objects moving freely above its surface, except at the equator, exhibit curved paths.

7. Imagine yourself far above the North Pole, looking down on the Earth below. Think of B in the AMS Rotator as representing Earth. As seen against the background stars, the Earth rotates in a counterclockwise direction. From your perspective, an object moving freely across the Earth's surface would move along a **[(straight) (curved)]** path relative to the background stars (depicted by the ★ on the AMS Rotator). Now think of yourself on the Earth's surface at the North Pole at the dot position while watching the same motion. From this perspective, you observe the object's motion relative to the Earth's surface. You see the object moving along a path that **[(is straight) (curves to the right) (curves to the left)]**.
8. Imagine yourself located far above the South Pole. As seen against the background stars, the Earth rotates in a clockwise direction. The sense of rotation is reversed from the North Pole because you are now looking at the Earth from the opposite direction. An object moving freely across the Earth's surface is observed to move along a **[(straight) (curved)]** path relative to the background stars. Now think of yourself on the Earth's surface at the South Pole while watching the same motion. From this perspective, you observe the object's motion relative to the Earth's surface. You see the object moving along a path that **[(is straight) (curves to the right) (curves to the left)]**.
9. In summary, the Coriolis effect causes objects freely moving horizontally over Earth's surface to curve to the **[(right) (left)]** in the Northern Hemisphere and to curve to the **[(right) (left)]** in the Southern Hemisphere.

Further Investigations

1. Again, begin with B in the "cross" position. Create paths that originate on the straight scale at one division below the curved scale and move toward the original Start Position (X). Do this for B rotating clockwise and then counterclockwise. Earlier we found that curvature to the right was associated with counterclockwise rotation and curvature to the left was associated with clockwise rotation. In these cases, the same associations between curvature and direction of rotation **[(apply) (do not apply)]**.
2. Try moving across B while it rotates by using the straight edge as a pencil guide. Orient the straight edge at a right angle to the cut edge in A, about halfway between X and the ★, and tape its ends so that B rotates freely. While rotating B counterclockwise, draw a line several scale units long from left to right beginning at the cut edge. Repeat the process for B rotating clockwise. Curvature was to the **[(right) (left)]** with counterclockwise rotation and to the **[(right) (left)]** with clockwise rotation.
3. Investigate changes in the relative speed of rotation and the curvature by moving one division along the straight scale for every two divisions of the curved scale, or two divisions of the straight scale for every one of the curved scale. Does the direction of curvature change? Does the amount of curvature change?

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Coriolis Deflection and Earth Latitude

Introduction

The Coriolis deflection is greatest at the North and South Poles and is absent at the equator. What happens to the Coriolis deflection at latitudes in between? The purpose of this activity is to investigate how the Coriolis effect changes with latitude. You may recall from earlier discussions that the significance of the Coriolis depends upon where you are on Earth. In this activity, you will construct your own generalizations concerning the influence of the Coriolis effect on objects moving horizontally and freely over different latitudes. It assists in understanding why there are no rotating storms near the equator, but they are common at higher latitudes such as where Manitoba is located.

Materials

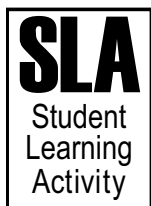
- Transparent plastic in a hemispheric shape, 10 to 15 cm (4 to 6 inches) in diameter
- Scissors
- Tape
- Washable overhead-projection pen or other washable-ink pen that writes on plastic
- **AMS Rotator**

Directions

The plastic hemisphere represents the Earth's Northern Hemisphere surface. Place the hemisphere on the AMS Rotator (taped flat on your desk) so that the pole position of the hemisphere is directly above the rotational axis (dot location) of the **AMS Rotator**.

1. With your eyes about one-half metre above the hemisphere, look down at the curved line you drew on B in Item 2 of the *Because the Earth Turns* activity in Appendix 4.7. Using the overhead-projection pen, draw on the hemisphere surface the path of the curved line as viewed from your perspective. Examine the curve that you drew on the hemisphere's surface. The curvature of the path **[(decreases) (increases)]** as the latitude decreases. This happens because the effect of the Earth's rotation on freely moving objects is greatest in a plane (flat surface) oriented perpendicular to Earth's rotational axis (i.e., at one of the poles). As the plane representing the surface of the Earth tilts more and more from this perpendicular position, the effects of the rotation on motion along that plane decreases. This activity visually depicts this change.
2. Consequently, the effect of the Earth's rotation on horizontally moving objects becomes less and less with decreasing latitude. At the equator, an object moving freely across the Earth's surface would exhibit no deflection due to the Earth's rotation. Stating it another way, the Coriolis deflection increases with increasing latitude. The change in deflection varies as the sine of the latitude. The sine of 0 degrees (equator) is 0, no Coriolis deflection; the sine of 90 degrees (poles) is 1, the maximum Coriolis deflection. The sine of 45 degrees is 0.707, so at 45 degrees latitude the Coriolis deflection is 0.707 of what it is at 90 degrees latitude.

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Convection Currents

Purpose

To model convection currents generated by temperature differences in a fluid.

Materials

- Hot water
- Cold water
- Red and blue food colouring
- Five polystyrene cups
- Eyedropper
- Clear plastic or glass tray (e.g., 8 x 8 or 8 x 12 baking dish)

Procedure

1. Fill the clear tray with cold water. Place the tray on top of four inverted polystyrene cups. Be sure the tray is well supported and stable.
2. Fill the fifth cup with hot water. Slide it under the centre of the tray.
3. Gently add a few drops of red food colouring to the bottom of the tray, directly above the heat source (hot water).
4. Add a few drops of blue food colouring to the bottom, outside edge of the tray.
5. Observe for 5–10 minutes.

Questions

1. Which way does the warm water move?
2. Which way does the cold water move?
3. Sketch a diagram of your observations.
4. a. Is warm water more or less dense than cold water?
b. Do warm water molecules move faster or slower than cold water molecules?
5. Where can we find convection currents?
6. Predict what would happen if the tray held hot water and a cup of ice water was placed under the tray. Sketch a diagram to explain your prediction.

Explanation

The heat source warms the water directly above it. Warm water molecules are less dense and move faster than cold water molecules. The warm water molecules rise to the surface and are pushed to the edges of the tray by the molecules that follow. As they reach the edge of the tray, they cool, become more dense, and sink to the bottom. As cool water molecules, they now are drawn to the centre and heated. The cycle continues as long as there is a temperature difference.



The Atmosphere-Ocean Connection: El Niño and La Niña (For Further Exploration)

After completing this set of activities, you will be able to:

- Describe the characteristics of an El Niño event (the Southern Oscillation), such as sea-surface temperatures and trade wind circulation
- Contrast an El Niño event with a contrasting event known as a La Niña
- Describe, on a global scale, the environmental effects—particularly weather changes—that result from an El Niño event in the Pacific Ocean
- Conduct an Internet “webquest” in order to learn more about how El Niño and La Niña events alter Canadian climate in the short-term

Key Words

- El Niño/La Niña
- El Niño and Southern Oscillation (ENSO)
- Wind and ocean currents in tropical Pacific Ocean
- Sea-surface temperature
- Thermocline

Introduction

The term El Niño originally described a weak warming of the ocean water that ran southward along the coast of Peru and Ecuador around the time of the Winter Solstice each year, resulting in poor fishing. Today, El Niño refers to a large-scale disturbance of the ocean and atmosphere in the tropical Pacific. A persistent El Niño can be accompanied by major shifts in planetary-scale atmospheric and oceanic circulations and weather extremes that bring major ecological, social, and economic disruptions world-wide.

Most of the time, westward-blowing trade winds drive warm surface water westward, away from the west coast of South America. In the western tropical Pacific, this pool of transported warm surface water results in low air pressure and abundant rainfall. In the eastern tropical Pacific, the warm surface water is replaced by colder water that wells up from below, a process known as upwelling. Relatively cold surface water favours high air pressure and meagre precipitation. Upwelling also exposes nutrient-rich water from below to sunlight, stimulating the growth of phytoplankton, which supports fisheries.

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The first sign of El Niño in progress is a weakening of the trade winds. Normally, the contrast between relatively high air pressure over the eastern tropical Pacific and low air pressure over the western tropical Pacific drives the trade winds. With the onset of El Niño, air pressure falls over the eastern tropical Pacific and rises in the west, with the greatest pressure drop over the central Pacific. As the air pressure gradient across the tropical Pacific weakens, trade winds slacken and may even reverse in the west. The see-saw variation in air pressure between the western and central tropical Pacific is known as the Southern Oscillation. El Niño and Southern Oscillation are abbreviated as **ENSO**.

During El Niño, changes in atmospheric circulation over the tropical Pacific are accompanied by changes in ocean currents and **sea-surface temperature** (SST) patterns. The pool of warm surface water normally driven westward by the trade winds now drifts eastward. At the same time, changes take place in the thermocline, the zone of transition between relatively warm surface water and cold deep water. The thermocline sinks in the east, greatly weakening or even cutting off cold-water upwelling along the west coast of South America. Changes in the trade wind circulation alter tropical weather patterns. In turn, these changes shift the planetary-scale winds, including jet streams, that steer storms and air masses at higher latitudes, causing weather extremes in many areas of the globe outside of the tropics.

El Niño, lasting an average 12 to 18 months, occurs about once every two to seven years. Ten El Niños occurred during a recent 42-year period, with one of the most intense of the century in 1997-98. Sometimes, but not always, El Niño alternates with La Niña, a period of unusually strong trade winds and vigorous upwelling over the eastern tropical Pacific. During La Niña, changes in SSTs and extremes in weather are essentially opposite those observed during El Niño.

Basic Understandings—El Niño

El Niño, the Southern Oscillation, ENSO, and La Niña

Originally, El Niño was the name given by Peruvian fishermen to a period of warm waters and poor fishing that often occurred in late December.

Today, El Niño refers to a significant departure from the average state of the ocean-atmosphere system in the tropical Pacific that has important consequences, including those for weather and climate in the tropics and other regions of the globe.

The Southern Oscillation is a see-saw variation in air pressure between the central and western tropical Pacific. These pressure changes alter the strength of the trade winds and affect surface ocean currents as parts of El Niño. Scientists often combine El Niño and the Southern Oscillation as the acronym, ENSO.

The occurrence of ocean/atmosphere conditions essentially opposite those of El Niño is called La Niña. La Niña sometimes, but not always, alternates with El Niño.

Long-Term Average Conditions in the Tropical Pacific

Normally, strong trade winds drive warm surface water westward and away from the west coast of South America.

In the tropical eastern Pacific, colder water rising up from the depths replaces the warm surface water that is driven westward from the area, a process called upwelling.

Upwelling delivers cold nutrient-rich water from below into sunlit surface regions, greatly enhancing biological productivity. Most of the important commercial fisheries are located in areas of upwelling.

In the tropical eastern Pacific, offshore transport of warm surface water results in a locally lower sea level, a rise in the thermocline (the transition zone separating warmer surface water from colder deep water), and a drop in sea-surface temperature. Cooler surface waters are responsible for relatively high air pressure and mostly fair weather. Low precipitation amounts over adjacent land areas give rise to desert conditions.

Piling up of wind-driven warm surface water in the western tropical Pacific causes a higher sea level, a deeper thermocline, and higher sea-surface temperatures than in the central and eastern tropical Pacific. Warm surface waters produce relatively low air pressure and spur atmospheric convection that is responsible for heavy rainfall.

El Niño Conditions in the Tropical Pacific

During El Niño, the trade winds are weaker than average over the tropical Pacific and may even reverse direction, especially in the west.

In the tropical western Pacific, weakening or reversal of the trade winds causes the pool of warm surface water in the western tropical Pacific to drift eastward along the equator toward the coast of South America.

In the tropical western Pacific, an eastward transport of warm surface water is accompanied by a drop in sea level and a rise in the thermocline. Slightly cooler surface waters produce higher than usual air pressure, weaker atmospheric convection, and reduced rainfall.

Arrival of the pool of warm surface water along the coast of South America greatly diminishes or eliminates upwelling of nutrient-rich cold bottom water so that biological productivity declines sharply.

In the tropical eastern Pacific, the piling up of warm surface water results in a local rise in sea level, a deeper **thermocline**, and higher sea-surface temperatures. Warm surface waters produce relatively low air pressure and enhance atmospheric convection that brings higher than usual amounts of rainfall.

The concurrent rise in air pressure over the western tropical Pacific and fall in air pressure over the central tropical Pacific (which weakens the trade winds) is part of a regular see-saw variation in surface air pressure known as the Southern Oscillation.

Global El Niño and La Niña Conditions

Changes in oceanic and atmospheric circulation in the tropical Pacific affect weather and climate in the tropics and well beyond.

Temperature governs the rate at which water molecules escape a water surface and enter the atmosphere; that is, warm water evaporates more readily than cool water. Regions of relatively warm surface waters heat and add moisture to the atmosphere. Thunderstorms more readily develop in this warm, humid air. Towering thunderstorms help shape the planetary-scale atmospheric circulation, altering the course of jet streams and moisture transport at higher latitudes.

Changes in the planetary-scale atmospheric circulation during El Niño and La Niña often give rise to weather extremes, including drought and excessive rainfall, in many areas of the globe outside the tropics.

No two El Niño or La Niña events are exactly the same, so that in some areas weather extremes may or may not accompany a particular El Niño or La Niña.

In Canada, El Niño winters tend to be mild and less wet than normal. The exceptions are the Atlantic provinces and the territory of Nunavut in the Canadian Arctic, which are usually milder but wetter than normal. La Niña, on the other hand, usually results in colder temperatures in Canada in winter. La Niña winters are usually also wetter than normal in western Canada, southern Ontario and Quebec, and the Atlantic provinces, while being drier than normal elsewhere.

Ecological, Social, and Environmental Impacts

Many aspects of the environment and global economy are affected by variations in the ocean/atmosphere system of the tropical Pacific. These impacts also have human and social consequences. Some of the larger impacts of El Niño and La Niña are experienced by developing countries in the tropical and subtropical regions that are most vulnerable to climate catastrophes.

Too little or too much precipitation can have devastating effects. In some areas, drought, especially when accompanied by high temperatures, causes crops to wither and die, reduces the public water supply, and increases the likelihood of wildfire. In other areas, exceptionally heavy rains trigger flash flooding that drowns crops, washes away motor vehicles, destroys houses and other buildings, and disrupts public utilities.

Weather extremes associated with El Niño and La Niña have implications for public health by creating conditions that increase the incidence of diseases such as malaria, dengue fever, encephalitis, cholera, and plague. Also, smoke from wildfires in drought-stricken regions can cause respiratory problems for people living up to 1,500 kilometres from the fires.

Advance warning of El Niño and La Niña and their accompanying weather extremes could save lives and billions of dollars in property and crop damage by allowing adequate time for preparedness and development of appropriate response strategies.

More details on how El Niño can affect Canadian temperature and precipitation patterns can be found at:

<http://www.msc-smc.ec.gc.ca/elNiño/index_e.cfm>

Similarly, Canadian La Niña effects can be found at:

<http://www.msc-smc.ec.gc.ca/laNiña/index_e.cfm>

El Niño and La Niña Research

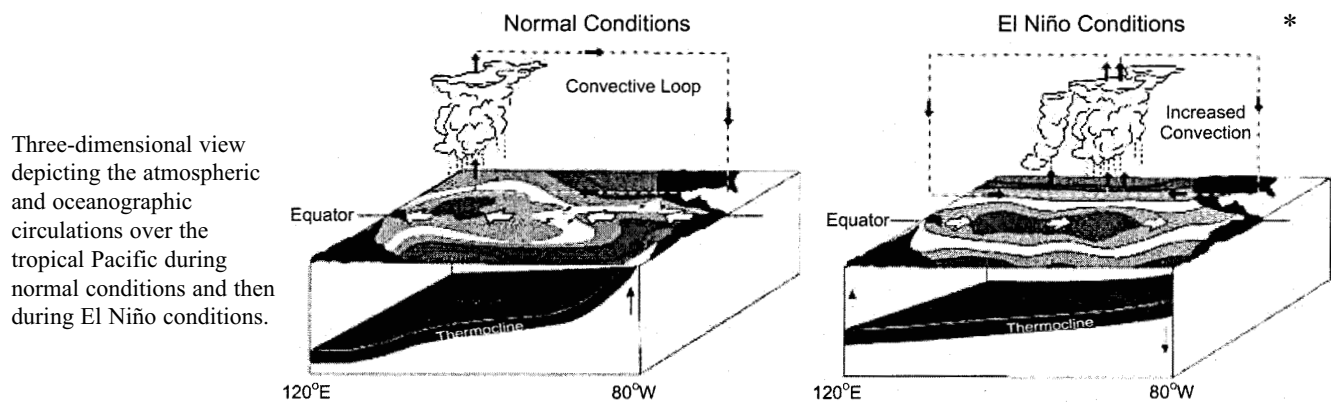
Scientists are actively investigating the tropical Pacific ocean/atmosphere system for answers to many questions including: What gets El Niño and La Niña started? Why do they stop? Why do regional impacts differ from one El Niño (or La Niña) to the next? When will scientists be able to reliably predict the duration and impact of El Niño and La Niña?

Observations of conditions in the tropical Pacific are essential for the investigation and prediction of short-term climate variations like El Niño. A wide variety of sensors are used to obtain ocean and atmospheric data from this vast and remote region of the ocean.

Satellite-borne temperature sensors and altimeters are being used to track the movement of warm surface water across the tropical Pacific. Additional information is provided by a network of buoys that directly measures temperature, currents, and winds along the equatorial band.

Predicting the onset and duration of El Niño and La Niña is critical in helping water, energy, and transportation managers, and farmers plan for, mitigate, or avoid potential losses.

Advances in El Niño and La Niña prediction are expected to significantly enhance economic opportunities, particularly for the agriculture, fishing, forestry, and energy sectors, as well as provide opportunities for social benefits.



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Student Activity—El Niño and La Niña Web-Based Activities (“Theme Pages”)

MSC Issues and Topics <http://www.msc-smc.ec.gc.ca/contents_e.html>

Canadian El Niño page <http://www.msc-smc.ec.gc.ca/elNiño/index_e.cfm>

Canadian La Niña page <http://www.msc-smc.ec.gc.ca/laNiña/index_e.cfm>

NOAA El Niño page <<http://www.pmel.noaa.gov/tao/elNiño/Niño-home.html>>

The El Niño Theme Pages will help you explore the workings of the tropical Pacific marine environment. Stretching nearly one-third of the way around the globe and covering a fifth of the Earth’s surface, the tropical Pacific is a coupled ocean/atmosphere system that makes its presence known far beyond its boundaries. Its influence on world-wide weather and climate can lead to major ecological, societal, and economic disruptions. Occurrences of El Niño every two to seven years, and the less frequent occurrences of La Niña, demonstrate that there are swings in ocean/atmosphere conditions, weather, and climate that operate on other than annual timetables.

With the El Niño Theme Pages, you can investigate and compare ocean and atmospheric conditions that occur during El Niño and La Niña with long-term average conditions.

The Tropical Pacific During Long-Term Average Conditions

Examine the Basic Understandings pages, or the web-based “Theme Pages” listed above, where you will find information on “What is El Niño?” and “What is La Niña?” Click on the links found there (or consult the text earlier in this activity) to help you identify the correct answers in the statements below that have solutions contained in **[brackets]**. Circle your answers for later discussion with classmates.

The winds in the equatorial Pacific Ocean during long-term average conditions blow toward the **[(east) (west)]** and the wind speed is **[(higher) (lower)]** in the eastern Pacific than in the western Pacific.

During long-term average conditions in the equatorial Pacific Ocean, surface water flows towards the **[(east) (west)]**.

The highest sea surface temperatures (SSTs) during long-term average conditions occur in the **[(eastern) (western)]** tropical Pacific. This SST pattern is caused by relatively strong trade winds pushing Sun-warmed surface water **[(eastward) (westward)]** as evidenced by the direction of surface currents.

Strong trade winds also cause the warm surface waters to pile up in the western tropical Pacific so that the sea surface height in the western Pacific is **[(lower) (higher)]** than in the eastern Pacific. Transport of surface water to the west also causes the thermocline (the transition zone between warm surface water and cold deep water) to be **[(deeper) (shallower)]** in the eastern Pacific than in the western Pacific.

Warm surface water transported by the wind away from the South American coast is replaced by cold water rising from below in a process called upwelling. Upwelling of cold deeper water results in relatively **[(high) (low)]** SSTs in the eastern Pacific compared to the western Pacific.

Cold surface water cools the air above it, which leads to increases in the surface air pressure. Warm surface water adds heat and water vapour to the atmosphere, lowering surface air pressure. These effects result in tropical surface air pressure being **[(highest) (lowest)]** in the eastern Pacific and **[(highest) (lowest)]** in the western Pacific.

Whenever air pressure changes over distance, a force will act on air to move it from where the pressure is relatively high to where pressure is relatively low. The trade winds blow from east to the west because from east to west the surface air pressure **[(increases) (decreases)]**.

Rainfall in the tropical Pacific is also related to SST patterns. There are reasons for this relationship. The higher the SST, the greater the rate of evaporation of seawater and the more vigorous is atmospheric convection. Consequently, during long-term average conditions, rainfall is greatest in the **[(western) (eastern)]** Pacific where SSTs are **[(highest) (lowest)]**.

The Tropical Pacific During El Niño and La Niña

While no two El Niño or La Niña episodes are exactly alike, all of them exhibit most of the characteristics described in the El Niño Theme Pages. Click on the links found there (or consult the text earlier in this activity) to help you identify the correct answers in the statements below that have solutions contained in **[brackets]**.

During long-term average conditions, the surface air pressure in the central Pacific is higher than to the west. During El Niño, the surface air pressure to the west is **[(higher) (lower)]** than in the central Pacific. During La Niña, the surface air pressure to the west is **[(higher) (lower)]** than in the central Pacific. This see-saw pattern of pressure variation is called the Southern Oscillation.

In response to changes in the air pressure pattern across the tropical Pacific, the speed of the trade winds decreases (and wind directions can reverse, especially in the western Pacific). No longer being pushed toward and piled up in the western Pacific, the warm surface water reverses flow direction. This causes SSTs in the eastern tropical Pacific to be **[(higher) (lower)]** than long-term average values. Conversely, the surface water currents during La Niña flow toward the **[(east) (west)]**.

In response to surface currents, sea surface heights in the eastern tropical Pacific are **[(higher) (lower)]** than long-term average levels during El Niño events. At the same time, the arrival of the warmer water causes the surface warm-water layer to thicken during El Niño. Evidence of this is the **[(shallower) (deeper)]** depth of the thermocline compared to long-term average conditions.

In response to surface currents, sea surface heights in the eastern tropical Pacific are **[(higher) (lower)]** than long-term average levels during La Niña events. At the same time, the arrival of the warmer water causes the surface warm-water layer to thicken during La Niña. Evidence of this is the **[(shallower) (deeper)]** depth of the thermocline compared to long-term average conditions.

Differences between existing conditions and long-term average conditions are called anomalies. If readings are higher than the respective long-term averages, the anomalies are positive. If values are lower, the anomalies are negative. In the eastern tropical Pacific during El Niño, the SST anomaly is **[(negative) (positive)]**, the sea-surface height anomaly is **[(negative) (positive)]**, the surface air pressure anomaly is **[(negative) (positive)]**, and the rainfall anomaly is **[(negative) (positive)]**.

Differences between existing conditions and long-term average conditions are called anomalies. If readings are higher than the respective long-term averages, the anomalies are positive. If values are lower, the anomalies are negative. In the eastern tropical Pacific during La Niña, the SST anomaly is **[(negative) (positive)]**, the sea-surface height anomaly is **[(negative) (positive)]**, the surface air pressure anomaly is **[(negative) (positive)]**, and the rainfall anomaly is **[(negative) (positive)]**.

Continue your investigations of the tropical Pacific Ocean/atmosphere system by predicting how the changes shown by the El Niño Theme Page might affect people living along the Peruvian coast and on the island nations of the western tropical Pacific. Return back to the El Niño Theme Page to study the potential impacts of El Niño in those areas and elsewhere, including Canada.

Canadian Winter Climate Prediction

Using the Canadian El Niño or La Niña web pages or the maps at the end of this section that show average temperature and precipitation changes that occur during El Niño and La Niña conditions, give a forecast for the winter for the following Canadian cities **assuming that a La Niña will be occurring in the tropical Pacific.**

Example: If a La Niña occurs this winter, Churchill, Manitoba should experience temperatures about two degrees colder than normal but with less snowfall than normal.

Write a forecast for your hometown for the upcoming winter. First, using the Canadian El Niño or La Niña web pages, find out if one of these tropical events is expected to be occurring in the upcoming winter. Second, using the maps at the end of this activity that show average temperature and precipitation changes that occur during El Niño and La Niña conditions, give a forecast for the winter for your hometown. Try **one** other Canadian city listed below—perhaps a place you would like to travel to one day—to see if there are any differences across the Canadian experience.

1. Vancouver
2. Victoria
3. Edmonton
4. Calgary
5. Regina
6. Winnipeg
7. Thunder Bay
8. Toronto
9. Ottawa
10. Quebec City
11. Montreal
12. Fredericton
13. Halifax
14. St. John's
15. Yellowknife
16. Whitehorse
17. Iqaluit
18. Prince George
19. Kelowna

My Forecast (hometown)

Temperature Predictions:

Precipitation Predictions:

Overall Weather Picture for My Hometown in Manitoba:

My Forecast (alternate location to visit)

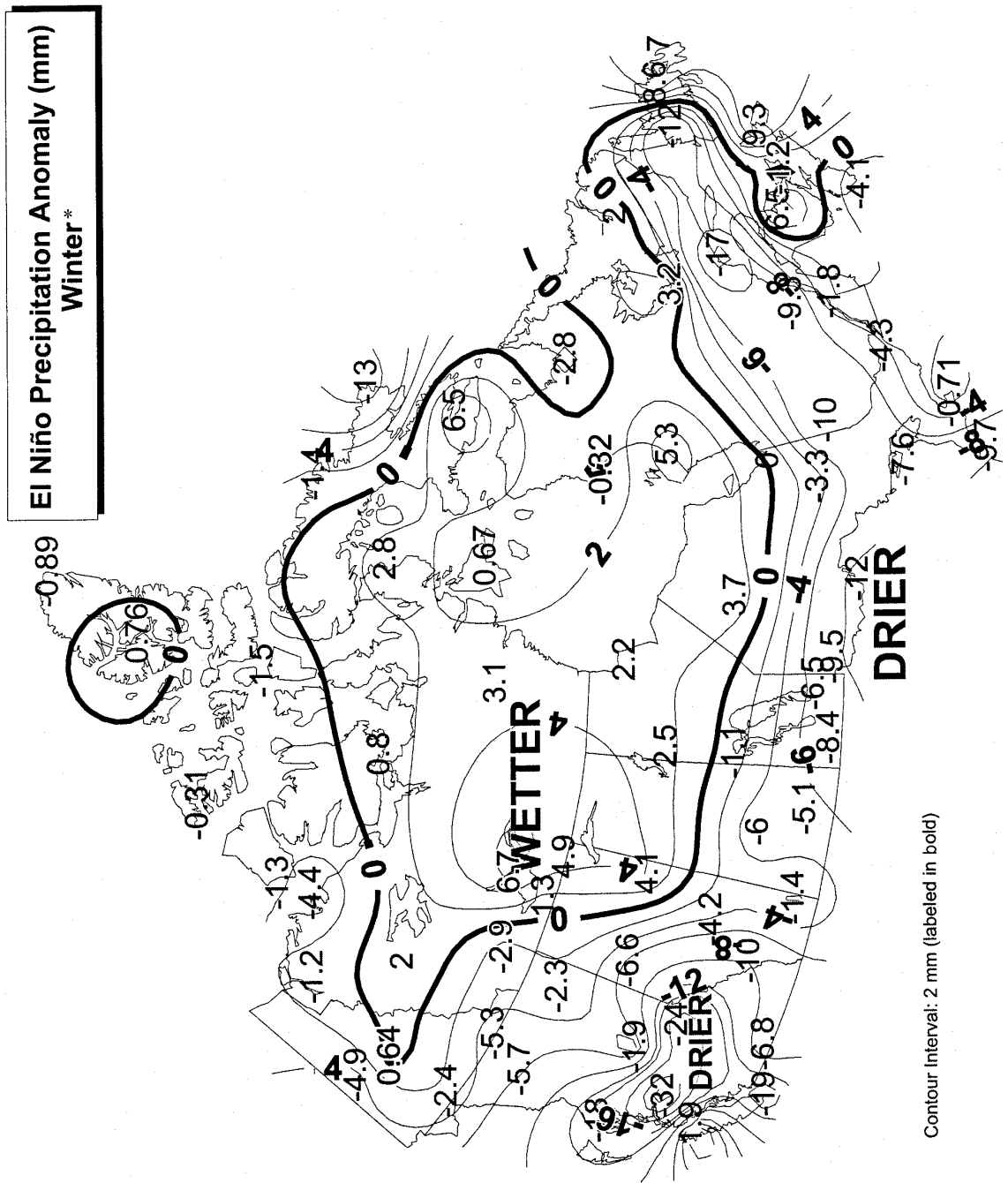
Temperature Predictions:

Precipitation Predictions:

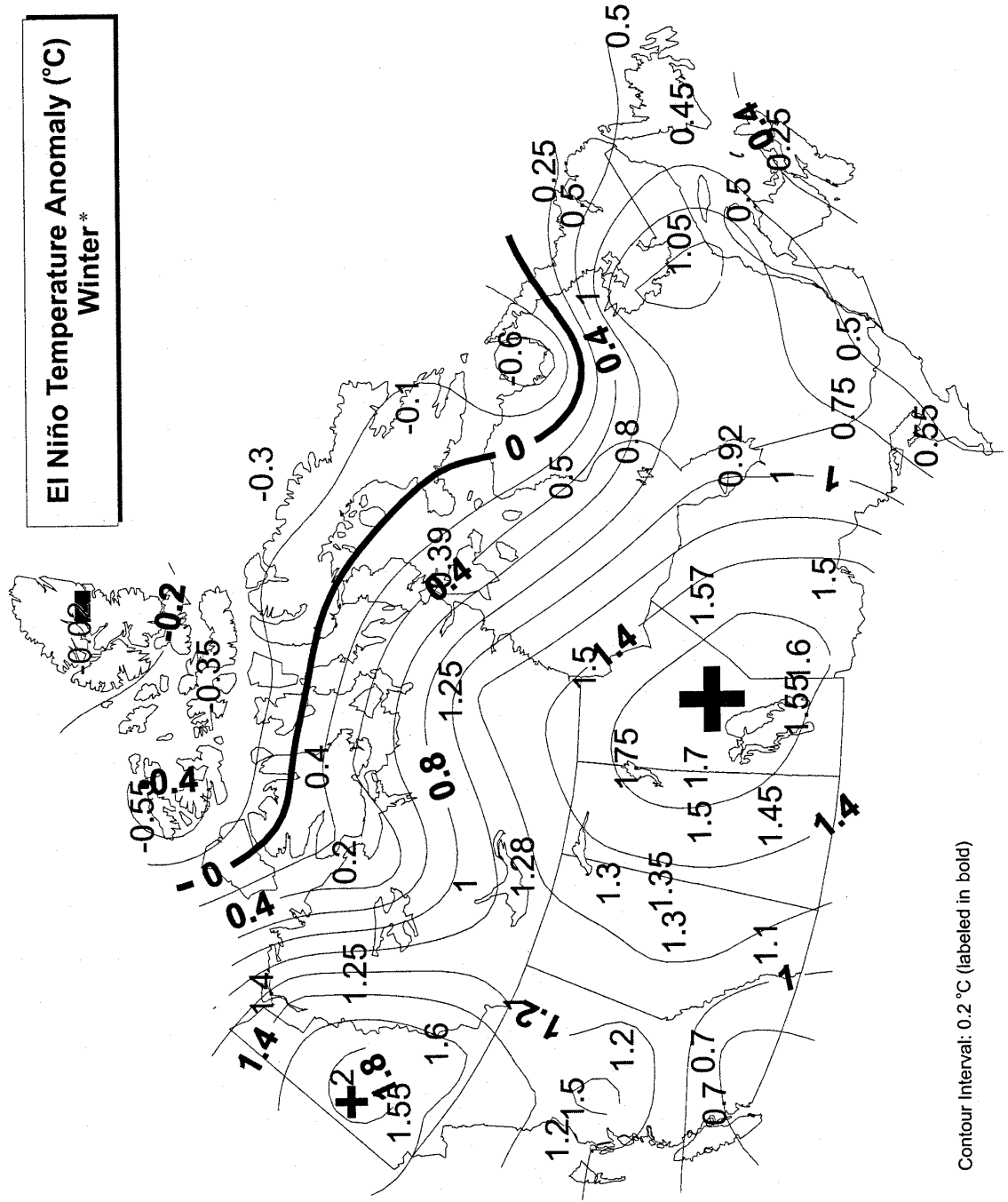
Overall Weather Picture for City Elsewhere in Canada:

Weather Maps

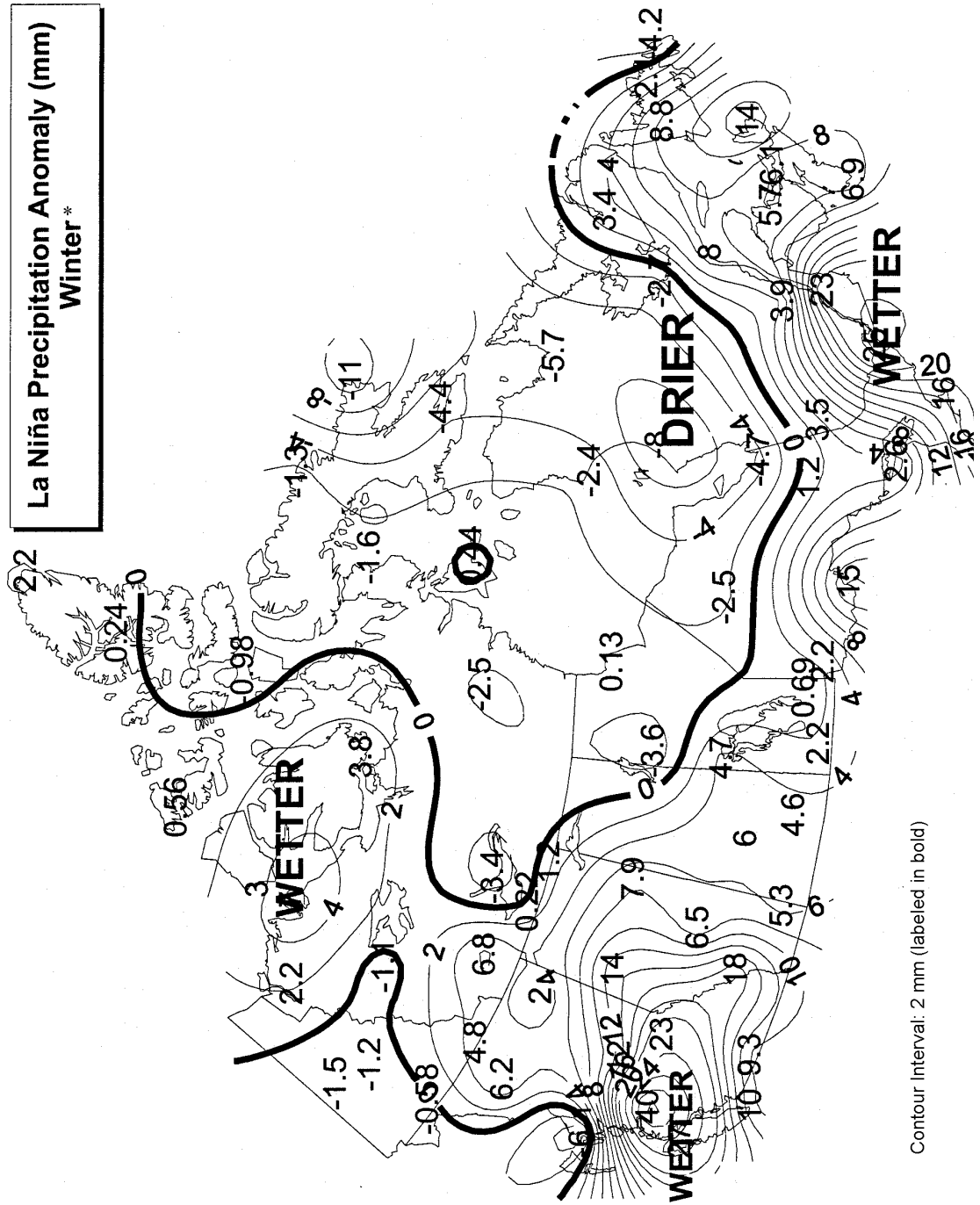
Note: There are two maps for each type of event—two for El Niño and two for a La Niña. One map is for expected changes in temperature (temperature anomaly map), and the other is for expected changes in precipitation amounts (precipitation anomaly map).



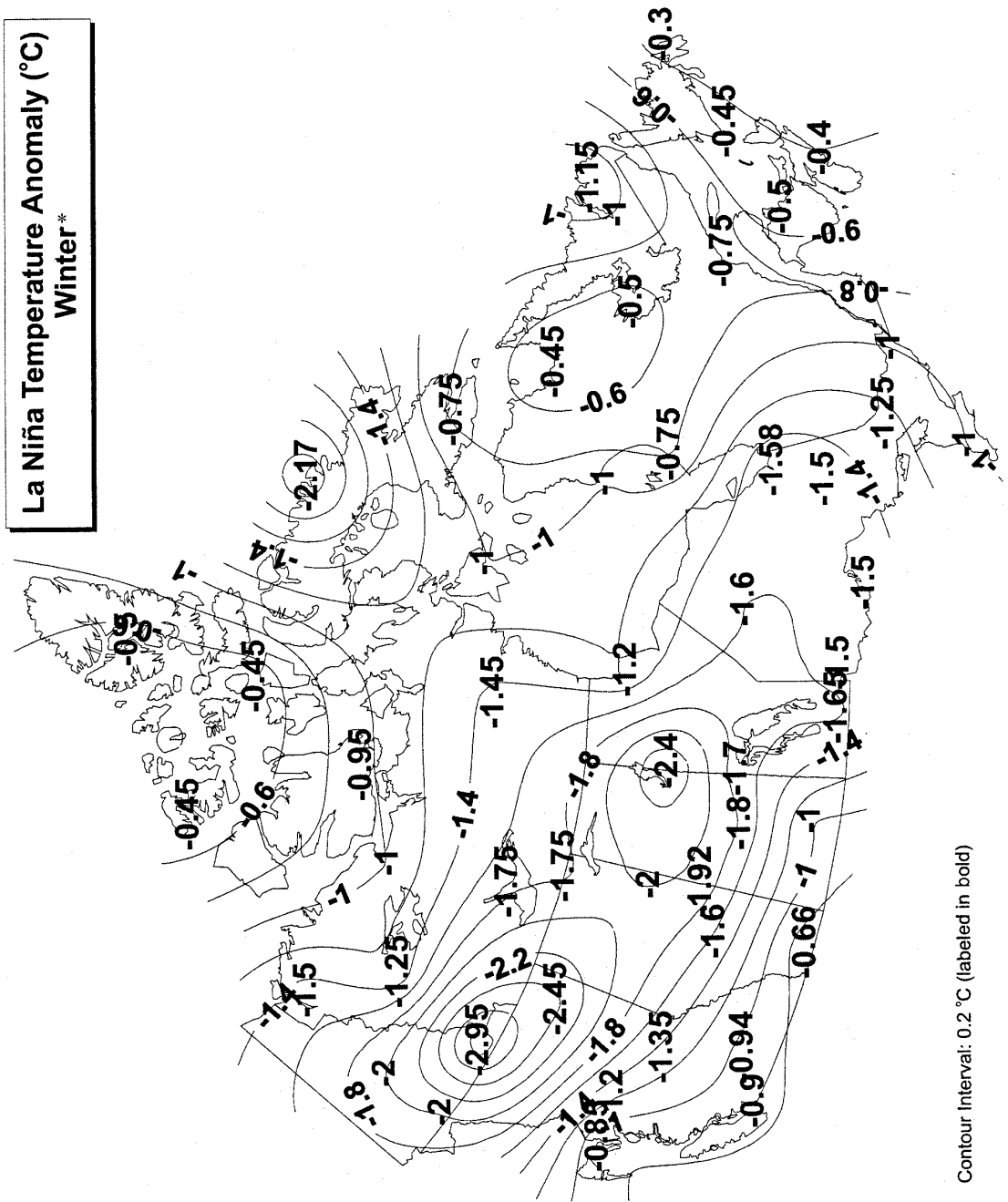
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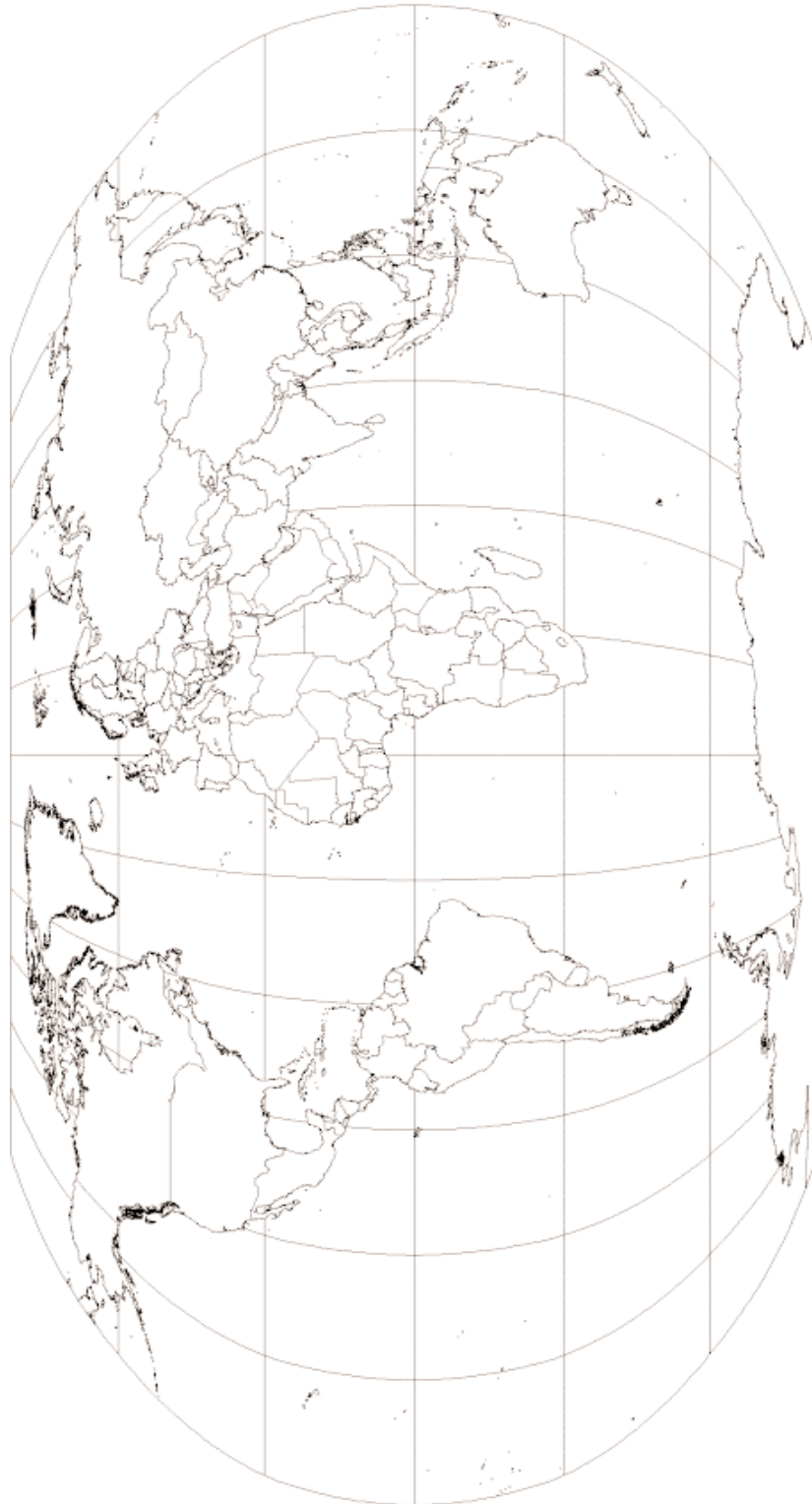
World Map (Globe Projection)*



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World Map*



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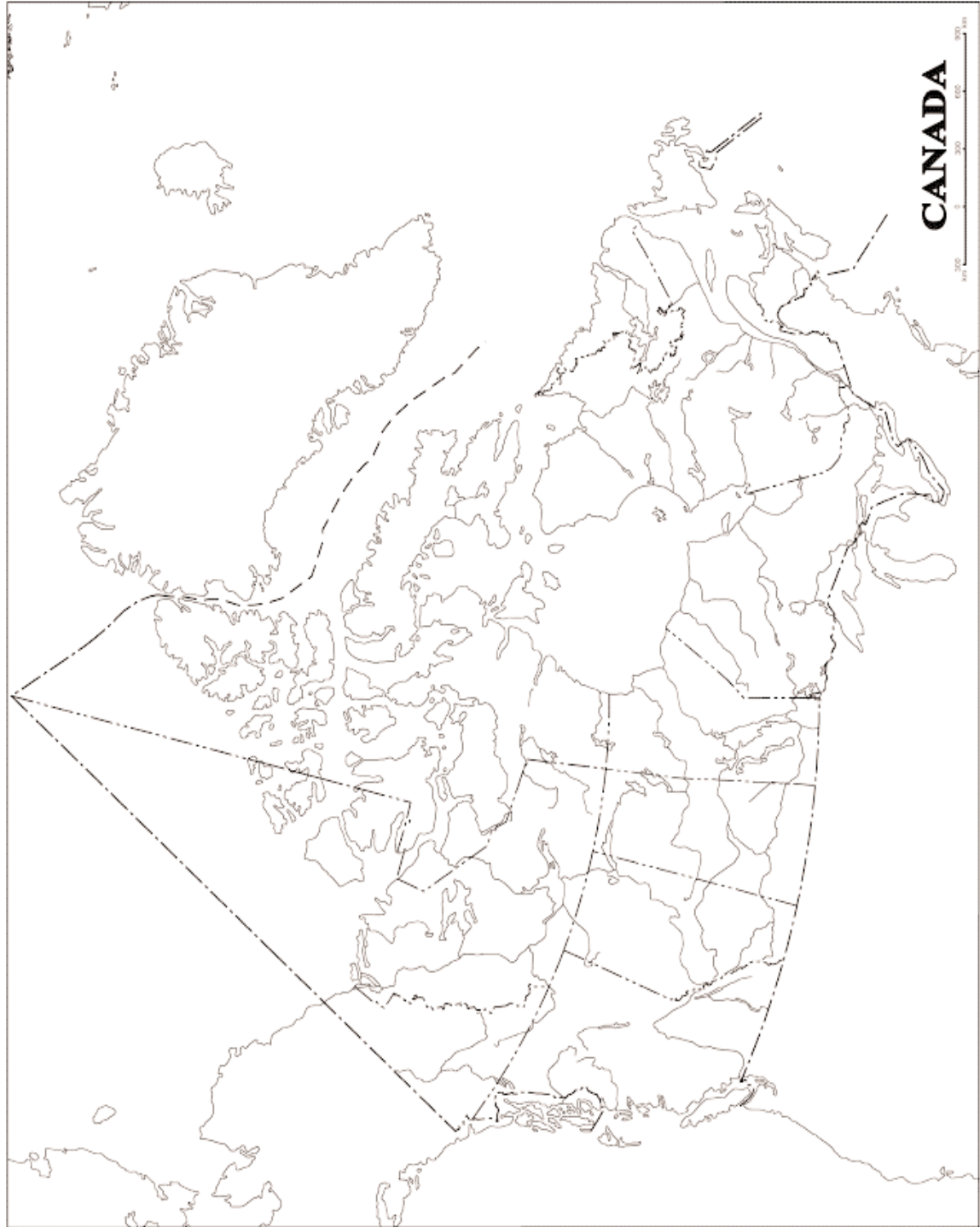
Map of North America*



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Map of Canada with Major Rivers*



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Circumpolar Map*



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The Beaufort Wind Scale

The Beaufort Scale was long in use as a system for estimating wind speeds. It was introduced in 1806 by Admiral Sir Francis Beaufort (1774–1857) of the British navy to describe wind effects on a fully rigged man-of-war sailing vessel, and it was later extended to include descriptions of effects on land features as well. Today the accepted international practice is to report wind speed in knots (1 knot equals a wind speed of about 1.85 km/hour).

The Beaufort scale is divided into a series of values, from 0 for calm winds to 12 and above for hurricanes. Each value represents a specific range and classification of wind speeds with accompanying descriptions of the effects on surface features, as follows:

Beaufort	Average km/h	Knots	Surroundings
0 (calm)	0	0–1	Smoke rises vertically and the sea is mirror smooth.
1 (light air)	2–5	1–3	Smoke moves slightly with breeze and shows direction of wind.
2 (light breeze)	6–12	4–6	You can feel wind on your face and hear the leaves start to rustle.
3 (gentle breeze)	13–20	7–10	Smoke will move horizontally and small branches will sway. Wind extends a light flag.
4 (moderate breeze)	21–30	11–16	Loose dust or sand on the ground will move and larger branches will sway, loose paper blows around, and fairly frequent whitecaps occur.
5 (fresh breeze)	31–40	17–21	Surface waves form on water and small trees sway.
6 (strong breeze)	41–50	22–27	Trees bend with the force of the wind, and wind causes whistling in telephone wires and some spray on the sea surface.
7 (moderate gale)	51–61	28–33	Large trees sway.
8 (fresh gale)	62–74	34–40	Twigs break from trees, and long streaks of foam appear on the ocean.
9 (strong gale)	75–89	41–47	Branches break from trees.
10 (whole gale)	90–103	48–55	Trees are uprooted, and the sea takes on a white appearance.
11 (storm)	104–119	56–63	There is widespread damage.
12 (hurricane)	120+	64+	There is structural damage on land, and there are storm waves at sea.



Understanding Highs and Lows (For Further Exploration)

After completing this activity, you will be able to:

- Draw lines of equal pressure (isobars) to show the pattern of surface air pressures on a weather map
- Locate regions of relatively high and low air pressure on a surface weather map
- Locate regions on a surface weather map exhibiting relatively large air pressure changes over short horizontal distances and broad areas with gradually varying air pressure

Key Words

- High pressure centre
- Low pressure centre
- Surface analysis maps
- Spacing of isobars
- Kilopascal, hectopascal, millibar

Introduction

The Earth's atmosphere and oceans are in continual motion. This motion results from an unequal distribution of energy within the earth-atmosphere system. Forces arise from this non-uniform distribution and work to move heat and energy from where it is warmer to where it is colder (e.g., from the tropics to mid and high latitudes). Motion is initiated by differences in pressure (pressure is the amount of force acting on a unit surface area). Atmospheric pressure is the force exerted on an object or person by the weight of the air above. Atmospheric scientists and oceanographers monitor pressure as part of their investigation of Earth's dynamic atmosphere and ocean.

The force of gravity pulls molecules and particles in the atmosphere toward the centre of the Earth. The resulting weight of the air pushing down on itself and on the surface of the planet creates atmospheric pressure. Air is treated as a fluid in the study of the dynamics of the atmosphere. Although it's common to refer to the atmosphere pressing "down," we know that pressure acts in all directions in a fluid. All sides of an object, then, are subjected to practically the same pressure. For example, atmospheric pressure pushing down on the surface of a bucket of water is transmitted equally through the liquid to the walls of the bucket and is balanced by the same atmospheric pressure acting on the outside walls of the bucket.

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In Canada, the unit of atmospheric pressure most often heard on weather broadcasts is the **kilopascal (kPa)**. The average pressure exerted by the atmosphere at sea level is one kilogram per square centimetre or 101.325 kPa. A **pascal (Pa)** is defined as “a pressure of one newton (the basic unit of force) per square metre” and is named after the 17th-century mathematician and physicist Blaise Pascal, who demonstrated that air pressure decreased with altitude. Because a pascal is such a small pressure unit, the kilopascal, which is equal to 1000 newtons per square metre, is more commonly used.

When one studies the concepts of pressure in the upper atmosphere, the common unit becomes the **hectopascal (hPa)** which is simply the kilopascal times 10 or 10,000 Pa. Scientists involved in the measurement and analysis of atmospheric pressure may also use the term **millibar** as the unit of atmospheric pressure. One millibar is equal to one hectopascal.

Atmospheric pressure can also be expressed in other units such as “pounds per square inch” and “inches of mercury,” which refers back to the historical use of the mercury barometer in measuring air pressure.

Mathematics Connection

For conversion purposes, one pound per square inch equals 6.895 kPa and one inch of mercury equals 3.386389 kPa.

The analysis of the distribution of pressure on a surface weather map consists of drawing a series of lines called isobars, which connect points of equal pressure. After the isobaric analysis is completed, the familiar weather map with its highs and lows takes form.

Highs and Lows

“What’s the weather?” and “What’s the weather going to be?” are questions people frequently ask because weather and its changes strongly influence our activities and lives. When we are aware of current and anticipated weather, we can make informed choices that range from selecting appropriate clothing for the day to those that might be related to work and recreation. Less frequently, but by no means less importantly, the decisions and actions we take can reduce the amount of property damage and the number of injuries and fatalities due to hazardous weather.

Adequate answers to our questions about the weather can often be found on the daily weather map. Prominently featured on television and newspaper maps are the words “high” and “low” or the letters H and L. These are the symbols for centres of broad-scale pressure systems. They and their locations are key to describing and understanding probable weather conditions throughout the map area.

The highs and lows or the Hs and Ls on maps represent centres of broad regions of relatively high or low surface air pressure. They also provide information that enables meteorologists to predict possible atmospheric conditions up to a day or more in advance. Highs and lows govern atmospheric conditions throughout their expanses. Highs are generally fair weather systems. Widespread cloud and stormy weather conditions are generally associated with lows.

Mid-latitude highs and lows tend to move from west to east, changing the weather at locations along their paths. In the Northern Hemisphere, the mid- or middle latitude is the zone between the Tropic of Cancer, at latitude 23.5 degrees North, and the Arctic Circle latitude, 66.5 degrees North. Highs follow lows and lows follow highs in an endless procession. No two highs or two lows are exactly alike, but they share enough common characteristics that descriptive models of each can be employed to make sense of the weather.

One purpose of this activity is to introduce you to atmospheric pressure and the descriptive models of highs and lows. As a result of successfully completing this activity, you will be able to summarize in general terms the descriptive models of highs and lows, and the weather associated with each. You will also be able to apply these models to interpret weather maps and to describe probable current and future weather at different locations on a weather map.

Surface Air Pressure Patterns

Upon completing this activity, you should be able to:

- Draw lines of equal pressure (isobars) to show the pattern of surface air pressures on a weather map
- Locate regions of relatively high and low air pressure on a surface weather map
- Locate regions on a surface weather map exhibiting relatively large air pressure changes over short horizontal distances and broad areas with gradually varying air pressure

Materials

- Pencil

Introduction

Air pressure is determined by the weight of the overlying air, and it varies from place to place and over time. Surface air pressure is the force exerted per unit area on an object at the Earth's surface by the air above, approximately 100,000 newtons per square metre or 100 kilopascals (100 kPa). Pressure variations bring about atmospheric motions that set the stage for much of the weather we experience. Knowing the patterns of pressure is basic to understanding what the weather is and what it is likely to be where you live.

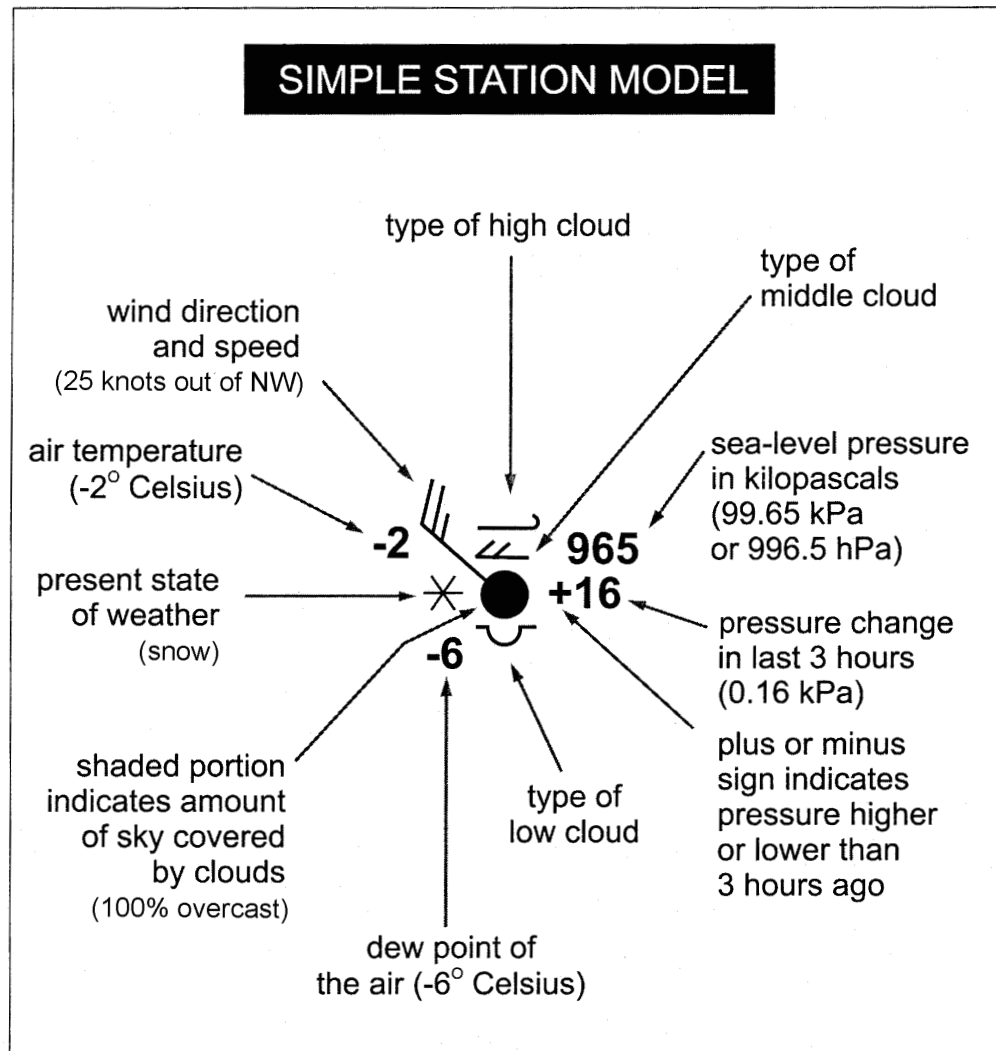
Air pressures routinely reported on surface weather maps are values “corrected” to sea level. That is, air pressure readings are adjusted to what they would be if the reporting stations were actually located at sea level. Adjustment of air pressure readings to a common elevation (sea level) removes the influences of the Earth's relief (topography) on air pressure readings. This adjustment allows comparisons of horizontal pressure differences that can lead to the recognition of weather patterns.

Horizontal air pressure patterns on a weather map are revealed by drawing lines joining points of **equal pressure**, or representing equal pressure, on the map. These lines are called **isobars** because every point on a given line has the same air pressure value. Each isobar separates stations reporting pressure values higher than that of a particular isobar's value from stations reporting pressure values lower than that isobar.

Station Pressure Plotting and Analysis on Weather Maps

The standard unit of atmospheric pressure at the surface of the Earth is the kilopascal (kPa). Today's barometers read the station pressure accurately to the second decimal point (e.g., 101.25 kPa). In the plotting of weather maps, it is common practice to **drop the decimal points** from the map to facilitate legibility and to avoid confusion with station symbols. The plot on a weather map thus shows the station pressure of 101.25 kPa simply as “125” (or the last three digits of the pressure value) as depicted in the station plot model shown on the following page.

The initial 10, or 9 in case the pressure is below 100 kPa, is also dropped for convenience on most maps. Since most sea-level pressures fall between 970 and 1050 hPa, there is little chance for confusion. By convention, isobars on surface weather maps are usually drawn using standard intervals. Remembering that 100.0 kilopascals is the approximate force exerted per unit area on an object at the Earth's surface by the air above, a pressure value of 100.0 kilopascals (kPa) or 1000 hectopascals (hPa) becomes an easily recognized reference value. Again, remembering that the use of the decimal point in map plotting is avoided whenever possible, the **1000 hectopascal (hPa) value becomes a reference for isobaric analysis**. See the graphic (next page) for details of a surface station weather glyph.



Activity 1—Practice Drawing of Isobars

Figure 1 below represents a surface map plot which shows air pressure in hectopascals (hPa) at various locations. (The example uses whole numbers and not the traditional station plot format for the purpose of this exercise only.) Each pressure measurement is placed on the location it represents. A 1012-hPa isobar, which encircles one station on this map, has been drawn. Complete the 1008-hPa isobar that has already been started. Finally, draw the 1004-hPa isobar. **Label each isobar by writing the appropriate pressure value at its end point.**

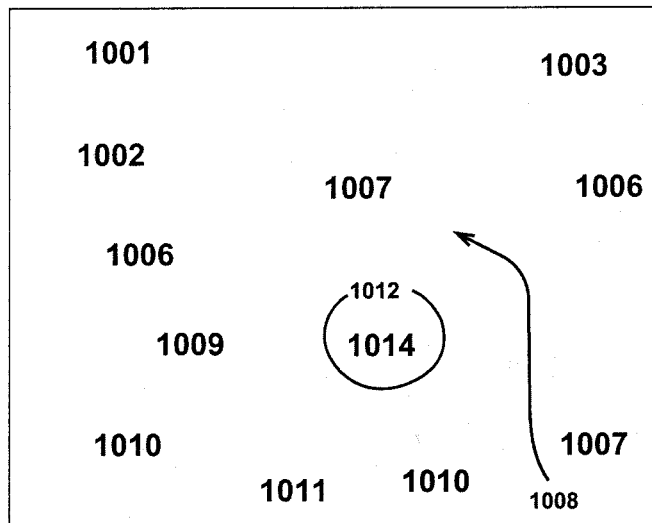


Figure 1—Sample plot of surface pressure values in hectopascals (hPa) at various stations. (For the purpose of this exercise only, this example uses whole numbers and not the traditional station plot format.)

Tips for Drawing Isobars

- A. Always draw an isobar so that air pressure readings greater than the isobar's value are consistently on one side of the isobar and lower values are on the other side.
- B. When positioning isobars, assume a steady pressure change with distance between neighbouring stations. For example, a 1012-hPa isobar would be drawn between the observations of 1013 hPa and 1010 hPa, about one-third the way from the 1013 hPa reading.
- C. Adjacent isobars tend to follow a similar pattern. The isobar that you are drawing will generally parallel the curves of its neighbours because horizontal changes in air pressure from place to place are usually gradual.
- D. Continue drawing an isobar until it reaches the boundary of the plotted data or “closes” to form a loop by making its way back to its starting point.
- E. Isobars never stop or end within a data field, and they never fork, touch, or cross one another.
- F. Isobars cannot be skipped if their values fall within the range of air pressure reported on the map. Isobars must always appear in sequence; for example, there must always be a 1000-hPa isobar between a 996-hPa and 1004-hPa isobar.
- G. Always label isobars with a number (e.g., 996, 1000, 1004).

Some Sample Surface Analysis Maps from Environment Canada*

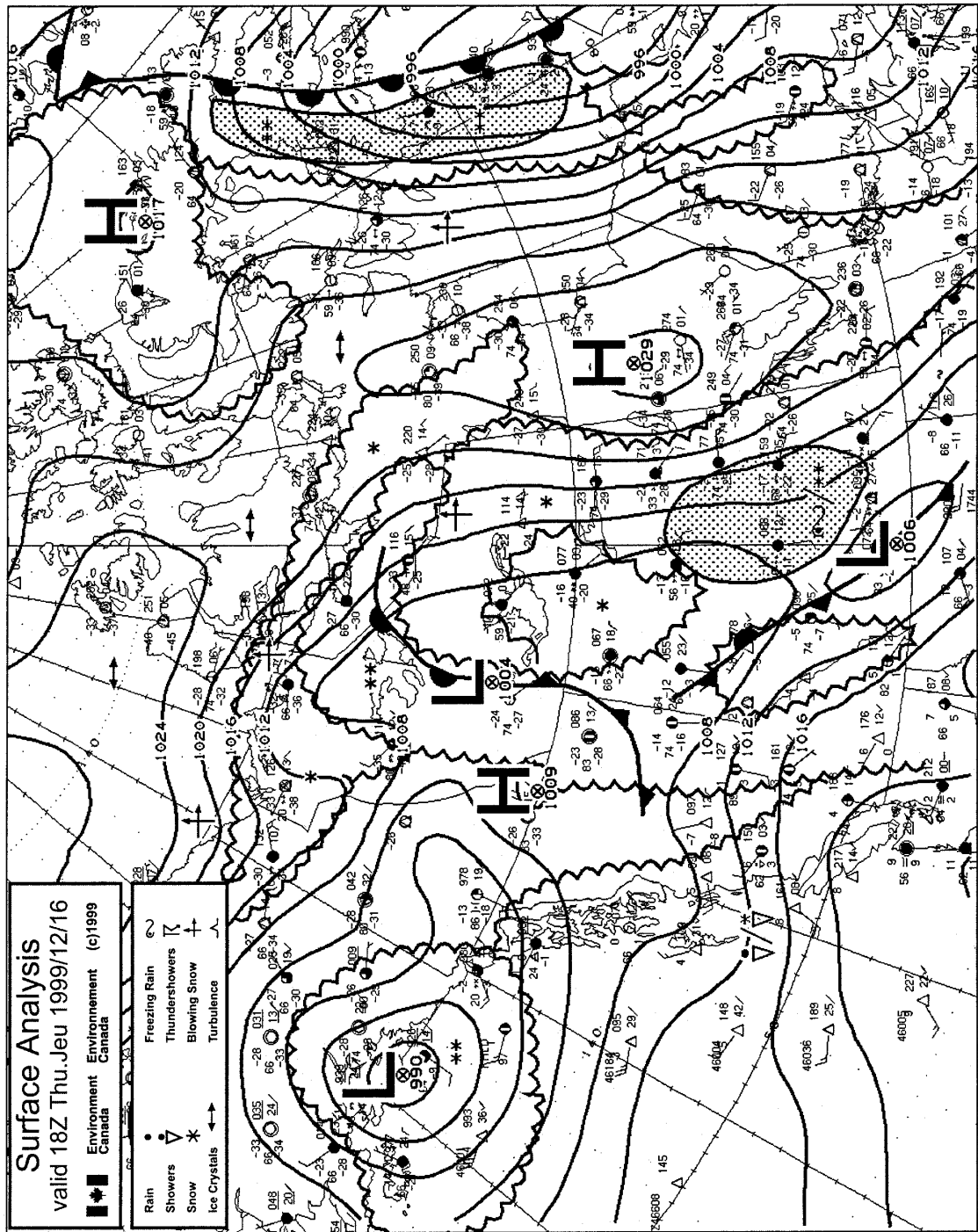


Figure 2—An example of a regional surface map analysis showing isobars, highs, lows, fronts, clouds, and precipitation.

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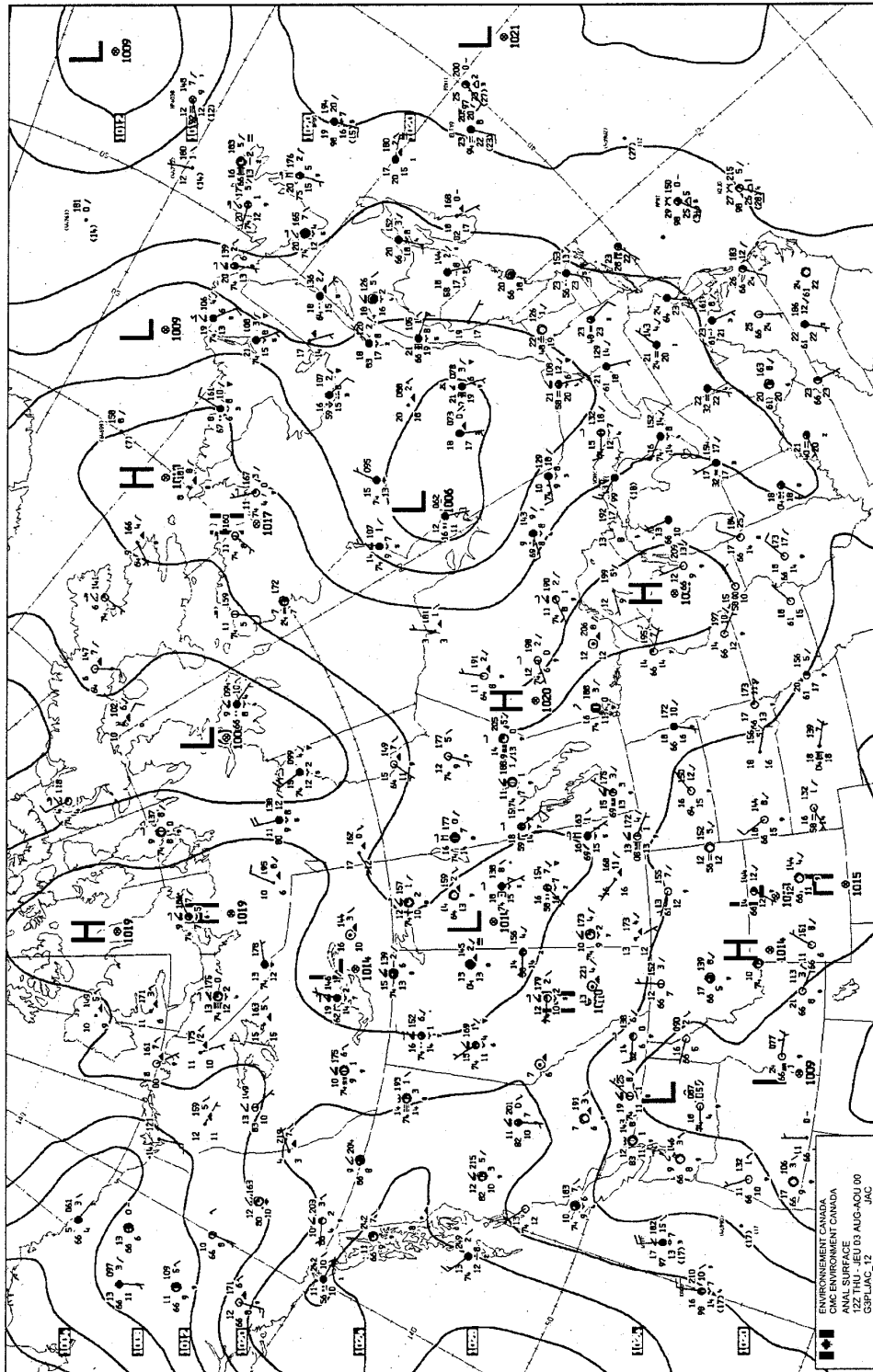


Figure 3—An example of a computerized national surface analysis map showing isobars, highs, and lows. The time is 0700 CDT.

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Introduction to Weather Maps and Symbols

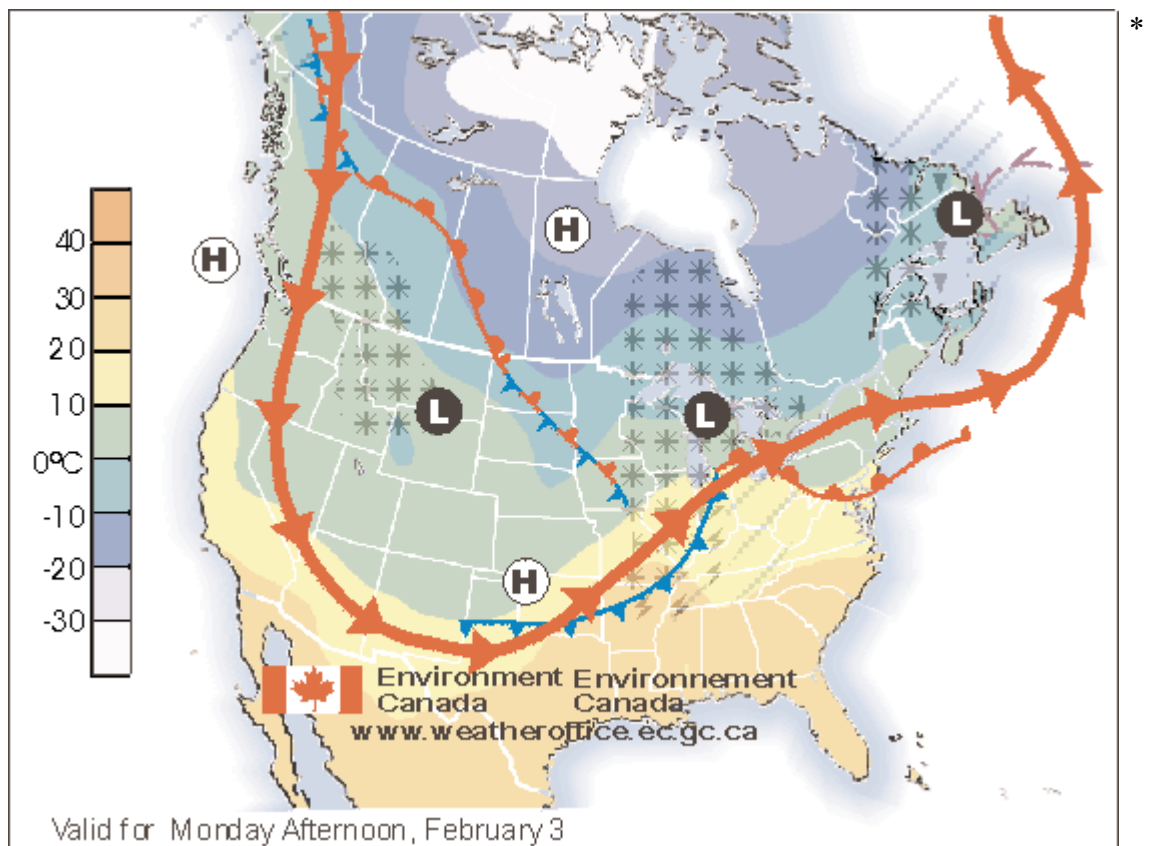
Introduction

This sequence of weather maps and associated questions are designed to give you an introduction into effectively reading information from a weather map. By the end of this activity sequence, you will be able to go significantly beyond a typical “weather channel” approach to the features on a weather map.

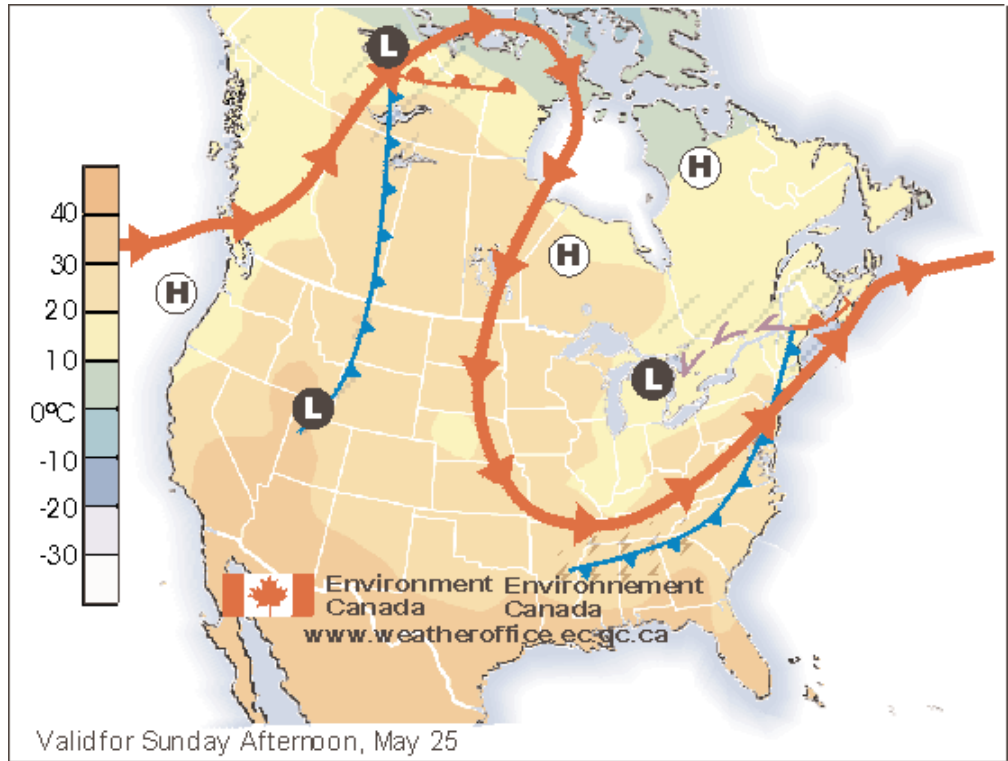
Begin by looking at what you would typically see on a weather-related website or TV station forecast image. The ones that follow are available through Environment Canada’s weather chart website found at:

<http://weatheroffice.ec.gc.ca/charts/index_e.html>.

What follows is a legend that allows you to interpret the features of these types of simplified “at-a-glance” weather maps.



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*

Legend

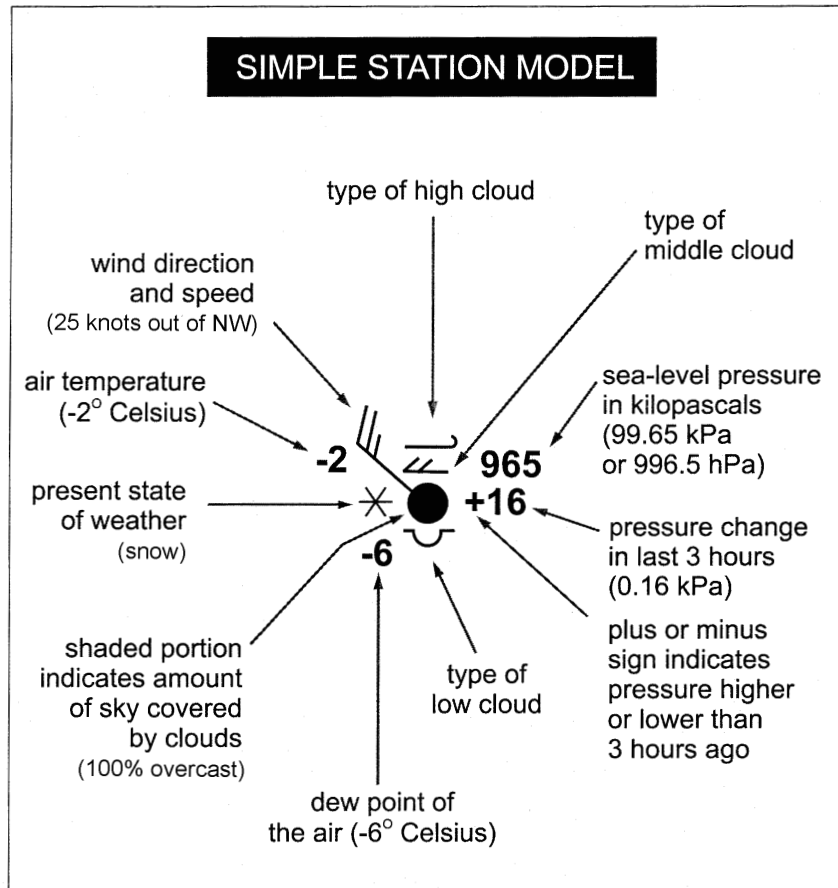
- High Pressure
- Low Pressure
- Warm Front
- Cold Front
- Trough - Trough of Warm Air Aloft
- Jet Stream
- Rain
- Freezing Rain
- Snow
- Thunder Showers

The series of maps that follow have been prepared to assist you in becoming familiar with weather mapping techniques and symbols. In order to fully appreciate events such as severe storms, winter blizzards, hurricanes, thunderstorms, and tornadoes, it is important to have a working knowledge of maps. That knowledge puts you in a position to analyze the atmospheric conditions before, during, and after a significant weather event has occurred. The approach we will take is to introduce the weather map components in a sequence, rather than all at once. The maps, however, will still have plenty of other information, so be patient with the process. Most importantly, do not let yourself be overwhelmed with the amount of information contained on each map. Simply focus on the “guiding questions” that accompany each map panel.

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Elements of a Surface Weather Station Glyph

In the graphic that follows, the weather station glyph has each symbol described in detail. Familiarity with these features helps us understand what the weather is doing at a location.



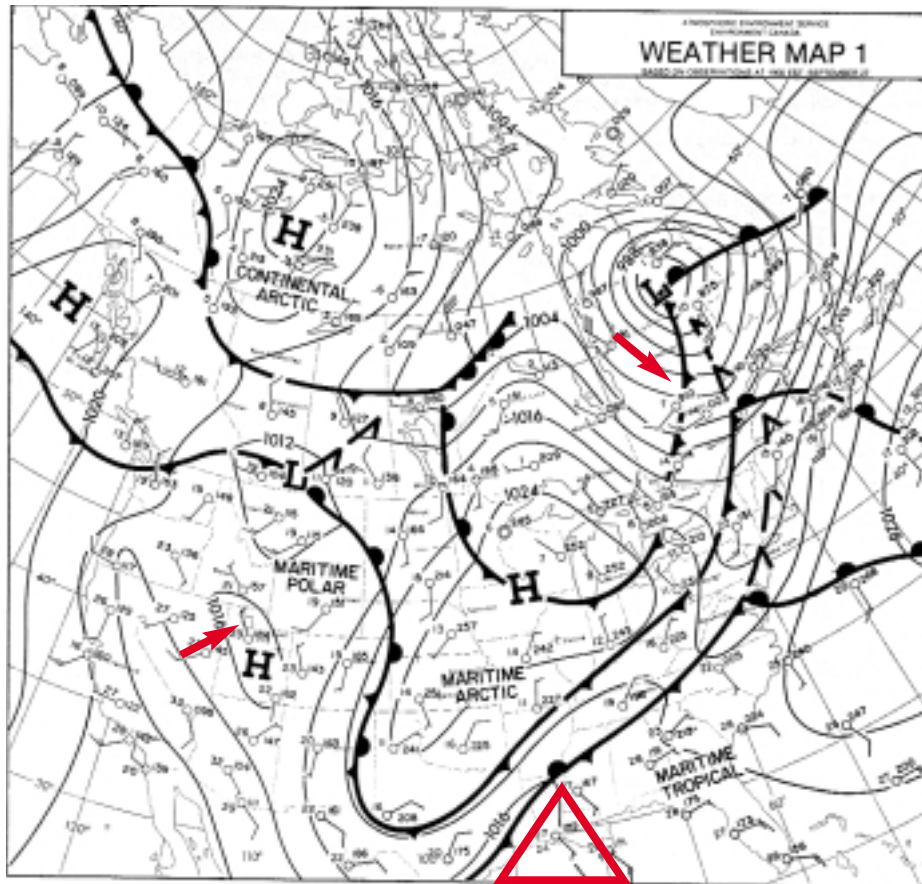
From Where Do the Maps Originate...Are They Real?

The map series covers a 60-hour time period, during the month of September. The time goes from 1900 EST (that is 7 p.m. EST, or 6:00 p.m. CST for Manitobans) on September 27th to 0700 EST (0600 CST) on September 30th of the same month.

The series also gives us a look at a typical early fall pattern of weather across North America. Try to see the following features on Surface Analysis Chart 1:

- a well-developed storm over northern Quebec
- fresh, cold arctic air covering the Northwest Territories
- warm “Chinook” winds keeping temperatures warm in southern Alberta and Montana in the USA
- extremely warm conditions in the U.S. southwest in the deserts of California, Nevada, Arizona, and New Mexico
- very windy conditions in Nova Scotia and northern Quebec

Surface Analysis Chart 1—September 27, 1900 EST



*

Some Questions

- Were temperatures above or below freezing at this time where you live?
 Location: _____
 Freezing? _____
- Take note of the time of this map (1900 EST). What time is it in Manitoba?

- Will the air temperature drop below 0° C this night anywhere in the southern Prairies? If your answer is “yes,” give the name of the town or city.

- Take a close look at the direction of the surface winds around the **LOW-pressure system** centred on northern Quebec. Take a pencil and, for as many stations as you can, draw ~2-cm-long arrows that show the direction the winds are blowing. One is done for you on the map.

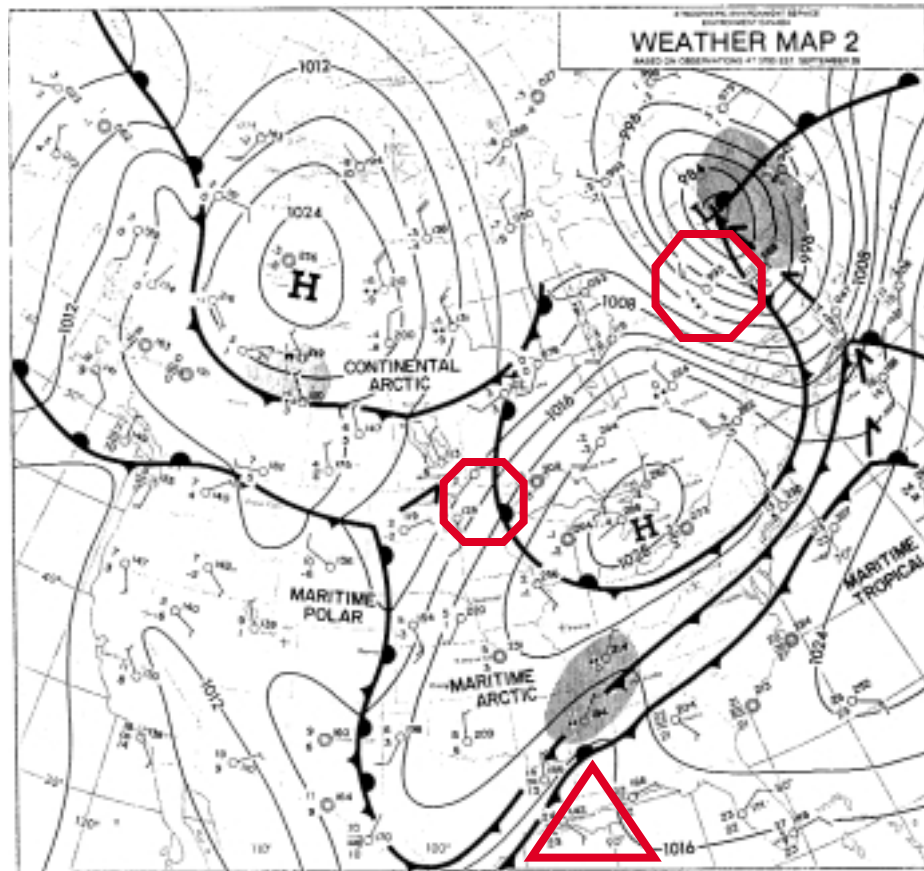
* Graphic reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.

5. Is there a pattern to the wind directions as you look at the region around the big low-pressure system?

6. Now, take a close look at the direction of the surface winds around the **HIGH-pressure system** centred on southwestern United States. Take a pencil and, for as many stations as you can, draw ~2-cm-long arrows that show the direction the winds are blowing. One is done for you on the map.

7. Is there a pattern to the wind directions as you look at the region around the big high-pressure system?

Surface Analysis Chart 2—September 28, 0700 EST



Some Questions

1. Note that the surface winds are blowing around the H and the L centres, as you found out with your work on Surface Analysis Map 1. Are there any areas that seem to have wind directions that disregard the general rules?

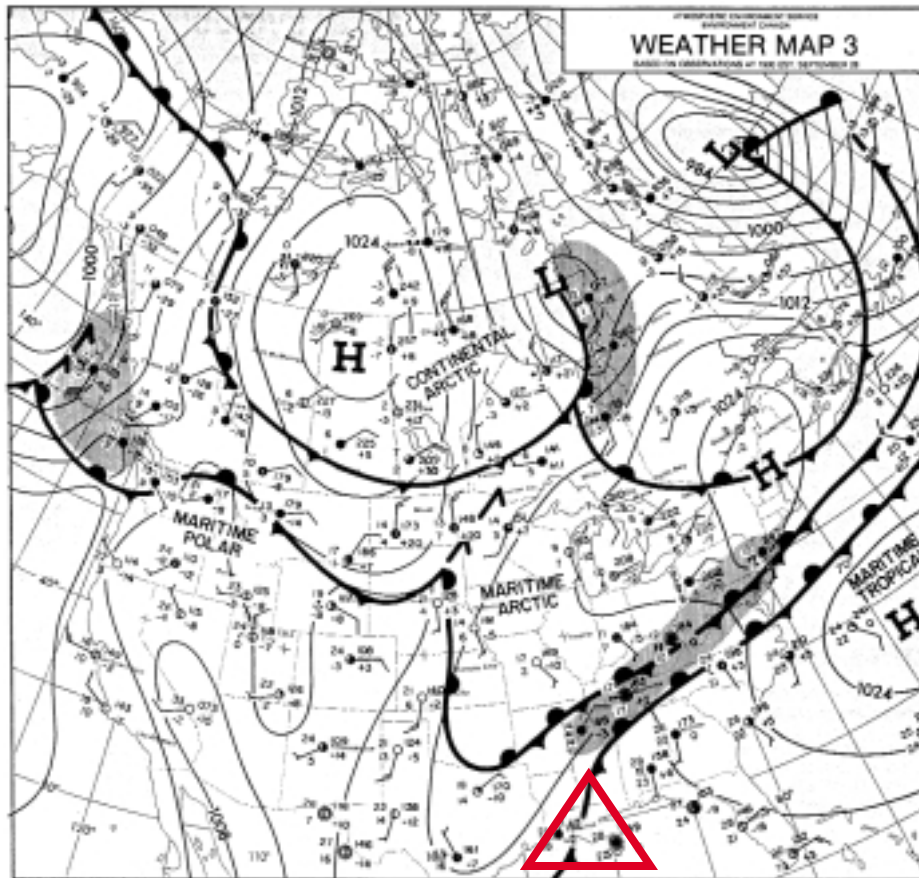
2. What temperature change has occurred during the last 12 hours at Schefferville, Quebec? _____

Kenora, Ontario? _____

These two localities are CIRCLED on your map to make them easier to find.

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Surface Analysis Chart 3—September 28, 1900 EST



Some Questions

- 1 The isobars (lines on the map joining points having equal air pressure) mark out two types of pressure systems, high- and low-pressure areas. Do these highs and lows move?

Find the point or area of highest pressure in northwestern Canada on September 27 at 1900 EST (on Map 1). Mark this point on the chart for 1900 EST September 28 (the map on this page). Similarly, locate the high of September 28 at 0700 EST (from Map 2) and mark its position on Map 3 for September 28 (this page).

In what direction is the high moving?

About how fast is it going on a 24-hour basis?

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For measuring distances, remember that a **degree of latitude is about 100 km**. Therefore, Sept-Iles is almost 480 km south of Schefferville in Quebec.

About how far is Churchill, MB from Baker Lake, NU?

Or Winnipeg, MB from Regina, SK?

2. Follow the same procedures with the low-pressure area near northern Quebec, beginning on September 27th (Map 1) and ending with its position on this map (Map 3).

How fast is it moving?

In what direction is this low-pressure system moving?

3. Symbols for sky cover have also been included in this activity, prior to Map 3.

In general, do you find cloudy or clear skies in low-pressure areas?

In high-pressure areas, what occurs with cloud cover?

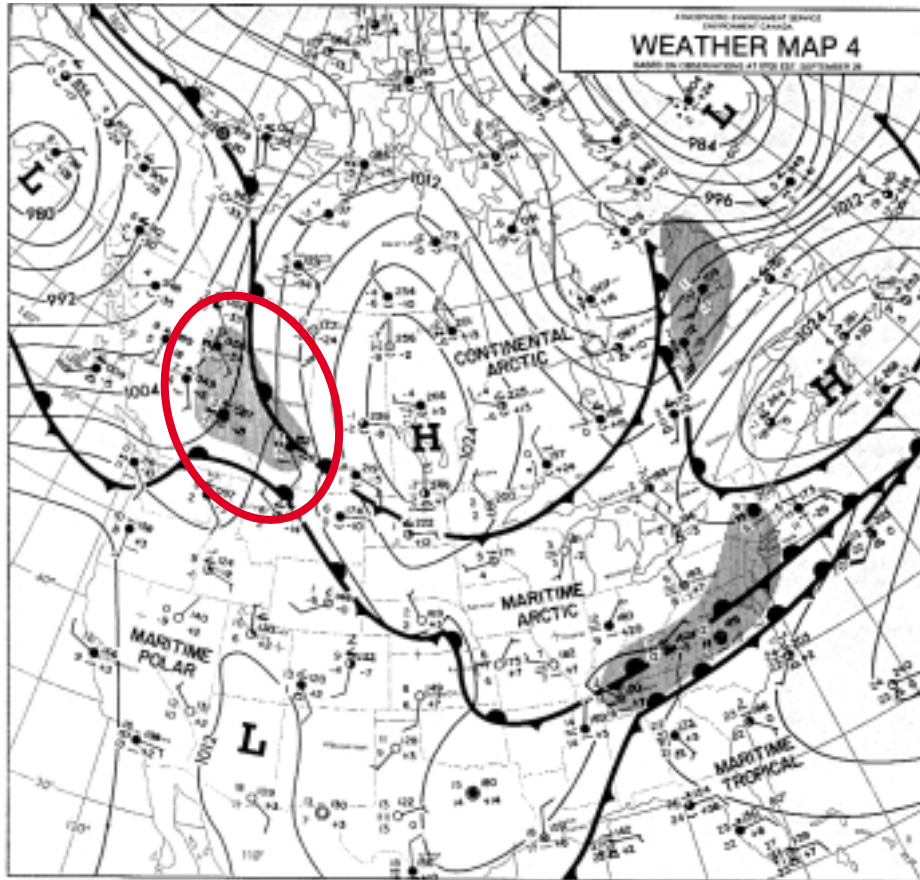
What are the skies like in areas where precipitation is falling?

What happened to the **temperature** and **dew point** at Lake Charles (in Louisiana), when the cold front passed east of this station from Map 1 to Map 3? A triangle appears on maps 1–3 to help you find Lake Charles.

Compare this report with the previous map of September 27th. What happened to the wind at this station over this 24-hour period? What sort of FRONT passed through this station over the same time period?

4. What changes occurred at The Pas, MB in the preceding 24 hours? Why?

Surface Analysis Chart 4—September 29, 0700 EST



Some Questions

1. Take note of the large area of precipitation in eastern British Columbia and western Alberta (outlined by the shaded oval shape). How far has this moved in the last 24 hours (since Map 2)? Where would you expect to find this rain 24 hours from now on September 30th?

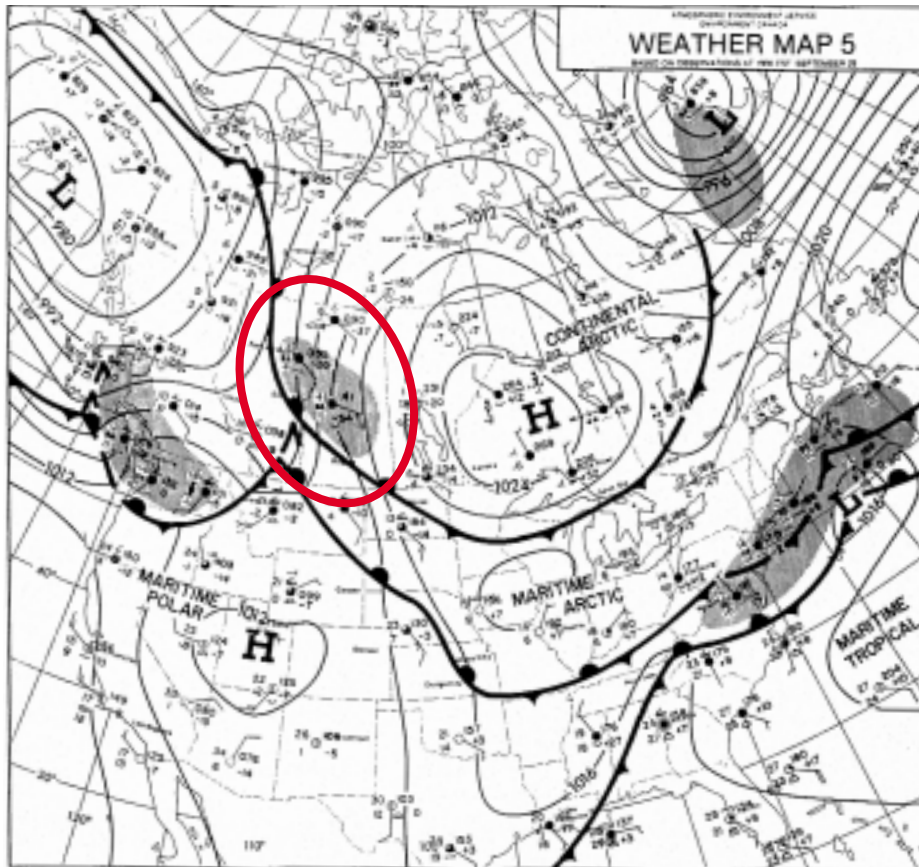
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2. Have you been watching the large area of high pressure that is now sitting over Manitoba's Interlake region on this map? Where will it likely be in 24 hours? In 48 hours?

3. Using the symbols on this map, attempt to identify what the weather is like in these three Manitoba centres (include % cloud cover, temperature, wind speed/direction):

- a. Winnipeg: _____
- b. The Pas: _____
- c. Churchill: _____

Surface Analysis Chart 5—September 29, 1900 EST



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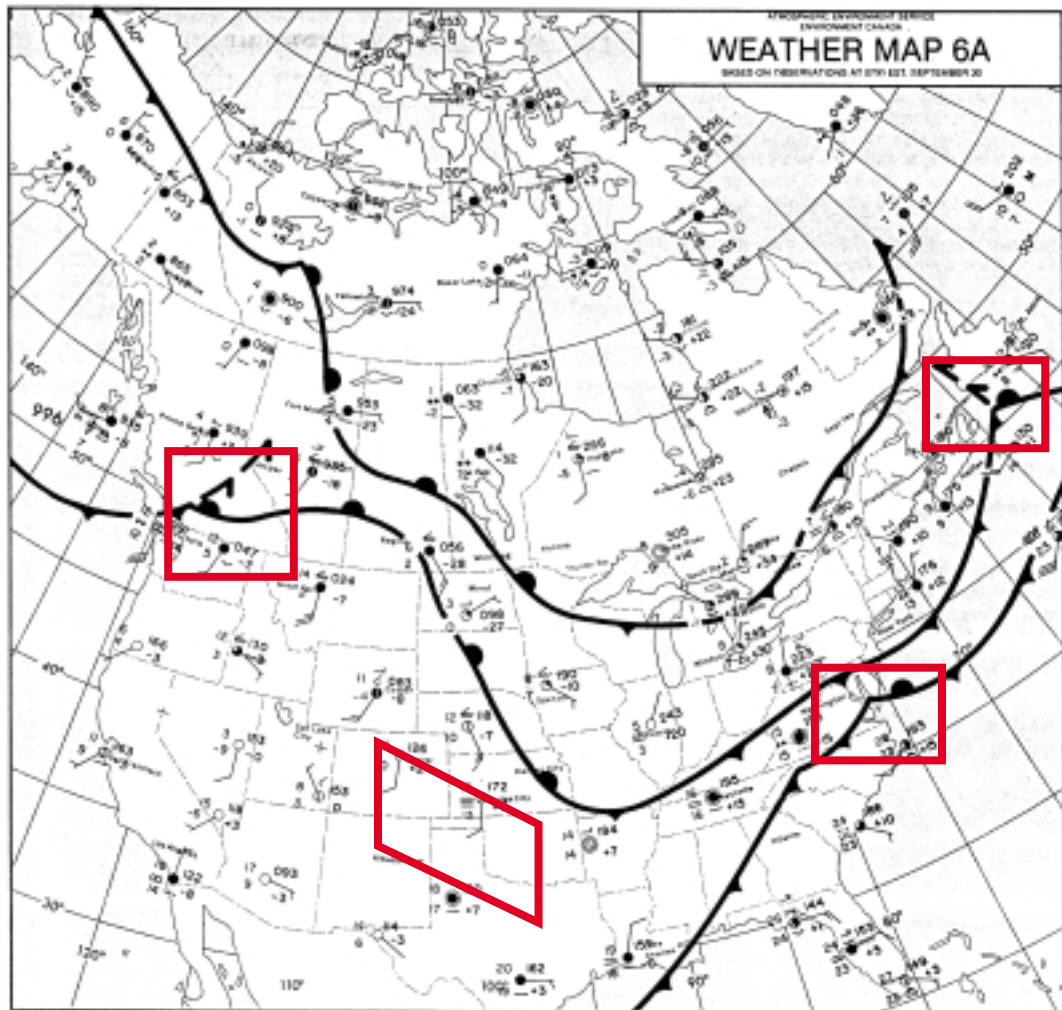
Some Questions

1. Take a close look at the relationship between the location of large precipitation areas and **pressure systems**. What kind of systems, **high** or **low**, seem to be regularly associated with rain or snow?

2. Did the area of **high pressure** that was over Manitoba on the previous day move as you expected it?

Where will it be in another 24 hours (i.e., who will have fine weather tomorrow)?

Surface Analysis Chart 6a—September 30, 0700 EST



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Some Final Questions

1. What would you expect to find happening with the weather in the three areas outlined with boxes on Map 6a?

2. What do these three areas have in common in terms of weather map symbols or features?

3. Note the two cities inside the parallelogram on the map—Dodge City, Kansas and Denver, Colorado.
 - a. What can you say about the **relative humidity** at Dodge City? (Hint: look at the air temperature and dew point readings.)

 - b. Account for the fact that Denver reports no fog whereas Dodge City does.

4. Examine the temperatures of the stations under the influence of the Arctic air mass that is behind the **cold front** in eastern Ontario and Quebec. Now, look back 48 hours to Map 2 when the large region of high pressure was centred over Great Slave Lake in the Northwest Territories.
 - a. Have there been any temperature changes at these stations in the last 48 hours? If so, could you explain briefly what has occurred?

 - b. The cold, Arctic-origin cold front that is approaching Toronto has been moving steadily southeastward in the period covered by maps 1–6a.
 1. How far has the front moved since 0700 EST on September 28th when we started this process?

 2. What was its average velocity (in kilometres per hour) over this period?

 3. Has this cold front changed its velocity over the three-day period (either sped up or slowed down)?



Using Satellites to Track Weather

In this activity, students will:

- Describe how information is acquired by satellites, sent to Earth, and interpreted to construct images
- Explain how pixel size influences the detail (resolution) on weather satellite images
- Utilize different types of satellite imagery to understand a particular weather system or event that is occurring, or has happened in the past

Key Words

- Visible and infrared wavelengths
- Geostationary and polar orbiting satellites
- Water vapour images

Introduction

Our everyday view of the atmosphere is from the bottom looking up and around. Our field of view is limited since most of us can see only a few kilometres in any direction. At the same time, the systems that dominate our weather can be hundreds or even thousands of kilometres across. Weather maps and radar have extended our views, but it is the weather satellite that gives us a completely different perspective on weather. Orbiting satellites are platforms from which the atmosphere and surfaces below can be observed from the outside.

By looking down on weather, we can see that fair and stormy weather are somehow related. Clear areas and giant swirls of clouds fit together. In the continually changing atmosphere, we can observe evidence of predictability through the order and evolution of weather systems.

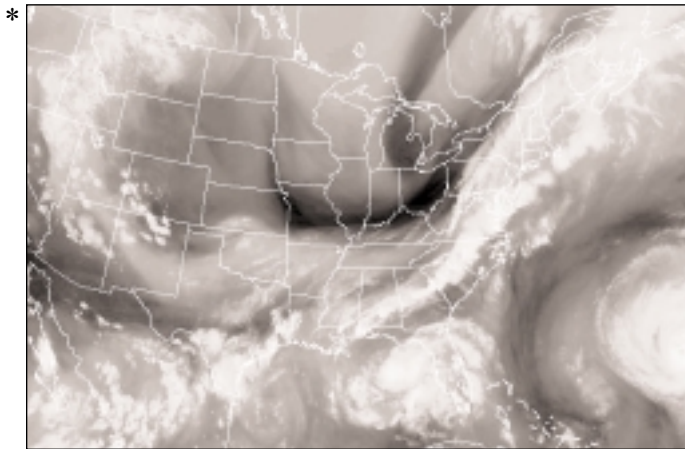
With the launch of TIROS-1 (Television Infra-red Observational Satellite) in 1960, we gained our first total views of the cloud patterns that accompany low-pressure systems and fronts. Areas of high pressure and fair weather also became apparent by their general lack of clouds. The launch of TIROS culminated a long march of technological advance in electronics and space exploration. The use of electronics for the sensors, information storage, and transmissions to Earth depended upon the newest transistor technology.

The sensors themselves depended upon television research for their images. Later sensors were outgrowths of this and went on to solid-state extensions where heat radiation, as well as light, from the Earth could be measured.

Finally, the signals that are measured electrically are converted to digital values for storage and are later transmitted down to Earth. There, the visual images we are familiar with are produced. This last step is highly dependent on computer technology for the assembly, organization, and interpretation of the data.

We now have two basic types of satellite systems. The descendants of TIROS are known as polar-orbiting satellites. They revolve around the Earth at relatively low altitudes, 800 kilometres or so, passing over the polar regions as the Earth rotates underneath. Such an orbit takes about 100 minutes to complete. Most places are scanned twice a day, once in daylight and once in darkness. Large-scale views are made from composites of several orbital strips that are about 1900 kilometres in width.

The satellite pictures most often displayed on television and in the newspapers are taken by geostationary orbiters known as Geostationary Operational Environmental Satellites (GOES). Today's images are commonly from GOES-8 and GOES-10 and on May 17, 2000, the first images from GOES-11 were received. At 35,800 kilometres above the equator, such satellites will make one revolution in 24 hours. Because this is the same time as one Earth rotation, and the satellite revolves in the



same direction the Earth is turning, such a satellite remains over the same equatorial surface location. Successive views from the same geostationary satellite can be provided to observe development of storm systems. They do not picture details as well as the closer polar-orbiting type of satellite, but they do provide more frequent views, every half hour, of the same Earth surfaces.

The sensors on-board the satellites react to two basic types of radiant energy. Visible light is produced by the Sun and reflected off Earth

surfaces and clouds back up to the satellite. These images look like black-and-white television pictures. All clouds look white to the sensor as they do to our eyes. Darker ground surfaces and water bodies in clear areas reflect little sunlight back up to space and therefore appear dark gray or black. Visible images from the current geostationary weather satellites can resolve objects such as clouds that are as small as one kilometre in width.

The second main type of sensor detects infrared or heat energy given off by surfaces with temperatures in the range of the Earth's land and water surfaces and cloud tops. The intensity of the infrared energy is related to the specific temperature of the emitting surface. In this way, infrared (IR) images are temperature maps of the Earth view. Because the Earth and atmosphere emit heat day and night, infrared images are always available. The infrared sensor on the geostationary weather satellites can distinguish areas as small as four kilometres in width.

Visible light images, when containing a portion of the daylight half of the globe, show clouds to be uniformly white whether they are at low, middle, or high levels in the atmosphere. Earth surface details are usually dark. In contrast, infrared images

* Graphic reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2003. Reproduced by permission.

can provide continuous information, day and night, because heat is constantly being emitted from all surfaces, day and night. Land and water surfaces are usually warm and therefore shown as dark. Cooler surfaces are typically displayed as gray with decreasing temperatures having lighter shading. In this way, low, warm clouds will be contrasted with high, cold ones. Temperature variations between warmer land and cooler water surfaces can be seen, as can the temperature cycle on land where daytime warming changes to nighttime cooling.

The variation in temperature across land and water surfaces is a major factor in the development of weather systems. These temperature variations are also displayed in cloud features associated with severe weather situations. Therefore, it has been useful to enhance or process infrared images to accentuate the temperature variations by displaying differing shades of gray or by using colour coding. The 24-hour availability and the colour coding make the enhanced infrared imagery ideally suited to display on television weathercasts, as successive views are looped into movies of cloud motions.

The solid and liquid water found in clouds is very well monitored by the visible and infrared images of weather satellites. The existence of water vapour in the atmosphere is much more difficult to detect. A knowledge of water vapour patterns is very important to understanding weather systems. Water vapour is the supply material for the creation of clouds and precipitation, but it is invisible to the eye and only measured by instruments at widely separated locations. Fortunately, a specific range of infrared energy wavelengths interacts with water vapour. This finely tuned infrared sensor on the geostationary satellites can provide images, and sequences, of cloud locations and the regions of large water vapour content in cloud-free areas at altitudes between 3 and 7 km. Current water vapour imagery can resolve areas down to widths of eight kilometres. Water vapour images are especially helpful in detecting the atmospheric circulation patterns that lead to later cyclone formation and their associated cloud shapes.

The combination of satellite types provides much valuable information about the Earth below. In addition to monitoring weather systems, the satellites provide other data, including vertical temperature profiles and moisture measurements.

To view the latest satellite imagery, you can go to the Environment Canada website: <<http://weatheroffice.ec.gc.ca>>.

Navigate to the **Satellite page**. The menu offers a number of choices, such as:

GOES-East Eastern Canada
 IR (infra-red: 10.7 μm)
 Visible & Topography
 IR + Visible

Note: 10.70 μm (micron) is an infrared (IR) image where 10.70 microns simply refers to the infrared wavelength being used for this specific image. 1 μm (micron) = 10^{-6} metres

Basic Understandings About Satellite Imagery

Weather Satellite Characteristics

1. Weather satellites are orbiting platforms from which onboard instruments can sense light and heat energy from the atmosphere and underlying surfaces.
2. Because weather satellites can view a large area at one time anywhere on Earth, they provide meteorological information over the oceans and sparsely populated land regions.
3. Weather satellite pictures are received as composites of tiny blocks (called pixels) of varying energy intensities, often shown in shades of gray or in colour. The area each block covers determines how detailed the image can be. The smaller the block, the greater the detail in a satellite image.
4. In addition to sending back pictures of Earth, weather satellites can determine the temperature and water vapour content at different heights in the atmosphere. They can also monitor the ozone layer and detect energetic particles in the space environment.

Polar Orbiting Weather Satellites

5. One type of weather satellite orbit passes near the Earth's poles, making north and south journeys at an altitude of about 800 kilometres.
6. Polar-orbiting satellites scan a strip of Earth, taking less than two hours to complete an orbit. With each pass, they survey a strip approximately 1900 km wide that is further west because of the Earth's eastward rotation. Many hours elapse between passes over the same mid- or low-latitude location.
7. These satellites provide us with information on the condition of the ozone "hole" and composite pictures of snow cover and ocean surface temperatures.

Geostationary Weather Satellites

8. A second type of weather satellite orbit is located 35,800 kilometres directly over the equator. These satellites make one revolution, moving in the same direction as the Earth's rotation, in the time it takes Earth to make one rotation. This keeps them above the same spot on the equator, making them appear stationary, hence their name, Geostationary Operational Environmental Satellites (GOES).
9. Ordinarily, there are two geostationary satellites covering Canada and the United States, one for the eastern part, and one for the west coast and Pacific Ocean. Each one has a field of view covering about one-third of the Earth's surface.
10. Each satellite's view remains the same, so sequential images may be viewed in rapid succession to show development and movement of weather systems.

Visible Satellite Images

11. Visible satellite images are views produced from reflected sunlight. Thus, these pictures look similar to pictures made with an ordinary camera.
12. On visible satellite imagery, clouds appear white, and the ground and water surfaces are dark gray or black. Since this imagery is produced by sunlight, it is only available during daylight hours.
13. Low clouds and fog are usually distinguishable from nearby land surfaces. In addition, the hazy conditions associated with air pollution can be tracked.
14. The shadows of thunderstorm clouds can be seen on lower clouds in the late afternoon. Snow cover can be monitored because it does not move as clouds do. Land features, such as streams, can be visible.

Below is a sample image from a satellite using **visible wavelengths**:

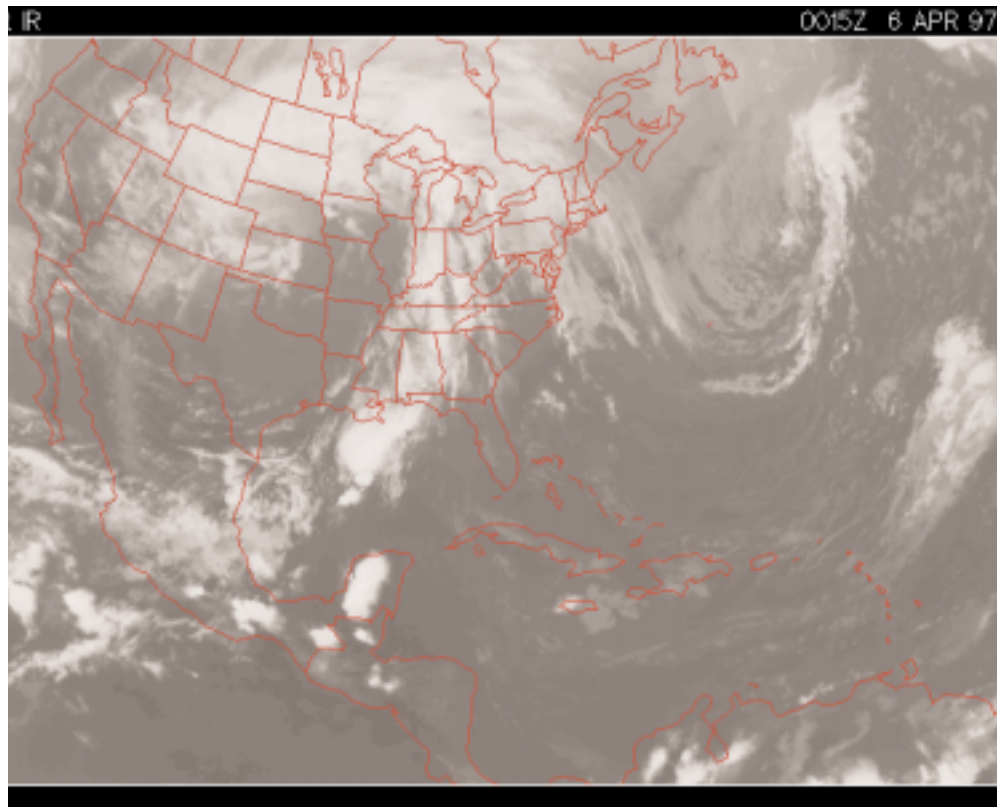


Figure 1: The above image happens to be from the April 6, 1997, Spring blizzard that just preceded the great Red River “Flood of the Century.” Note the well-developed, comma-shaped form of the clouds making up this very large mid-latitude cyclone.

Infrared Satellite Images

15. Infrared satellite images are produced by the infrared (heat) energy Earth radiates to space. Since Earth is always radiating heat, infrared images are available day and night.

* Image courtesy of NOAA. Used with permission.

16. On infrared images, warm land and water surfaces appear dark gray or black. The cold tops of high clouds are white and lower-level clouds, being warmer, are gray. Low clouds and fog are difficult to detect in the infrared when their temperatures are nearly the same as the nearby Earth surfaces.
17. An additional advantage of infrared imagery is that it can be processed to produce enhanced views. The data from the usual infrared pictures are specially treated to emphasize temperature details or structure by assigning contrasting shades of gray or colour to narrow temperature ranges. Such imagery, often seen colour-coded, appears regularly on television weathercasts and computer displays.
18. The enhanced images make it possible to keep track of land and oceanic surface temperatures. These surface temperatures play major roles in making and modifying weather. The high, cold clouds associated with severe weather are also easily monitored.
19. Enhanced imagery can be interpreted to produce rainfall rate estimates. This information is used in flash-flood forecasting.

Below is a sample image from a satellite using **infrared wavelengths**:

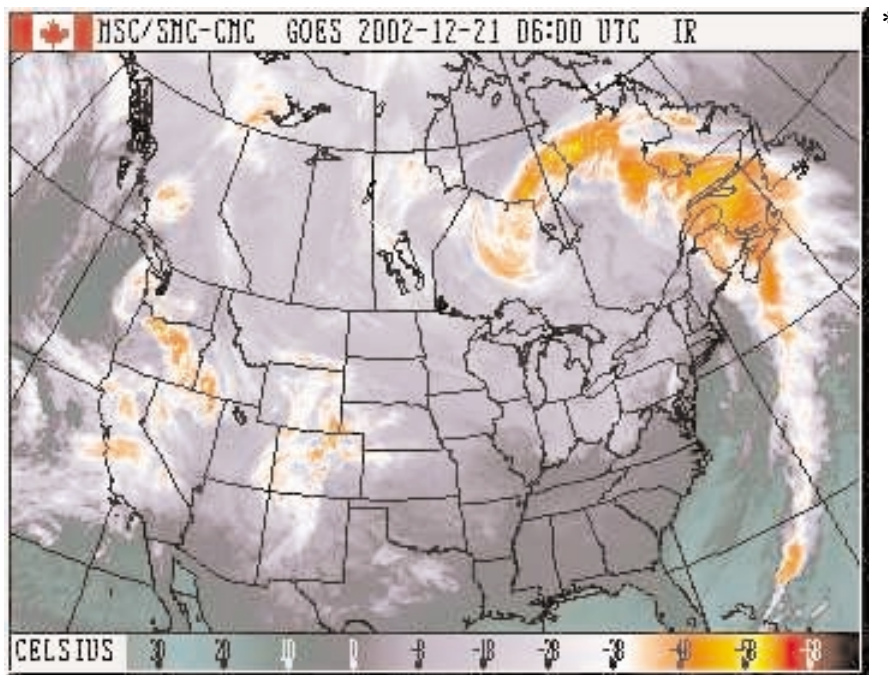


Figure 2: Infrared image of North America on December 21, 2002. Note the large winter storm in eastern Canada, with classic “comma-shaped” cloud structure.

Water Vapour Images

20. Solid, liquid, and vapour forms of water interact with specific ranges of infrared energy. Specially tuned geostationary weather satellite sensors can detect water vapour in the atmosphere, in addition to clouds.

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21. The water vapour sensors aboard weather satellites reveal regions of high atmospheric water vapour concentration in the troposphere between altitudes of 3 and 7 km. These regions, sometimes resembling gigantic swirls or plumes, can be seen to flow within and through broad-scale weather patterns.
22. Recent studies suggest that, at any one time, atmospheric water vapour may be found concentrated in several large flowing streams, forming the equivalent of “rivers in the sky.”

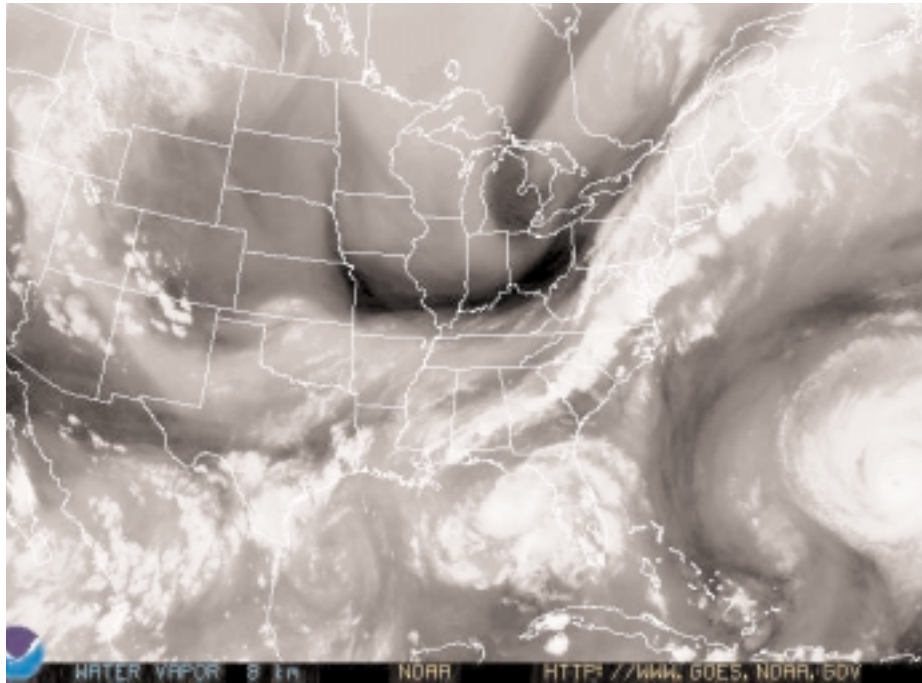


Figure 3: Water vapour image of the western Atlantic/Caribbean region. Dark areas represent dry (low humidity) air, and white areas are areas of moisture saturation (e.g., clouds). The fluid nature of Earth’s atmosphere is well represented in water vapour images. Note the very dry air adjacent to the hurricane on the right side of the image.

Weather Features in Satellite Imagery

23. Hurricanes look like pinwheels of clouds. More often than not, the beginnings of hurricanes are detected from satellite views, because they occur over broad expanses of oceans.
24. Large comma-shaped cloud shields give shape and form to mid-latitude low-pressure systems.
25. Clouds from which showers fall can look like grains of sand, especially on visible satellite pictures. Thunderstorms appear as “blobs” or “chains of blobs.” Their high tops spread downwind from them as wispy cirrus clouds. They may have neighbouring lower clouds appearing as tiny curved “tails” to the southwest. Such “tails” can also be indicators of the possibility of tornadoes.

* Image courtesy of NOAA. Used with permission.

26. Movements of cloud patterns detected by viewing sequential satellite images indicate the circulations of broad-scale weather systems. Wind speeds can be estimated at different levels and even upper-air jet streams can be identified.
27. Meteorologists use satellite images to determine cloud shapes, heights, and type. Changes in these cloud properties, along with cloud movement, provide valuable information to weather forecasters to determine what is happening and what is likely to happen to weather in the hours and days ahead.
28. Visible, infrared, and water vapour satellite imagery complement one another. There are weather features that can be clearly seen in one kind of image that are difficult to see in the others.

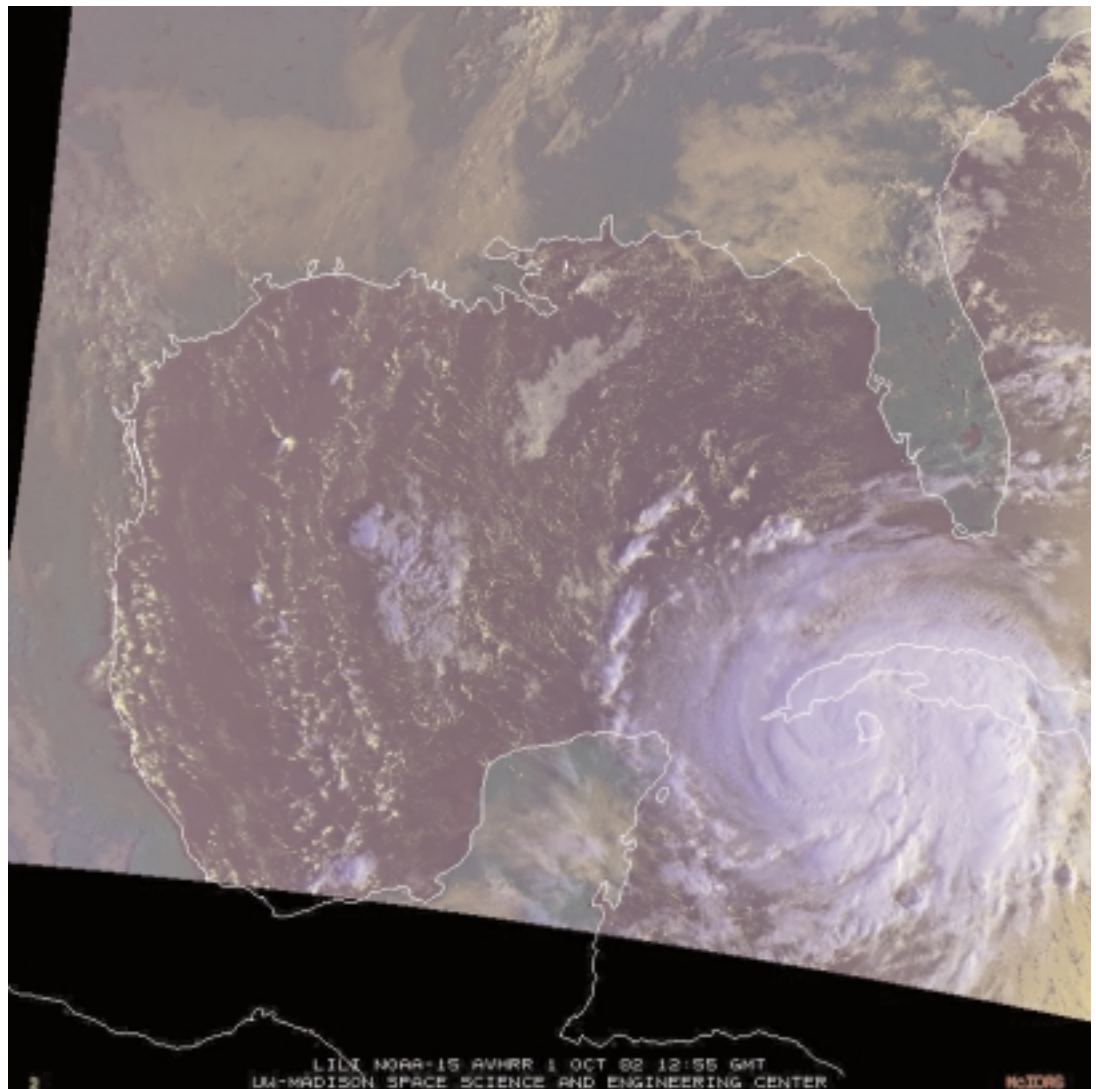


Figure 4: The image above is of Hurricane Lili (with the storm eye in western Cuba) from October 2002.

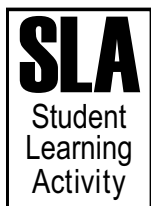
* Image courtesy of NOAA. Used with permission.



The Fujita Scale of Tornado Intensity

The Fujita Tornado Scale, usually referred to as the F-Scale, classifies tornadoes based on the resulting damage. This scale was developed by Dr. T. Theodore Fujita (University of Chicago) in 1971.

F-Scale	Winds	Type of Damage	Frequency
F0	40–72 mph 64–116 km/h	MINIMAL DAMAGE: Some damage to chimneys, TV antennas, roof shingles, trees, and windows.	29%
F1	73–112 mph 117–180 km/h	MODERATE DAMAGE: Automobiles overturned, carports destroyed, trees uprooted.	40%
F2	113–157 mph 181–253 km/h	MAJOR DAMAGE: Roofs blown off homes, sheds and outbuildings demolished, mobile homes overturned.	24%
F3	158–206 mph 254–332 km/h	SEVERE DAMAGE: Exterior walls and roofs blown off homes. Metal buildings collapsed or severely damaged. Forests and farmland flattened.	6%
F4	207–260 mph 333–418 km/h	DEVASTATING DAMAGE: Few walls, if any, standing in well-built homes. Large steel and concrete missiles thrown far distances.	2%
F5	261–318 mph 419–512 km/h	INCREDIBLE DAMAGE: Homes leveled with all debris removed. Schools, motels, and other larger structures have considerable damage with exterior walls and roofs gone. Top storeys demolished.	less than 1%



Canadian Tornado Frequency Data— An Applied Mathematics (20S) Approach

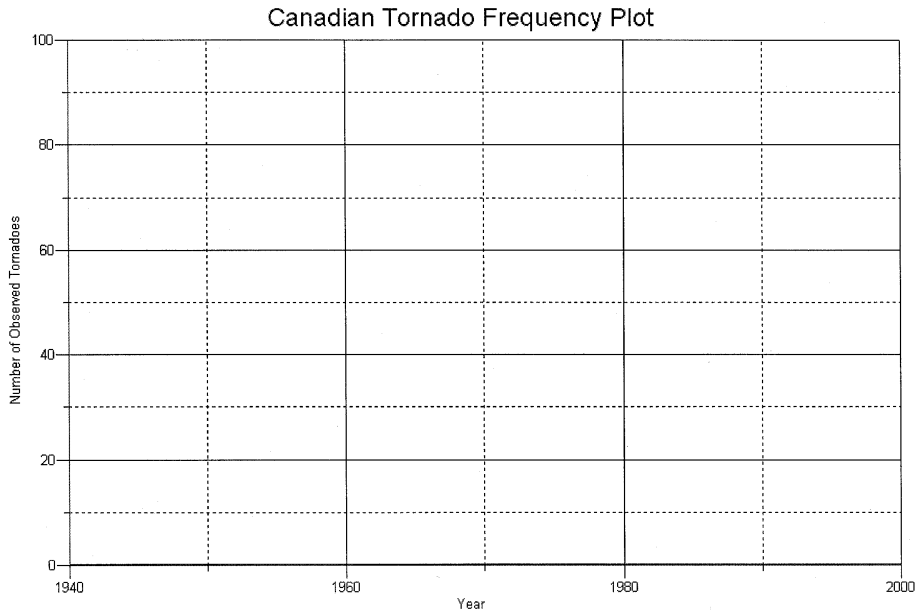
The Data*

Year	Number of Recorded Tornadoes in Canada	Year	Number of Recorded Tornadoes in Canada
1950	10	1974	28
1951	10	1975	68
1952	15	1976	45
1953	31	1977	54
1954	16	1978	95
1955	14	1979	58
1956	23	1980	61
1957	22	1981	39
1958	15	1982	55
1959	19	1983	61
1960	27	1984	76
1961	20	1985	42
1962	29	1986	71
1963	27	1987	72
1964	45	1988	68
1965	26	1989	86
1966	36	1990	52
1967	22	1991	69
1968	58	1992	39
1969	61	1993	57
1970	42	1994	96
1971	40	1995	40
1972	28	1996	59
1973	59	1997	46

Working with the Data

1. The table of data represents an approximately 50-year baseline of tornado sightings that are considered reliable. The data come from every region of Canada where tornado funnel clouds have been spotted.
2. Load these data into a spreadsheet program of your choice, a graphics calculator, or a plotting program such as *Curve Expert*[®] or *Graphical Analysis*[™].
3. Produce a scatter plot of the data, paying attention to the axes on which the “year” and “number of tornadoes” should be placed.
4. As an alternative, use plotting technology to produce a histogram (vertical bar graph) of the same data.
5. On the grid below, reproduce a rough sketch of the scatter plot, label the axes, and comment briefly on any patterns that appear in the data plot (e.g., are there any unusual years of many tornadoes?).

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Comments on the Appearance of the Scatter Plot:

- _____

- _____

- _____

6. Using your graphics calculator or plotting software, produce the **linear regression** (least squares line of best fit) for the data, and record the following (to two decimal places):

a. Equation of the line in the form $y = mx + b$

b. Determine the value of the **slope**:

- c. Determine the **significance** of the slope (state in words, and point out whether the slope is positive or negative):

- d. Determine the value of the correlation coefficient, “r”, to three (3) decimal places:

r = _____

- e. Does the value of “r” give you confidence that there is indeed a correlation between the calendar year and the frequency of tornadoes in Canada? State clearly the evidence for your decision.

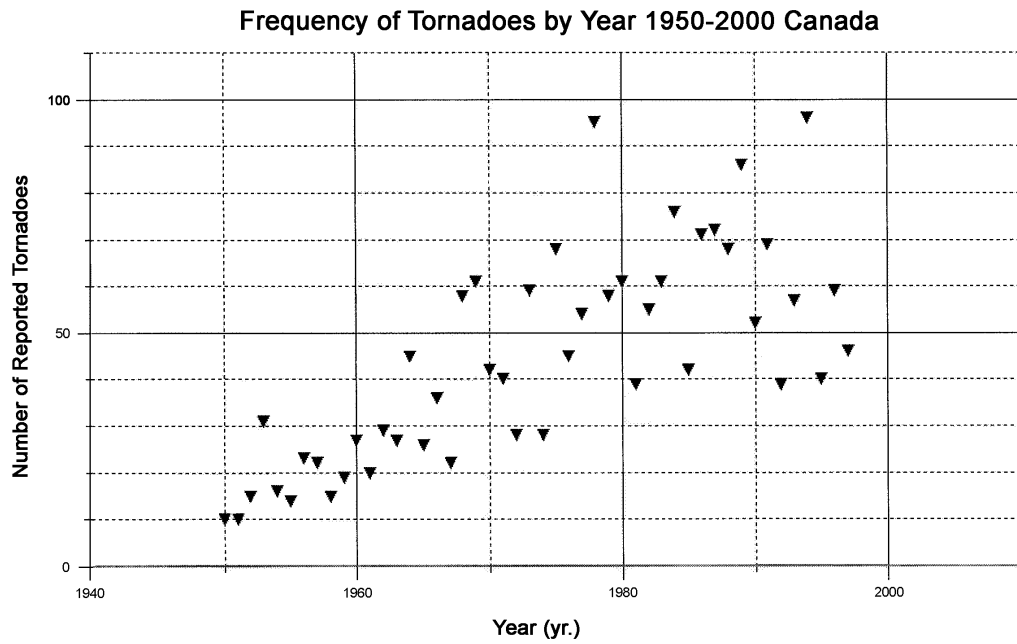
- f. What other factors could be affecting these data? Is there a possibility that the data or your “best fit” line are biased in some way?

- g. According to your model, how many tornadoes can we expect in the year 2051?

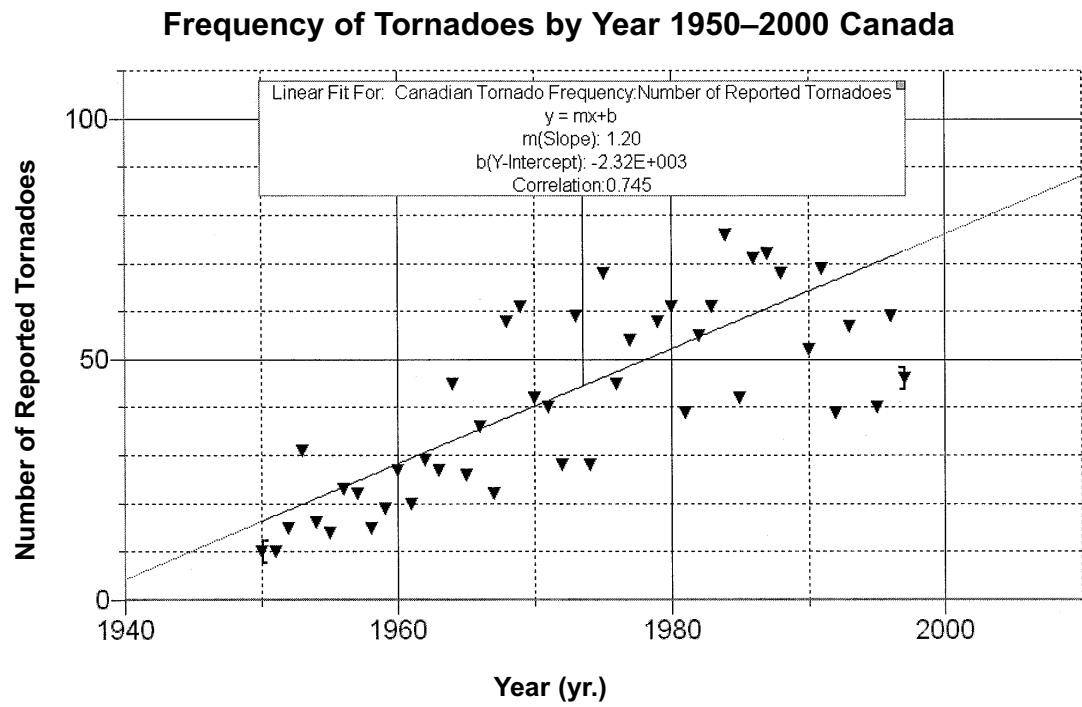
Is this a realistic projection into Canada’s severe weather future? How far back in time does your model indicate no Canadian tornadoes?

Some Possible Plots

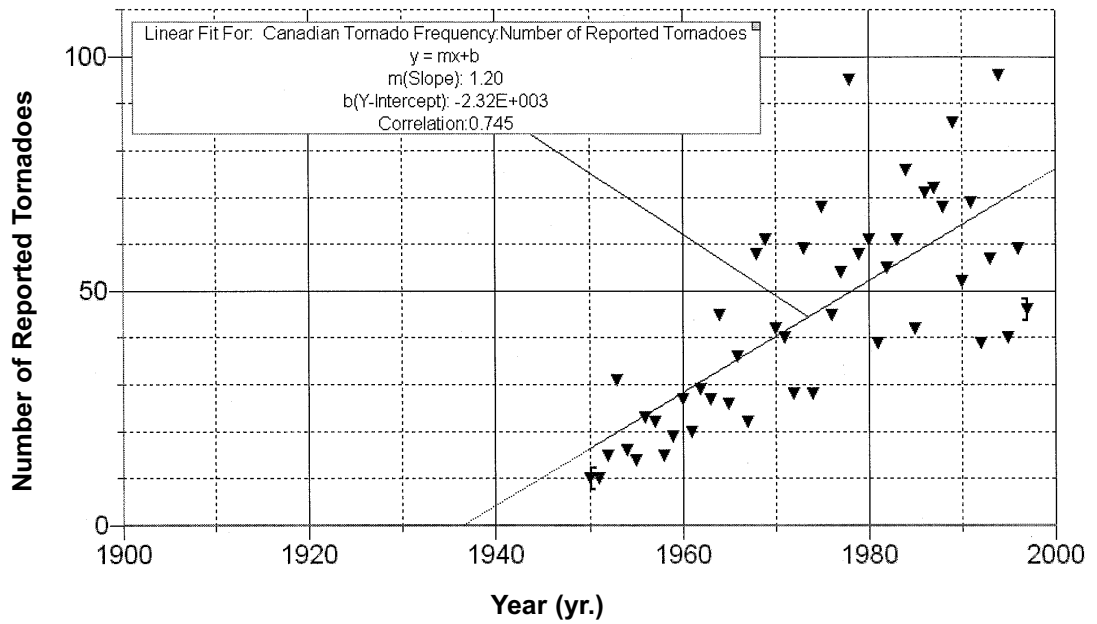
Scatter Plot



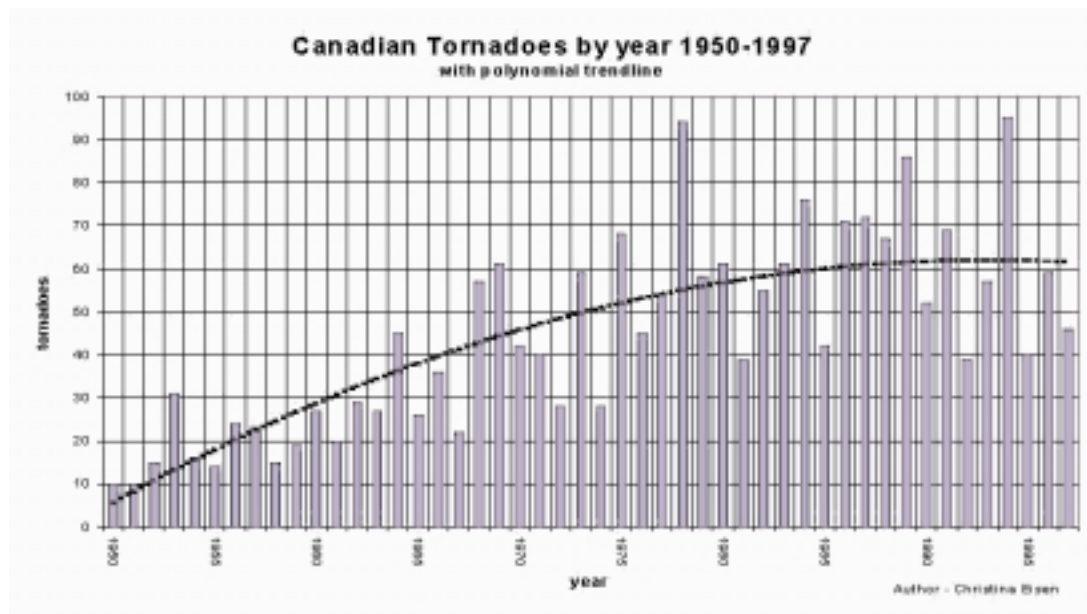
Scatter Plot and “Line of Best Fit” for a Linear Model



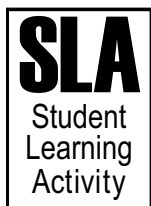
Linear Model for Years 1900–2000 Canada



Histogram with “Polynomial Best Fit”*



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Canadian Tornado Frequency Data— A Consumer Mathematics (20S) Approach

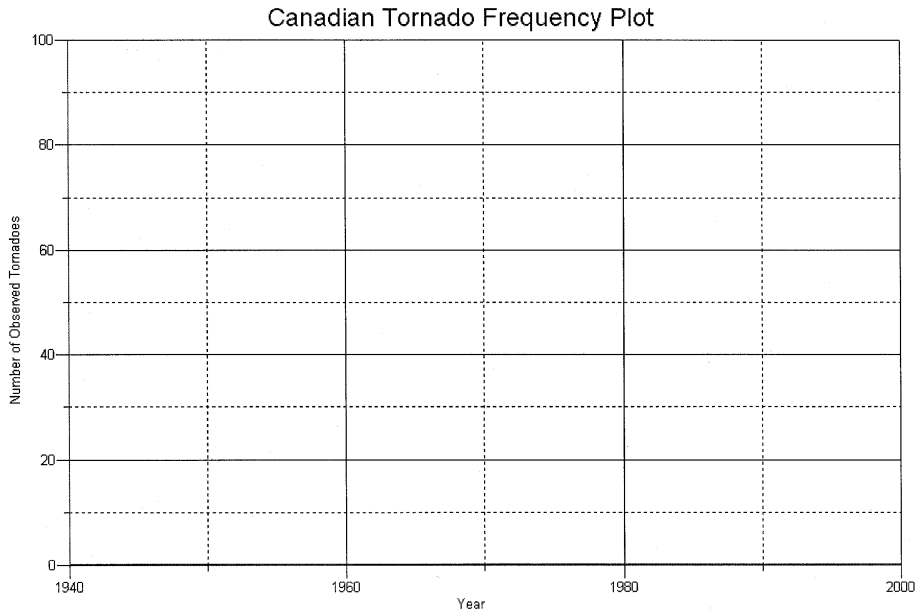
The Data*

Year	Number of Recorded Tornadoes in Canada	Year	Number of Recorded Tornadoes in Canada
1950	10	1974	28
1951	10	1975	68
1952	15	1976	45
1953	31	1977	54
1954	16	1978	95
1955	14	1979	58
1956	23	1980	61
1957	22	1981	39
1958	15	1982	55
1959	19	1983	61
1960	27	1984	76
1961	20	1985	42
1962	29	1986	71
1963	27	1987	72
1964	45	1988	68
1965	26	1989	86
1966	36	1990	52
1967	22	1991	69
1968	58	1992	39
1969	61	1993	57
1970	42	1994	96
1971	40	1995	40
1972	28	1996	59
1973	59	1997	46

Working with the Data

1. The table of data represents an approximately 50-year baseline of tornado sightings that are considered reliable. The data come from every region of Canada where tornado funnel clouds have been spotted.
2. Load these data into a spreadsheet program of your choice, a graphics calculator, or a plotting program such as *Curve Expert*[®] or *Graphical Analysis*[™].
3. Produce a scatter plot of the data, paying attention to the axes on which the independent and dependent variables should be placed.
4. As an alternative, use plotting technology to produce a histogram (vertical bar graph) of the same data.
5. On the grid below, reproduce a rough sketch of the scatter plot by plotting one point every 10 years. Label the axes, and comment briefly on any patterns that appear in the data plot (e.g., are there any unusual years of many tornadoes?)
6. Now, plot a detailed scatter plot, using technology.

* Data reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.



Comments on the Appearance of the Scatter Plot:

- _____

- _____

- _____

6. Construct a **LINE** that passes through the middle of most of the points on your plot.

- Have you chosen to draw a **straight line** or a **curved line** through your data points? Write a statement to explain why you chose your particular line type.

7. Do the points indicate any of the following conclusions? Explain briefly why you think the following statements either apply to the data or why they are false.

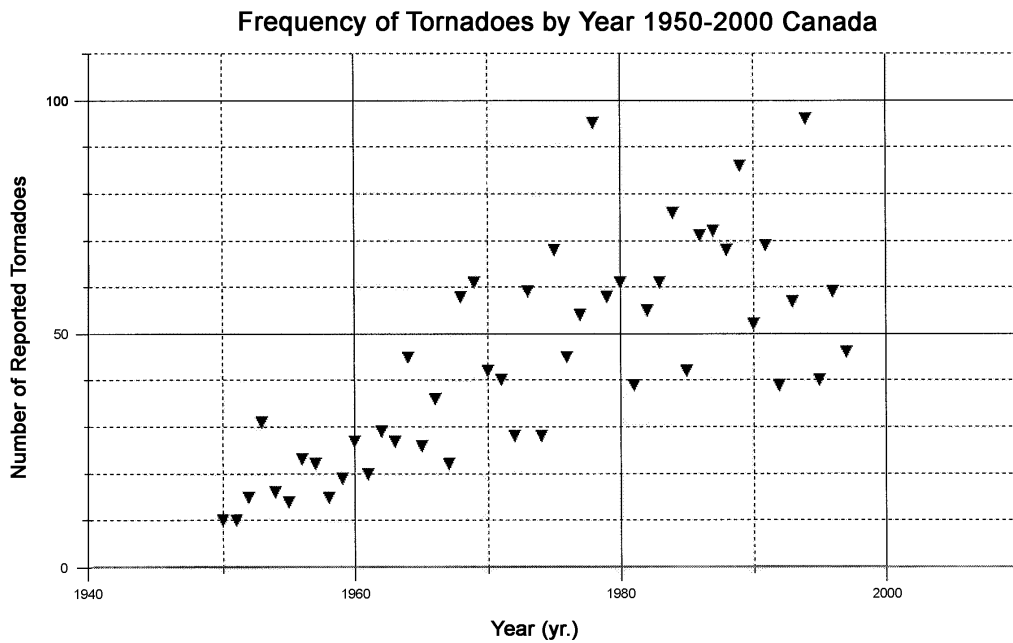
- The number of tornadoes is increasing every year in Canada.

- The number of tornadoes **sighted** in Canada each year is increasing.

- New technologies for detecting tornadoes in Canada are allowing more and more to be sighted each year.

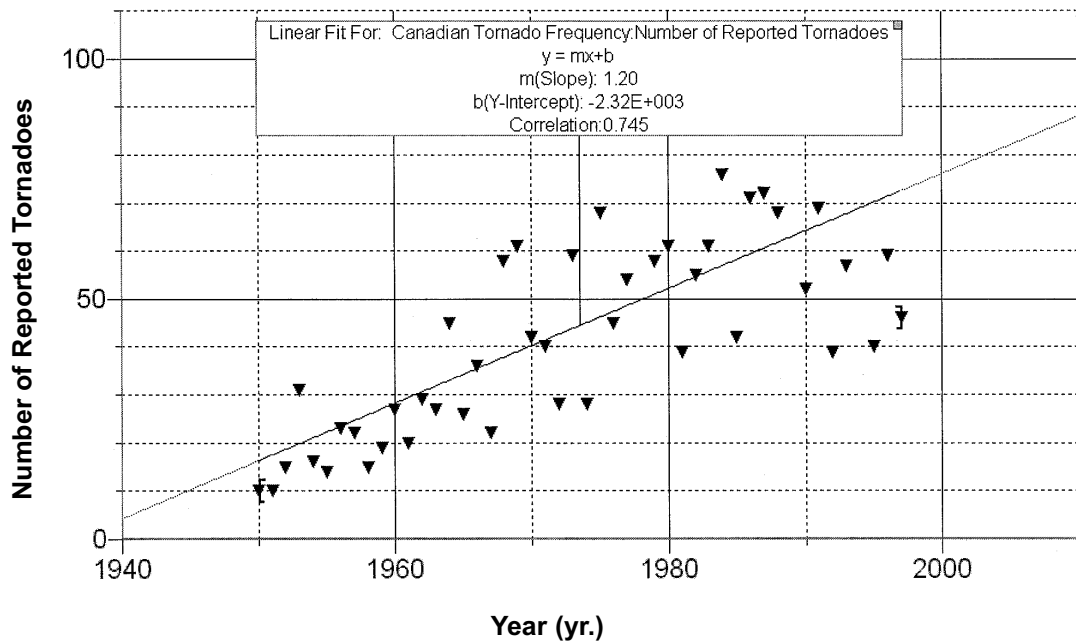
Some Possible Plots

Scatter Plot

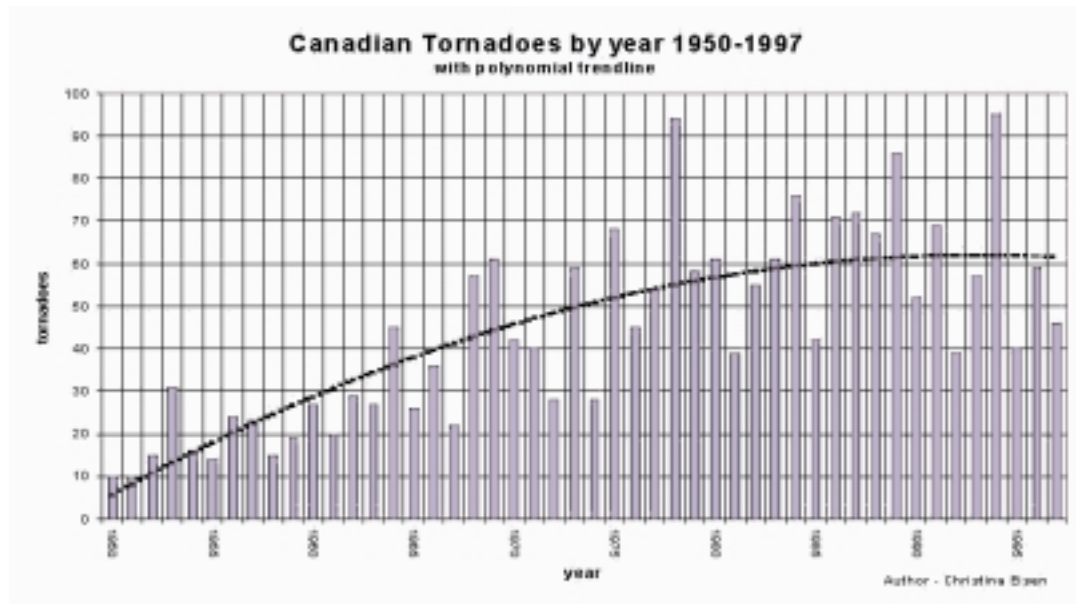


Scatter Plot and “Line of Best Fit” for a Straight Line

Frequency of Tornadoes by Year 1950–2000 Canada



Bar Graph (Histogram) with a Curved Line of Best Fit*



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8. Using the histogram appearing above, determine the following:

- In what two years were there more than 90 tornadoes?
- How many tornadoes were sighted in the year you were born?

Year: _____ Number of Tornadoes: _____

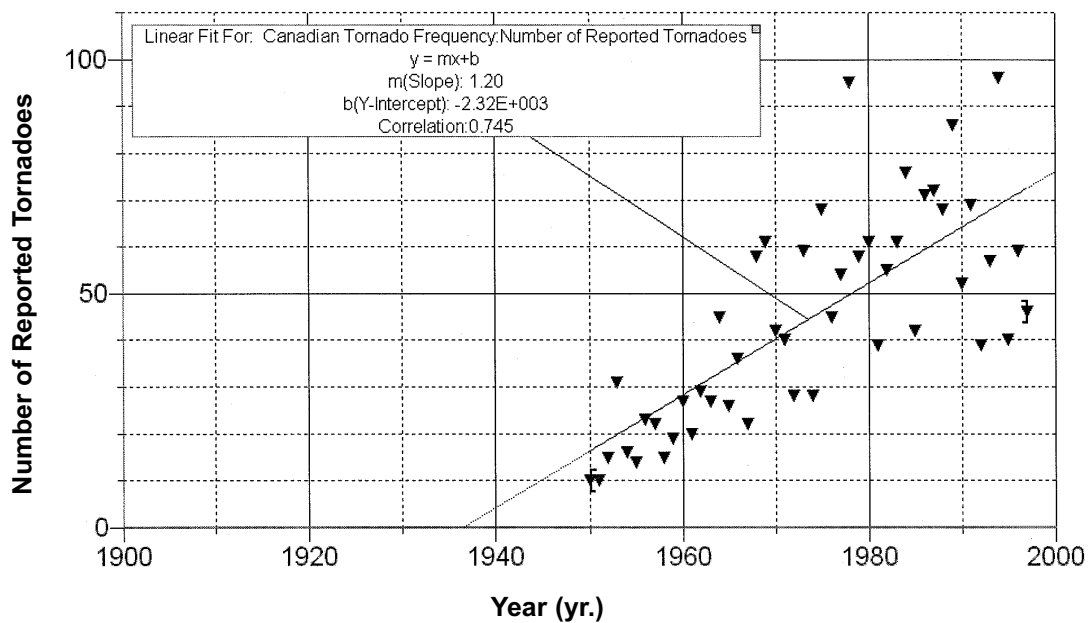
- For what years is the curved line exactly predicting the number of tornadoes that were observed?

- Which time span contains the higher probability that a tornado will occur in Canada?

1965–1975? 1975–1985? 1985–1995?

- What possible biases could occur in these data to give a misleading picture of what is taking place?

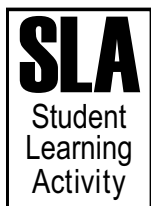
Linear Model for Years 1900–2000 Canada



9. The above plot is using a “best fit” line that is a straight line. In comparing this to an earlier plot, what effect does extending the timeline to 1900–2050 have on the story?

10. The plot appearing above in #8 uses what we call a **linear** (straight line) of “best fit.” If the line is actually predicting what is happening with Canadian severe storms (such as tornadoes), does it make sense?

For example, according to the line, how many tornadoes would you have expected in the year 1945?



Canadian Tornado Frequency Data— A Pre-Calculus (20S) Approach

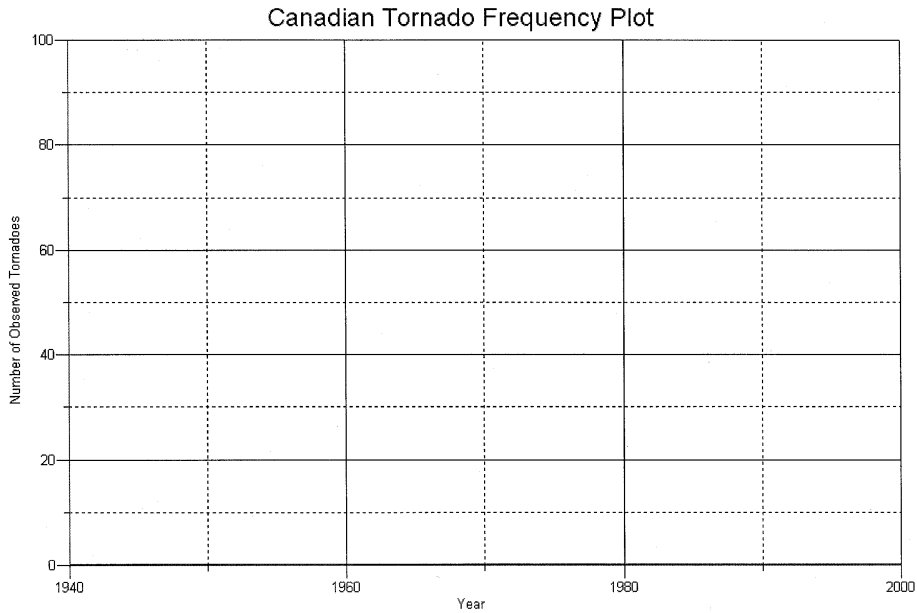
The Data*

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Working with the Data

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2. Load these data into a spreadsheet program of your choice, a graphics calculator, or a plotting program such as *Curve Expert*® or *Graphical Analysis*™.
3. Produce a scatter plot of the data, paying attention to the axes on which the independent and dependent variables should be placed.
4. As an alternative, use plotting technology to produce a histogram (vertical bar graph) of the same data.
5. On the grid below, reproduce a rough sketch of the scatter plot, label the axes, and comment briefly on any patterns that appear in the data plot (e.g., are there any unusual years of many tornadoes?). Plot one point for every five years.

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Comments on the Appearance of the Scatter Plot:

- _____

- _____

- _____

6. Using your graphics calculator or plotting software, produce the **linear regression** (least squares line of best fit) for the data, and record the following (to two decimal places):

a. Equation of the line in the form $y = mx + b$ and $Ax + By = C$

b. Determine the value of the **slope** using the values of “A” and “B,” and then compare with the value given by technology:

- c. Determine the slope directly from the line of best fit, using the following definition, and compare to earlier results in (a) and (b). What rate of change does the slope represent?

$$m = \Delta y / \Delta x$$

- d. Using your slope from part (c) above, and one point from the data, write an equation in **standard form** for the line of best fit, using the **point-slope** method. Compare results with those in part (a).

$$y - y_1 = m(x - x_1)$$

- e. Using **function notation**, rewrite the equation of the line of best fit, with “N(t)” and “t” as your variables

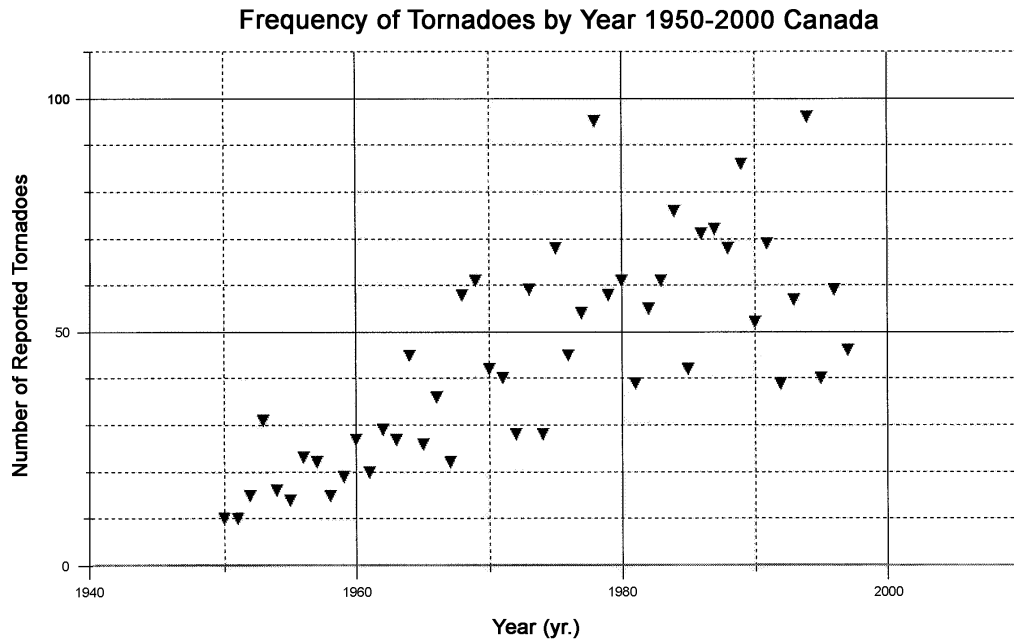
- f. According to your model, how many tornadoes can we expect in the year 2050?

$$N(2050) = \underline{\hspace{2cm}}$$

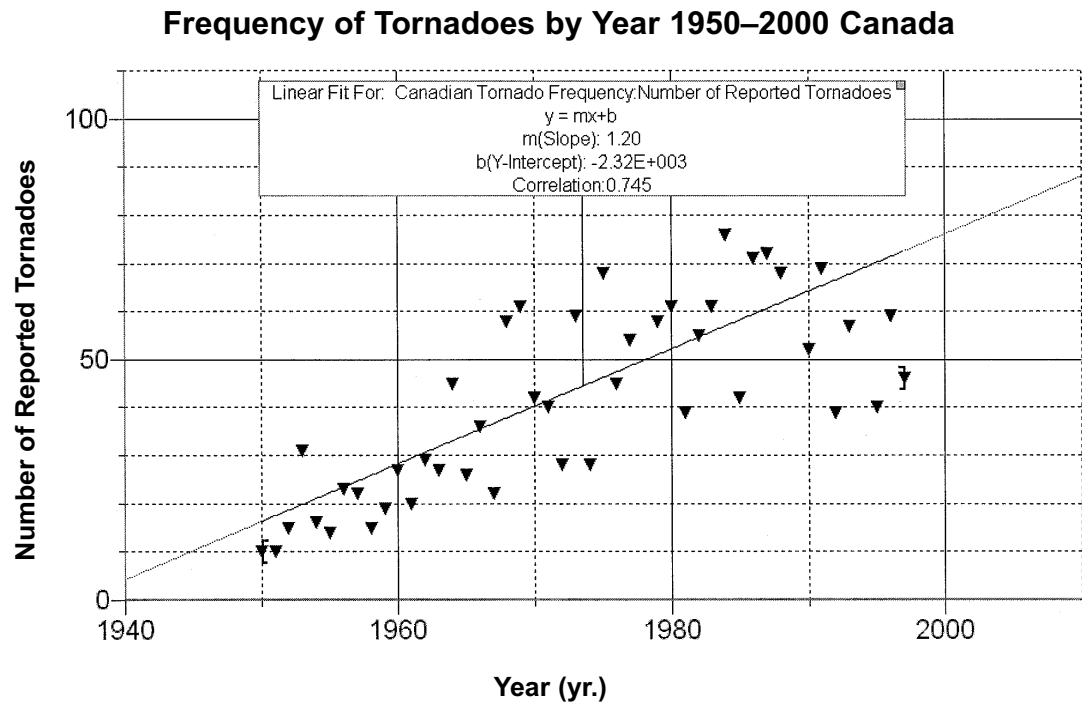
Is this a realistic projection into Canada’s severe weather future? How far back in time does your model indicate no Canadian tornadoes (e.g., for what value of “t” does $N(t) = 0$)?

Some Possible Plots

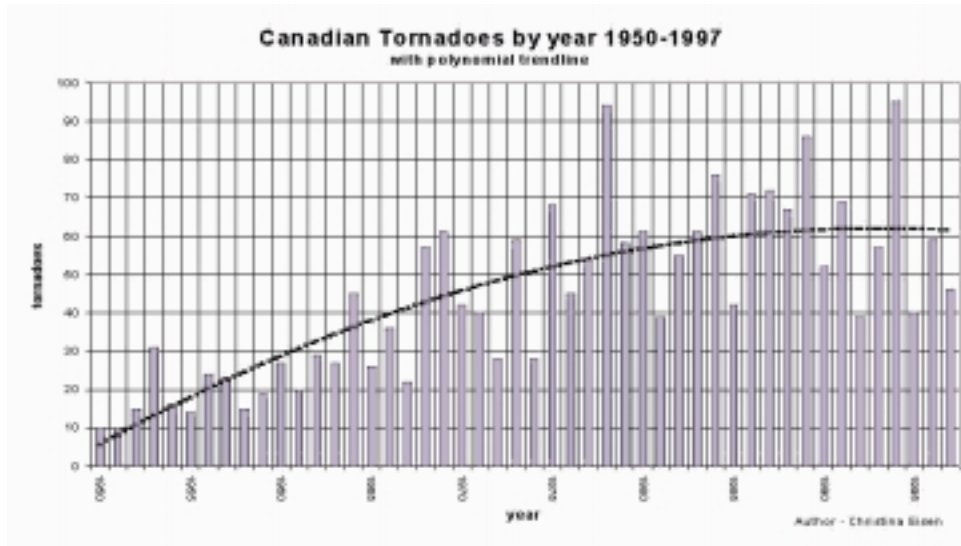
Scatter Plot



Scatter Plot and “Line of Best Fit” for a Straight Line



Histogram with “Polynomial Best Fit”*



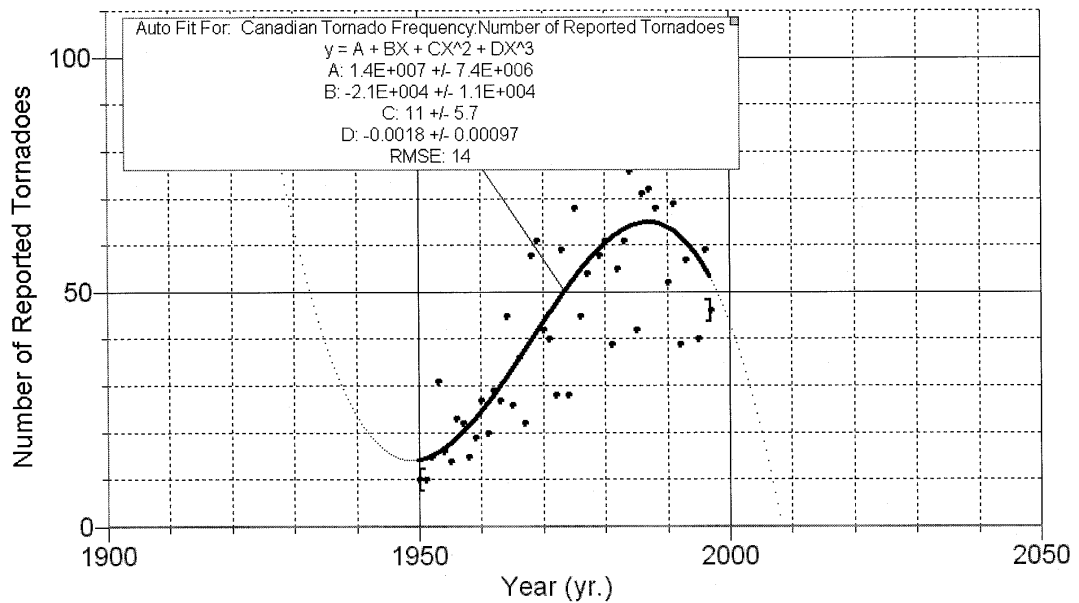
g. Using the histogram appearing above, determine the following:

- For what two years does $N(t) = 55$? _____ & _____
- For what year(s) does $N(t) = 95$? _____ & _____
- What are the values of: $N(1950)$ _____ $N(1980)$ _____
- Which time span contains the greater probability that a tornado will occur in Canada?
 1965–1975? 1975–1985? 1985–1995?
- What possible **biases** could occur in these data to give a misleading picture of what is taking place?

7. The following plot is using a “best fit” line that is a polynomial function. In comparing this to earlier plots, what effect does extending the **domain** and **range** beyond the 1950–1997 data have on how the past and future of Canadian tornadoes is interpreted?

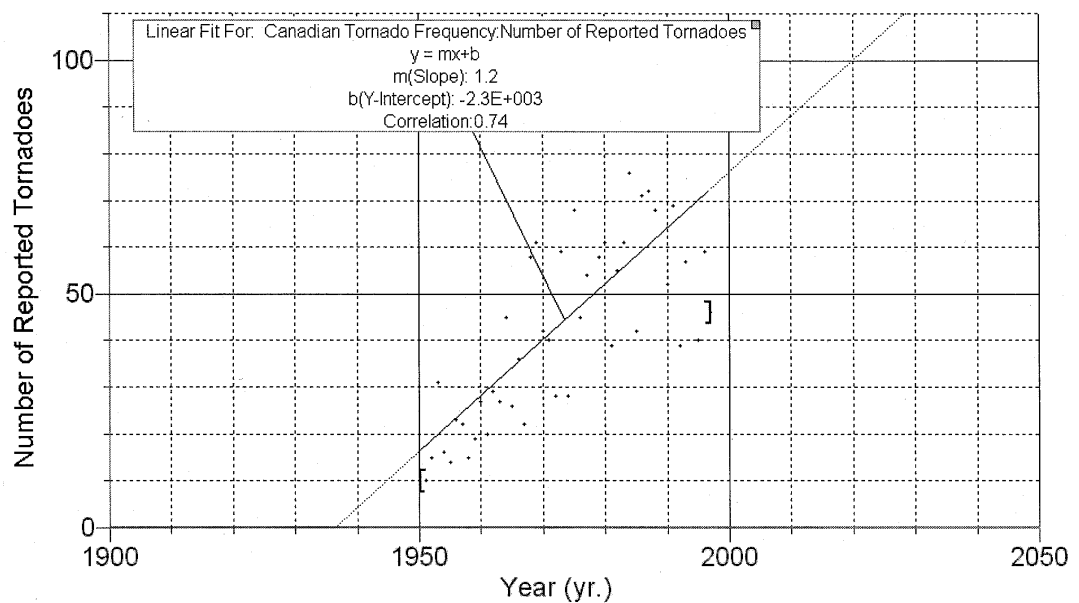
* Graphic reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.

Polynomial Model for Years 1950–2050 Canada



8. The plot appearing below uses a **linear** “best fit.” Does this graph suffer the same potential faults as the previous example? Explain in detail.

Linear Model for Years 1950–2050 Canada





Watch Out! There May Be a Tornado in Your Backyard!!

A **histogram** showing tornado frequency by province provides the information students need to define tornado risk regions. Because the average number of tornadoes changes gradually from one province to another, the decision on where to draw the outline of each of the regions is more subjective than what students may prefer. The intent of the activity is to initially encourage students to provide a “rough sketch” based on their own interpretations of the data.

Teacher Notes

Provide each student with a copy of the Tornado Plotting Map of Canada, found at the end of this activity.

Expectations

Students will

- Use or construct a wide variety of graphs, charts, diagrams, maps, and models to organize information
- Demonstrate an understanding of the regions theme as applied to tornadic activity frequency in Canada
- Identify and describe regions where natural hazards such as tornadoes exist

Assessment

- Formative self-assessment of the final map (see Appendix 6.9; Rubric for Map Drawing).
- Formative assessment by teacher of the explanation of the method used in drawing up the three regions (see Appendix 6.6: Assessing Region Explanations).

Teaching/Learning Strategies

1. Using the Tornado Plotting Map of Canada, and the Canadian Tornado Distribution Graph, students outline three regions on the blank map of Canada according to tornado risk. Teachers may wish to include the density map of Canadian tornadoes for student use, or clip it off for later discussion and/or assessment of student results. The three regions could be colour coded.
 - 1 — high risk of tornadoes*
 - 2 — moderate risk of tornadoes*
 - 3 — little or no risk of tornadoes*
2. Students describe the method used to outline their regions (how they went about drawing the lines on their map).
3. Display the maps to enable students to see the similarities and differences from one map to another.

4. Conduct a general discussion on why all the maps are not exactly the same and whether or not this is what should have happened (i.e., as long as each region has a similar range of tornadoes throughout and is different from the other two regions, then it is acceptable that slightly different interpretations could result).
5. Point out the position of Manitoba (or the student's province of origin, if applicable) within the tornado regions of Canada, and ask if any students have had personal experiences with, or seen, an actual tornado or the damage one can cause.

Modifications/Expanded Opportunities

- Vary this activity by using a variety of natural phenomena (cyclonic storms, storm tracks, forest fires, severe weather-related events) or human phenomena connected to severe natural events (such as population density, income per person) that are shown using dot maps or maps similar to the one showing tornadoes. It is important to emphasize STSE connections where climate and weather phenomena are in operation.
- Students with advanced mathematical or algorithmic experiences (such as computer modeling, use of mapping or GIS software systems) may wish to approach the data representation in a more symbolic manner.
- Use the datasets to plot histograms, scatter plots, or frequency distributions. Presentation of graphs from manual drawing, spreadsheet applications, and graphics calculators are to be encouraged where mathematics development makes this feasible. Sample graphs are included in the teacher version of this activity for reference.

Resources

- Tornado Plotting Map of Canada
- Atlas, particularly the world or regional distribution maps of physical and human activities that are often found in the front or back sections, or within the regional sections of the atlas
- Textbooks with maps of this type
- Internet information from tornado sites (e.g., The Tornado Project at <www.tornadoproject.com/index.html>)
- Data sets found in this activity: Canadian Tornado Occurrence (Table 1) and Canadian Tornado Distribution by Province/Region 1950–1997 (Table 2)

Activity Data Sets***Table 1: Canadian Tornado Occurrence as Percentage by Month (30-year avg.)**

Month	Percent of Total Annual Tornadoes Occurring
January	0.5%
February	0.4%
March	0.4%
April	2.2%
May	11.0%
June	32.5%
July	30.8%
August	14.0%
September	6.0%
October	2.0%
November	0.2%
December	0.0%

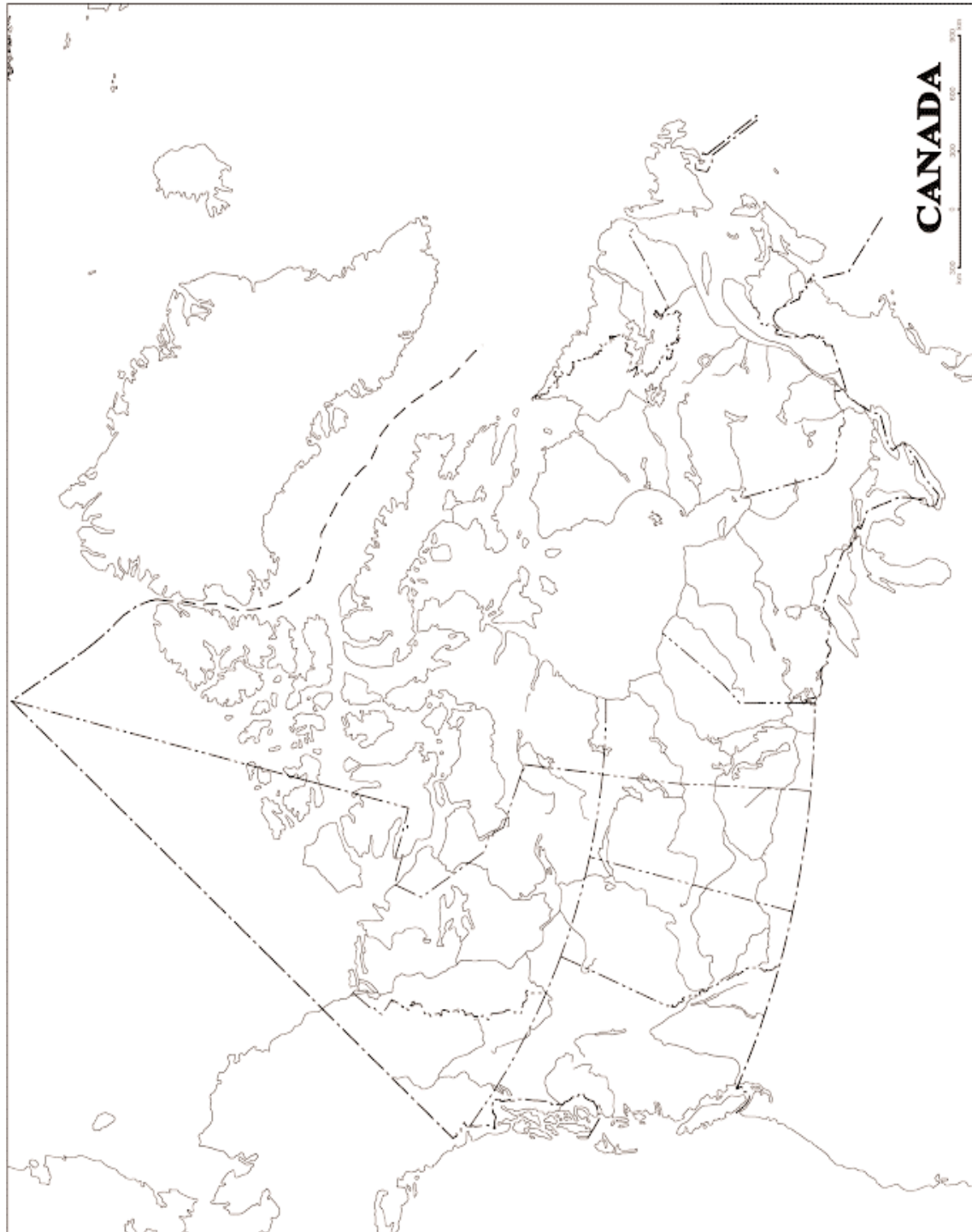
Table 2: Canadian Tornado Distribution by Province/Region 1950–1997

Province/Region	Percentage of Annual Tornadic Activity
Interior British Columbia	1.4%
Alberta	23.1%
Saskatchewan	22.4%
Manitoba	13.2%
Central/Southern Ontario	31.9%
Quebec	6.6%
Maritimes/Newfoundland and Labrador	1.5%

* Reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.



Tornado Plotting Map of Canada*

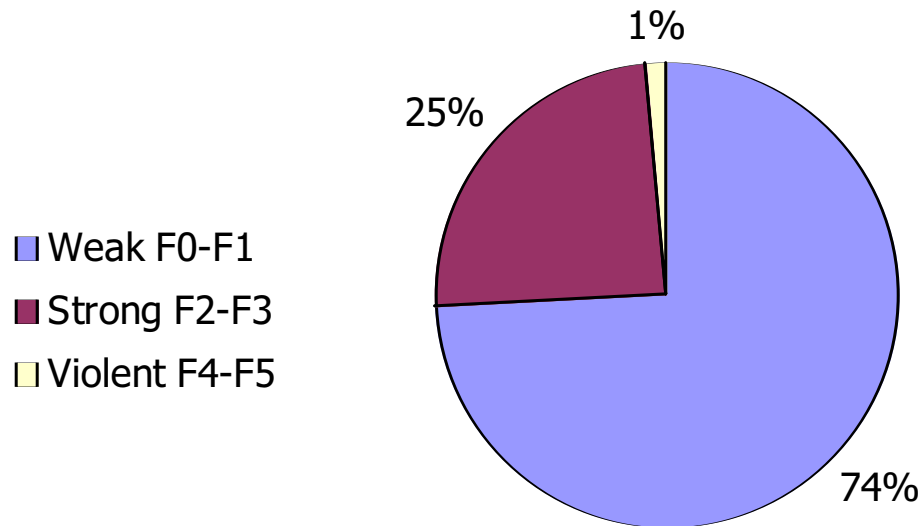


* Graphic reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.

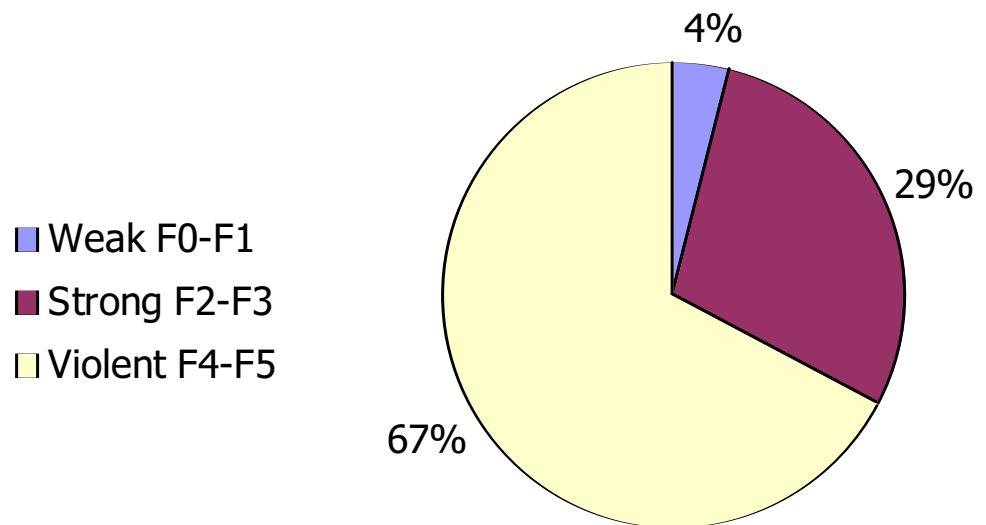


Tornado-Related Statistics and Graphing*

Percentage of All Tornadoes 1950–1994
by Fugita Scale Class



Percentage of Tornado-Related Deaths 1950–1994
by Fugita Scale Class



* Data from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Used with permission.

Table 1: Tornado Funnel Cloud Dimensions and the Fujita Intensity Scale

F Scale Intensity	Length of Tornado Path (km)	Width of Funnel Cloud (km)	Area Covered by Ground Contact (km ²)	Average Wind Speeds (kph)
0	1.77	0.04	0.08	90
1	4.18	0.10	0.36	149
2	9.14	0.15	1.40	217
3	19.49	0.27	5.17	293
4	36.16	0.40	14.29	375

Working with the Data

1. Plot a graph of LENGTH OF TORNADO PATH versus F SCALE INTENSITY.
2. Plot a graph of WIDTH OF FUNNEL CLOUD versus F SCALE INTENSITY.
3. Plot a graph of AREA versus F SCALE INTENSITY.
4. Plot a graph of LENGTH OF TORNADO PATH versus WIDTH OF FUNNEL CLOUD.
5. Plot a graph of AREA OF GROUND CONTACT versus (LENGTH x WIDTH). What do you notice?
6. Plot a graph of AVERAGE WIND SPEEDS versus F SCALE INTENSITY.

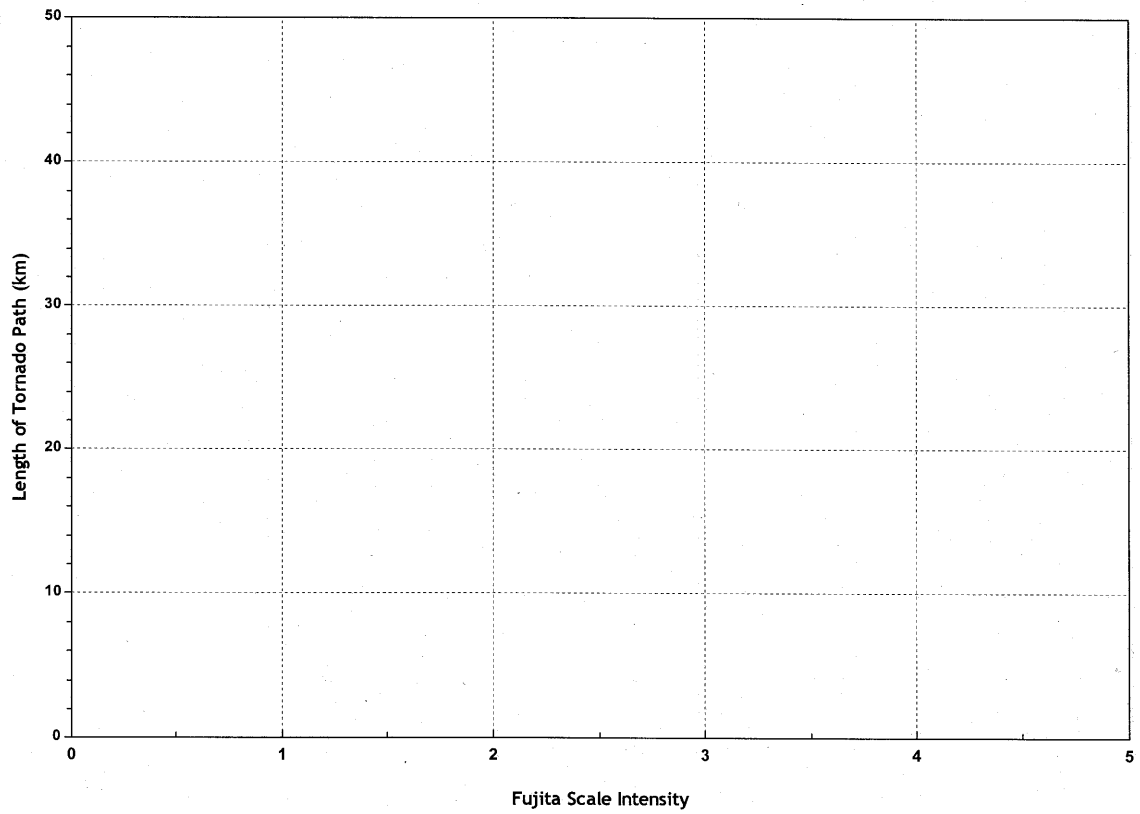
Follow-up Questions

1. Of the six (6) plots that you have completed, which of the relationships seem to be LINEAR (the points form an almost straight line)?
2. Of the graphs that were plotted, are there any that are curved?
3. Could there be a mathematical explanation for why Graph #3 (Area of Funnel Cloud versus Fujita Intensity) curves in the manner that it does? Hint: Think about exponents.
4. By looking at your last graph—Graph #6 (Average Tornado Speeds versus Fujita Intensity Scale), is the Fujita Tornado Intensity Scale a LINEAR SCALE? Justify your answer with some evidence.

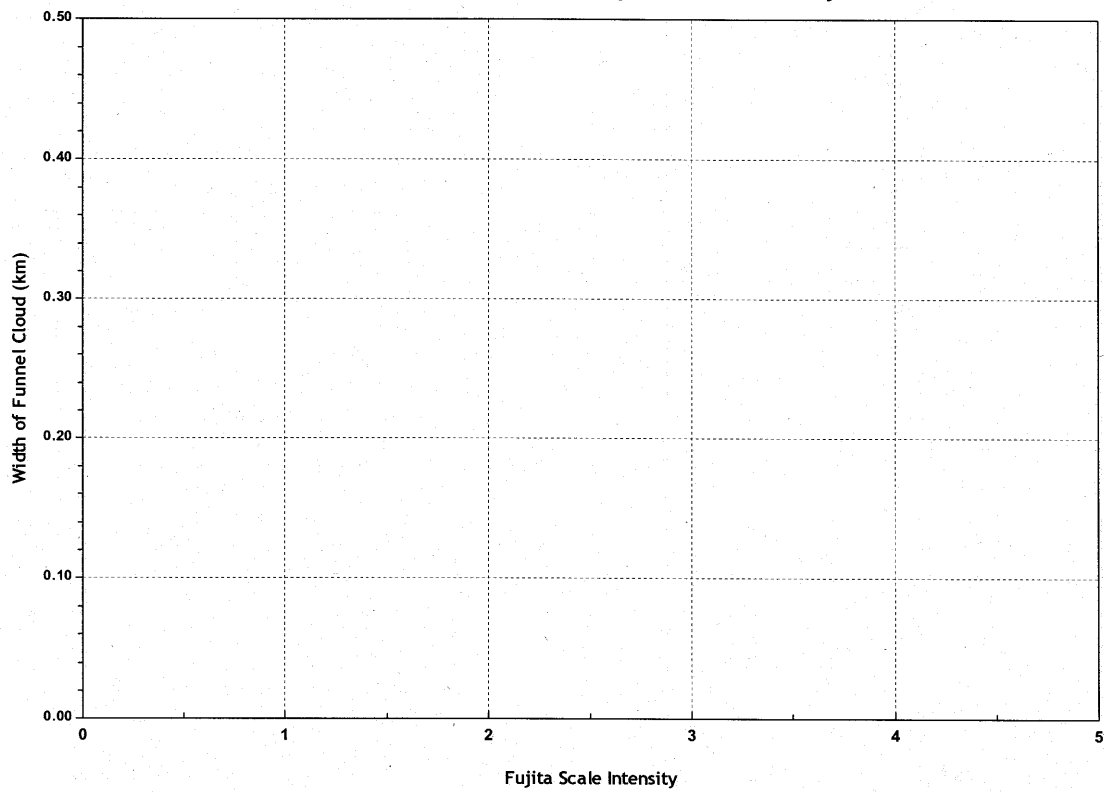
If a tornado was an F5, what would be the average wind speeds be?

_____ kph

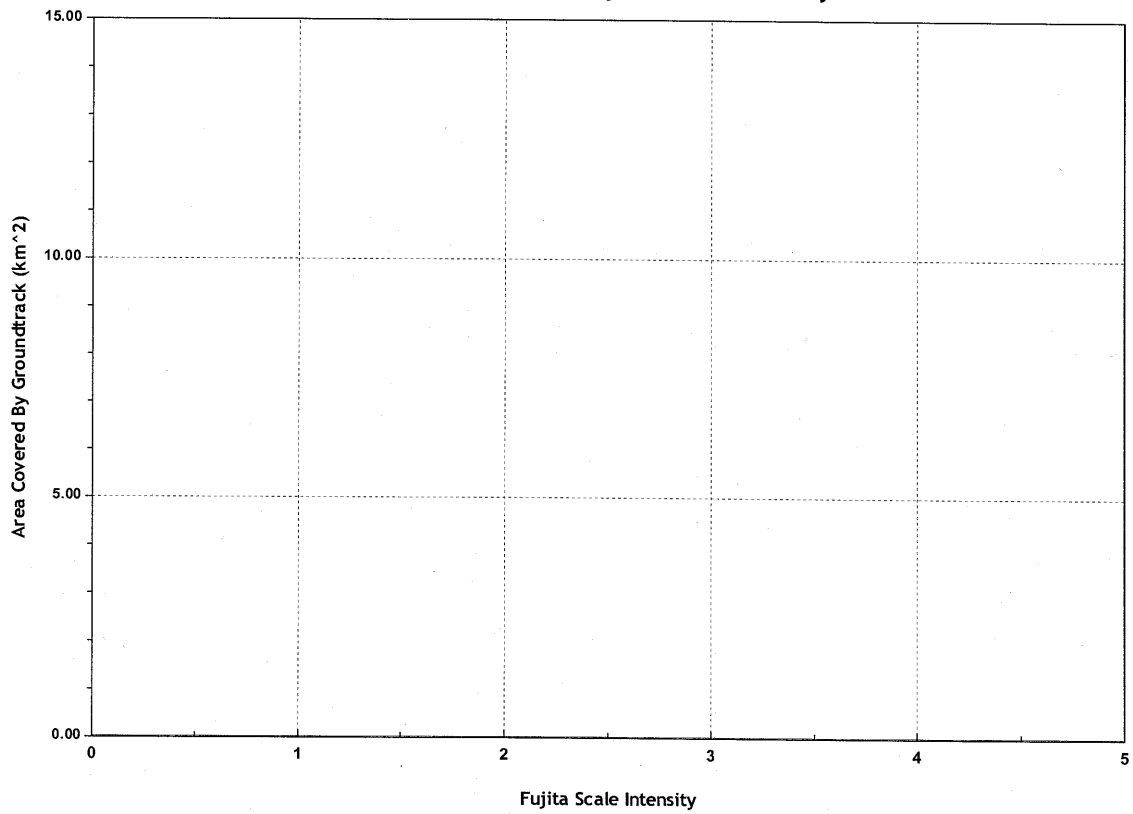
Length of Tornado Path vs. Fujita Scale Intensity



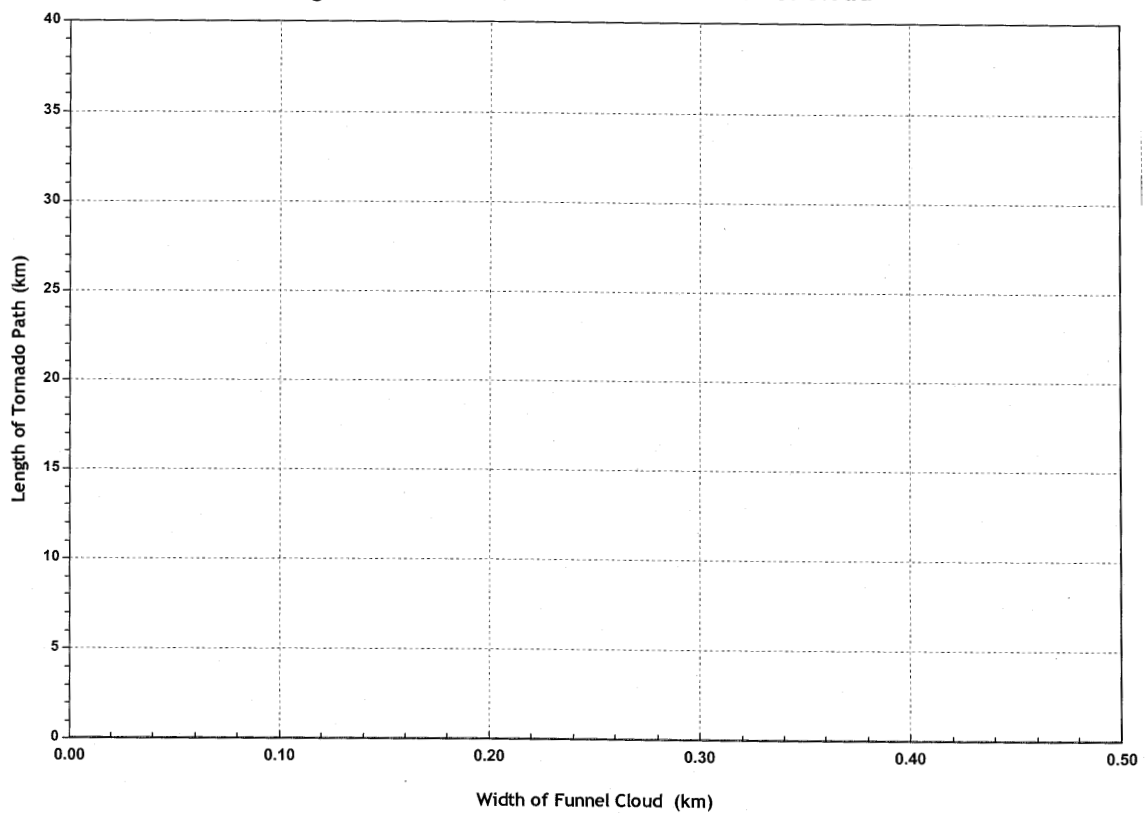
Width of Funnel Cloud vs. Fujita Scale Intensity

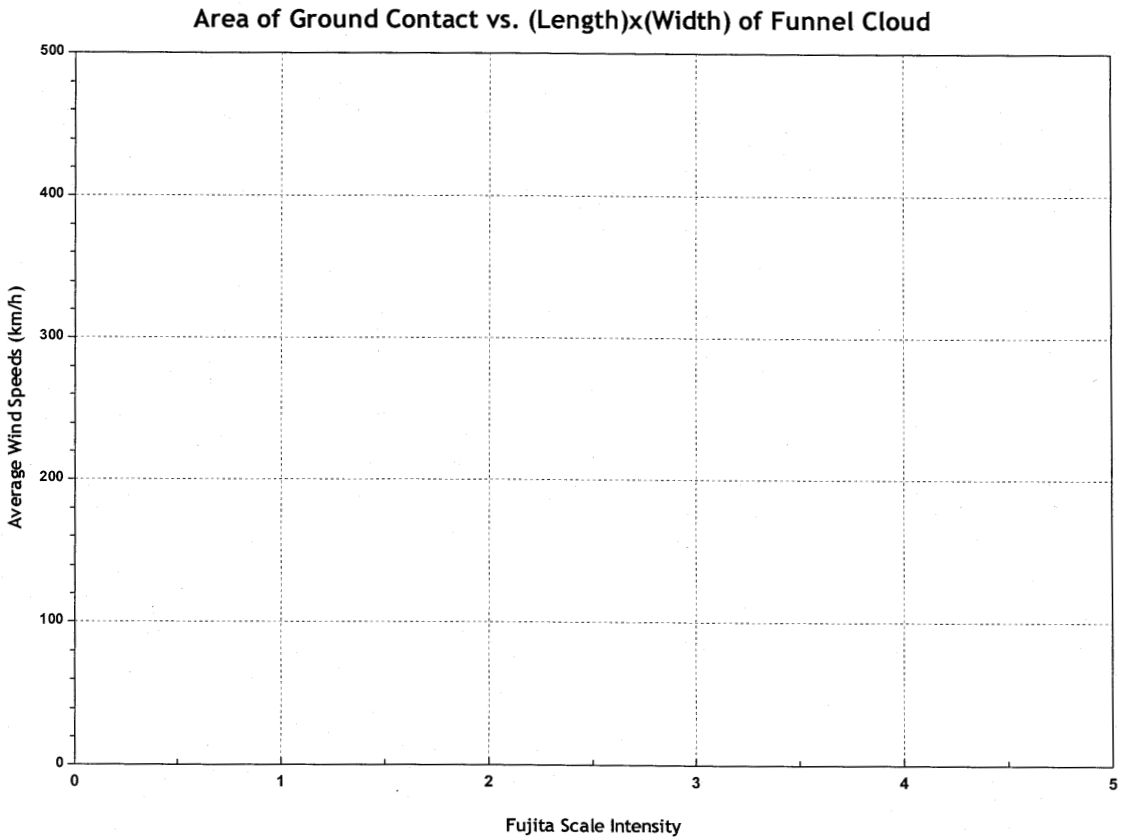
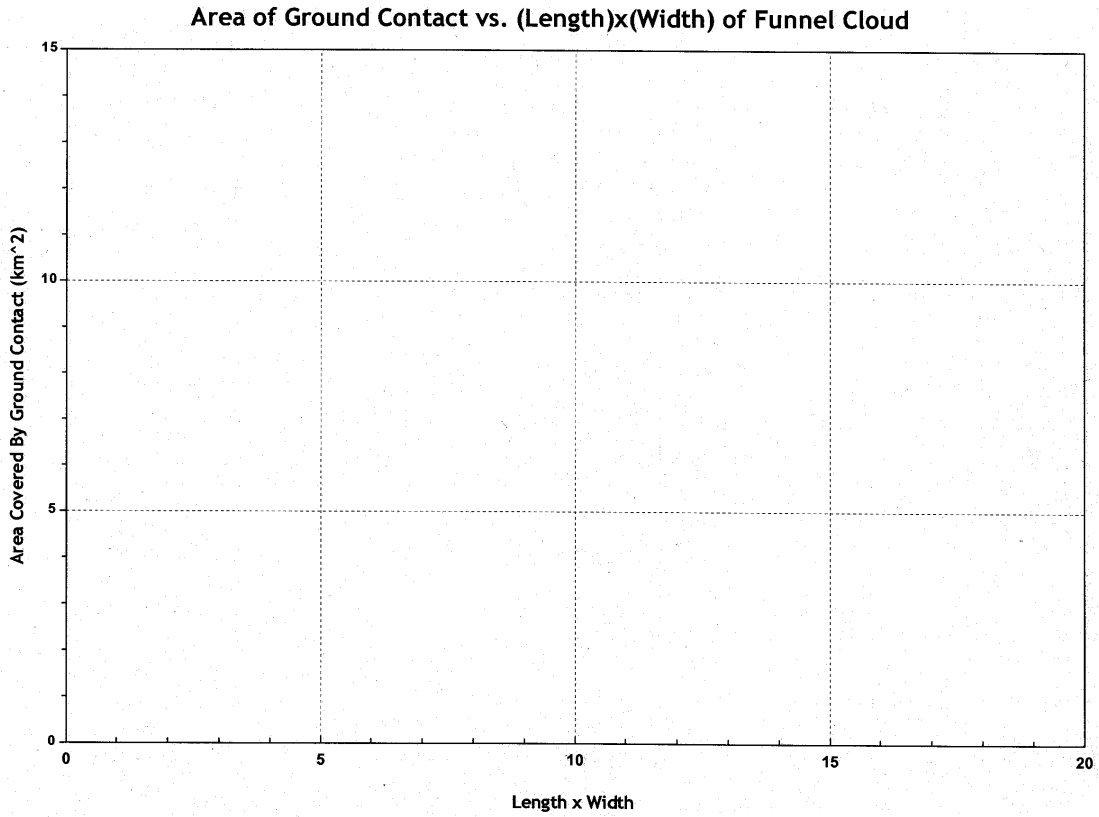


Groundtrack Area vs. Fujita Scale Intensity



Length of Tornado Path vs. Width of Funnel Cloud







Location/Place—Where in the World Can Severe Storm Events Happen?

Students first map and describe the locations of sports or other events of interest to them and explain why the organizers decided on these locations to stage such events. Students then research a weather-related natural disaster of their choice and prepare a TV news report to explain where they expect such a disaster to strike in the future.

Teacher Note

Book time in the library/resource centre for student research on the locations of sports or other events and then natural disasters. If the Internet is to be used, bookmark useful sites (see suggestions in the Resources section below). Students may bring in any magazines or other sources of information on these topics. If CD-ROMs on natural disasters are available in the school, have them on hand for students to use. Atlases and textbooks with information on natural weather disasters should be available to each group of students. Designate two or three students per class as evaluators for oral presentations. The remaining students are part of the audience listening to the presentations. Provide students with copies of Appendix 6.8: Rubric for Map Drawing, and Appendix 6.10: Rubric for Student Presentation.

Expectations

Students will

- Demonstrate an understanding of the location/place theme in geographic inquiry
- Locate relevant information from a variety of primary and secondary sources
- Analyze, synthesize, and evaluate data
- Construct a wide variety of graphs, charts, diagrams, maps, and models to organize information
- Communicate the results of inquiries, stating different points of view on an issue, using media works, oral presentations, written notes, descriptions, drawings, tables, charts, and graphs
- Produce a report on current environmental events (weather-related) in the news

Assessment

- Formative assessment by teacher of student ability to locate relevant information from primary and secondary sources, and to analyze, synthesize, and evaluate data (Appendix 6.10: Rubric for Research Skills)
- Formative self-assessment of the map produced in Appendix 6.9: Rubric for Map Drawing
- Peer assessment of the oral presentations from Appendix 6.8: Rubric for Student Presentation
- Formative assessment by teacher of the oral presentation for accuracy in describing the place/location of the natural event, using absolute and relative locations, valid reasons for their predictions, the accuracy of their location map and graphics, and their decision-making steps (see Appendix 6.3: Rubric for the Assessment of a Decision-Making Process Activity and Appendix 6.9: Rubric for Map Drawing)

Teaching/Learning Strategies

1. In groups of two to four, students map the locations of at least three to four events of interest to them on a world map (see Appendix 4.12). Suggestions include the sites of the Winter Olympic Games, World Cup Soccer finals, the Summer Olympics, various entertainment award ceremonies (such as the Oscars, Junos, or Golden Globes), or the performance sites of their favourite music group(s). Their research could be done in the library/resource centre, on the Internet, magazines and books on the topic, or with their own resources at home. Students look for ideas on why these locations/places were chosen for such sites. What unique characteristics did they have? How did their absolute or relative locations influence people to choose them over others?
2. Before students start their research on this activity, outline the features that make an effective and complete map by reviewing with the class Appendix 6.9: Rubric for Map Drawing.
3. Upon completing their research, students draw their maps, describe where their chosen activity occurred in the world in both absolute and relative terms, and suggest what unique features might have been considered in choosing such places.
4. Review Appendix 6.8: Rubric for Student Presentation so students know how they will be evaluated.
5. Each group makes a brief oral presentation to the class, describing the place(s) or location(s) for their event(s) and their explanation(s) for the choice of these locations.
6. Collect, assess, and evaluate the maps and reasons for the choices of locations of the researched event(s).

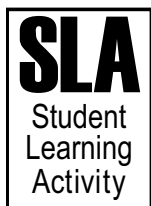
7. Groups of two to four students choose to research one of the following natural weather-related events that interests them most (or they are chosen “out of a hat”).
 - hurricane
 - earthquake
 - blizzard
 - tornado
 - avalanche
 - volcanic eruption
 - forest fire (lightning-caused)
 - ice storm
 - waterspouts over Lake Winnipegosis
 - or other natural event
8. Using an atlas, Internet sites, or textbooks, students find out where their type of event has occurred most frequently in the past and mark this information on a map of the world, or one of the continents. You may wish to restrict the area of research to one continent rather than the whole world. Students would then decide which continent to use to map their event.
9. After the research is completed, review the criteria that will be used to assess a five-minute TV news report using a TV news report rubric generated by the class with teacher assistance (see Appendix 5 for details).
10. Each group prepares a five-minute TV news report on their event describing the place/location (absolute and relative) where it is most likely to occur in the future. They include valid reasons for their prediction, backed up by a map, graphics, and a three- to four-step diagram outlining the steps used in reaching their conclusion (the decision-making model could be used as a guide).
11. Each group presents its five-minute report to the class.
12. Students peer-assess the map, showing the areas where the chosen natural disaster often occurs and the place/location predicted for a similar disaster.
13. Assess the research skills using Appendix 6.10: Rubric for Research Skills, and the content of the oral presentation, using the class-generated TV news report rubric.

Extension Ideas

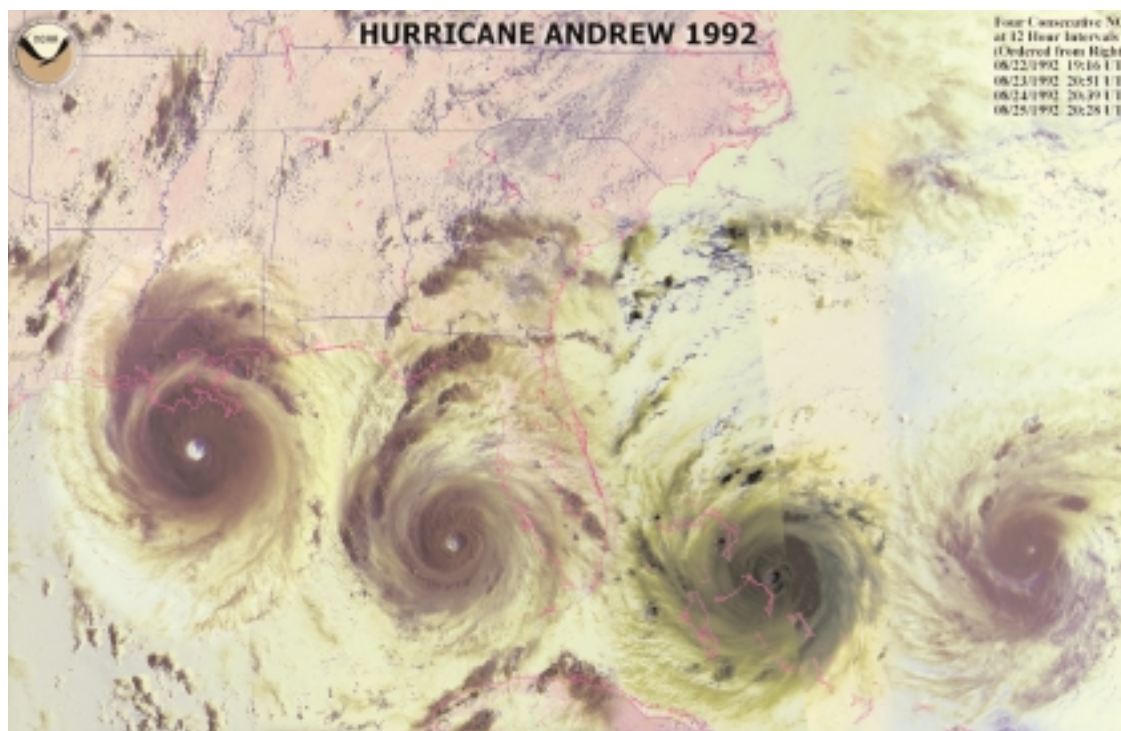
- Provide the sites of various types of events or have students do research in the classroom, library/resource centre, or at home. Depending on the level of group skills of the students, this activity might be done individually, rather than in groups.
- A less challenging variation: provide the locations of the events for mapping. In small groups, students then discuss the reasons for choosing such places or locations. Groups share ideas in a whole-class discussion session. Summarize ideas into a note for students.
- Show a portion of a live newscast (such as CBC Newsworld or CNN) as a model of what is expected in this activity. Try <www.cbc.ca> for streaming news video.
- Have students produce a poster or display board to present their findings instead of the TV news report.
- Students prepare maps of locations using computer mapping, paint/draw programs, or storm-tracking software.

Resources

- World Outline Map or Globe Map (see Appendices 4.11-4.15)
- Access to library/resource centre, atlases, magazines and encyclopedias, home materials
- Internet browser software or the special sections devoted to severe weather events found at the Lycos, AltaVista, Infoseek, and Excite search sites
- Internet sites for volcanoes, earthquakes, cyclones, hurricanes, tornadoes, thunderstorms, and related natural weather-related events suggested in the pre-planning section of this unit
- Local newspaper articles or maps that identify significant natural events (past copies of maps can be found on the Internet at <www.earthweek.com> or its new address at <www.discovery.com/news/earthalert/earthalert.html>, or at the NASA Earth Observatory site at <<http://earthobservatory.nasa.gov>>)
- Textbooks on physical geography written for this level (Senior Years)



Tracking a Killer Hurricane*



The Background

On August 16, 1992, Hurricane Andrew first became a tropical depression. On August 17, it became the first tropical storm of the season. The storm moved rapidly west and northwest during the next few days and on August 22 it had reached hurricane strength. Landfall was made in southern Florida on August 24th at approximately 5:00 a.m. Having become a Category 4 storm, the central pressure fell to 922 millibars (92.2 kPa) and wind gusts were estimated in excess of 280 kph (175 mph). Andrew moved west at 29 kph (18 mph).

Once over the open waters of the Gulf of Mexico, a moderate intensification ensued as the storm turned northwestward. August 26, Andrew made landfall again, this time in south central Louisiana, with a central pressure of 956 millibars (95.6 kPa) and sustained winds approaching 190 kph (120 mph). The hurricane quickly weakened and became a depression 24 hours later, as it was turned sharply northeastward and merged with a frontal system over the eastern United States.

When all was said and done, Andrew was by far the most expensive natural disaster in history (up to that date), with estimated damages exceeding \$20 billion. More than 60 people were killed and approximately 2 million people were evacuated from their homes.

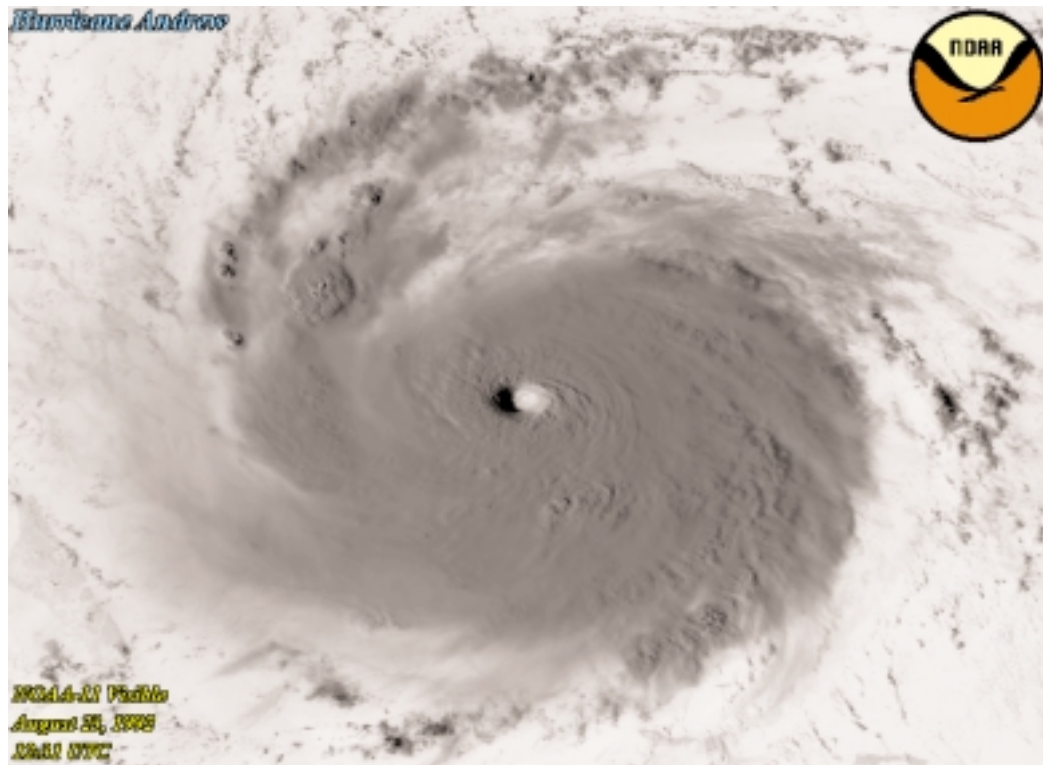
* Satellite image courtesy of NOAA. All rights reserved.

Procedure for the Activity

- Observe the location of Hurricane Andrew on a set of satellite images that can be used with this activity. Download from <<http://lwf.ncdc.noaa.gov/servlets/GoesBrowser>>.
- Using the *Hurricane Tracking Map* provided in Appendix 4.26b, carefully plot the location of Hurricane Andrew as it approaches landfall in Florida. Create an appropriate symbol for the storm, and be consistent in its use. The chart below should provide information on location and the time for each plot. Plot 12 points on the tracking chart—one for each full day.

Note: Meteorologists use UNIVERSAL TIME (UT) (often referred to as Greenwich Mean Time, or GMT) for all observations. For instance, a time recorded as 1600z on a satellite image represents 1600–500, or 11:00 a.m. Manitoba time. The “500” represents the five-hour time difference between GMT and local Central Daylight Time (CDT). When we are on Standard Time (CST), the time difference increases to six hours.

Sample Satellite Image of Hurricane Andrew*



Note: The time of the image, “12:31 UTC,” appearing in the lower-left corner of this image means “August 23, 1992 at 1231z, Coordinated Universal Time (UTC).” For Manitobans, the time would be 1231–500 or 731 = 7:31 a.m. CDT.

* Satellite image courtesy of NOAA. All rights reserved.

Hurricane Andrew—Tracking Information

The chart that follows contains information that will allow you to track Andrew's progress as it began as a tropical low-pressure system (a "depression" in weather terms) far out in the eastern Atlantic ocean. The chart includes information such as:

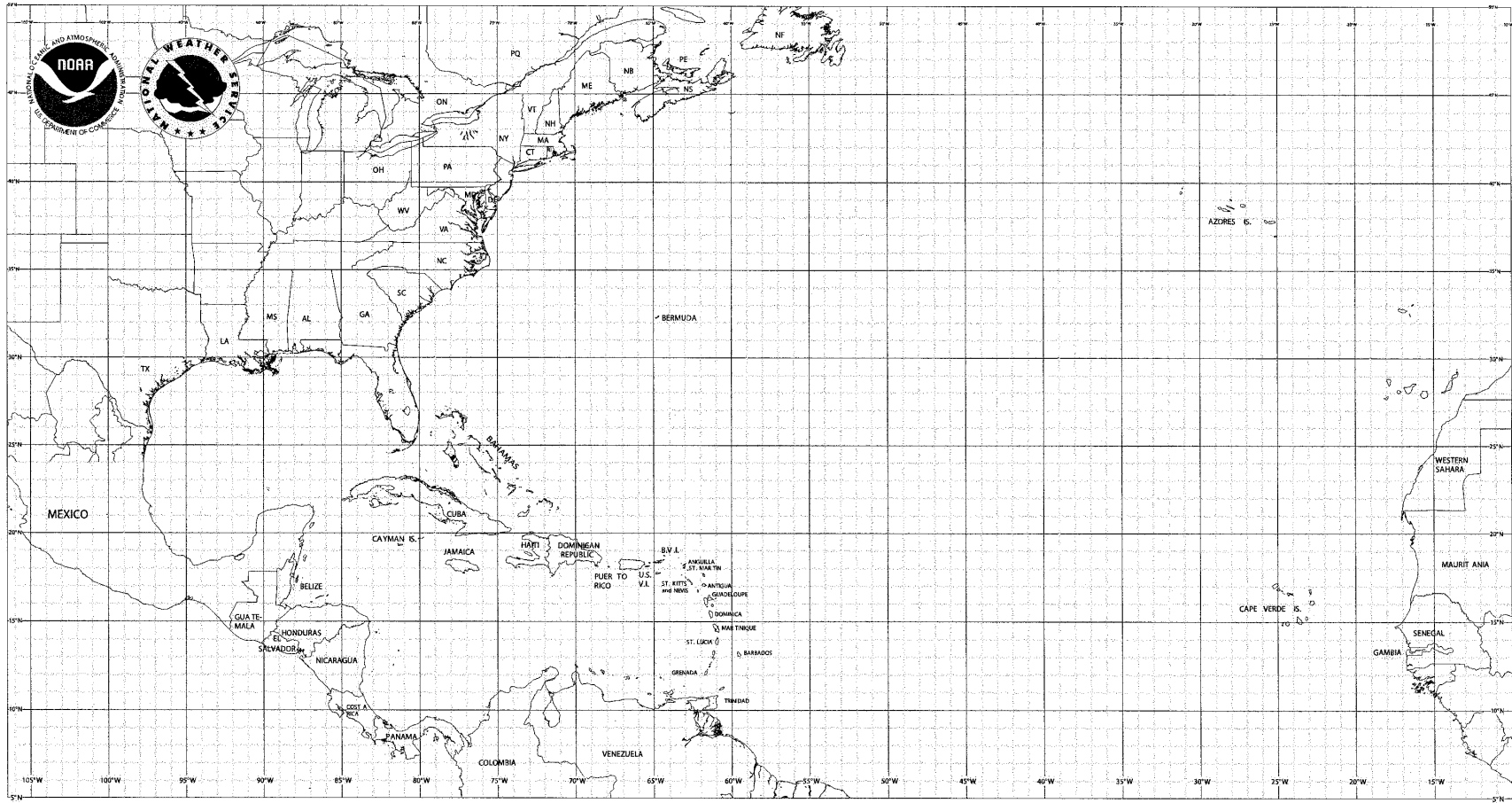
- Adv = Advisory Number
- Latitude and longitude of the centre of the storm (negative values for longitude indicate west of Greenwich, England)
- Date and time (the time is in "zulu" format, which is equivalent to Greenwich Mean Time). For instance, 18Z = 1800 GMT = 13:00 CDT here in Manitoba.
- Maximum sustained winds (measured in "nautical miles per hour (knots)"), where 1 knot = 2 km/hr). For example, 150 kt = 300 km/hr.
- Minimum air pressure in the "eye" of the storm (in millibars (mb), where 10 mb = 1.0 kPa). For instance, 1000 mb = 100.0 kPa.
- Classification of the storm

Dates: 16-28 AUG 1992

Adv	Latitude	Longitude	Time	Wind	Pressure	Status
1	10.80	-35.50	08/16/18Z	25	1010	Tropical Depression
2	11.20	-37.40	08/17/00Z	30	1009	Tropical Depression
3	11.70	-39.60	08/17/06Z	30	1008	Tropical Depression
4	12.30	-42.00	08/17/12Z	35	1006	Tropical Storm
5	13.10	-44.20	08/17/18Z	35	1003	Tropical Storm
6	13.60	-46.20	08/18/00Z	40	1002	Tropical Storm
7	14.10	-48.00	08/18/06Z	45	1001	Tropical Storm
8	14.60	-49.90	08/18/12Z	45	1000	Tropical Storm
9	15.40	-51.80	08/18/18Z	45	1000	Tropical Storm
10	16.30	-53.50	08/19/00Z	45	1001	Tropical Storm
11	17.20	-55.30	08/19/06Z	45	1002	Tropical Storm
12	18.00	-56.90	08/19/12Z	45	1005	Tropical Storm
13	18.80	-58.30	08/19/18Z	45	1007	Tropical Storm
14	19.80	-59.30	08/20/00Z	40	1011	Tropical Storm
15	20.70	-60.00	08/20/06Z	40	1013	Tropical Storm
16	21.70	-60.70	08/20/12Z	40	1015	Tropical Storm
17	22.50	-61.50	08/20/18Z	40	1014	Tropical Storm
18	23.20	-62.40	08/21/00Z	45	1014	Tropical Storm
19	23.90	-63.30	08/21/06Z	45	1010	Tropical Storm
20	24.40	-64.20	08/21/12Z	50	1007	Tropical Storm
21	24.80	-64.90	08/21/18Z	50	1004	Tropical Storm
22	25.30	-65.90	08/22/00Z	55	1000	Tropical Storm

23	25.60	-67.00	08/22/06Z	65	994	Hurricane—1
24	25.80	-68.30	08/22/12Z	80	981	Hurricane—1
25	25.70	-69.70	08/22/18Z	95	969	Hurricane—2
26	25.60	-71.10	08/23/00Z	110	961	Hurricane—3
27	25.50	-72.50	08/23/06Z	130	947	Hurricane—4
28	25.40	-74.20	08/23/12Z	145	933	Hurricane—5
29	25.40	-75.80	08/23/18Z	150	922	Hurricane—5
30	25.40	-77.50	08/24/00Z	125	930	Hurricane—4
31	25.40	-79.30	08/24/06Z	130	937	Hurricane—4
32	25.60	-81.20	08/24/12Z	115	951	Hurricane—4
33	25.80	-83.10	08/24/18Z	115	947	Hurricane—4
34	26.20	-85.00	08/25/00Z	115	943	Hurricane—4
35	26.60	-86.70	08/25/06Z	115	948	Hurricane—4
36	27.20	-88.20	08/25/12Z	120	946	Hurricane—4
37	27.80	-89.60	08/25/18Z	125	941	Hurricane—4
38	28.50	-90.50	08/26/00Z	125	937	Hurricane—4
39	29.20	-91.30	08/26/06Z	120	955	Hurricane—4
40	30.10	-91.70	08/26/12Z	80	973	Hurricane—1
41	30.90	-91.60	08/26/18Z	50	991	Tropical Storm
42	31.50	-91.10	08/27/00Z	35	995	Tropical Storm
43	32.10	-90.50	08/27/06Z	30	997	Tropical Depression
44	32.80	-89.60	08/27/12Z	30	998	Tropical Depression
45	33.60	-88.40	08/27/18Z	25	999	Tropical Depression
46	34.40	-86.70	08/28/00Z	20	1000	Tropical Depression
47	35.40	-84.00	08/28/06Z	20	1000	Tropical Depression

Atlantic Basin Hurricane Tracking Chart* National Hurricane Center, Miami, Florida



* Tracking chart courtesy of NOAA. All rights reserved.
A larger (11 x 17 inch) version of this chart is available at the National Hurricane Centre. <<http://www.nhc.noaa.gov/>>

Follow-up Responses

Use the Atlantic Basin Hurricane Tracking Chart provided for you on page A172.

1. Carefully trace the path of Hurricane Andrew by joining each of your plotted positions. Then, attempt to trace eastward out into the Atlantic to where you believe this storm first became hurricane-class. Then, verify your projections by looking over a 1992 Hurricane Tracking Map provided by a relevant website such as the National Hurricane Center <<http://www.nhc.noaa.gov/>>.
2. By determining how long the time span is between each plotted position, you can work out the average speed of the storm for a 72-hour period.

$$\text{AVERAGE SPEED} = \text{DISTANCE TRAVELED} \div \text{TIME}$$

Work out the speed of the storm, first in miles per day, then convert to kilometres per hour using an appropriate conversion that you can look up in tables of measurement. Do this for each of the following 72-hour periods:

- i. August 16th to August 18th

- ii. August 21st to August 23rd

- iii. August 24th to August 26th

- iv. August 26th to August 28th

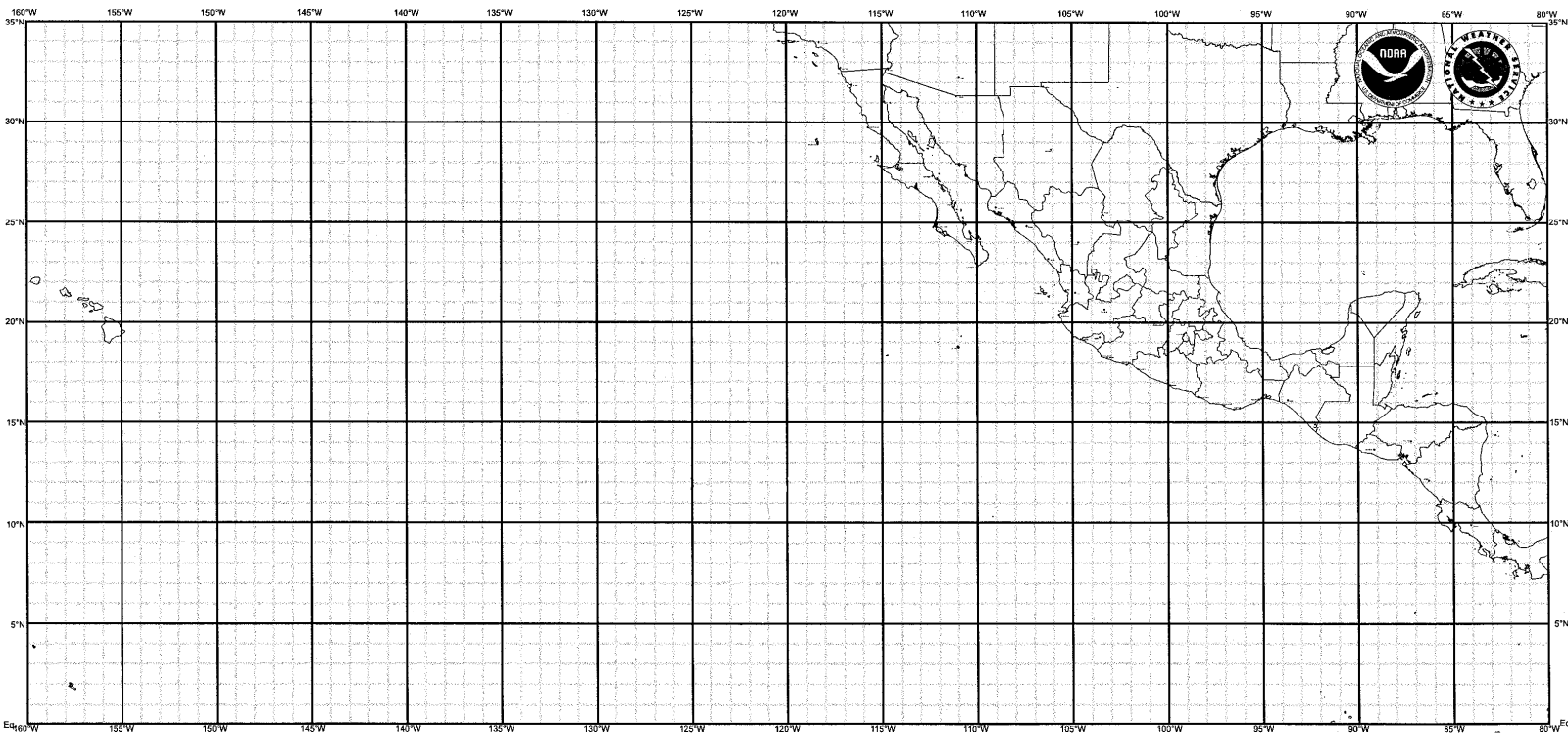
3. Describe the nature of any changes in average speed over a 72-hour period for the hurricane, and link these to changes in direction observed on the tracking chart.

4. After landfall, did Andrew “join forces” with any continental weather systems moving eastward across the southern United States? You will need to consult a satellite image from the archive listed at the beginning of this activity.



East Pacific Hurricane Tracking Chart

East Pacific Hurricane Tracking Chart *
National Hurricane Center, Miami, Florida



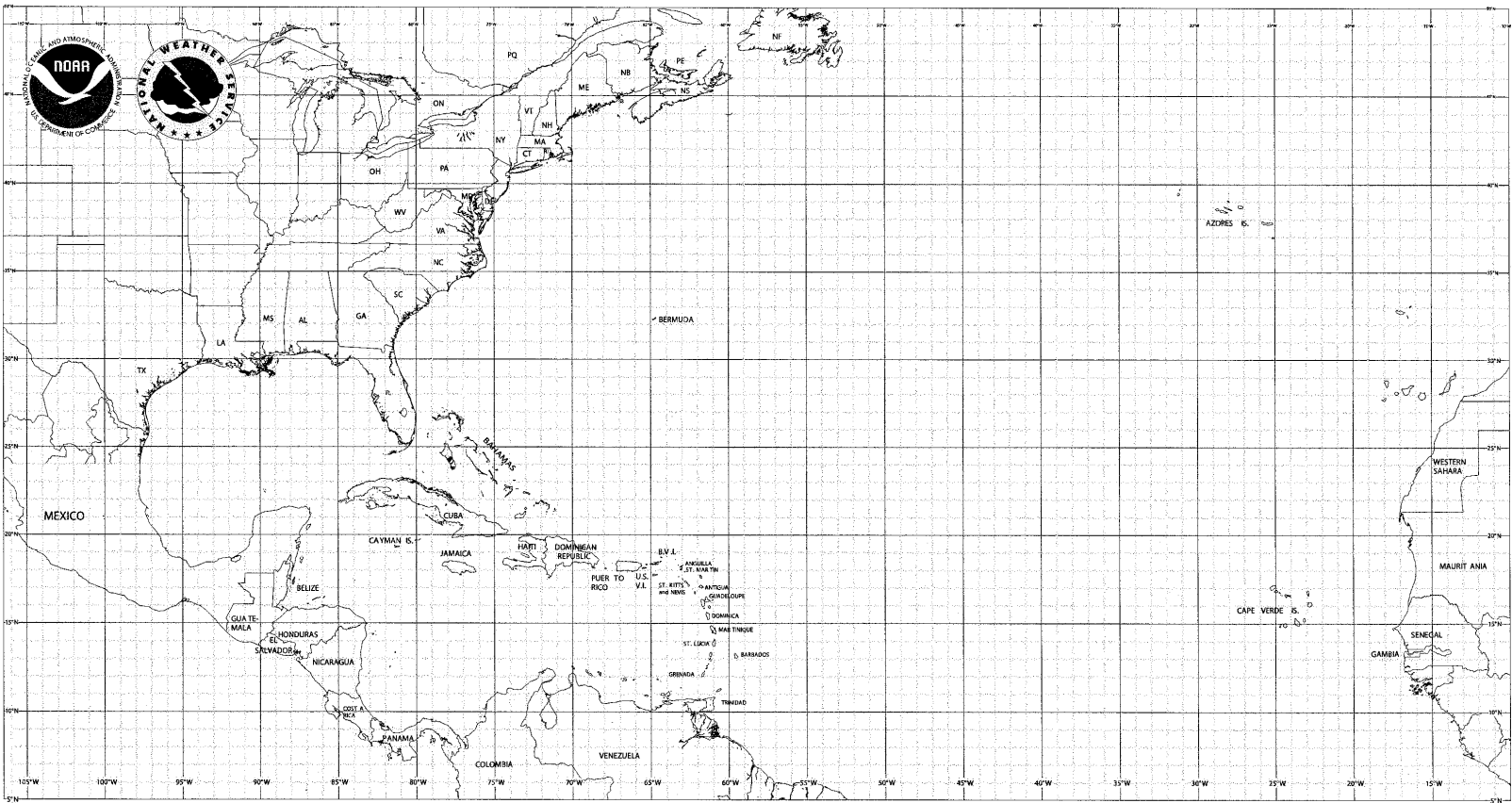
This is a reduced version of the chart used to track hurricanes at the National Hurricane Center

* Tracking chart courtesy of NOAA. All rights reserved.
A larger (11 x 17 inch) version of this chart is available at the National Hurricane Centre. <<http://www.nhc.noaa.gov/>>



Atlantic Hurricane Track Chart

Atlantic Basin Hurricane Tracking Chart*
National Hurricane Center, Miami, Florida



* Tracking chart courtesy of NOAA. All rights reserved.
A larger (11 x 17 inch) version of this chart is available at the National Hurricane Centre. <<http://www.nhc.noaa.gov/>>



The Saffir-Simpson Hurricane Scale and Fujita Tornado Scale

The Saffir-Simpson Hurricane Scale

The Saffir-Simpson Hurricane Scale is a 1–5 rating based on a hurricane’s present intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf in the landfall region. Note that all winds are using the U.S. one-minute average.

Category One Hurricane

Winds 119–153 km/h (64–82 kt or 74–95 mph). Storm surge generally 4–5 feet above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage. Hurricanes Allison of 1995 and Danny of 1997 were Category One hurricanes at peak intensity.

Category Two Hurricane

Winds 154–177 km/h (83–95 kt or 96–110 mph). Storm surge generally 6–8 feet above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2–4 hours before arrival of the hurricane centre. Small craft in unprotected anchorages break moorings. Hurricane Bonnie of 1998 was a Category Two hurricane when it hit the North Carolina coast, while Hurricane Georges of 1998 was a Category Two Hurricane when it hit the Florida Keys and the Mississippi Gulf Coast.

Category Three Hurricane

Winds 178–209 km/h (96–113 kt or 111–130 mph). Storm surge generally 9–12 feet above normal. Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Damage to shrubbery and trees with foliage blown off trees and large trees blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3–5 hours before arrival of the hurricane centre. Flooding near the coast destroys smaller structures with larger structures damaged by battering of floating debris. Terrain continuously lower than 5 feet above mean sea level may be flooded inland 8 miles (13 km) or more. Evacuation of low-lying residences within several blocks of the shoreline may be required. Hurricanes Roxanne of 1995 and Fran of 1996 were Category Three hurricanes at landfall on the Yucatan Peninsula of Mexico and in North Carolina, respectively.

Category Four Hurricane

Winds 131–155 mph (114–135 kt or 210–249 km/hr). Storm surge generally 13–18 feet above normal. More extensive curtainwall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3–5 hours before arrival of the hurricane centre. Major damage to lower floors of structures near the shore. Terrain lower than 10 feet above sea level may be flooded, requiring massive evacuation of residential areas as far inland as 6 miles (10 km). Hurricane Luis of 1995 was a Category Four hurricane while moving over the Leeward Islands. Hurricanes Felix and Opal of 1995 also reached Category Four status at peak intensity.

Category Five Hurricane

Winds greater than 155 mph (135 kt or 249 km/hr). Storm surge generally greater than 18 feet above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3–5 hours before arrival of the hurricane centre. Major damage to lower floors of all structures located less than 15 feet above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5–10 miles (8–16 km) of the shoreline may be required. Hurricane Mitch of 1998 was a Category Five hurricane at peak intensity over the western Caribbean. Hurricane Gilbert of 1988 was a Category Five hurricane at peak intensity and is the strongest Atlantic tropical cyclone of record. Hurricane Andrew (1992) made landfall as a Category Five storm (not known until 2002).

Fujita Scale of Tornado Force

The Fujita Tornado Scale, usually referred to as the F-Scale, classifies tornadoes based on the resulting damage. This scale was developed by Dr. T. Theodore Fujita (University of Chicago) in 1971.

F-Scale	Winds	Type of Damage	Frequency
F0	40–72 mph 64–116 km/h	MINIMAL DAMAGE: Some damage to chimneys, TV antennas, roof shingles, trees, and windows.	29%
F1	73–112 mph 117–180 km/h	MODERATE DAMAGE: Automobiles overturned, carports destroyed, trees uprooted.	40%
F2	113–157 mph 181–253 km/h	MAJOR DAMAGE: Roofs blown off homes, sheds and outbuildings demolished, mobile homes overturned.	24%
F3	158–206 mph 254–332 km/h	SEVERE DAMAGE: Exterior walls and roofs blown off homes. Metal buildings collapsed or severely damaged. Forests and farmland flattened.	6%
F4	207–260 mph 333–418 km/h	DEVASTATING DAMAGE: Few walls, if any, standing in well-built homes. Large steel and concrete missiles thrown far distances.	2%
F5	261–318 mph 419–512 km/h	INCREDIBLE DAMAGE: Homes leveled with all debris removed. Schools, motels, and other larger structures have considerable damage with exterior walls and roofs gone. Top storeys demolished.	less than 1%



Weather Map Symbols*

Selected Weather Map Symbols

Surface Station Model

	Temp (F) Weather Dewpoint (F)	Pressure (mb) Sky Cover Wind (kts)	Data at Surface Station: Temp 5°C, dewpoint –2°C, overcast, wind from SE at 15 knots, weather light rain, pressure 1004.5 mb
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Upper Station Model

	Height (m) Wind (kts)	Data at Pressure Level: Temp –5°C, dewpoint –12°C, wind from S at 75 knots, height of level 1564 m
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Forecast Station Model

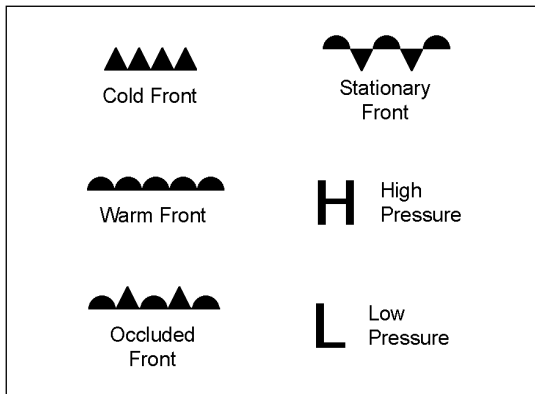
	PoP (%) Sky Cover Wind (kts)	Forecast at Valid Time Temp 25°C, dewpoint 10°C, scattered clouds, wind from E at 10 knots, probability of precipitation 70% with rain showers
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* Graphics reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.

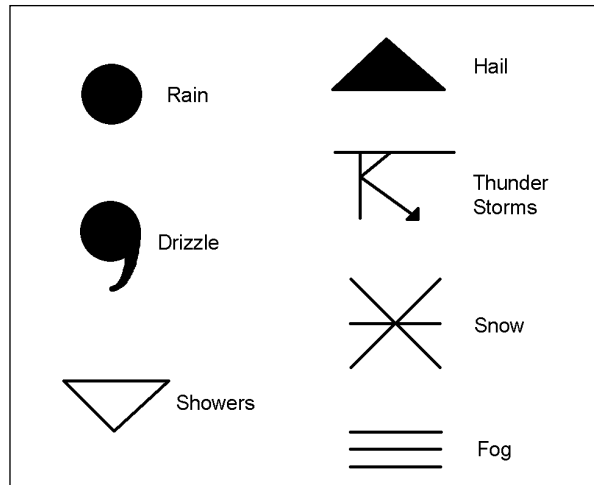


Weather Map Symbols—A Student’s Guide*

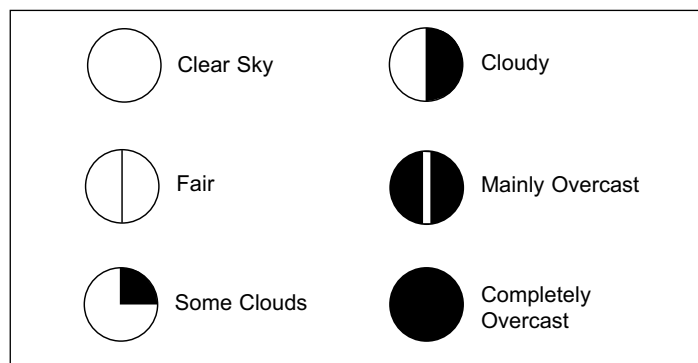
Fronts and Pressure



Precipitation Types

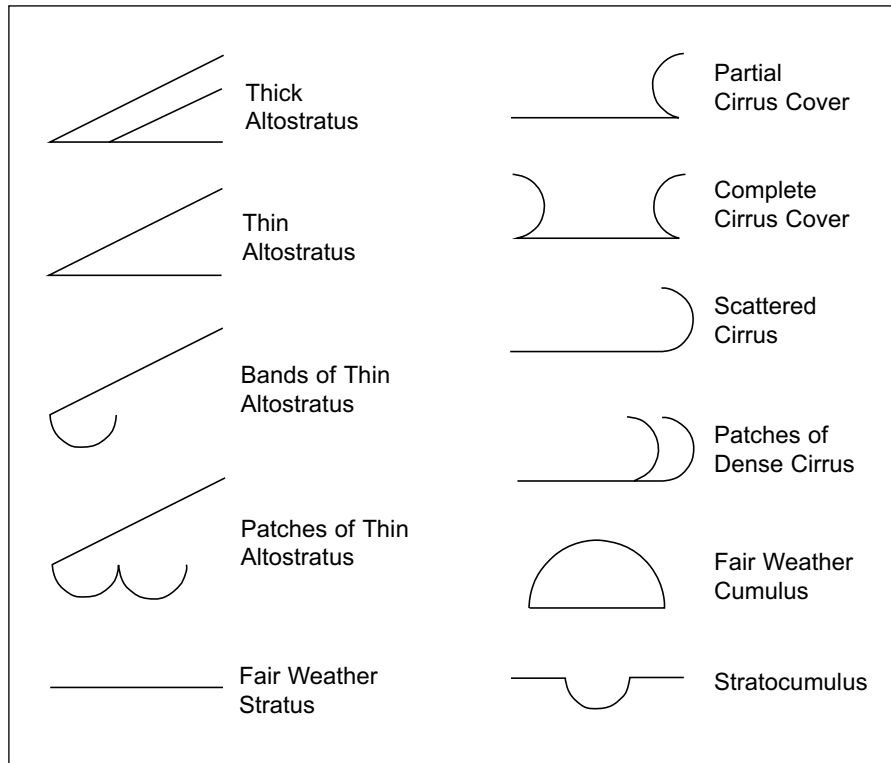


Cloud Cover

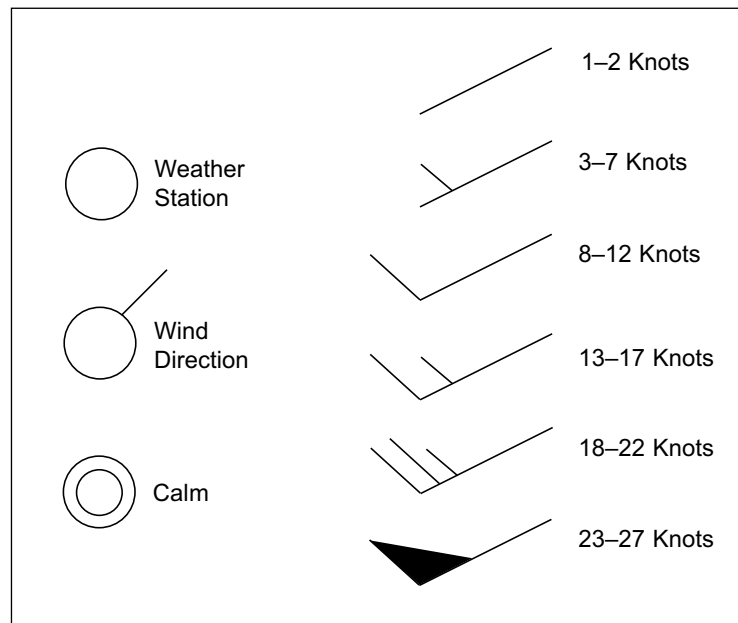


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Cloud Types



Wind Direction and Speed





Tracking a Severe Winter Storm: The 1997 Manitoba Blizzard

In this activity, you will:

- Analyze the early conditions as a winter storm system develops
- Track the path of the cyclone as it moves into Manitoba
- Determine the relationship between the major storm and corresponding hazardous weather it produced
- Connect your knowledge of storm systems to the spring blizzard of 1997 in Manitoba, the year of the “Flood of the Century”

Key Words

- Warm moist air/cool dry air
- Frontal boundary
- Cyclogenesis
- Jet stream flow
- Low pressure system

Introduction

During the period December 1996 to March 1997, the southern prairies in Canada and the northern plains in the United States (i.e., North and South Dakota) received almost record levels of snowfall. The sidewalks in Fargo, North Dakota, for instance, were piled high with three-metre-high snowbanks such that a pedestrian on the sidewalk could not even see the road. It was apparent that, as this snow melted in the spring of 1997, the risk of flooding along the Red River Basin was going to be significant. In the first week of April 1997, a major winter storm developed over Colorado (we often call these systems “**Colorado Lows**”) and began to track northeastward, heading directly for southern Manitoba. This particular storm was among the largest ever seen, spanning almost the entire North American continent from the Arctic to the Gulf of Mexico.

Between November 1996 and April 1997, the Red River Valley received almost double its average precipitation. Then on April 4, a blizzard struck the region, dumping 50 centimetres of snow over three days. Cold weather after the blizzard in April delayed the snow melt until the last week of April. The subsequent spring melt turned the Red River into the “Red Sea,” covering some 2000 square kilometres, an area equivalent to the size of Prince Edward Island. More than 28,000 people had been evacuated from southern Manitoba by the time the Red River crested in Winnipeg on May 1, reaching its highest peak since 1826. Undertaking its largest military operation since the Korean War, 8500 Canadian soldiers participated in the sandbagging and evacuating. Total damages have been estimated at more than \$150 million.

Major snowstorms are generally associated with winter storm systems that move across the central plains like this one did. The purpose of this lesson is to demonstrate the relationship between the track of the winter cyclone and areas of heavy snowfall and strong winds—real blizzard conditions!

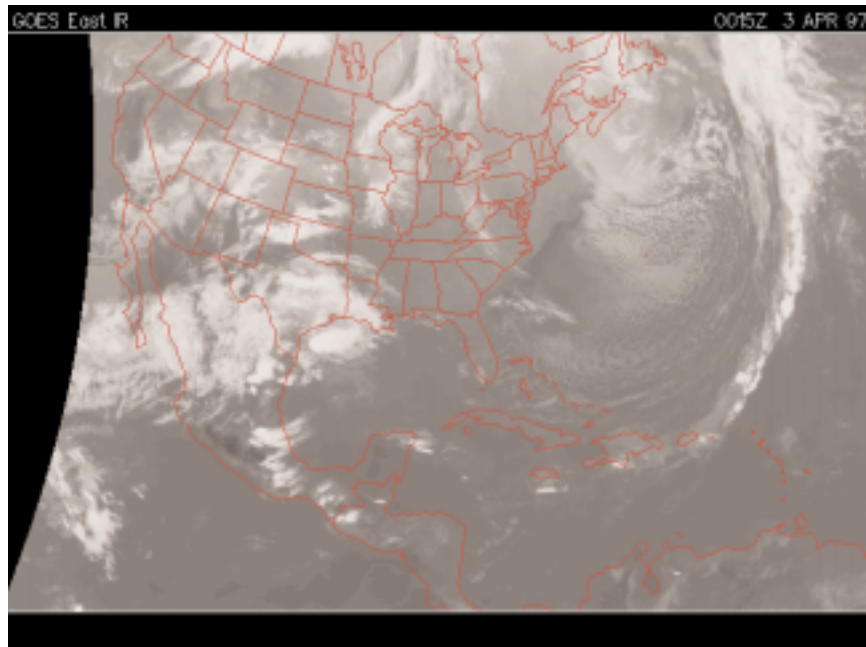
Activity—Tracking the Blizzard of April 1997

In this activity, you will examine a sequence of satellite images that come from the period April 3–8, 1997. Your task is as follows:

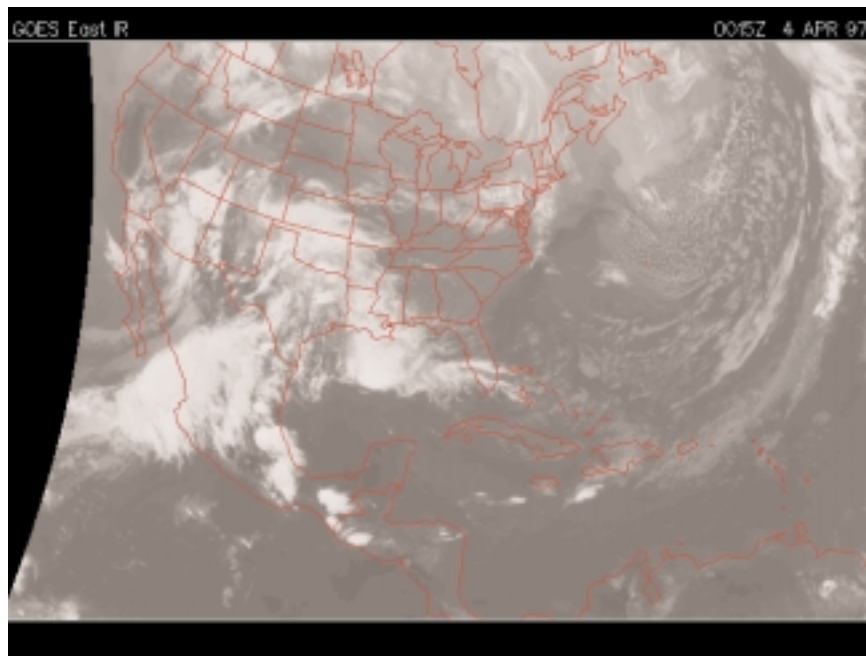
1. Look very carefully at each image, beginning with the first one from April 3, 1997.
2. Use your prior knowledge about **storm fronts** and **low pressure systems** to locate the centre of the LOW as it moves across North America.
3. On the map of North America that appears after the images, track the storm **every two days**; draw the following for each of the three days that you plot (the first one will already be done for you):
 - a. Label the centre of the LOW with a large “L.”
 - b. Draw the trailing **cold front** (look for the “comma-shaped” cloud pattern) that advances with the storm.
 - c. With large arrows, draw in the direction of flow for the following air masses colliding—**cold, dry air** and **warm, moist air**. Do this only ONCE for April 6, 1997.
 - d. Label these locations: Colorado (state) and Winnipeg (city).
4. What seems to be forming in the southern United States on April 8th, just after the conclusion of the blizzard event? Answer in the space below:

Satellite Images—April, 1997 Blizzard*

April 2nd, 6 p.m.

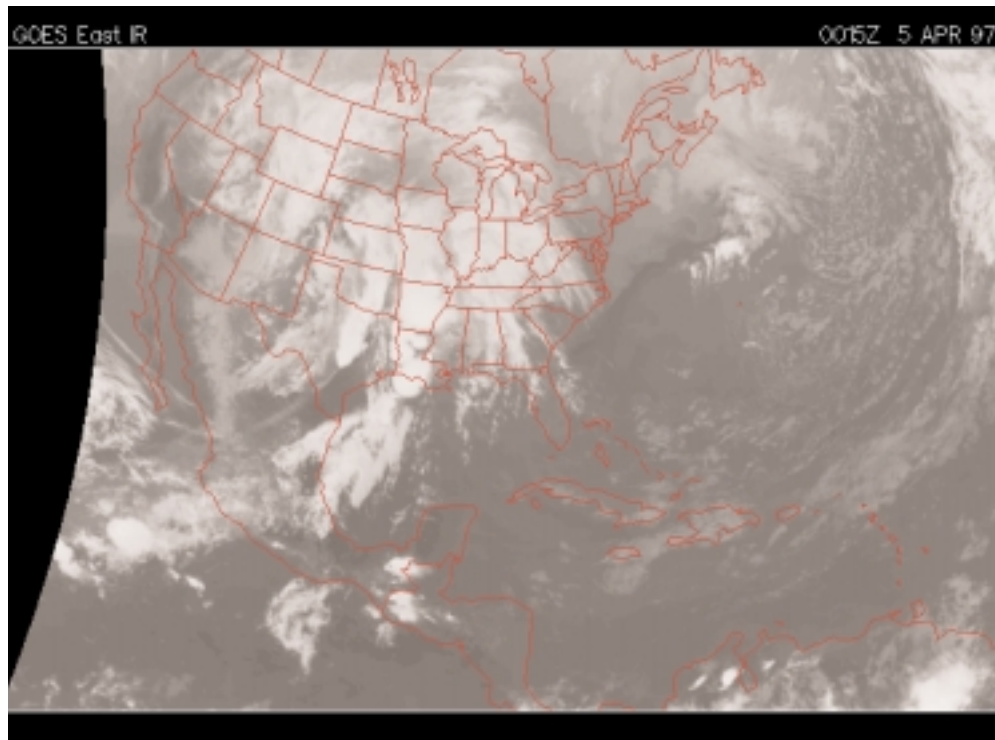


April 3rd, 6 p.m.

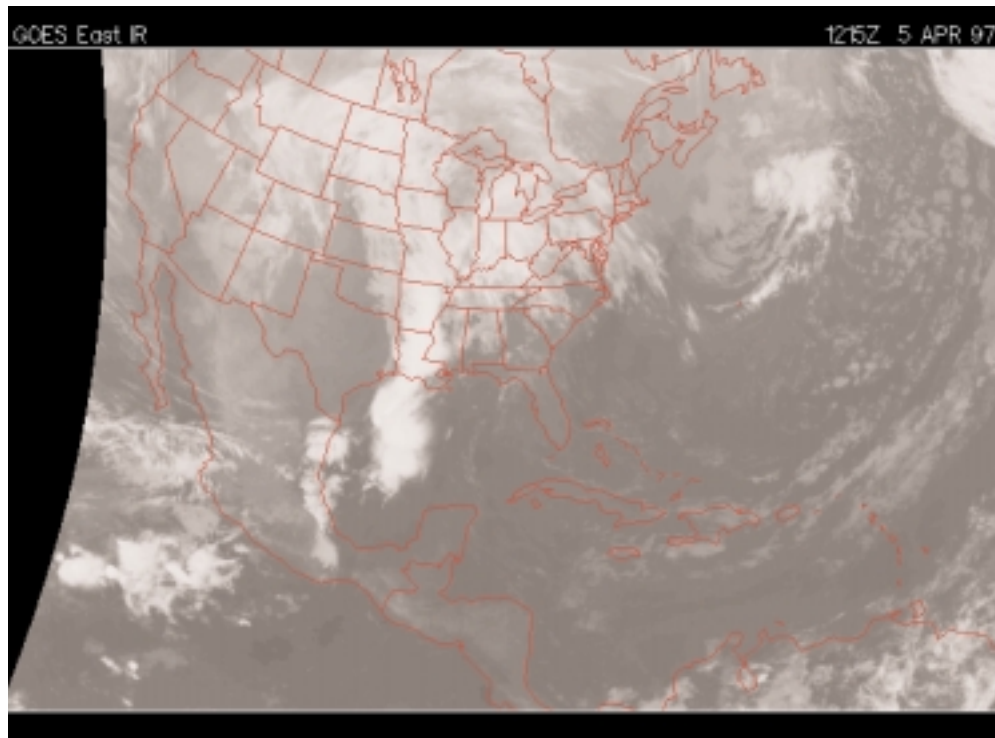


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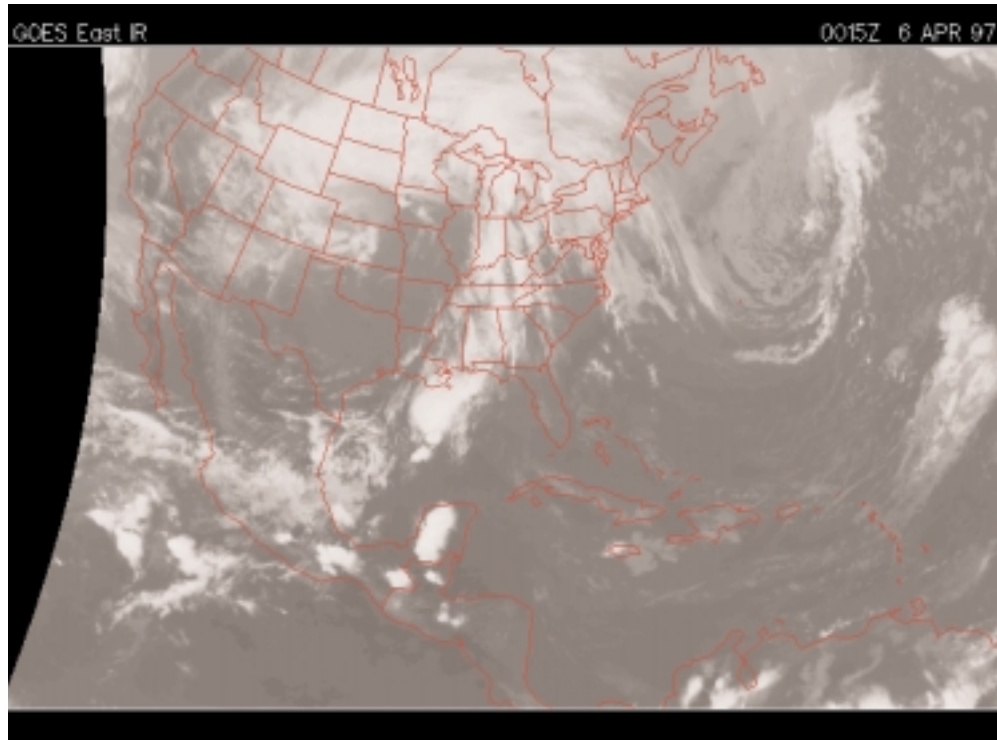
April 4th, 6 p.m.



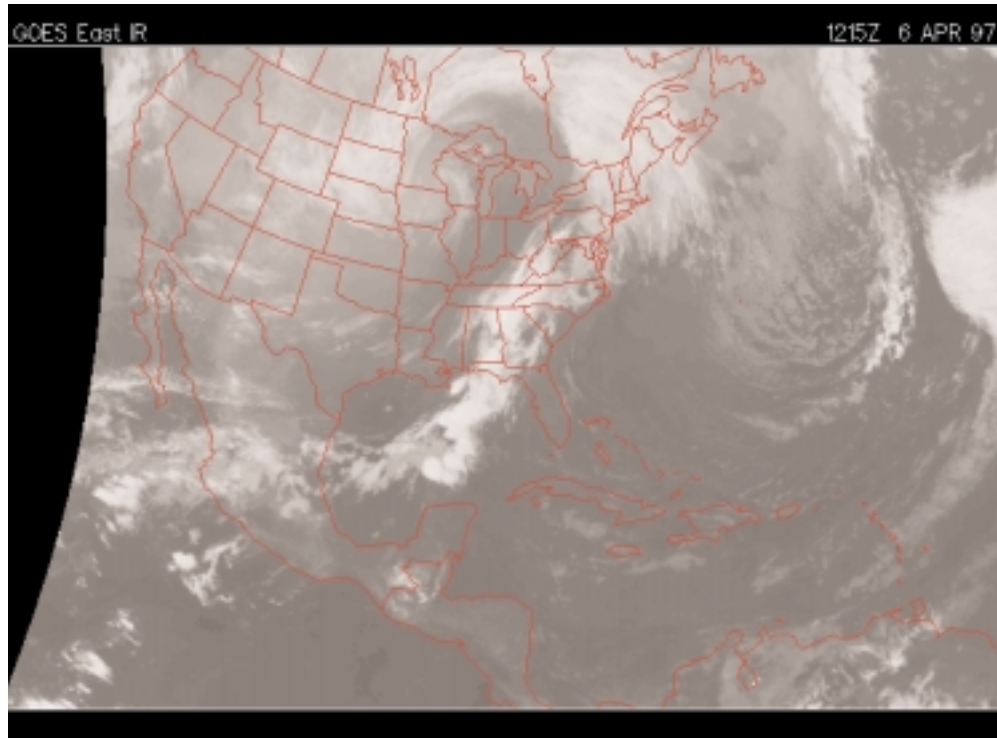
April 5th, 6 a.m.



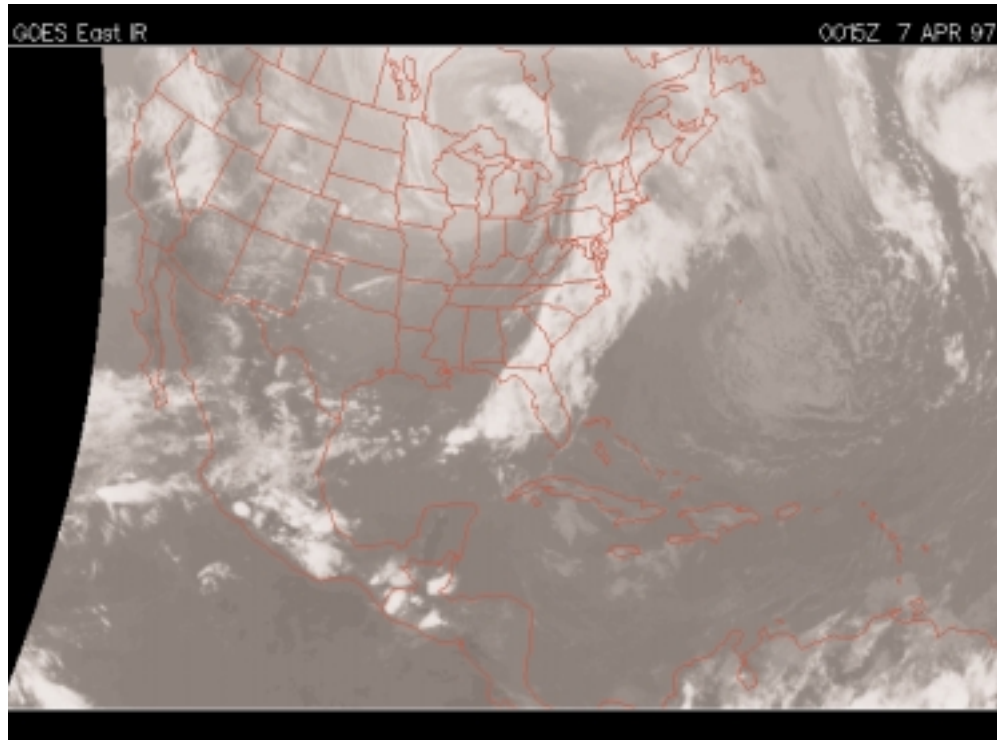
April 5th, 6 p.m.



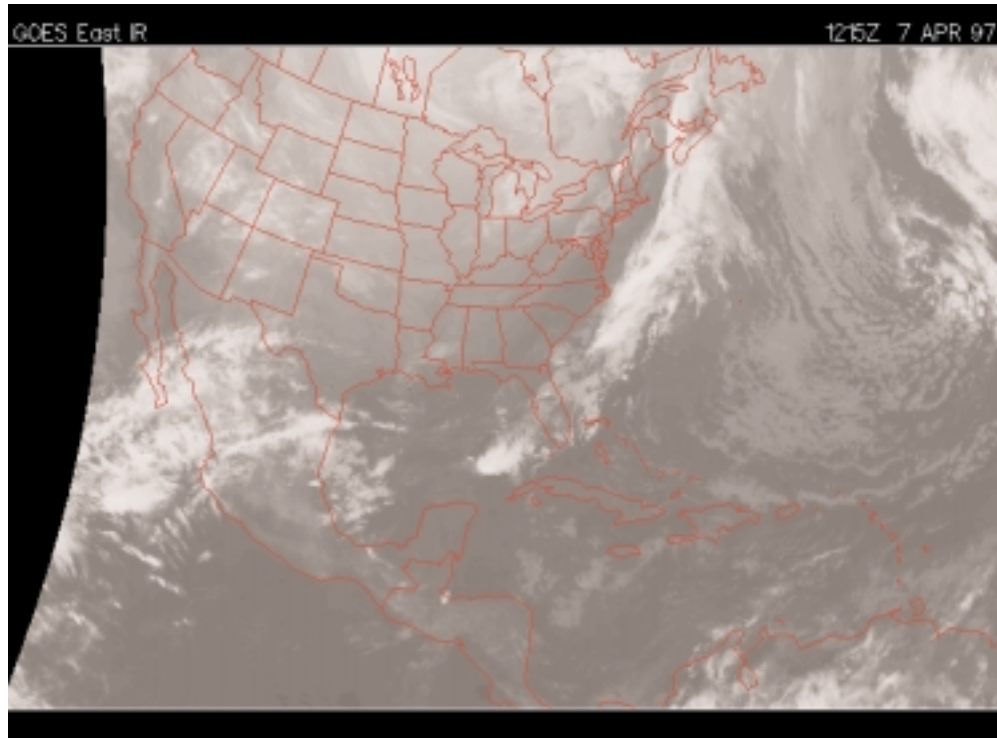
April 6th, 6 a.m.



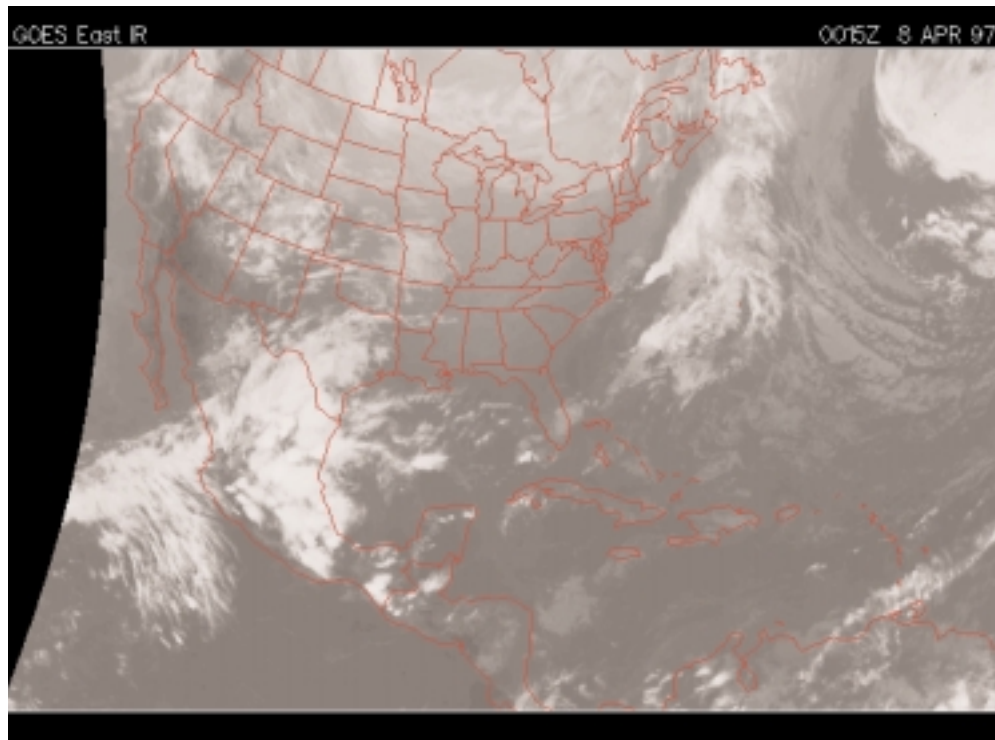
April 6th, 6 p.m.



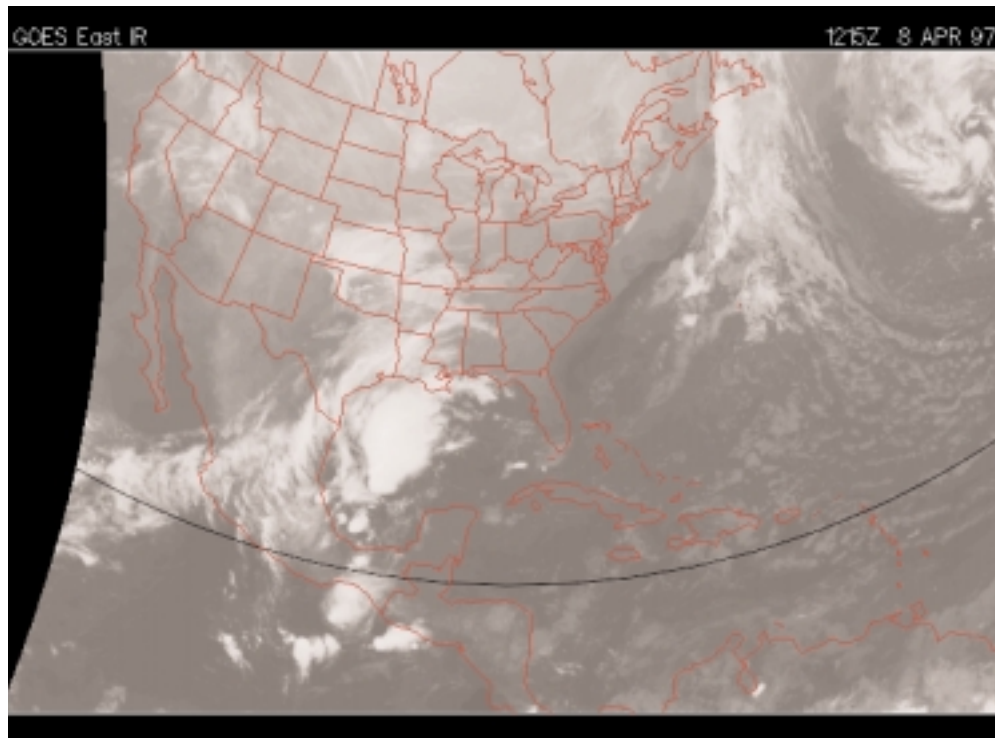
April 7th, 6 a.m.



April 7th, 6 p.m.



April 8th, 6 a.m.



Tracking the Storm—North American Weather Map*

As indicated earlier in this activity, use the map blank below to chart the progress of the storm over the period April 3–8, 1997.



* Graphic reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.



Climates Do Change Naturally*

After completing this activity, you will be able to:

- Understand that climate change is a naturally occurring, long-term set of processes
- Describe how changing climates may have influenced the development of stable populations and then modern civilization as we know it
- Describe how the polar ice caps have allowed science to better understand past climates and atmospheric conditions through ice core research
- Interpret data sets that indicate past, current, and possible future trends in global temperatures

Key Words

- Weather and climate
- Long-term climate change
- Temperature profiles
- Ice cores

Introduction

If you don't like the climate, just wait a while...a long while.

Warming and cooling trends are part of the Earth's normal climatic cycles. Temperatures vary within a given year, from one year to the next, and, on longer time scales, over decades, centuries, and millennia. In fact, there have been frequent changes in climate, with repeated swings from colder to warmer conditions. Past changes in climate have had a significant impact on human development. At the peak of the last ice age (about 16,000 years ago), most of Canada was covered with ice.

Question: How might climate stability, or instability, have influenced the early development of human civilization here in North America?

* Source: Natural Resources Canada: The Winds of Change—Climate Change on the Prairies Poster. Used with permission. Available online at <<http://www.adaptation.nrcan.gc.ca/posters/>>.

What Has Happened over the Last 500,000 Years?

Since the 1980s, a great effort has taken place to search for evidence of weather and climate change on Earth. We have a unique “library” or database available to us where that information has been stored—the polar ice caps. You see, when snow falls at the poles, it rarely ever melts. Year after year, for thousands of years, snowfalls are eventually packed down into a set of layers called **firn**. Eventually, firn becomes solid ice. As this happens, all the air bubbles in the ice become forever trapped—locked up in ice—and become a sample of ancient atmosphere.

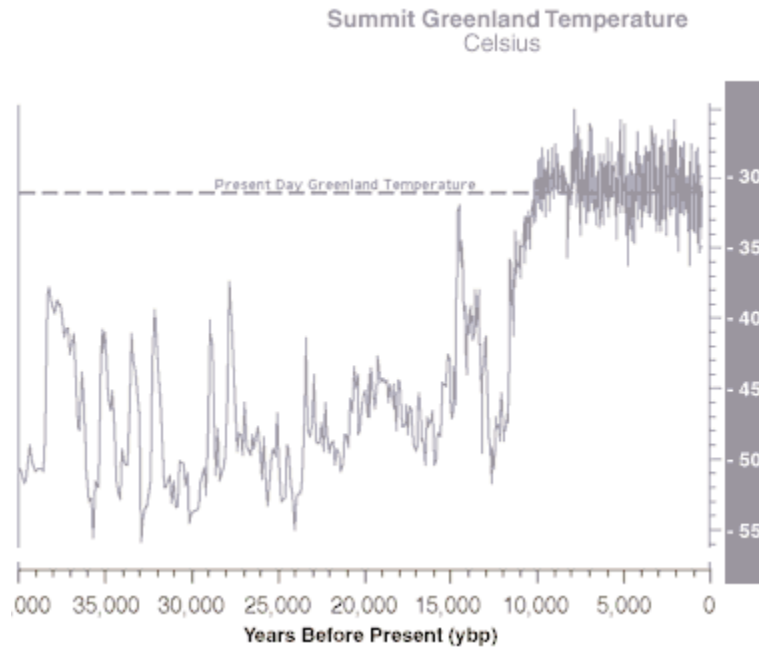
We have drilled deep into the ice caps on Greenland and in Antarctica for a number of years, and the ice cores that are taken out are examined carefully by scientists who are interested in what they contain. In addition to the air bubbles that can be extracted, each thin layer of the ice core can be sampled to see how much airborne dust fell with the snow. Volcanic eruptions are very good at leaving behind dust in the atmosphere that eventually gets “cleaned up” by snowflakes falling. We can determine how much volcanic activity occurred in the past 500,000 years or so simply by finding out what kind of dust, and how much of it, can be found in each layer of a four-kilometre-long tube of ice from Greenland.



Dr. Eric Wolff, a British Antarctic researcher, examining a section of ice core drilled out of the ice cap near the South Pole.

http://www.antarctica.ac.uk/BAS_Science/Highlights/2001/drilling.html

The graph presented here shows the average temperature above the Greenland ice sheet over the past 40,000 years or so.

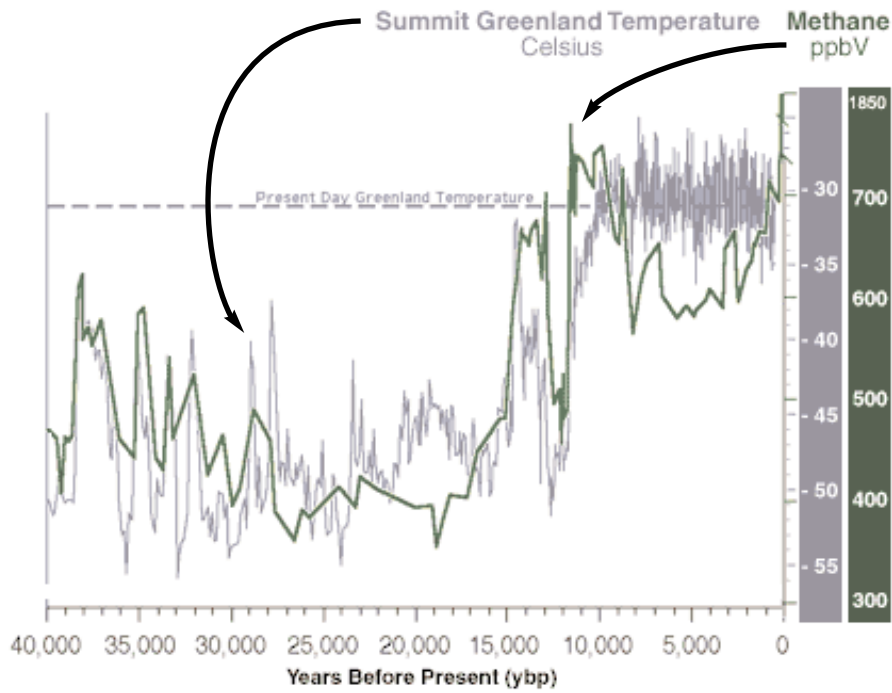


Question: Look carefully at the shape of the temperature profile above. What conclusions can you make about the following aspects of climate?

Has it become generally warmer or cooler in the last 40,000 years according to the graph?

How have temperatures fluctuated (gone up and down) during the period 10,000 to 40,000 years ago when compared to the period 0–10,000 years ago?

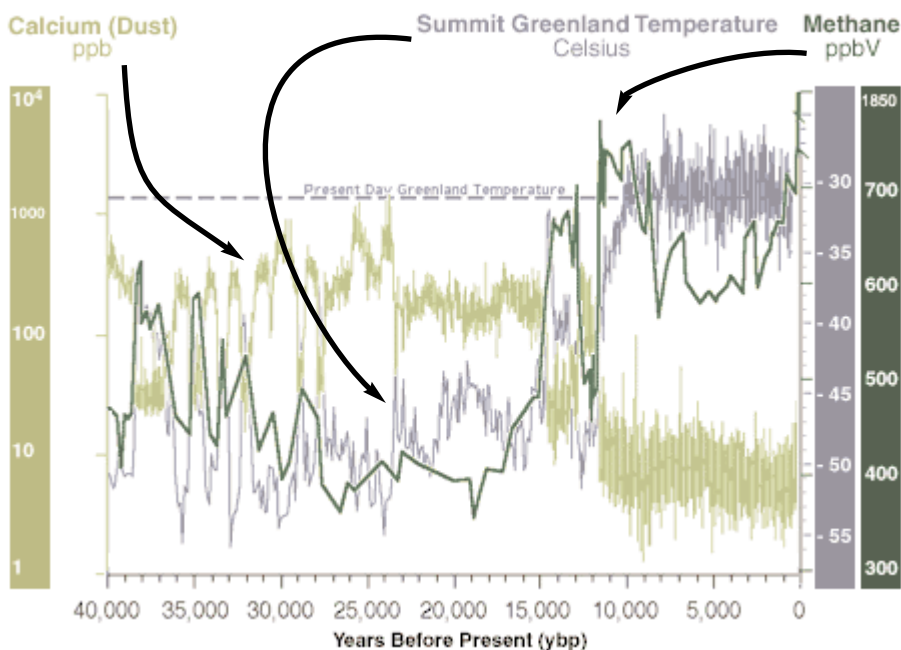
Below is the same temperature graph, but this time we have included a second graph that shows the amount of **methane** (CH₄)—a so-called “greenhouse gas”—in the atmosphere as measured from small bubbles of air trapped in the ice core from Greenland.



Question: How is the amount of methane in the atmosphere connected to the temperature that existed at a particular time?

Question: What parts of the graph **do not** seem to show the relationship that you noticed from the previous question? Express these as periods of years (e.g. 30,000 to 35,000 years ago, et cetera).

We will now add a third piece of information to the graph—the effect of dust in the atmosphere. The calcium dust found in ice cores (such as those drilled in Greenland or Antarctica) was blown by the wind from areas with little or no vegetation, falling to Earth with rain or snow. Calcium dust originates from continental shelves that are exposed to the atmosphere as the sea level drops around the world during an ice age.



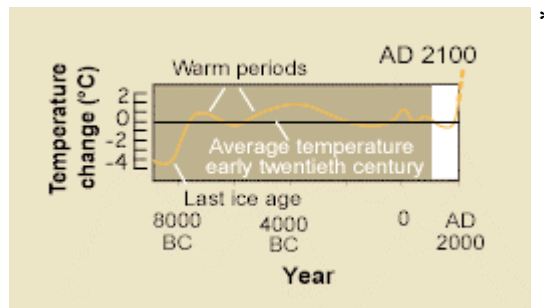
Question: When there is very little calcium dust in the ice core record, what does that seem to predict about temperature during that same period of time (e.g., from 0–10,000 years ago)?

Question: From the calcium dust information given on the graph, identify the following two periods of time:

1. A period when worldwide sea levels were probably much **lower** than they are now.

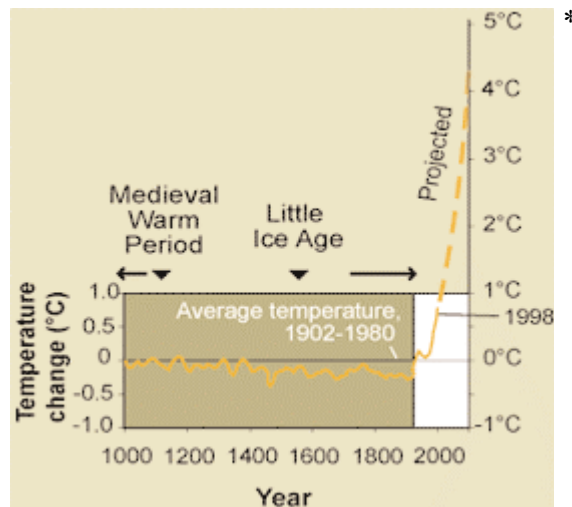
2. A short period when there was a sharp rise in global temperatures and an increase of methane in the atmosphere in the last 15,000 years.

After the Ice Age: The Last 10,000 Years



The global climate warmed rapidly at the end of the last ice age. By about 4000 BCE, the Prairies were warm and dry, and prairie grasslands probably extended more than 80 kilometres farther north than they do today. Later, increased moisture and cooler temperatures caused renewed glacial ice accumulation to the west of us in the Rockies.

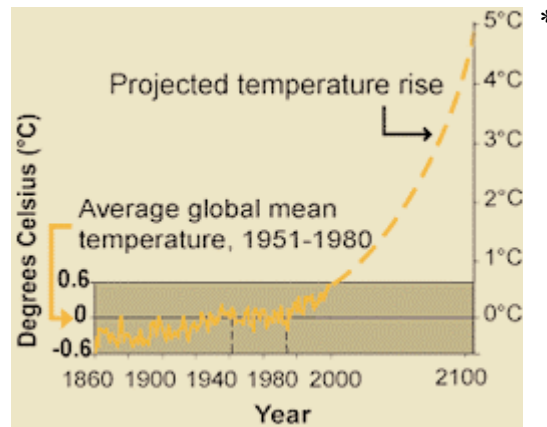
Warmer—Cooler—Hotter in the Last 1000 Years?



During the Medieval Warm Period, between about AD 1000 and AD 1200, temperatures were comparatively warm—this is the time when Vikings traveled to Greenland and Newfoundland. During a subsequent cooling trend called the Little Ice Age, the Vikings abandoned their settlements, Europe experienced colder weather, and the glaciers in the Canadian Rockies expanded. By AD 1860, temperatures began to rise again.

* Source: Natural Resources Canada: The Winds of Change—Climate Change on the Prairies Poster. Used with permission. Available online at <<http://www.adaptation.nrcan.gc.ca/posters/>>.

Turning Up the Heat in the 1980s and 1990s



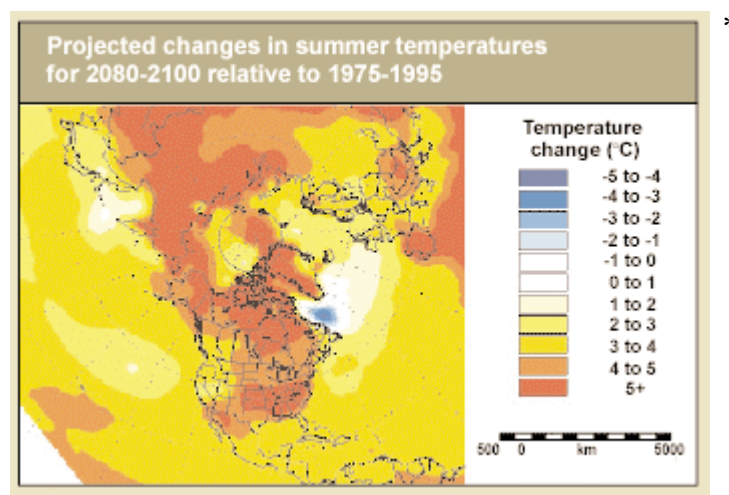
Over the past 140 years, Earth's atmosphere has warmed. Since the 1980s, the rate of this warming trend has increased. Scientists are concerned that we are entering a period of unprecedented global warming that will be caused, in part, by human activity—particularly, as we will see later on, by the tremendous increase in the burning of carbon-based fuels such as coal, oil, and natural gases like propane and methane.

Did you know?

The 20th century was the warmest century of the last 1000 years, and the 1990s was the warmest decade of the 20th century.

A Much Different Future...

This map shows a predicted summer surface air temperature change for the northern hemisphere that could occur in the next century. The greatest differences are predicted to occur in the Arctic and the interior of North America.



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Canadian Climatology Datasets*

Table 1: Winter national temperature departures, warmest/coolest 10 years in the period 1948–2001

Rank	10 Warmest		10 Coolest	
	Year	Departure °C	Year	Departure °C
1	1987	3.0	1972	-3.2
2	1998	2.8	1950	-2.6
3	1960	2.6	1965	-1.9
4	2000	2.5	1957	-1.7
5	1999	2.5	1949	-1.6
6	1981	2.4	1979	-1.5
7	1953	2.4	1971	-1.3
8	1980	1.8	1962	-1.2
9	1995	1.7	1994	-1.2
10	1986	1.7	1952	-1.1

Note: “Departure” refers to the percentage above (10.0) or below (-10.0) the 30-year normals for the data.

Table 2: Winter national precipitation departures, wettest/driest 10 years in the period 1948–2001

Rank	10 Wettest		10 Driest	
	Year	Departure %	Year	Departure %
1	1965	19.4	1978	-20.1
2	1997	14.6	1966	-17.6
3	1963	14.4	1957	-14.6
4	1958	11.7	1979	-14.5
5	1956	11.0	1961	-12.7
6	1968	9.2	1970	-12.2
7	1977	9.0	1994	-12.1
8	1996	8.2	1998	-11.4
9	1981	6.5	1983	-10.4
10	1969	6.0	2001	-10.3

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Table 3: Winter regional temperature departures: trend, extremes and current season ranking, 1948–2001 (54 years)

Region	Trend °C	Extreme years				Winter 2001	
		Coldest	Depart. °C	Warmest	Depart. °C	Rank*	Depart. °C
Atlantic Canada	-1.2	1959	-2.8	1958	3.2	33	-0.6
Great Lakes/St. Lawrence Lowlands	0.3	1994	-2.9	1998	3.7	37	-0.3
Northeastern Forest	0.3	1994	-2.5	1998	4.1	26	0.0
Northwestern Forest	3.6	1950	-5.5	1987	7.6	17	2.5
Prairies	2.9	1950	-5.8	1987	7.0	32	0.0
South British Columbia Mountains	2.3	1950	-5.0	1992	5.0	29	0.7
Pacific Coast	1.6	1950	-3.8	1992	2.6	19	0.8
North British Columbia/Yukon	3.9	1969	-6.9	1977	8.7	4	5.7
Mackenzie District	3.8	1965	-3.8	1987	6.7	8	3.7
Arctic Tundra	1.3	1972	-3.2	1999	3.6	13	1.6
Arctic Mountains and Fjords	0.0	1949	-4.4	1969	3.4	20	0.4
Canada	1.6	1972	-3.2	1987	3.0	14	1.3

Table 4: Winter regional precipitation departures: extremes and current season ranking, 1948–2001 (54 years)

Region	Extreme years				Winter 2001	
	Driest	Depart. %	Wettest	Depart. %	Rank*	Depart. %
Atlantic Canada	1949	-26.1	1982	29.9	38	-9.9
Great Lakes/St. Lawrence Lowlands	1961	-33.3	1997	47.3	16	8.0
Northeastern Forest	1987	-29.6	1969	19.9	48	-20.1
Northwestern Forest	1978	-43.1	1956	44.5	52	-41.8
Prairies	1988	-48.0	1956	40.6	49	-39.0
South British Columbia/Mountains	2001	-51.0	1972	44.1	54	-51.0
Pacific Coast	2001	-41.2	1999	31.2	54	-41.2
North British Columbia/Yukon	1978	-58.0	1955	46.3	44	-21.3
Mackenzie District	1979	-53.3	1962	70.1	41	-19.4
Arctic Tundra	1967	-47.6	1980	50.6	18	17.1
Arctic Mountains and Fjords	1966	-48.9	1951	78.5	7	37.8
Canada	1978	-20.1	1965	19.4	45	-10.3

Table 5: Annual national temperature departures, warmest/coolest 10 years in the period 1948–2000

Rank	10 Warmest		10 Coolest	
	Year	Departure °C	Year	Departure °C
1	1998	2.5	1972	-1.8
2	1981	2.0	1950	-1.0
3	1999	1.7	1982	-0.9
4	1987	1.4	1974	-0.8
5	1953	1.0	1965	-0.6
6	1952	1.0	1956	-0.6
7	2000	0.9	1964	-0.5
8	1977	0.9	1978	-0.4
9	1988	0.8	1951	-0.4
10	1958	0.7	1967	-0.3

Table 6: Annual national precipitation departures, wettest/driest 10 years in the period 1948–2000

Rank	10 Wettest		10 Driest	
	Year	Departure %	Year	Departure %
1	1996	10.2	1956	-7.3
2	1981	8.8	1957	-6.8
3	1982	7.5	1958	-6.0
4	1973	6.8	1948	-4.4
5	1980	6.6	1961	-4.2
6	1979	6.5	1967	-4.0
7	1988	6.3	1955	-3.4
8	1991	5.7	1952	-3.4
9	1999	5.6	1950	-2.4
10	1984	5.5	1969	-2.3

Table 7: Annual regional temperature departures: trend, extremes, and current season ranking, 1948–2000 (53 years)

Region	Trend °C	Extreme years				Winter 2001	
		Coldest	Depart. °C	Warmest	Depart. °C	Rank*	Depart. °C
Atlantic Canada	-0.2	1972	-1.4	1999	2.0	11	0.7
Great Lakes/St. Lawrence Lowlands	0.2	1978	-1.0	1998	2.3	13	0.4
Northeastern Forest	0.3	1972	-1.9	1998	2.1	10	0.8
Northwestern Forest	1.6	1950	-2.1	1987	3.0	19	0.6
Prairies	1.3	1950	-2.1	1987	3.1	25	0.3
South British Columbia Mountains	1.3	1955	-1.8	1998	2.0	27	0.2
Pacific Coast	1.1	1955	-1.2	1958	1.6	21	0.4
North British Columbia/Yukon	1.8	1972	-2.1	1981	2.8	5	1.7
Mackenzie District	1.9	1982	-1.5	1998	3.9	8	1.3
Arctic Tundra	1.0	1972	-2.4	1998	3.3	5	1.3
Arctic Mountains and Fjords	0.3	1972	-1.9	1981	2.2	8	0.9
Canada	0.9	1972	-1.8	1998	2.5	7	0.9

Table 8: Annual regional precipitation departures: extremes and current season ranking, 1948–2000 (53 years)

Region	Extreme years				Winter 2001	
	Driest	Depart. %	Wettest	Depart. %	Rank*	Depart. %
Atlantic Canada	1966	-15.5	1990	19.2	22	3.6
Great Lakes/St. Lawrence Lowlands	1963	-16.0	1996	22.4	15	6.9
Northeastern Forest	1962	-10.3	1979	13.2	43	-4.8
Northwestern Forest	1981	-21.8	1973	16.5	45	-9.7
Prairies	1961	-29.1	1951	26.8	26	-2.4
South British Columbia/Mountains	2000	-21.7	1996	30.4	53	-21.7
Pacific Coast	2000	-26.3	1997	21.5	53	-26.3
North British Columbia/Yukon	1998	-51.4	1974	22.7	10	10.2
Mackenzie District	1995	-29.7	1974	27.6	30	-3.2
Arctic Tundra	1954	-19.8	1996	24.2	19	8.8
Arctic Mountains and Fjords	1948	-46.4	1953	44.2	13	16.6
Canada	1956	-7.3	1996	10.2	32	0.4



Annual Regional Temperature and Precipitation Datasets

Table 1: Annual regional temperature departures: trend, extremes, and current season ranking, 1948–2000 (53 years)*

Region	Trend °C	Extreme years				Annual 2000	
		Coldest	Depart. °C	Warmest	Depart. °C	Rank*	Depart. °C
Atlantic Canada	-0.2	1972	-1.4	1999	2.0	11	0.7
Great Lakes/St. Lawrence Lowlands	0.2	1978	-1.0	1998	2.3	13	0.4
Northeastern Forest	0.3	1972	-1.9	1998	2.1	10	0.8
Northwestern Forest	1.6	1950	-2.1	1987	3.0	19	0.6
Prairies	1.3	1950	-2.1	1987	3.1	25	0.3
South British Columbia Mountains	1.3	1955	-1.8	1998	2.0	27	0.2
Pacific Coast	1.1	1955	-1.2	1958	1.6	21	0.4
North British Columbia Mountains/Yukon	1.8	1972	-2.1	1981	2.8	5	1.7
Mackenzie District	1.9	1982	-1.5	1998	3.9	8	1.3
Arctic Tundra	1.0	1972	-2.4	1998	3.3	5	1.3
Arctic Mountains and Fjords	0.3	1972	-1.9	1981	2.2	8	0.9
Canada	0.9	1972	-1.8	1998	2.5	7	0.9

The rank for the most recent value in the series (the 2000 annual value for each region in this case) is calculated on series data arranged in descending order, from warmest to coolest values. Note: the 2000 data are preliminary.

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/ccrm/bulletin/annual00/ttabsumm_e.html>.

Table 2: Annual national temperature departures ranked from warmest to coolest, for the period 1948–2000*

Rank	Year	Dep. °C	Rank	Year	Dep. °C	Rank	Year	Dep. °C	Rank	Year	Dep. °C
01	1998	2.5	15	1993	0.5	29	1949	0	43	1959	-0.3
02	1981	2	16	1991	0.5	30	1996	0	44	1967	-0.3
03	1999	1.7	17	1994	0.5	31	1948	0	45	1951	-0.4
04	1987	1.4	18	1980	0.4	32	1971	0	46	1978	-0.4
05	1953	1	19	1969	0.4	33	1990	0	47	1964	-0.5
06	1952	1	20	1963	0.3	34	1985	0	48	1956	-0.6
07	2000	0.9	21	1984	0.2	35	1957	0	49	1965	-0.6
08	1977	0.9	22	1954	0.2	36	1979	-0.1	50	1974	-0.8
09	1988	0.8	23	1968	0.2	37	1961	-0.1	51	1982	-0.9
10	1958	0.7	24	1983	0.2	38	1975	-0.1	52	1950	-1
11	1995	0.7	25	1962	0.1	39	1992	-0.1	53	1972	-1.8
12	1973	0.6	26	1986	0.1	40	1989	-0.2			
13	1997	0.6	27	1955	0	41	1966	-0.2			
14	1960	0.6	28	1976	0	42	1970	-0.2			

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/ccrm/bulletin/annual00/ttabnafu_e.html>.

Table 3: Annual national temperature departures, warmest/coolest 10 years in the period 1948–2000*

Rank	10 Warmest		10 Coolest	
	Year	Depart. °C	Year	Depart. °C
1	1998	2.5	1972	−1.8
2	1981	2.0	1950	−1.0
3	1999	1.7	1982	−0.9
4	1987	1.4	1974	−0.8
5	1953	1.0	1965	−0.6
6	1952	1.0	1956	−0.6
7	2000	0.9	1964	−0.5
8	1977	0.9	1978	−0.4
9	1988	0.8	1951	−0.4
10	1958	0.7	1967	−0.3

* Chart reproduced from Environment Canada (2003). Used with permission.
<http://www.msc-smc.ec.ca/ccrm/bulletin/annual00/table_ttabna10_e.html>.

Table 4: Annual regional temperature departures, wettest 10 years in the period 1948–2000.*

Rank	10 Wettest		10 Driest	
	Year	Depart. °C	Year	Depart. °C
1	1996	10.2	1956	−7.3
2	1981	8.8	1957	−6.8
3	1982	7.5	1958	−6.0
4	1973	6.8	1948	−4.4
5	1980	6.6	1961	−4.2
6	1979	6.5	1967	−4.0
7	1988	6.3	1955	−3.4
8	1991	5.7	1952	−3.4
9	1999	5.6	1950	−2.4
10	1984	5.5	1969	−2.3

* Chart reproduced from Environment Canada (2003). Used with permission.
<http://www.msc-smc.ec.ca/ccrm/bulletin/annual00/table_ttabna10_e.html>.

Table 5: Annual regional temperature departures, warmest 10 years in the period 1948–1998*

Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C
Atlantic Canada			Northwestern Forest			Pacific Coast			Arctic Tundra		
1	1998	1.2	1	1987	3.0	1	1958	1.6	1	1998	3.3
2	1953	1.2	2	1981	2.5	2	1997	1.3	2	1981	2.2
3	1951	1.1	3	1998	2.3	3	1998	1.2	3	1996	1.4
4	1981	1.0	4	1993	1.5	4	1992	1.1	4	1977	1.3
5	1952	0.9	5	1977	1.3	5	1987	1.1	5	1995	1.2
6	1979	0.8	6	1991	1.2	6	1995	1.1	6	1973	1.1
7	1960	0.8	7	1953	1.2	7	1981	0.9	7	1952	1.0
8	1983	0.8	8	1988	1.2	8	1963	0.9	8	1969	1.0
9	1969	0.7	9	1976	1.2	9	1993	0.8	9	1988	1.0
10	1966	0.6	10	1986	1.2	10	1994	0.8	10	1953	0.8
Great Lakes/St. Lawrence			Prairies			North BC/Yukon			Arctic Mountains/Fjords		
1	1998	2.3	1	1987	3.1	1	1981	2.8	1	1981	2.2
2	1953	1.5	2	1981	2.5	2	1993	2.7	2	1998	1.9
3	1987	1.2	3	1988	1.9	3	1987	2.6	3	1988	1.3
4	1991	1.2	4	1998	1.8	4	1997	1.8	4	1996	1.3
5	1990	1.1	5	1986	1.5	5	1988	1.6	5	1995	1.2
6	1973	1.1	6	1991	1.3	6	1976	1.5	6	1960	1.0
7	1949	1.1	7	1963	1.3	7	1998	1.5	7	1980	0.9
8	1952	0.9	8	1953	1.3	8	1977	1.5	8	1955	0.9
9	1955	0.7	9	1976	1.2	9	1995	1.5	9	1969	0.9
10	1983	0.7	10	1961	1.1	10	1978	1.4	10	1958	0.9
Northeastern Forest			South British Columbia			Mackenzie District			Canada		
1	1998	2.1	1	1998	2.0	1	1998	3.9	1	1998	2.5
2	1987	1.7	2	1987	1.9	2	1981	2.8	2	1981	2.0
3	1981	1.5	3	1958	1.7	3	1987	2.4	3	1987	1.4
4	1952	1.2	4	1992	1.6	4	1993	2.3	4	1953	1.0
5	1953	1.1	5	1981	1.3	5	1997	1.8	5	1952	1.0
6	1973	0.9	6	1994	1.3	6	1953	1.4	6	1977	0.9
7	1955	0.8	7	1997	1.1	7	1995	1.3	7	1988	0.8
8	1977	0.8	8	1953	1.0	8	1980	1.2	8	1958	0.7
9	1983	0.5	9	1991	1.0	9	1973	1.2	9	1995	0.7
10	1960	0.5	10	1988	0.9	10	1976	1.2	10	1997	0.7

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/corn/bulletin/annua198/tabrgwm_e.html>

Table 6: Annual regional temperature departures, coolest 10 years in the period 1948–1998*

Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C
Atlantic Canada			Northwestern Forest			Pacific Coast			Arctic Tundra		
1	1972	-1.4	1	1950	-2.1	1	1955	-1.2	1	1972	-2.4
2	1974	-0.9	2	1951	-1.7	2	1950	-1.1	2	1974	-1.4
3	1992	-0.9	3	1972	-1.6	3	1972	-0.8	3	1964	-1.1
4	1993	-0.8	4	1982	-1.4	4	1971	-0.7	4	1982	-0.9
5	1965	-0.8	5	1966	-1.2	5	1975	-0.7	5	1986	-0.8
6	1985	-0.7	6	1996	-1.1	6	1985	-0.6	6	1950	-0.8
7	1986	-0.7	7	1955	-1.1	7	1949	-0.6	7	1978	-0.8
8	1978	-0.6	8	1965	-0.9	8	1948	-0.6	8	1956	-0.7
9	1989	-0.6	9	1979	-0.4	9	1964	-0.5	9	1967	-0.7
10	1980	-0.6	10	1970	-0.4	10	1973	-0.5	10	1965	-0.6
Great Lakes/St. Lawrence			Prairies			North BC/Yukon			Arctic Mountains/Fjords		
1	1978	-1.0	1	1950	-2.1	1	1972	-2.1	1	1972	-1.9
2	1972	-0.9	2	1951	-2.1	2	1966	-1.7	2	1992	-1.3
3	1976	-0.7	3	1996	-1.7	3	1996	-1.5	3	1984	-1.1
4	1980	-0.7	4	1972	-1.3	4	1950	-1.3	4	1961	-0.9
5	1963	-0.6	5	1955	-1.3	5	1982	-1.3	5	1987	-0.9
6	1992	-0.6	6	1982	-1.2	6	1955	-1.3	6	1989	-0.8
7	1989	-0.6	7	1965	-1.1	7	1971	-1.2	7	1974	-0.8
8	1950	-0.4	8	1966	-0.9	8	1973	-1.1	8	1979	-0.8
9	1958	-0.4	9	1969	-0.8	9	1951	-1.0	9	1983	-0.7
10	1956	-0.4	10	1970	-0.7	10	1956	-0.9	10	1986	-0.7
Northeastern Forest			South British Columbia			Mackenzie District			Canada		
1	1972	-1.9	1	1955	-1.8	1	1982	-1.5	1	1972	-1.8
2	1950	-1.1	2	1950	-1.2	2	1966	-1.4	2	1950	-1.0
3	1974	-0.9	3	1951	-1.1	3	1972	-1.3	3	1982	-0.9
4	1965	-0.9	4	1972	-1.0	4	1961	-1.2	4	1974	-0.8
5	1992	-0.8	5	1975	-0.7	5	1974	-1.1	5	1965	-0.6
6	1978	-0.8	6	1996	-0.7	6	1951	-1.0	6	1956	-0.6
7	1982	-0.8	7	1985	-0.6	7	1950	-0.9	7	1964	-0.5
8	1989	-0.7	8	1949	-0.6	8	1959	-0.8	8	1978	-0.4
9	1976	-0.7	9	1982	-0.6	9	1955	-0.8	9	1951	-0.4
10	1956	-0.6	10	1964	-0.5	10	1964	-0.8	10	1967	-0.3

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/corn/bulletin/annual98/page2_c.html>

Table 7: Annual regional temperature departures: trend, extremes, and current season ranking, 1948–1998 (51 years)*

Region	Trend °C	Extreme years				Annual 1998	
		Coldest	Depart. °C	Warmest	Depart. °C	Rank*	Depart. °C
Atlantic Canada	-0.5	1972	-1.4	1998	1.2	1	1.2
Great Lakes/St. Lawrence Lowlands	0.0	1978	-1.0	1998	2.3	1	2.3
Northeastern Forest	0.1	1972	-1.9	1998	2.1	1	2.1
Northwestern Forest	1.4	1950	-2.1	1987	3.0	3	2.3
Prairies	1.2	1950	-2.1	1987	3.1	4	1.8
South British Columbia Mountains	1.4	1955	-1.8	1998	2.0	1	2.0
Pacific Coast	1.1	1955	-1.2	1958	1.6	3	1.2
North British Columbia Mountains/Yukon	1.7	1972	-2.1	1981	2.8	7	1.5
Mackenzie District	1.6	1982	-1.5	1998	3.9	1	3.9
Arctic Tundra	0.8	1972	-2.4	1998	3.3	1	3.3
Arctic Mountains and Fjords	0.3	1972	-1.9	1981	2.2	2	1.9
Canada	0.7	1972	-1.8	1998	2.5	1	2.5

The rank for the most recent value in the series (the 2000 annual value for each region in this case) is calculated on series data arranged in descending order, from warmest to coolest values. Note: the 2000 data are preliminary.

Table 8: Annual regional precipitation departures, extremes and current season ranking, 1948–1998 (51 years)*

Region	Extreme years				Annual 1998	
	Driest	Depart. %	Wettest	Depart. %	Rank*	Depart. %
Atlantic Canada	1966	-15.5	1990	19.2	20	3.9
Great Lakes/St. Lawrence Lowlands	1963	-16.0	1990	19.1	47	-11.5
Northeastern Forest	1962	-10.3	1979	13.2	43	-7.0
Northwestern Forest	1998	-24.8	1973	16.5	51	-24.8
Prairies	1961	-29.1	1951	26.8	17	4.7
South British Columbia Mountains	1952	-21.3	1959	25.3	19	4.0
Pacific Coast	1985	-24.6	1980	17.4	40	-8.0
North British Columbia Mountains/Yukon	1998	-33.8	1997	23.0	51	-33.8
Mackenzie District	1995	-27.9	1974	27.6	23	1.0
Arctic Tundra	1954	-19.8	1996	24.9	6	15.7
Arctic Mountains and Fjords	1948	-46.4	1953	44.2	36	-7.8
Canada	1956	-7.3	1981	8.8	43	-2.7

The rank for the most recent value in the series (the 2000 annual value for each region in this case) is calculated on series data arranged in descending order, from wettest to driest values. Note: the 2000 data are preliminary.

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/ccrm/bulletin/annual98/page2_e.html>.

Table 9: Annual regional precipitation departures, wettest 10 years in the period 1948–1998*

Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C
Atlantic Canada			Northwestern Forest			Pacific Coast			Arctic Tundra		
1	1990	19.2	1	1973	16.5	1	1980	17.4	1	1996	24.9
2	1981	19.1	2	1955	11.2	2	1997	17.2	2	1981	22.8
3	1979	17.6	3	1988	11.2	3	1953	15.5	3	1987	21.7
4	1983	13.1	4	1962	10.7	4	1971	14.3	4	1980	18.8
5	1993	10.8	5	1949	9.0	5	1981	13.2	5	1993	17.7
6	1972	10.5	6	1984	8.9	6	1983	12.3	6	1998	15.7
7	1976	10.1	7	1976	7.7	7	1974	10.9	7	1960	15.2
8	1977	9.5	8	1954	7.5	8	1984	9.4	8	1994	14.9
9	1982	8.9	9	1977	7.5	9	1975	9.1	9	1982	14.8
10	1994	8.6	10	1974	7.1	10	1968	8.9	10	1985	14.2
Great Lakes/St. Lawrence			Prairies			North BC/Yukon			Arctic Mountains/Fjords		
1	1990	19.1	1	1951	26.8	1	1997	23.0	1	1953	44.2
2	1972	16.9	2	1954	26.1	2	1974	22.7	2	1951	43.1
3	1983	15.8	3	1993	23.9	3	1991	21.5	3	1979	35.7
4	1954	12.9	4	1975	22.4	4	1962	21.2	4	1978	31.0
5	1973	12.9	5	1953	21.6	5	1988	17.5	5	1981	30.4
6	1986	12.1	6	1991	20.5	6	1975	11.0	6	1989	29.4
7	1977	10.6	7	1978	15.8	7	1961	10.8	7	1968	27.7
8	1995	10.2	8	1965	15.3	8	1990	10.6	8	1982	25.4
9	1979	9.6	9	1955	14.9	9	1976	9.5	9	1984	23.8
10	1992	9.6	10	1956	11.1	10	1949	9.2	10	1952	21.1
Northeastern Forest			South British Columbia			Mackenzie District			Canada		
1	1979	13.2	1	1959	25.3	1	1974	27.6	1	1981	8.8
2	1983	9.2	2	1990	24.3	2	1988	27.0	2	1996	8.0
3	1982	7.9	3	1996	18.1	3	1962	25.1	3	1982	7.5
4	1965	7.3	4	1964	12.7	4	1960	21.6	4	1973	6.8
5	1966	6.2	5	1995	11.8	5	1991	19.8	5	1980	6.6
6	1968	5.5	6	1948	11.1	6	1997	15.8	6	1979	6.5
7	1971	5.3	7	1953	11.0	7	1981	15.8	7	1988	6.3
8	1996	4.9	8	1980	10.5	8	1963	15.6	8	1991	5.7
9	1964	4.9	9	1972	9.7	9	1961	15.3	9	1984	5.5
10	1973	4.5	10	1966	9.7	10	1948	15.2	10	1990	5.0

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/corn/bulletin/annual98/page2_c.html>

Table 10: Annual regional precipitation departures, driest 10 years in the period 1948–1998*

Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C	Rank	Year	Depart. °C
Atlantic Canada			Northwestern Forest			Pacific Coast			Arctic Tundra		
1	1966	-15.5	1	1998	-24.8	1	1985	-24.6	1	1954	-19.8
2	1965	-14.6	2	1981	-21.8	2	1957	-20.5	2	1962	-14.3
3	1960	-13.7	3	1967	-18.9	3	1970	-17.3	3	1951	-12.9
4	1985	-11.7	4	1992	-15.3	4	1993	-16.5	4	1952	-11.0
5	1952	-10.7	5	1958	-14.2	5	1951	-13.8	5	1956	-10.7
6	1997	-10.2	6	1995	-12.0	6	1952	-12.2	6	1972	-9.8
7	1957	-8.7	7	1961	-10.3	7	1989	-10.6	7	1965	-8.8
8	1950	-8.0	8	1985	-10.2	8	1969	-10.1	8	1961	-8.6
9	1978	-7.7	9	1994	-8.4	9	1955	-10.1	9	1958	-7.8
10	1989	-7.4	10	1952	-8.2	10	1979	-9.5	10	1949	-7.5
Great Lakes/St. Lawrence			Prairies			North BC/Yukon			Arctic Mountains/Fjords		
1	1963	-16.0	1	1961	-29.1	1	1998	-33.8	1	1948	-46.4
2	1953	-15.6	2	1960	-21.8	2	1951	-24.7	2	1956	-37.9
3	1958	-13.5	3	1979	-18.6	3	1955	-22.8	3	1955	-23.1
4	1964	-12.9	4	1997	-15.9	4	1957	-22.5	4	1967	-20.0
5	1998	-11.5	5	1958	-15.8	5	1950	-20.7	5	1958	-18.3
6	1955	-10.4	6	1967	-15.7	6	1969	-14.0	6	1964	-17.1
7	1952	-8.3	7	1952	-15.6	7	1995	-12.8	7	1972	-14.2
8	1948	-8.0	8	1988	-15.3	8	1958	-8.7	8	1974	-13.4
9	1956	-7.9	9	1957	-14.4	9	1971	-8.4	9	1966	-12.2
10	1949	-7.3	10	1987	-13.1	10	1982	-8.3	10	1987	-11.8
Northeastern Forest			South British Columbia			Mackenzie District			Canada		
1	1962	-10.3	1	1952	-21.3	1	1995	-27.9	1	1956	-7.3
2	1987	-10.0	2	1970	-20.0	2	1955	-18.0	2	1957	-6.8
3	1948	-9.9	3	1987	-19.0	3	1951	-17.6	3	1958	-6.0
4	1997	-9.8	4	1979	-18.3	4	1979	-17.1	4	1948	-4.4
5	1957	-9.0	5	1985	-17.3	5	1953	-16.1	5	1961	-4.2
6	1989	-7.4	6	1973	-14.5	6	1994	-13.8	6	1967	-4.0
7	1956	-7.2	7	1978	-10.9	7	1983	-12.7	7	1955	-3.4
8	1961	-7.1	8	1960	-10.0	8	1978	-11.4	8	1952	-3.7
9	1998	-7.0	9	1967	-9.0	9	1949	-10.1	9	1998	-2.7
10	1963	-6.3	10	1991	-5.6	10	1971	-10.1	10	1950	-2.4

* Chart reproduced from Environment Canada (2003). Used with permission. <http://www.msc-smc.ec.ca/corm/bulletin/annual98/page2_e.html>.



Greenhouse Gases and Climate Change*

Figure 1: Percentage Abundance of Common “Greenhouse” Gases

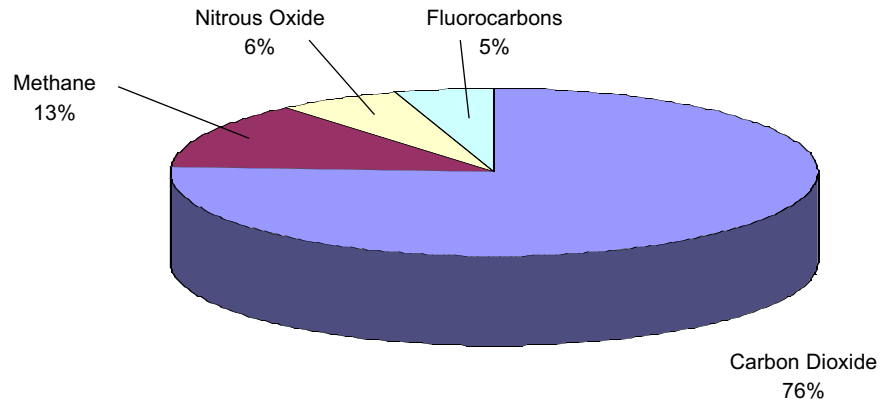
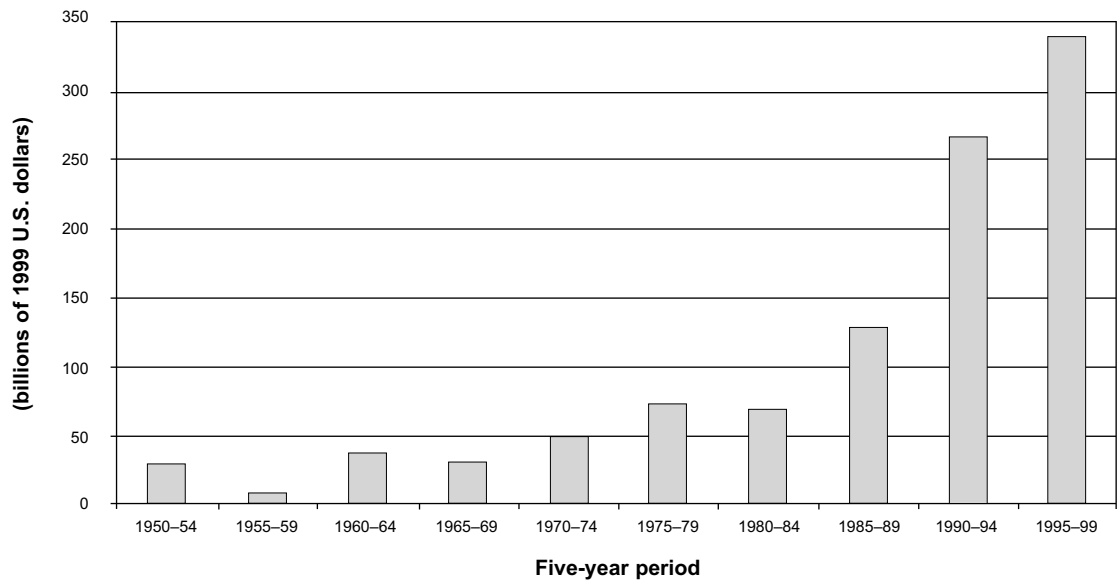
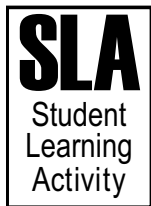


Figure 2: Economic Effects of Natural Catastrophes

Global Direct Economic Losses from Natural Catastrophes



* Figure 2 reproduced from <www.ec.gc.ca> (Government of Canada with permission from Natural Resources Canada), © 2001. Reproduced by permission.



Plotting CO₂ and Temperature*

Directions

- The table that follows shows temperature (actually the difference, or anomaly, from the current 30-year normal), and the concentration of CO₂ in the Earth's atmosphere back to 1840.
- We will assume that the pre-industrial global temperatures (before 1800) were about the same as they were in 1840.
- Use the rectangular graph paper provided for you at the end of this activity to plot the data.
- Label the vertical scale on **Graph 1** from 200 to 400 ppm (parts per million) of CO₂, and the horizontal scale from 1800 to 2100.
- Label the vertical scale on **Graph 2** from -1.00 to +1.00 (for the temperature anomaly data) and the horizontal scale from 250 to 450 ppm (parts per million) of CO₂.
- We will place the zero of the vertical scale in the middle, and label it -1 to +1 degree Celsius, using tick marks every 0.1 degree. The middle of this scale corresponds to the reference line of average temperature in the other figures in this activity showing temperature versus time.
- Now, using the table of temperature and CO₂ concentration, plot a graph of the **year (on the x-axis)** and the **carbon dioxide concentration (on the y-axis)** for each year.
- Plot a second graph of **temperature anomaly (on the x-axis)** and **carbon dioxide concentration (on the y-axis)**.
- You should plot all the data from 1840 to 2000, and should see a scatter of points sloping upward to the right in both graphs. Draw a line of best fit through the centre of the points and extend it straight to the lower left and upper right of each graph.

* All data and graphics courtesy of Environment Canada. <<http://www.ec.gc.ca>>. Used with permission.

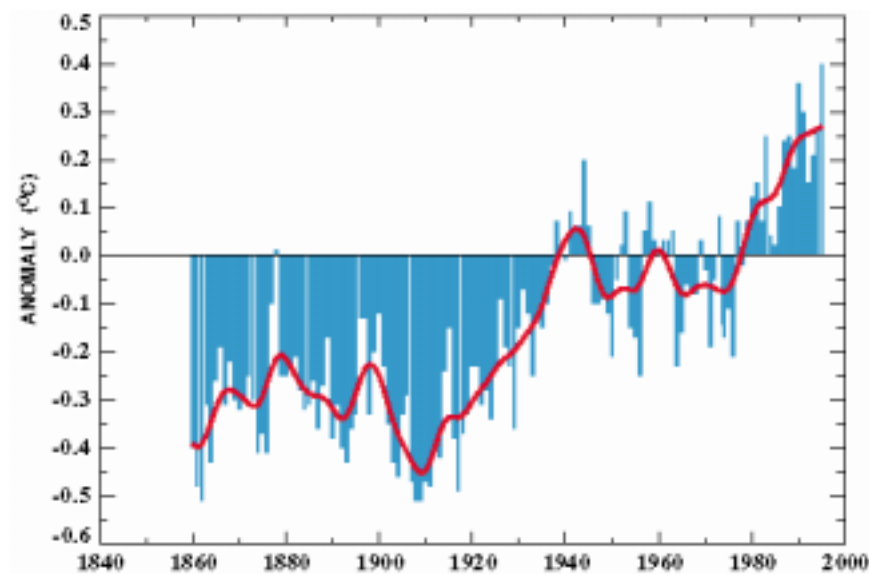
Table 1: Carbon Dioxide (CO₂) concentrations in the atmosphere and temperature changes (anomaly) in the period 1840–2000

Year	CO ₂ Concentration (in parts per million by volume, ppmv**)	Temperature Anomaly (°C above/below normal)
1840	280	−0.40
1955	310	−0.05
1960	312	0.00
1965	316	−0.10
1970	320	−0.08
1975	327	−0.08
1980	335	−0.08
1985	345	+0.10
1990	352	+0.15
1995	355	+0.25
2000	360	+0.28

* 300 ppmv (300 parts per million by volume) would be equivalent to 300 CO₂ molecules / 1,000,000 molecules of dry air or, expressed as a percent, 0.03%

What follows are a number of graphs that highlight the relationships among global CO₂ concentration in the atmosphere, time, and temperature trends.

Figure 1: Graph of the temperature anomaly* over the years 1840–2000



Note: The temperature anomaly is the deviation of average global temperatures over the past 30 years (what we call “climate normals”). The horizontal “zero” line represents this 30-year normal for temperatures.

Figure 2: Plot of temperature changes over the last 1,000,000 years from ice core research

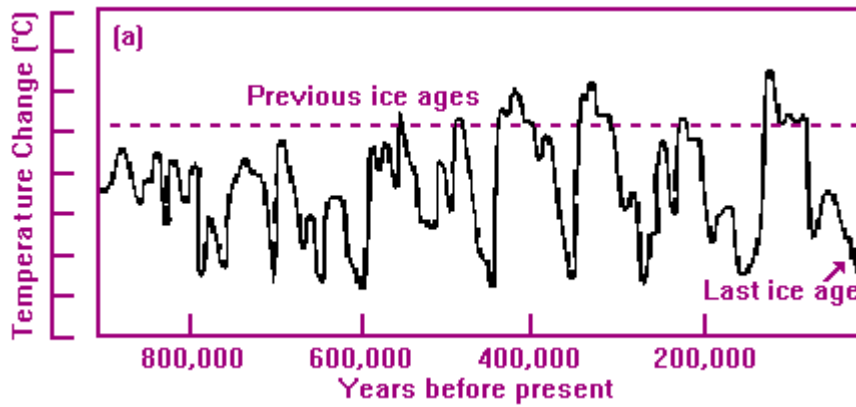


Figure 3: Plot of temperature changes over the last 10,000 years since the end of the most recent ice age

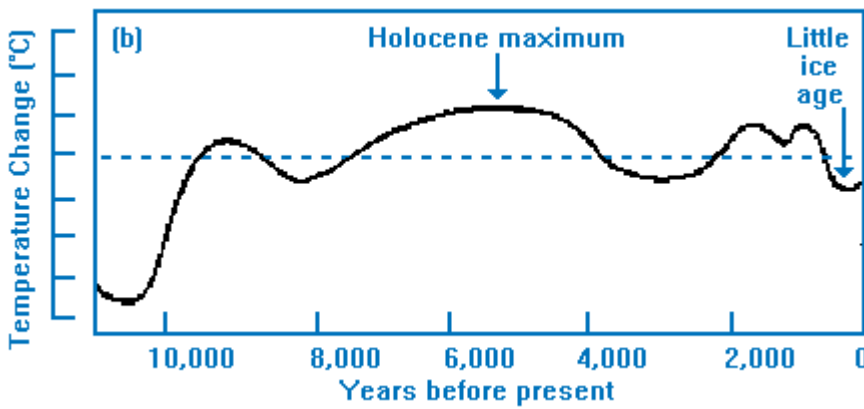
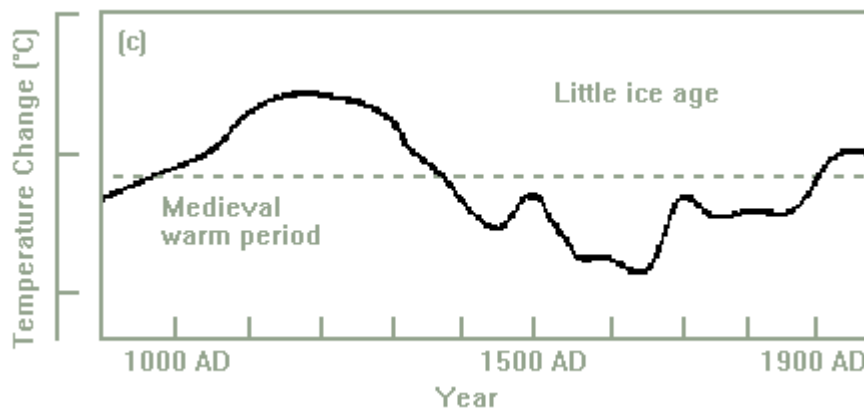
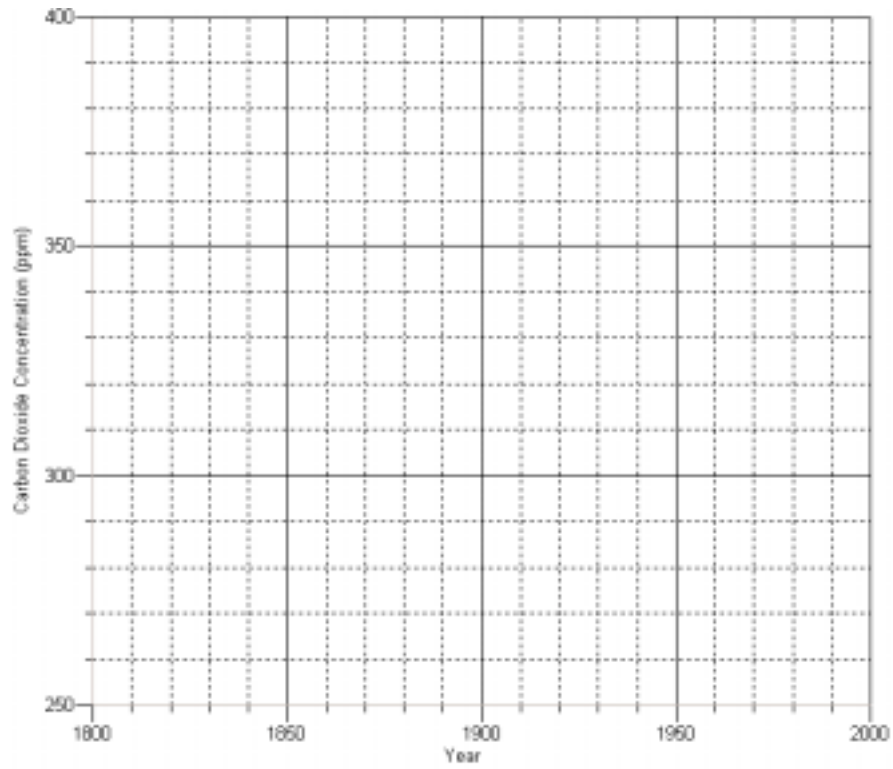


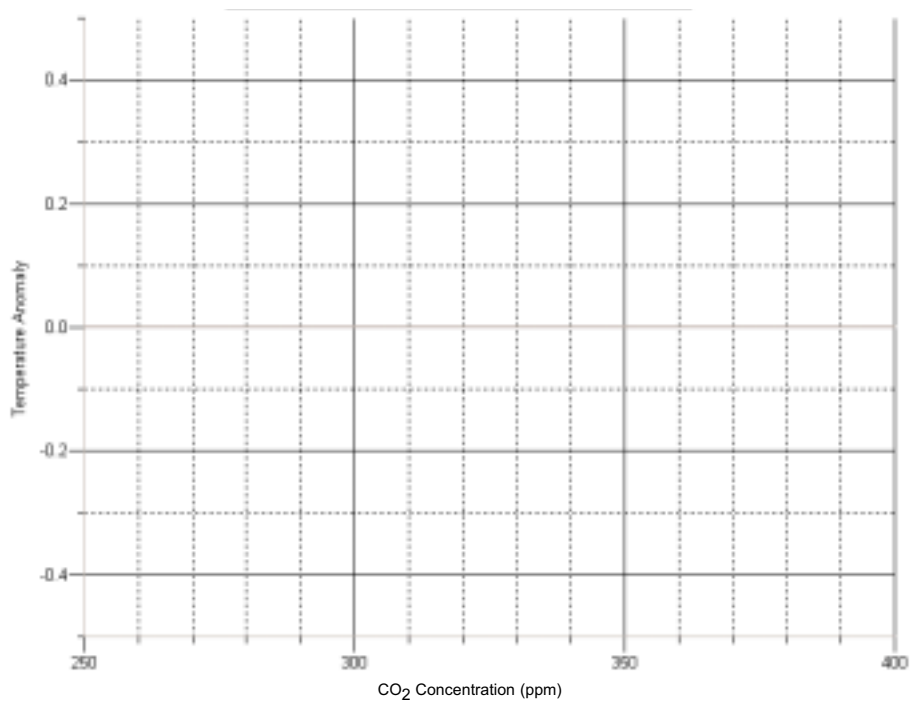
Figure 4: Plot of temperature changes over the last 1,000 years



Graph 1

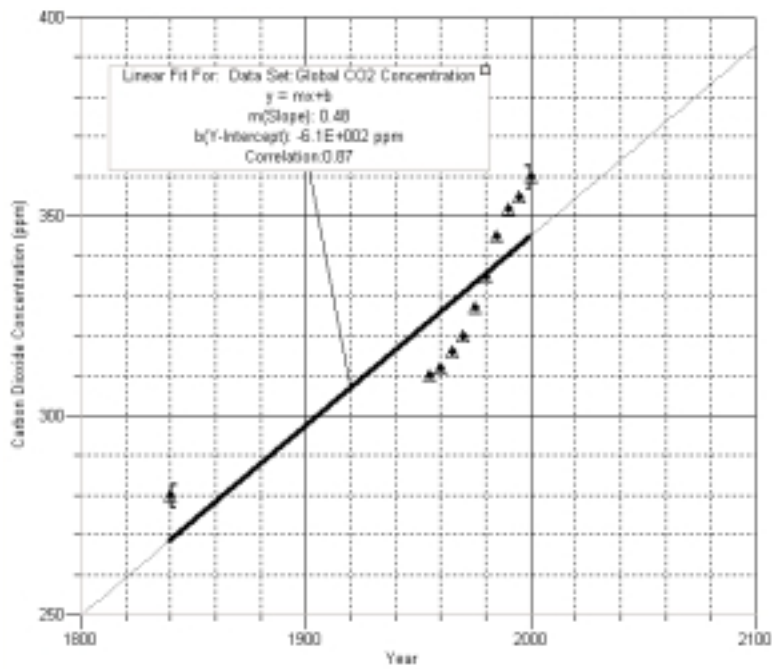


Graph 2



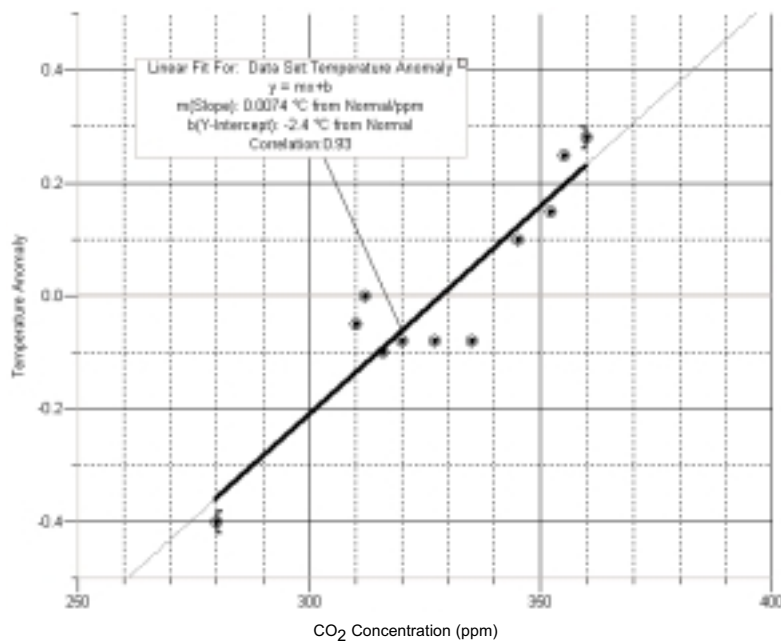
Possible Results (including line of best fit)—Graph 1

Global CO₂ Concentrations in the Period 1840–2000



Possible Results (including line of best fit)—Graph 2

Temperature Anomaly and CO₂ Concentration



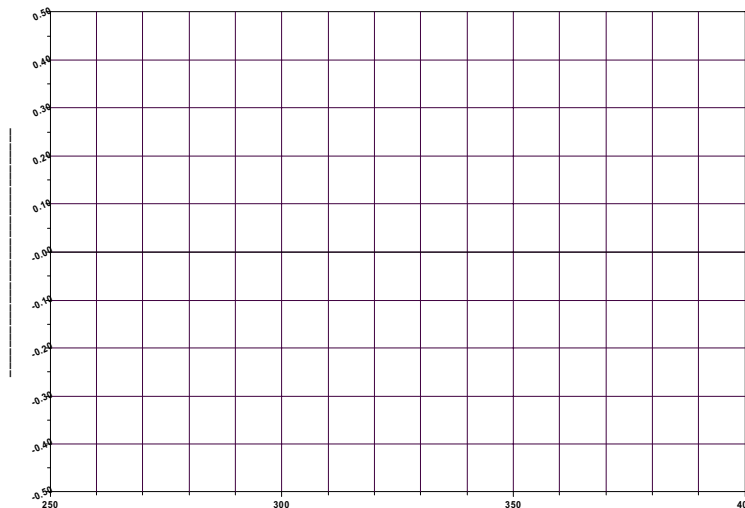
Follow-Up Questions

- Look carefully at the graph in Figure 2 on page A211 (the last 1,000,000 years). What evidence exists for regular, dramatic shifts in temperature over this time span?

- Note that the line acts like a wave (rising and falling in a pattern). How long does it take for one complete cycle—50,000 years, 100,000 years, 200,000 years, or 400,000 years?

- What relationship exists between the following two measured variables:
CO₂ Concentration and **Temperature Changes**?

- How could you demonstrate that the relationship identified in (3) above actually may be supported by the data in the table? If you were to say “why not draw a graph?” you would be on the right track. So let’s get at it and plot a graph to see what the relationship might be. This time you will be responsible for setting up the x- and y-axes, deciding which variable goes on which axis, labeling the axes correctly as the **independent** and **dependent** variables, and giving your graph a title when it’s complete. Use the axes on this page for your graph.



- Based on your plot in part (4) above, what relationship exists (if any) between the CO₂ content of Earth’s atmosphere and global temperatures?



Ozone—What Is It, and Why Do We Care About It?

Ozone is a relatively unstable molecule found in the Earth's atmosphere. Most ozone is concentrated below a 48-km (30-mile) height. An ozone molecule is made up of three atoms of oxygen. Although it represents only a tiny fraction of the atmosphere, ozone is crucial for life on Earth.

Depending on where ozone resides, it can protect or harm life on Earth. High in the atmosphere at about 24 kilometres (15 miles) up, ozone acts as a shield to protect the Earth's surface from the Sun's harmful ultraviolet radiation. Without this shield, we would be more susceptible to skin cancer, cataracts, and impaired immune systems. Closer to Earth, in the air we breathe, ozone is a harmful pollutant that causes damage to lung tissue and plants.

The amounts of “good” and “bad” ozone in the atmosphere depend on a balance between processes that create ozone and those that destroy it. An upset in the ozone balance can have serious consequences for life on Earth. Scientists are finding evidence that changes are occurring in ozone levels—the “bad” ozone is increasing in the air we breathe, and the “good” ozone is decreasing in our protective ozone shield. This article describes processes that regulate “good” ozone levels.

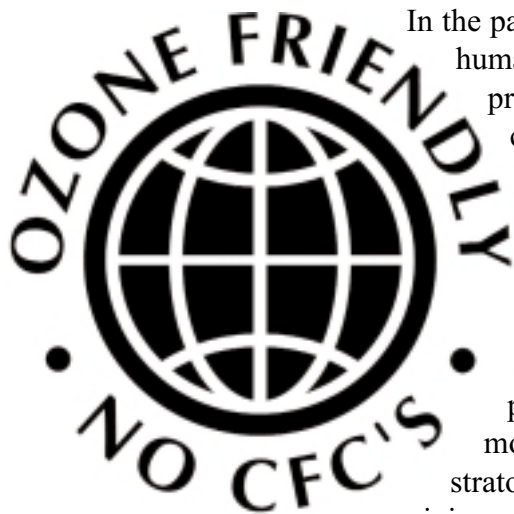
About 24 kilometres up in the atmosphere, in the region called the stratosphere, ozone is created and destroyed primarily by ultraviolet radiation. The air in the stratosphere is bombarded continuously with ultraviolet radiation from the Sun. When high-energy ultraviolet rays strike molecules of ordinary oxygen (O_2), they split the molecule into two single oxygen atoms, known as atomic oxygen. A freed oxygen atom then can bump into an oxygen molecule (O_2), and form a molecule of ozone (O_3).

The characteristic of ozone that makes it so valuable to us—its ability to absorb a range of ultraviolet rays—also causes its destruction. When an ozone molecule (O_3) absorbs even low-energy ultraviolet radiation, it splits into an ordinary oxygen molecule (O_2) and a free oxygen atom (O). The free oxygen atom then may join up with an oxygen molecule to make another ozone molecule, or it may steal an oxygen atom from an ozone molecule to make two ordinary oxygen molecules. These processes of ozone production and destruction that are initiated by ultraviolet radiation are often called the “Chapman Reactions.”

Natural forces other than the Chapman Reactions also affect the concentration of ozone in the stratosphere. Because ozone is a highly unstable molecule, it reacts very easily, readily donating its “extra” oxygen molecule to the nitrogen, hydrogen, and chlorine found in natural compounds. These elements always have existed in the stratosphere, released from sources such as soil, water vapour, and the oceans.

In addition, scientists are finding that ozone levels change periodically as part of regular, natural cycles such as the changing seasons, Sun cycles, and winds. Moreover, volcanic eruptions may inject materials into the stratosphere that can destroy ozone.

Over the Earth's lifetime, natural processes have regulated the balance of ozone in the stratosphere. A simple way to understand the ozone balance is to think of a leaky bucket. As long as water is poured into the bucket at the same rate that water is leaking out, the amount of water in the bucket will remain the same. Likewise, as long as ozone is being created at the same rate that it is being destroyed, the total amount of ozone will remain the same.



In the past two decades, however, scientists have found evidence that human activities are disrupting the ozone balance. Human production of chlorine-containing chemicals, such as chlorofluorocarbons (CFCs), has added an additional force that destroys ozone. CFCs are compounds made up of chlorine, fluorine, and carbon bound together. Because they are such stable molecules, CFCs do not react easily with other chemicals in the lower atmosphere. One of the few forces that can break up CFC molecules is ultraviolet radiation. In the lower atmosphere, however, CFCs are protected from ultraviolet radiation by the ozone layer. CFC molecules are therefore able to migrate intact up into the stratosphere. Although the CFC molecules are heavier than air, the mixing processes of the atmosphere carry them into the stratosphere.

Once in the stratosphere, however, the CFC molecules no longer are shielded from ultraviolet radiation by the ozone layer. Bombarded by the Sun's ultraviolet energy, CFC molecules break up and release their chlorine atoms. The free chlorine atoms then can react with ozone molecules, taking one oxygen atom to form chlorine monoxide and leaving an ordinary oxygen molecule.

If each chlorine atom released from a CFC molecule destroyed only one ozone molecule, CFCs probably would pose very little threat to the ozone layer. However, when a chlorine monoxide molecule encounters a free atom of oxygen, the oxygen atom breaks up the chlorine monoxide, stealing the oxygen atom and releasing the chlorine atom back into the stratosphere to destroy more ozone. This reaction happens over and over again, allowing a single atom of chlorine to destroy many molecules of ozone.

Fortunately, chlorine atoms do not remain in the stratosphere forever. When a free chlorine atom reacts with gases such as methane (CH_4), it is bound up into a molecule of hydrogen chloride (HCl), which can be carried from the stratosphere into the troposphere, where it can be washed away by rain. Therefore, if humans stop putting CFCs and other ozone-destroying chemicals into the stratosphere, the ozone layer eventually may repair itself.

Ozone Depletion

The term “ozone depletion” means more than just the natural destruction of ozone; it means that ozone loss is exceeding ozone creation. Think again of the “leaky bucket.” Putting additional ozone-destroying compounds such as CFCs into the atmosphere is like causing the “bucket” of ozone to spring extra leaks. The extra leaks cause ozone to leak out at a faster rate—faster than ozone is being created. Consequently, the level of ozone protecting us from ultraviolet radiation decreases.

In the area over Antarctica, stratospheric clouds hold ice particles that are not present at warmer latitudes. Reactions occur on the surface of the ice particles that accelerate the ozone destruction caused by stratospheric chlorine. This phenomenon has caused documented decreases in ozone concentrations over Antarctica. In fact, ozone levels drop so low in spring in the southern hemisphere that scientists have observed what they call a “hole” in the ozone layer. In addition, scientists have observed declining concentrations of ozone over the whole globe. In the second half of 1992, for example, world-wide ozone levels were the lowest ever recorded.

Monitoring Ozone from Space

Since the 1920s, ozone has been measured from the ground. Scientists place instruments at locations around the globe to measure the amount of ultraviolet radiation getting through the atmosphere at each site. From these measurements, they calculate the concentration of ozone in the atmosphere above that location. These data, although useful in learning about ozone, are not able to provide an adequate picture of global ozone concentrations.

Contrary to the image created by the term “ozone layer,” the amount and distribution of ozone molecules in the stratosphere vary greatly over the globe. Ozone molecules drift and swirl around the stratosphere in changing concentrations—much as clouds do in the satellite weather pictures you see on television news. Therefore, scientists observing ozone fluctuations over just one spot could not be confident that a change in local ozone levels meant an alteration in global ozone levels, or simply a fluctuation in the concentration over that particular spot. Satellites have given scientists the ability to overcome this problem because they provide a picture of what is happening simultaneously over the entire Earth.

Scientists now are confident that ozone is being depleted worldwide—partly due to human activities. However, scientists still need to determine how much of the loss is the result of human activity, and how much is the result of fluctuations in natural cycles.

Predicting Ozone Levels

If scientists can separate the human and natural causes of ozone depletion, they can formulate improved models for predicting ozone levels. The predictions of early models already have been used by policy makers to determine what can be done to reduce the ozone depletion caused by humans. For example, faced with the strong possibility that CFCs could cause serious damage to the ozone layer, policy makers from around the world in 1987 signed a treaty known as the Montreal Protocol. This treaty set strict limits on the production and use of CFCs. By 1990, the growing amount of scientific evidence against CFCs prompted diplomats to strengthen the requirements of the Montreal Protocol. The revised treaty called for a complete phase-out of CFCs by the year 2000. Some countries have not met their targets for CFC elimination.

However, scientists agree that much remains to be learned about the interactions that affect ozone. To create accurate models, scientists must study simultaneously all of the factors affecting ozone creation and destruction. Moreover, they must study these factors from space continually, over many years, and over the entire globe. NASA's Earth Observing System (EOS) will allow scientists to study ozone in just this way. The EOS series of satellites will carry a sophisticated group of instruments that will measure the interactions of the atmosphere that affect ozone. Building on more than 20 years of data gathered by previous NASA missions, these measurements will increase dramatically our knowledge of the chemistry and dynamics of the upper atmosphere and our understanding of how human activities are affecting the Earth's protective ozone layer.



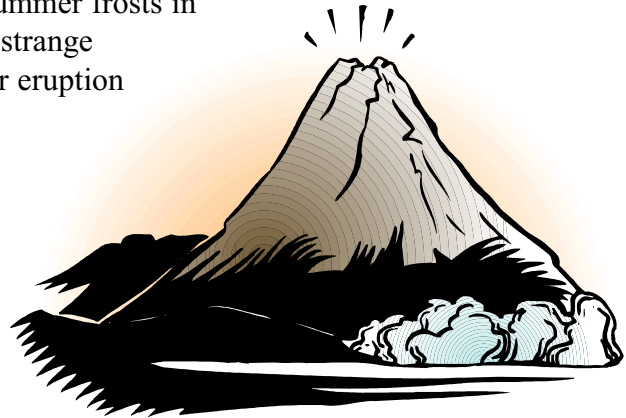
Volcanoes and Global Cooling

Volcanic eruptions are thought to be responsible for the global cooling that has been observed to occur for a few years after a major eruption. The amount and global extent of the cooling depend on the force of the eruption and, possibly, its latitude. When large masses of gases from the eruption reach the stratosphere, they can produce a large, widespread cooling effect. As a prime example, the effects of Mount Pinatubo, Philippines, which erupted in June 1991, may have lasted a few years, serving to temporarily offset the predicted greenhouse effect.

As volcanoes erupt, they blast huge clouds into the atmosphere. These clouds are made up of particles and gases, including sulfur dioxide. Millions of tons of sulfur dioxide gas can reach the stratosphere from a major volcano. There, the sulfur dioxide converts to tiny persistent sulfuric acid (sulfate) particles, referred to as aerosols. These sulfate particles reflect energy coming from the Sun, thereby preventing the Sun's rays from heating the Earth.

Global cooling often has been linked with major volcanic eruptions. The year 1816 often has been referred to as “the year without a summer.” It was a time of significant weather-related disruptions in New England and in Western Europe with killing summer frosts in the United States and Canada. These strange phenomena were attributed to a major eruption of the Tambora volcano in 1815 in Indonesia. The volcano threw sulfur dioxide gas into the stratosphere, and the aerosol layer that formed led to brilliant sunsets seen around the world for several years.

However, there is some confusion about the historical evidence that global cooling may be caused by volcanic emissions. Two recent volcanic eruptions have provided contradictory evidence on this point. Mount Agung, Malaysia in 1963 apparently caused a considerable decrease in temperatures around much of the world, whereas El Chichon, Mexico in 1982 seemed to have little effect, perhaps because of its different location or because of the El Niño that occurred the same year. El Niño is a Pacific Ocean phenomenon, but it causes worldwide weather variations that may have acted to cancel out the effect of the El Chichon eruption.



Volcanoes and Ozone Depletion

Another possible effect of a volcanic eruption is the destruction of stratospheric ozone. Researchers now are suggesting that ice particles containing sulfuric acid from volcanic emissions may contribute to ozone loss. When chlorine compounds resulting from the breakup of chlorofluorocarbons (CFCs) in the stratosphere are present, the sulfate particles may serve to convert them into more active forms that may cause more rapid ozone depletion.

Monitoring the Effects of Volcanoes

Even if one can get to a volcano, it's practically impossible to measure its gas output because one can't synoptically see the whole cloud. Even aircraft can't do it because they're too low and it's too dangerous. Space observations from NASA's Total Ozone Mapping Spectrometer (TOMS) instrument have contributed significantly to our knowledge of the total amount of sulfur dioxide emitted into the atmosphere in the course of major volcanic eruptions. Following the eruption of Mount Pinatubo, TOMS images show sulfur dioxide spreading across the Pacific. Several weeks later the sulfur dioxide had spread around the world, as observed by the Microwave Limb Sounder (MLS) instrument on NASA's Upper Atmosphere Research Satellite (UARS).

In addition to detecting the sulfur dioxide from Mount Pinatubo, TOMS has made similar observations of more than 100 volcanic events including a major eruption from the Cerro Hudson volcano in Chile in 1991. A TOMS instrument was launched on the Russian Meteor-3 spacecraft in 1991; it flew on a special-purpose NASA satellite, an Earth Probe, in 1994, and on the Japanese Advanced Earth Observing System (ADEOS) mission in 1996. Current plans are for TOMS to monitor volcanic eruptions well into the next century.

Data from the Stratospheric Aerosol and Gas Experiment (SAGE II) instrument on NASA's Earth Radiation Budget Satellite (ERBS) have shown that during the first five months after the Mount Pinatubo eruption, the optical depth of the stratospheric aerosol increased up to 100 times in certain locations. Optical depth is a general measure of the capacity of a region of the atmosphere to prevent the passage of visible light through it. Greater optical depth means greater blockage of the light. In this case, the increased optical depth meant that considerably less of the Sun's energy could get through the cloud to warm the Earth's surface.

Observations of the effects of Mt. Pinatubo aerosols on global climate have been used to validate scientists' understanding of climate change and our ability to predict future climate. Researchers at NASA's Goddard Institute for Space Studies in New York City have applied their general circulation model of the Earth's climate to the problem. They have reported success in correctly predicting the effects of the sulfate aerosols from Mount Pinatubo's eruption on lowering global temperatures.

Missions to Study Volcanoes

The first launch in the series of EOS satellites, the key element of NASA's Mission to Planet Earth took place in 1998.

The High Resolution Infrared Radiometer (HRIR), first flown on NASA's Nimbus-1 satellite in 1964, has been used to observe both active and dormant volcanoes. On Nimbus-2, HRIR recorded energy changes from the volcanic activity on Surtsey, Iceland in 1966. The Multispectral Scanner (MSS) and Thematic Mapper (TM) instruments on the Landsat satellite have provided a long series of images of volcanic activity (e.g., venting, volcanic ash falls, and lava flows).

The EOS program will incorporate a series of satellites that will carry advanced instruments to provide a highly accurate, self-consistent, and long-term database of many aspects of the Earth's atmosphere, land, and ocean characteristics. The information gained from this major effort to study Earth phenomena will expand our knowledge of the interactions between volcanoes and the Earth's climate.



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World Meteorological Organization. *WMO and the Ozone Issue*.

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Web-Based Resources for Teachers

Specific Sites on Weather-Related Topics and Publications

<http://www.weatheroffice.pyr.ec.gc.ca/skywatchers/index_e.html>

The National Skywatchers website can be used in conjunction with the Skywatchers weather resource kit.

<http://www.weatheroffice.pyr.ec.gc.ca/skywatchers/index_f.html>

This is the French equivalent of Skywatchers website.

<www.weatheroffice.ec.gc.ca>

Bilingual Environment Canada Weather site, shows current conditions across the country, local five-day forecasts, and satellite imagery.

<<http://www.cmc.ec.gc.ca>>

Bilingual Canadian Meteorological Centre site shows weather bulletins, satellite and radar imagery, and climate normals.

<<http://www.ec.gc.ca/acidrain/>>

This is the Environment Canada acid rain website.

<<http://www.ec.gc.ca/climate/>>

This is a bilingual site within Environment Canada's Green Lane, providing information on climate change.

<<http://www.epa.gov/air/acidrain/index.html>>

This is the U.S. Environmental Protection Agency Clean Air Markets website that deals with environmental issues, particularly acid rain.

<http://www.msc-smc.ec.gc.ca/cd/index_e.cfm#facts>

This site offers Canadian Meteorological Service Fact Sheets on weather-related topics.

<http://www.on.ec.gc.ca/pubs_e.html>

This site offers Environment Canada, Ontario Region Fact Sheets on weather and climate-related topics.

<<http://www.qc.ec.gc.ca/envcan/indexe.html>>

The Environment Canada, Quebec Region's bilingual website has substantive information on weather and climate, including material on the St. Lawrence Valley and Project Biosphere.

<<http://www.cmos.ca>>

Canadian Meteorological and Oceanographic Society homepage contains a link under Education–Schools to a series of classroom activities about weather by Dave Phillips.

<<http://www.atmos.uiuc.edu/>>

This is a useful all-round Meteorology Education site from University of Illinois at Urbana-Champaign.

<<http://www.ametsoc.org/dstreme>>

The American Meteorological Society site has a program on Weather Education for Grades K–12.

<<http://www.islandnet.com/~see/weather/doctor.htm>>

The Weather Doctor’s website by Keith Heidorn includes interesting information on weather events and phenomena, people in weather, effects of weather, and book reviews.

<<http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html>>

This site includes observations and forecasts for American and international locations.

<<http://www.ucar.edu/40th/webweather>>

This is a great website for kids from the University Corporation for Atmospheric Research. There is a lot of activities and information.

<<http://cimss.ssec.wisc.edu/>>

A website from Cooperative Institute for Meteorological Satellite Studies in Wisconsin is a comprehensive source of information on satellites, including GOES, and many photographs.

<http://www.msc-smc.ec.gc.ca/cd/brochures/elnino_e.cfm>

This MSC site includes description, animation, status of the El Niño phenomenon.

<http://www.msc-smc.ec.gc.ca/cd/brochures/lanina_e.cfm>

This MSC site includes description, animation, status of the La Niña phenomenon.

<<http://www.pmel.noaa.gov/toga-tao/el-nino/>>

This NOAA site gives excellent background information and current status of El Niño and La Niña.

<<http://www.elnino.noaa.gov/edu.html>>

This El Niño site also provides links to several other El Niño Educational Sites.

<http://www.epa.gov/students/global_warming_us.htm>

This is a website on global warming and climate change from the U.S. Environmental Protection Agency.

<<http://weather.unisys.com/hurricane>>

This site includes a hurricane database.

<<http://www.tornadoproject.com>>

This is a comprehensive resource for tornado information.

<<http://www.caps.ou.edu/outreach.htm>>

The Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma website offers a lot of information on tornadoes and summer severe weather events.

<http://www.msc-smc.ec.gc.ca/uvindex/index_e.html>

This MSC site includes information and activities on the UV Index.

<<http://www.worldclimate.com>>

This interesting site shows what the weather is normally like in thousands of places world-wide.

<<http://www.usatoday.com/weather/wfront.htm>>

This is one of the most useful general weather education sites with explanations in easily understandable terms. It also gives world weather conditions and forecasts.

<<http://www.australiansevereweather.com/>>

This Australian meteorology site demonstrates techniques on how to observe weather.

<<http://www.great-lakes.net>>

This site includes lots of information relating to the Great Lakes themselves and the surrounding region.

<<http://cbc4kids.ca/teachers/>>

The CBC's website for teachers includes some useful information and resources.

<<http://www.2learn.ca/mapset/mapset.html>>

This website from Alberta includes ideas for teachers and provides links to other sites with lesson plans and other activities.

<http://www.ace.mmu.ac.uk/Resources/Teaching_Packs/Key_Stage_4/Acid_Rain/contents.html>

This website is an acid rain teaching pack from the United Kingdom.

<<http://www.crh.noaa.gov/dtx/teach.htm>>:

The U.S. National Weather Service, Central Region's Education website has weather information and lesson plans for teachers.

<<http://www.education.noaa.gov>>

NOAA's website for teachers includes information on weather, climate change, oceans, and satellites, and gives links to many other useful sites.

<<http://www.ucar.edu/ucar/edout.html>>

The Education and Outreach website from the University Corporation for Atmospheric Research has great tips for teachers and lesson plans for all grade levels from K–12.

<<http://nsidc.org/links/index.html>>

The U.S. National Snow and Ice Data Center has links to many wonderful educational sites dealing with snow, ice, glaciers, and polar regions. There is a lot of information to explore.

<<http://www.weather.com:80/education>>

The Weather Channel's website has many lesson plans for teachers.

<<http://www.met.fsu.edu/explores/resources.html>>

The "Explores" website provides links to sites providing curricula information and learning activities.

<<http://www.bom.gov.au/lam/>>

The Australian Bureau of Meteorology website contains a comprehensive educational section on weather. It is of special interest to students and teachers, and also the general public.

<<http://www.homeworkcentral.com>>

This is a huge teacher resource site with a number of useful lesson plans.

<<http://www.explorescience.com>>

This is an exciting site that lets you design your own snowflake or learn about the Doppler effect, among many other experiments.

<<http://www.science.ca>>

The Great Canadian Scientists page includes the "Ask a Scientist" feature.

Useful National and International Meteorology-Related Sites

<<http://www.ec.gc.ca>>

Environment Canada's "Green Lane" has links to Regional Offices and EC publications.

<<http://www.msc-smc.ec.gc.ca>>

The Meteorological Service of Canada homepage has links to its services and publications.

<<http://www.noaa.gov>>

The U.S. National Oceanic and Atmospheric Administration (NOAA) homepage has links to many different services and current issues.

<<http://nsidc.org/links/index.html>>

The U.S. National Snow and Ice Data Center has links to many national and international organizations, providing excellent information on snow, ice, glaciers, and polar regions.

<<http://www.met-office.gov.uk>>

The British Met Office homepage has information on weather in Britain, Europe, and around the world.

<<http://www.meteo.fr>>

The Météo France homepage has information on local weather and links to other European weather sites.

<<http://www.bom.gov.au>>

Australia's Bureau of Meteorology homepage has weather information from the Southern Hemisphere.

<<http://www.wmo.ch>>

The World Meteorological Organization (WMO) homepage has links to many different national weather services around the world.

Senior 2

Appendix 5:
Developing Assessment
Rubrics in Science

APPENDIX 5: DEVELOPING ASSESSMENT RUBRICS IN SCIENCE

The Nature, Purposes, and Sources of Assessment Rubrics for Science

What Assessment Rubrics Are

Rubrics are assessment tools that identify criteria by which student processes, performances, or products will be assessed. They also describe the qualities of work at various levels of proficiency for each criterion.

The following types of assessment rubrics may be used in classroom assessment:

- **General rubrics** provide descriptions of proficiency levels that can be applied to a range of student performance processes, performances, or products. Using the same rubric for similar tasks helps teachers manage marking assignments based on student choice, and helps students internalize the common qualities of effective processes, performances, and products.
- **Task-specific rubrics** describe the criteria used in assessing specific forms, such as the use of a balance, writing a laboratory report, calibrating CBL probes. Complex student projects may require a different rubric for each phase (e.g., a group inquiry project may require a rubric for collaborative work, information-gathering processes, oral presentations, and written reports).
- **Holistic rubrics** are used to assign a single mark to a process, performance, or product on the basis of its adequacy in meeting identified criteria.
- **Analytic rubrics** are used to assign individual scores to different aspects of a process, performance, or product, based on their specific strengths and weaknesses according to identified criteria. See Appendix 6.3: Assessment of a Decision-Making Process Activity.
- **Checklists** are lists of criteria that do not distinguish between levels of performance. They are used to assess the presence or absence of certain behaviours, and are most suitable for assessing processes (e.g., “Did the student perform all the necessary steps?”). Because they require “Yes/No” judgements from the assessor, checklists are easy for students to use in peer assessment.
- **Rating scales** ask assessors to rate various elements of a process, performance, or product on a numerical scale. They do not provide complete descriptions of performance at various levels.

Why Teachers Use Assessment Rubrics

The best assessment tasks ask students to perform the sorts of scientific literacy tasks they will be called upon to perform in real-world situations. They allow students to demonstrate not only the declarative knowledge they have gained, but also the interplay of attitudes, skills, and strategies that constitute their learning. Authentic assessment tasks invite a range of responses and allow students to express their individuality. For all these reasons, assessing scientific literacy is a complex matter.

Assessment rubrics

- help teachers clarify the qualities they are looking for in student work
- ensure that all students are assessed by the same criteria
- help teachers communicate the goals of each assignment in specific terms
- allow teachers within schools, school divisions/districts, and the province to collaborate in assessment
- play an important part in instruction

How Assessment Rubrics Enhance Instruction

The best assessment tools do not simply sort and score student work; instead, they describe it in specific terms. This assessment information

- helps teachers adjust instruction to meet student learning requirements
- tells students what teachers expect and will look for in their work, and helps them to focus their efforts
- allows students to assess their own work using the criteria teachers will use to set goals and to monitor their progress
- aids in the development of metacognition by giving students a vocabulary for talking about particular aspects of their work

Sources of Assessment Rubrics

Teachers develop assessment rubrics in collaboration with students, on their own, and/or with other teachers—or obtain them through published sources.

- ***Classroom Development***

Developing assessment rubrics in collaboration with students can be a time-consuming process, but one that has many benefits in instruction and learning. (Both the benefits and the process are explored on the following pages.) Although it may not be possible to involve students in the process in every instance, some experience in developing rubrics will help students to use ready-made rubrics with more understanding.

- **Teacher-Developed**

Teachers develop general performance and product rubrics individually, in collaboration within a school or school division/district. Rubrics need to be adapted regularly to accurately reflect student performance levels.

It is important that teacher-developed rubrics use language that students understand, and that teachers provide an example of work at each level of proficiency. These examples (called anchors or exemplars) illustrate for students the descriptive phrases used in the rubrics.

- **Published Sources**

High-quality assessment rubrics are available in various educational resources. The disadvantage of ready-made rubrics is that they may not be congruent with the learning outcomes targeted in a particular assignment, and may not accurately describe Senior 2 performance levels and criteria.

Developing Rubrics in Collaboration with Students

Student Benefits

Developing rubrics in collaboration with students requires students to look at work samples, and to identify the attributes that make some samples successful and others unsuccessful. Teachers assist students by providing them with the vocabulary to articulate the various elements they see, and by ensuring the criteria are comprehensive and consistent with learning outcomes. This process

- requires students to make judgments about the work they see, and identify the qualities of effective writing, speaking, and representing science concepts.
- results in an assessment tool that students understand and feel they own. Assessment criteria are not perceived as arbitrary or imposed, but rather express students' own observations about what constitutes quality work.

The Development Process

For their first experience in designing a rubric, ask students to articulate the criteria they use in making judgments about something in everyday life—the quality of a restaurant, for example (McTighe, 1997). The model rubric that they develop for assessing restaurants may help students grasp how the parts of a rubric work.

Students may also find it helpful to develop rubrics after they have done some preliminary work on the assessment task, and so are familiar with the demands of the particular assignment.

The process of developing assessment rubrics in collaboration with students involves numerous steps:

1. Look at samples.

Develop assessment rubrics by analyzing genuine samples of student work that illustrate the learning outcomes that the assessment task in question addresses. Samples are usually drawn from student work from previous years, used with permission and with names removed. Beginning teachers who do not have files of samples may need to borrow from colleagues.

Select samples that are clear and characteristic of student work at various levels. Streamline the process by distributing examples at only three levels of proficiency: excellent, adequate, and inadequate. Provide two or three examples of each level. Allow students time to read the examples and to talk about them in groups.

2. Describe the samples.

Suggest that students focus on the examples of excellent work first. Pose the question: “What makes this piece successful?” Then ask students to brainstorm attributes of or criteria for success. Some of the attributes students list will describe behaviours that are useful in meeting the goals of the work (e.g., the topic is stated at the beginning, there are few spelling errors, a graph is used to represent statistical findings).

What rubrics must attempt to articulate, beyond identifying these behaviours, is the essence of a good product or performance. As Wiggins (1996) points out, eye contact may be important in the performance of an oral report, but it is possible to deliver a dreary talk while maintaining eye contact (V1-5: 6). Together with students, wrestle with identifying the salient qualities of works related to science that are engaging and effective. These may be qualities that are harder to define and illustrate (e.g., the speaker has moved beyond a superficial understanding of the subject, the producer of a video is aware of the audience, the writer’s voice is discernible in a science journalism piece).

3. Develop criteria categories.

From the brainstormed list of attributes, select the criteria categories that will make up the assessment rubric. Most rubrics are limited to three to five criteria categories. A greater number makes the rubrics difficult for assessors to use, especially in assessing live performances. Listing too many criteria can also overwhelm or confuse students who use the rubrics for self-assessment and goal setting.

Develop criteria categories by combining related attributes, and selecting three to five that are considered most important. Label the criteria categories in general terms (organization, style, content) and expand them by listing the specific elements to be examined in assessing quality in these criteria (e.g., in the “organization” category, the elements may be “statement of purpose, topic sentences, transition words and phrases, paragraph breaks, order of ideas”).

Ensure that no essential attribute that defines good performance is left out. This means including elements considered hard to assess (such as style or creativity). Ignoring elements such as these signals that they are not important. Addressing them helps students grasp the things they can do to improve their own work in these areas. If graphical analysis is identified as one criteria category, for example, the rubric may list elements that convey the details of such an analysis (e.g., placement of dependent and independent variables, placement of data points, line of best fit). It may also provide definitions.

As students collaborate to develop criteria categories, monitor whether the criteria chosen are related to the intended learning outcomes.

4. *Decide how many performance levels the rubric will contain.*

The first rubric students develop will have three performance levels, based on identifying student work samples as excellent, adequate, or inadequate. In later rubrics, students may move to finer distinctions between levels. The number of levels needed to make meaningful judgements regarding the full range of proficiency is best decided by the teacher. If the scale is large (e.g., seven levels), finer distinctions can be made, but it may be difficult to differentiate clearly one level from the next. In science, assessment rubrics designed to be used by students as well as teachers generally use three, four, or five performance levels.*

Using the same number of performance levels for various tasks throughout the course has the advantage of giving students and the teacher a common vocabulary in talking about ways to improve performance (e.g., “This piece does not have the concrete detail of level 4 writing”). Once the number of criteria categories and performance levels has been determined, a rubric template such as the following can be used in developing rubrics.

Rubric Template

		Criteria Categories			
Performance Levels	1				
	2				
	3				
	4				
	5				

* Many designers of rubrics advocate a five-level scale. Levels 1, 3, and 5 are developed from an initial sorting of student work into excellent, adequate, and inadequate samples. Levels 2 and 4 describe work that is between these anchor points. Other educators argue that an even-point scale (four or six levels) forces more care in judging than an odd number does; it prevents assessors from overusing a middle category for work that is difficult to assess.

5. Describe the performance levels.

In developing the assessment criteria (Step 3), students analyzed successful pieces of work. They now fill in descriptions of excellent, adequate, and inadequate performance in each criteria category.

There are two ways of describing performance levels:

- **Evaluative rubrics** use comparative adjectives (e.g., “weak organization”).
- **Descriptive rubrics** specify the qualities of work at each performance level with respect to the criteria (e.g., “unconnected ideas appear in the same paragraph”). The attributes listed may be negative (e.g., “subscripts and coefficients are incorrectly applied”), for sometimes the most telling characteristic of certain levels is their failure to do what they should be doing.

Descriptive rubrics have many advantages over evaluative rubrics. They are more helpful to students, because they spell out the behaviours and qualities students encounter in assessing their own and others’ work, and the things they can address in their own work in order to improve.

When beginning to write descriptive rubrics, students may suggest generally descriptive adjectives (such as “interesting,” “boring”), which may not convey information about what an interesting piece looks like, and how they can improve their work in this area. The description needs to go on to state the attributes that make a work interesting, and in acceptable style for scientific communication. Classes may need to begin by using comparative language or general descriptions. As the students and teacher collect examples, they can then fine-tune the rubric with specific descriptions.

By the end of this step, students will have a description of performance at three levels. If the class has decided to create a rubric with four, five, or six performance levels, it may be most efficient for the teacher to draft gradations of quality for the middle levels, and present them to the class for revision. These middle levels are the most difficult to write, and call on more experience and expertise in developing a smooth continuum of proficiency.

6. Use the rubric for student self-assessment, for teacher assessment, and for instruction.

Before using the rubric on an actual assignment, students and teachers may want to test it against unsorted samples of work from previous years. Applying the rubric to student work helps the class determine whether the rubric accurately describes the qualities of the work they see, and helps students make meaningful distinctions between work at different levels of proficiency. As students become more adept at using the rubric, and when they have internalized the performance levels, present them with more diverse samples and assessment challenges.

Rubrics make it possible for students to assess their own work on the basis of the criteria that the teacher will use. Any differences in scores between a student's and a teacher's assessment can be the subject of profitable and focused discussion in student conferences.

If numerical scores are required, point values assigned to each level can be totalled. If the teacher and students decide that certain criteria categories should be more heavily weighted than others, the points assigned to these categories can be multiplied by a factor.

A rubric developed collaboratively can also become a valuable instructional tool, encouraging students to look closely at the specific things they can do to improve a piece of work. If students decide that a writing sample in science is at level 3, they can be asked to work together in groups to improve it so that it fits the description for level 4 work.

7. *Continue to revise the rubric.*

Any assessment rubric can be considered a work in progress, especially if it is stored on the computer. Both teacher and students should carefully review the rubric each time they use it, asking, "Do these criteria capture the most important qualities of excellence in this work?" "What other words and phrases can we use to describe work at this level?" In keeping with this, the rubrics appearing in Appendix 6 of this document are intended as templates, open to situational revisions.

NOTES

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**Appendix 6:
Assessment Rubrics and
General Learning Outcomes**

Rubric for the Assessment of Class Presentations

Student Name(s) _____

Topic/Title _____

Criteria	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Content	<input type="checkbox"/> No understanding of the topic was evident.	<input type="checkbox"/> Basic understanding of the topic was evident. <input type="checkbox"/> Student(s) did not relate the material presented to their own experiences.	<input type="checkbox"/> Good understanding of the topic was evident. <input type="checkbox"/> Thorough and detailed knowledge was evident. <input type="checkbox"/> Student(s) attempted to relate the material presented to their own experiences.	<input type="checkbox"/> Excellent depth of understanding was evident. <input type="checkbox"/> Student(s) presented material that was further than what was required, and conducted excellent research. <input type="checkbox"/> Student(s) showed how the material presented relates to their own experiences.
Interest and Enthusiasm	<input type="checkbox"/> Little interest and enthusiasm for the topic was displayed in the presentation.	<input type="checkbox"/> Some interest and enthusiasm was evident in the presentation. <input type="checkbox"/> The class was not very interested or enthusiastic.	<input type="checkbox"/> The presenters were clearly interested in their topic and their enthusiasm was quite evident. <input type="checkbox"/> The class was noticeably attentive during the presentation.	<input type="checkbox"/> The interest of the presenter(s) was exceptional as was their enthusiasm. <input type="checkbox"/> The class was keenly attentive during the presentation.
Clarity and Organization of Material	<input type="checkbox"/> The information presented was confusing.	<input type="checkbox"/> The information was somewhat vague. <input type="checkbox"/> There was some organization.	<input type="checkbox"/> The information was clearly presented. <input type="checkbox"/> The presentation was well organized.	<input type="checkbox"/> All information was relevant and clearly presented. <input type="checkbox"/> The presentation was extremely well organized. <input type="checkbox"/> Main points were emphasized and reinforced with appropriate examples.
Use of Visual Aids	<input type="checkbox"/> Visual aids were not used.	<input type="checkbox"/> Visual aids were used. <input type="checkbox"/> Visual aids were not well done. <input type="checkbox"/> Visual aids used were somewhat relevant to the presentation.	<input type="checkbox"/> Visual aids were used. <input type="checkbox"/> Visual aids were quite well done. <input type="checkbox"/> Visual aids were relevant to the presentation.	<input type="checkbox"/> Strong visual aids were used. <input type="checkbox"/> Visual aids were extremely well done with colour, clarity, and care. <input type="checkbox"/> Visual aids were designed to emphasize and strengthen the presentation and were successful.

**Teachers are reminded that this rubric would vary with the assignment and format of the presentation.*

Rubric for the Assessment of a Research Project

Student Name(s) _____

Topic/Title _____

Criteria	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Source of Information	<input type="checkbox"/> Student(s) used only one source of information.	<input type="checkbox"/> Student(s) used two sources of information.	<input type="checkbox"/> Student(s) used a variety of sources.	<input type="checkbox"/> Student(s) used a wide variety of sources in a unique manner.
Information Collected	<input type="checkbox"/> The information collected was not relevant.	<input type="checkbox"/> The information collected was relevant to the topic but was not blended into a cohesive piece.	<input type="checkbox"/> The information collected was relevant to the topic and was somewhat organized into a cohesive piece.	<input type="checkbox"/> The information collected was relevant to the topic and was carefully organized into a cohesive piece of research.
Organization of Material	<input type="checkbox"/> The information collected was not organized.	<input type="checkbox"/> The information was somewhat organized.	<input type="checkbox"/> The information was organized and contained recognizable sections.	<input type="checkbox"/> The information was organized and contained recognizable sections that included an introduction, a main body with supporting evidence, and a conclusion that summarized the report.
Presentation of Material	<input type="checkbox"/> The report was handwritten, contrary to established guidelines.	<input type="checkbox"/> The report was neatly handwritten. <input type="checkbox"/> The report contained a bibliography that was not correctly formatted.	<input type="checkbox"/> The report was typed. <input type="checkbox"/> The report contained graphics. <input type="checkbox"/> The report contained a bibliography that was not correctly formatted.	<input type="checkbox"/> The report was typed and appropriately formatted. <input type="checkbox"/> The report contained a title page. <input type="checkbox"/> The report contained relevant graphics. <input type="checkbox"/> The report contained a complete, correctly formatted bibliography.

**Teachers are reminded that this rubric would vary with the assignment and format of the presentation.*

Rubric for the Assessment of a Decision-Making Process Activity

Student Name(s) _____

Topic/Title _____

Criteria	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Identification of STSE Issue	<input type="checkbox"/> Student(s) cannot identify an STSE issue without assistance.	<input type="checkbox"/> Student(s) have a basic understanding that an issue could have STSE implications, not necessarily differentiating among the four areas.	<input type="checkbox"/> Student(s) have a good understanding of a connection between an issue and its STSE applications. <input type="checkbox"/> Student(s) demonstrate some evidence of awareness of an individual response.	<input type="checkbox"/> Student(s) have excellent depth and sensitivity in connecting an issue with its STSE implications. <input type="checkbox"/> Student(s) demonstrate a level of social responsibility.
Evaluates Current Research on Issue	<input type="checkbox"/> Student(s) able to access a small amount of current research, with no evaluation of that research evident.	<input type="checkbox"/> Student(s) demonstrate some ability to recognize the positions taken in the research data, with no clear evaluative statements.	<input type="checkbox"/> Student(s) have secured an array of research, narrow in its scope, but clearly identify the positions taken. <input type="checkbox"/> Student(s) can offer personal opinions on issue, not necessarily evaluation.	<input type="checkbox"/> Student(s) present research that is current, relevant, and from a variety of perspectives. <input type="checkbox"/> Student(s) demonstrate insight into the stated positions, and can frame an evaluation.
Formulates Possible Options	<input type="checkbox"/> Student(s) unable to clearly identify the possible options. <input type="checkbox"/> Student(s) can form options that are not clearly connected to the problem to be solved.	<input type="checkbox"/> Student(s) can offer at least one feasible option that is connected to the problem. <input type="checkbox"/> Student(s) can offer other options that may be more or less related directly to the problem.	<input type="checkbox"/> Student(s) develop at least two feasible options that are internally consistent, and directly address the problem. <input type="checkbox"/> Student(s) recognize that some options will fail.	<input type="checkbox"/> Student(s) display level of sophistication of feasible options that is beyond expectations. <input type="checkbox"/> Student(s) present options that all demonstrate a reasonable chance of succeeding in being chosen.
Identifies Projected Impacts	<input type="checkbox"/> Student(s) not able to foresee the possible consequences of the options selected. <input type="checkbox"/> Student(s) appear to have a naïve awareness of consequences.	<input type="checkbox"/> Student(s) identify potential impacts of decisions taken in a vague or insubstantial way. <input type="checkbox"/> Student(s) view most of the feasible options as having projected impacts.	<input type="checkbox"/> Student(s) identify potential impacts of decisions taken in an organized way. <input type="checkbox"/> Student(s) view all of the feasible options as having projected impacts, some beneficial, some not.	<input type="checkbox"/> Student(s) are capable of offering a cost/benefits/risks analysis of each feasible solution. <input type="checkbox"/> Student(s) construct an organized report that clearly outlines the impacts of each.

(continued)

Rubric for the Assessment of a Decision-Making Process Activity (continued)

Student Name(s) _____

Topic/Title _____

Criteria	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Selects an Option and Makes a Decision	<input type="checkbox"/> Unable to come to a decision that clearly connects with the problem to be solved <input type="checkbox"/> Requires direction from the outside to make a choice	<input type="checkbox"/> Can identify a feasible option, but is faced with the inability to clearly decide on a plan <input type="checkbox"/> Still requiring outside influences to stand by a decision to proceed	<input type="checkbox"/> Clearly selects an option, decides on a course of action, but others can identify that a better course of action remains untried <input type="checkbox"/> Recognizes potential safety concerns	<input type="checkbox"/> A thorough analysis of all options was done collaboratively <input type="checkbox"/> Decision was firm, justified by the research base, and recognizes most of the safety concerns
Implements the Decision	<input type="checkbox"/> Unable to fully implement the decision, but there remains opportunity to modify it <input type="checkbox"/> Decision lacks the clarity to proceed	<input type="checkbox"/> Implements the decision with a recognition that not all details are laid out in advance <input type="checkbox"/> Some lack of clarity in having a plan for implementation	<input type="checkbox"/> Implements with some visible clarity of purpose <input type="checkbox"/> Confidence is demonstrated that the plan will be one that can be of a scientific inquiry approach	<input type="checkbox"/> Implements a plan with visible clarity of purpose, backed by the research base <input type="checkbox"/> It is clearly demonstrated that the plan will be one that can be carried to completion as inquiry
Identifies and Evaluates Actual Impacts of Decision	<input type="checkbox"/> Unable to clearly recognize more than one possible actual impact <input type="checkbox"/> Cannot effectively evaluate the effects of the decision(s) taken	<input type="checkbox"/> Can clearly recognize more than one possible actual impact for the decision taken <input type="checkbox"/> Cannot effectively evaluate the effects of the decision(s) taken in most instances	<input type="checkbox"/> Able to recognize and comment upon the actual impacts observed <input type="checkbox"/> Some ability in evaluating the impacts of the decision	<input type="checkbox"/> Able to recognize and comment deeply upon the actual impacts observed, noting unforeseen or unique outcomes <input type="checkbox"/> Facility in evaluating the impacts of the decision
Reflects on the Decision Making and Implementation of a Plan	<input type="checkbox"/> Begins to demonstrate an awareness of the need to review the plan <input type="checkbox"/> A reluctance to consider a re-evaluation of the plan	<input type="checkbox"/> Reflects and intends to communicate the results of the implementation plan <input type="checkbox"/> Has some difficulty in how to proceed with a re-evaluation of the problem-solving plan	<input type="checkbox"/> Reflects upon and does communicate the results of the implementation plan <input type="checkbox"/> Recognizes how to proceed with a re-evaluation of the problem-solving plan	<input type="checkbox"/> A higher order synthesis was visible in the reflection process <input type="checkbox"/> Evidence of a sophisticated environmental awareness that informs this post-implementation period

* Teachers are reminded that the above criteria are suggestions only, and will be adapted according to the needs of the assignment. It is preferable if this rubric is modified in consultation with the students, leading to clarity of purpose.

Lab Report Assessment

Project Title _____ Date _____

Team Members _____

Area of Interest	Possible Points	Self	Teacher
<p>Formulates Testable Questions: Question is testable and focused with cause and effect relationship identified.</p>			
<p>Formulates a Prediction/Hypothesis: Independent and dependent variables are identified and the prediction/hypothesis clearly identifies a cause and effect relationship between these two variables.</p>			
<p>Creates a Plan: All steps are included and clearly described in a logical sequence. All required materials/equipment are identified. Safety considerations are addressed; major intervening variables are controlled.</p>			
<p>Conducts a Fair Test and Records Observations: There is evidence of repeated trials and the inclusion of all data. Detailed data are recorded, and appropriate units are used; data are recorded in a clear/well-structured/appropriate format for later reference.</p>			
<p>Interprets and Evaluates Results: Patterns/trends/discrepancies are identified. Strengths and weaknesses of approach and potential sources of error are identified. Changes to the original plan are identified and justified.</p>			
<p>Draws a Conclusion: Conclusion explains cause and effect relationship between dependent and independent variables; alternative explanations are identified; hypothesis is supported or rejected.</p>			
<p>Makes Connections: Potential applications are identified and/or links to area of study are made.</p>			
<p>Total Points</p>			

Observation Checklist—Scientific Inquiry Conducting a Fair Test

Project Title _____ Date _____

Note: A group of students can be selected as a focus for observation on a given day, and/or one or more of the observational areas can be selected as a focus. The emphasis should be on gathering cumulative information over a period of time.

Names	Safe Work Habits (workspace, handling equipment, goggles, disposal)	Ensuring Accuracy/ Reliability (repeating measurements/ experiments)	Observing and Recording (carried out during experiment)	Follows a Plan	Evidence of Perseverance and/or Confidence	Comments

Assessing Region Explanations

A region that is prone to a severe weather-related event can be part of the Earth's surface that has similar physical and/or human characteristics and differs from other regions around it.

What defines a region can vary from physical factors (such as rock types, climate, meteorology, hydrology, soils, types of vegetation, or landforms) to human factors (such as population density, incomes, economic activities, agricultural activities, or industrial areas). Regions can be defined by considering only one factor at a time, like climate regions, or a combination of different factors, like the Great Lakes region, which considers both physical (lakes, drainage) and human characteristics (high density of population, similar economic activities). In fact, the choice of factors can be almost endless, with the major consideration being: can it be mapped?

Once a map is produced, geographers look for patterns of location. Do the events mapped seem to cluster in one or more areas or are they evenly distributed over the map. In either case, explanations are sought to help explain the patterns found. We can apply these regional map characteristics to severe weather events such as ice storms, tornadic activity, hurricane storm tracking, and precipitation patterns.

The student's map should follow the general guidelines established and listed in Appendix 6.9: Rubric for Map Drawing.

Use the following framework to assess answers:

Score each of the three factors on a scale of 0–4 with 4 representing the greatest agreement with the statement.

The student answer...	0	1	2	3	4
stated clearly that the region defined is part of the Earth's surface					
explained that feeling comfortable, having many friends, and/or knowing many neighbours are common characteristics of this "neighbourhood"					
stated it was a region because these characteristics were different from those of the areas lying outside its boundaries					

Peer/Self Assessment Sheet for Poster Project in Solving an Environmental Problem

Name of Peer Evaluator: _____

Name of Author/Presenter: _____

Total Mark: _____

Score the poster you are assessing, using the following scales. Circle only one number per category. The higher the number circled, the better that poster project is at showing what environmental problem is being dealt with and how to reduce its negative effects.

Title clearly states what information is shown on the poster	None 0	1	Incomplete 2	3	Complete 4
Content makes clear which environmental problem is being dealt with in the poster and the solution to that problem is practical	Unclear, impractical 0	1	Somewhat clear, somewhat, practical 2	3	Very clear, very practical 4
Legends/Labels —symbols/features identified by labels or legend	None 0	1	Some 2	3	All 4
Printing —labels are neatly printed so they are easy to read	No 0	1	Somewhat 2	3	Yes 4
Organization —information is carefully organized so reader understands it easily	No 0	1	Somewhat 2	3	Yes 4
Overall Appearance —general impression of poster related to its neatness, care in drawing, ease of understanding	Poor 0	1	Good 2	3	Excellent 4

Rubric for Student Presentation

Student Name(s) _____

Topic/Title _____

Criteria	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Organization	<input type="checkbox"/> Presentation shows poor organization and lack of preparation.	<input type="checkbox"/> Presentation shows signs of organization but some parts do not seem to fit the topic.	<input type="checkbox"/> Presentation is organized, logical, and interesting.	<input type="checkbox"/> Presentation is very well organized, logical, interesting, and lively.
Preparation	<input type="checkbox"/> Some student preparation is shown.	<input type="checkbox"/> A fair amount of student preparation is shown.	<input type="checkbox"/> An adequate amount of student preparation is shown.	<input type="checkbox"/> A great deal of student preparation is shown.
Content	<input type="checkbox"/> A small amount of presented material is related to the topic.	<input type="checkbox"/> Some material presented is not related to the topic.	<input type="checkbox"/> Almost all material presented is related to the topic.	<input type="checkbox"/> All material in the presentation is related to the topic.
Language	<input type="checkbox"/> Language used is hard to follow and understand.	<input type="checkbox"/> Some language used is hard to follow and understand.	<input type="checkbox"/> Most language used is easy to follow and understand.	<input type="checkbox"/> Language used is well chosen, easy to follow and understand.
Format	<input type="checkbox"/> Poor use of aids and support materials (diagrams, overheads, maps, pictures); does not support the topic.	<input type="checkbox"/> Adequate use of aids and support materials; most support the topic.	<input type="checkbox"/> Good use of aids and support materials; almost all support the topic.	<input type="checkbox"/> Excellent use of aids and support materials; all aids support the topic.
Delivery	<input type="checkbox"/> Many words unclear; voice is monotonous; spoke too quickly or slowly; no pausing for emphasis; voice too low to be heard easily.	<input type="checkbox"/> Some words unclear; voice somewhat varied; spoken too quickly at times; some pausing for emphasis; voice sometimes too low to be heard easily.	<input type="checkbox"/> Most words clear; voice often varied, interesting, generally spoken at the correct speed; frequent pausing for emphasis; voice loud enough to be heard easily.	<input type="checkbox"/> Words clear; voice frequently varied, interesting, generally spoken at the correct speed; effective pausing for emphasis; voice loud enough to be heard easily.
Audience	<input type="checkbox"/> Audience is not involved or interested.	<input type="checkbox"/> Audience is somewhat involved, sometimes interested.	<input type="checkbox"/> Audience is involved and interested.	<input type="checkbox"/> Audience is very involved and interested.

* Teachers are reminded that the above criteria are suggestions only, and will be adapted according to the needs of the assignment. It is preferable if this

Rubric for Map Drawing

Student Name(s) _____

Topic/Title _____

Criteria	Performance Levels			
Title	Level 1	Level 2	Level 3	Level 4
Title	<input type="checkbox"/> Written and not printed <input type="checkbox"/> Does not accurately describe the contents of the map	<input type="checkbox"/> Printed somewhere on the map and not easy to find	<input type="checkbox"/> Printed at the top of the page <input type="checkbox"/> States the purpose of the map adequately	<input type="checkbox"/> Printed neatly at the top of the map <input type="checkbox"/> Highlighted inside a box or underlined <input type="checkbox"/> Purpose clearly stated
Labels	<input type="checkbox"/> Written and not printed; not positioned carefully or accurately <input type="checkbox"/> Many inaccuracies <input type="checkbox"/> Spelling errors	<input type="checkbox"/> Printed, but hard to read, messy <input type="checkbox"/> Not very orderly <input type="checkbox"/> Some inaccuracies, spelling errors	<input type="checkbox"/> Printed neatly in an orderly fashion <input type="checkbox"/> Few inaccuracies or spelling errors	<input type="checkbox"/> Printed neatly in an accurate and orderly fashion <input type="checkbox"/> No missing, inaccurate, or misspelled labels
Legend	<input type="checkbox"/> Poorly positioned <input type="checkbox"/> Poor appearance <input type="checkbox"/> Written labels <input type="checkbox"/> Many inaccuracies <input type="checkbox"/> Difficult to use	<input type="checkbox"/> Well positioned <input type="checkbox"/> Frame/box is missing <input type="checkbox"/> Most symbols used on map are present <input type="checkbox"/> Several inaccuracies	<input type="checkbox"/> Well-positioned frame containing almost all symbols used on the map <input type="checkbox"/> Few inaccuracies	<input type="checkbox"/> Well-positioned frame with a neat and complete set of symbols <input type="checkbox"/> A compass indicator
Scale	<input type="checkbox"/> Missing or hard to find on the map <input type="checkbox"/> A poor choice of scale <input type="checkbox"/> Inaccurate, sloppy, hard to read	<input type="checkbox"/> Visible on the map <input type="checkbox"/> Hard to read <input type="checkbox"/> Features on map are not drawn to scale	<input type="checkbox"/> Relatively easy to find on the map <input type="checkbox"/> Most features are drawn to scale <input type="checkbox"/> Neat and easy to use	<input type="checkbox"/> Clearly visible on the map <input type="checkbox"/> Very easy to read <input type="checkbox"/> Neat and easy to use
Frame	<input type="checkbox"/> Frame drawn freehand <input type="checkbox"/> Appears hastily drawn	<input type="checkbox"/> Frame not neatly drawn	<input type="checkbox"/> Some deficiencies such as inaccurate right angles or join marks visible	<input type="checkbox"/> Lines meet at right angles and no joining marks visible
Appearance	<input type="checkbox"/> Inconsistent use of colour <input type="checkbox"/> Shading is inconsistent <input type="checkbox"/> Appears hastily drawn	<input type="checkbox"/> Mainly correct use of colour <input type="checkbox"/> Shading of varying intensity <input type="checkbox"/> Some care taken to be neat and accurate	<input type="checkbox"/> Correct use of colour <input type="checkbox"/> Neat and even shading <input type="checkbox"/> Care taken to be consistent in colouring	<input type="checkbox"/> Correct use of colour throughout <input type="checkbox"/> Great care taken to be consistent in colouring/shading <input type="checkbox"/> Stimulates interest, captures attention

*Teachers are reminded that this rubric would vary with the assignment and format of the presentation.

Rubric for Research Skills

Student Name(s) _____

Topic/Title _____

Research Skills	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Ability to formulate questions to identify problems for research purposes	<input type="checkbox"/> Shows limited ability	<input type="checkbox"/> Shows some ability	<input type="checkbox"/> Shows general ability	<input type="checkbox"/> Shows consistent and thorough ability
Ability to locate relevant primary and secondary sources of information	<input type="checkbox"/> Unable to locate	<input type="checkbox"/> Somewhat able to locate	<input type="checkbox"/> Generally able to locate	<input type="checkbox"/> Always or almost always able to locate
Ability to locate and record relevant information from a variety of sources	<input type="checkbox"/> Unable to locate and record	<input type="checkbox"/> Somewhat able to locate	<input type="checkbox"/> Generally able to locate and record	<input type="checkbox"/> Always or almost always able to locate and record
Ability to organize information related to identified problem(s)	<input type="checkbox"/> Shows limited ability	<input type="checkbox"/> Shows some ability	<input type="checkbox"/> Shows general ability	<input type="checkbox"/> Shows consistent and thorough ability
Ability to analyze, synthesize information related to identified problems	<input type="checkbox"/> Shows limited ability	<input type="checkbox"/> Shows some ability	<input type="checkbox"/> Shows general ability	<input type="checkbox"/> Shows consistent and thorough ability
Ability to communicate results of inquiries using a variety of appropriate presentation forms (oral, media, written, graphic, pictorial, other)	<input type="checkbox"/> Unable to communicate	<input type="checkbox"/> Somewhat able to communicate	<input type="checkbox"/> Generally able to communicate	<input type="checkbox"/> Always or almost always able to communicate

*Teachers are reminded that this rubric would vary with the assignment and format of the presentation.

General Learning Outcomes

The purpose of Manitoba science curricula is to help students gain a measure of scientific literacy that will assist them in becoming informed, productive, and fulfilled members of society. As a result of their Early, Middle, and Senior Years science education, Manitoba students will be able to:

Nature of Science and Technology

- A1. recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena
- A2. recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop
- A3. distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values
- A4. identify and appreciate contributions made by women and men from many societies and cultural backgrounds towards increasing our understanding of the world and in bringing about technological innovations
- A5. recognize that science and technology interact with and advance one another

Science, Technology, Society, and the Environment (STSE)

- B1. describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally
- B2. recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time
- B3. identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social
- B4. demonstrate a knowledge of and personal consideration for a range of possible science- and technology-related interests, hobbies, and careers
- B5. identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally

Scientific and Technological Skills and Attitudes

- C1. recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations
- C2. demonstrate appropriate scientific inquiry skills when seeking answers to questions
- C3. demonstrate appropriate problem-solving skills while seeking solutions to technological challenges

Reproduced from Manitoba Education and Training. *Senior 1 Science: Manitoba Curriculum Framework of Outcomes*. Winnipeg, MB: Manitoba Education and Training, 2000.

- C4. demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information
- C5. demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind
- C6. employ effective communication skills and utilize information technology to gather and share scientific and technological ideas and data
- C7. work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities
- C8. evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life

Essential Science Knowledge

- D1. understand essential life structures and processes pertaining to a wide variety of organisms, including humans
- D2. understand various biotic and abiotic components of ecosystems, as well as their interaction and interdependence within ecosystems and within the biosphere as a whole
- D3. understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter
- D4. understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts
- D5. understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them
- D6. understand the composition of the universe, the interactions within it, and the impacts of humankind's continued attempts to understand and explore it

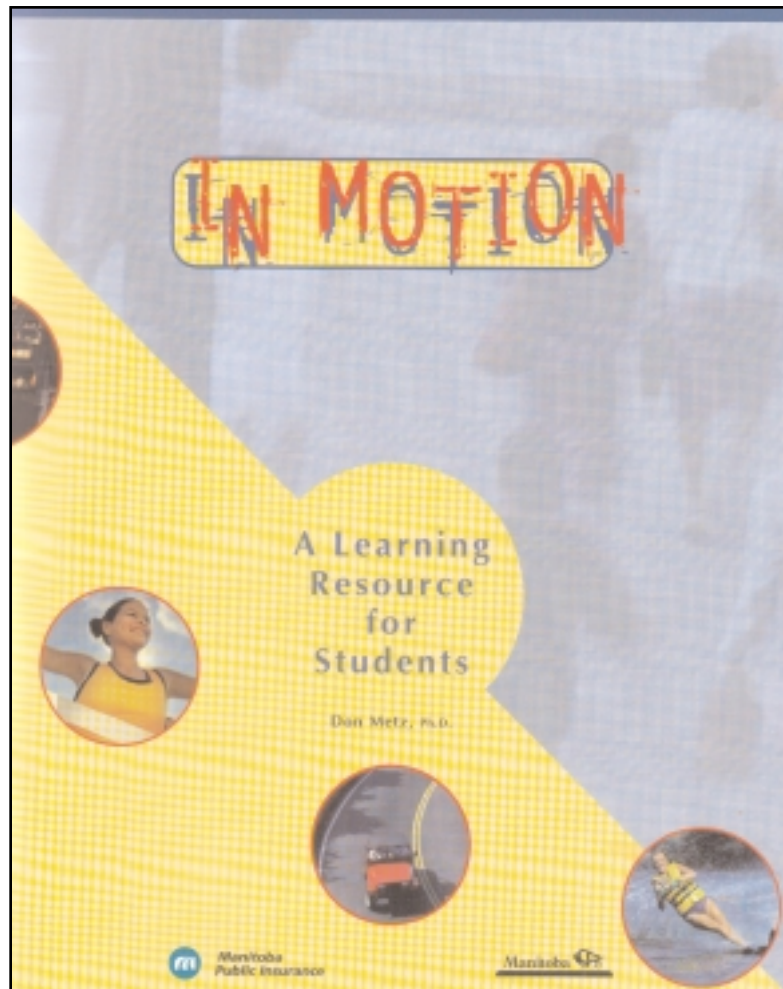
Unifying Concepts

- E1. describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world
- E2. describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems
- E3. recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved
- E4. recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them

NOTES

Senior 2

Appendix 7: In Motion—Teacher Resource Guide



Preface

This resource material is based on actual teacher experiences in Senior 2 Science (20F) classrooms. Therefore, the results of the student learning activities act as summaries of students' results. In many cases, the student-generated inquiry results do not coincide in a precise manner with predicted or theoretical results. This is positive insofar as it brings to light the difficulties in attempting to understand ideal situations from less than ideal (or controlled) circumstances. In a very real sense, this acts as a preliminary view through a window that looks at the nature of scientific inquiry. Inquiry in science, including high-grade research, is often less than tidy. In the cases presented here with students, sources of systematic or procedural error were actively sought, and suggestions were made for correcting or accounting for these errors.

Students are not required to do all the suggested activities and/or respond to all questions presented in the module. The most important consideration is recognizing that achievement of the specific learning outcomes for the *In Motion* thematic cluster is possible through in-depth use of this resource in the classroom. Moreover, it is estimated that approximately 30 to 40 hours would be required to complete the *In Motion* booklet if every student activity were to be addressed. Since time allotments suggest approximately 25 hours to complete this cluster, teachers are encouraged to be strategic in their selection of which activities to do with their students. Again, the primary focus in using this classroom-based resource rests in achieving the specific learning outcomes as outlined in *Senior 2 Science: A Foundation for Implementation*.

The mathematical connections to the content are an important component of the instructional design process that underpins *In Motion — A Student Learning Resource*. Teachers may wish to consult details of appropriate mathematical treatment for students at this grade level as contained in the Modes of Representation section of *Senior 2 Science: A Foundation for Implementation*. The gathering and subsequent analysis of the data is generally done manually by the students, through hand-drawn graphing techniques, calculation of slopes, and discussion of the results. If the opportunity exists, and equipment is available, some time could be saved through the use of Calculator-Based Laboratory (CBL) tools and probe connections to graphing calculators. Another alternative is for the students to perform some activities “virtually” in an Internet browser, using Java applets, which are readily available on the web. This teacher resource has selected a number of effective examples of these applets, and includes them in the Webquest chapter.

Most of the sections of *In Motion* can be taught as presented in the student learning resource. The booklet closely reflects the specific learning outcomes of the In Motion cluster of Senior 2 Science (20F), with virtually complete coverage of the student activities that are recommended in the *Foundation for Implementation*. In the case of Chapter 2: Analyzing Motion, considerable work has been provided as alternate material for the development of the relationships among position, displacement, velocity, acceleration, and time. These alternate materials are not prescriptive, but are examples of one instructional design approach, starting

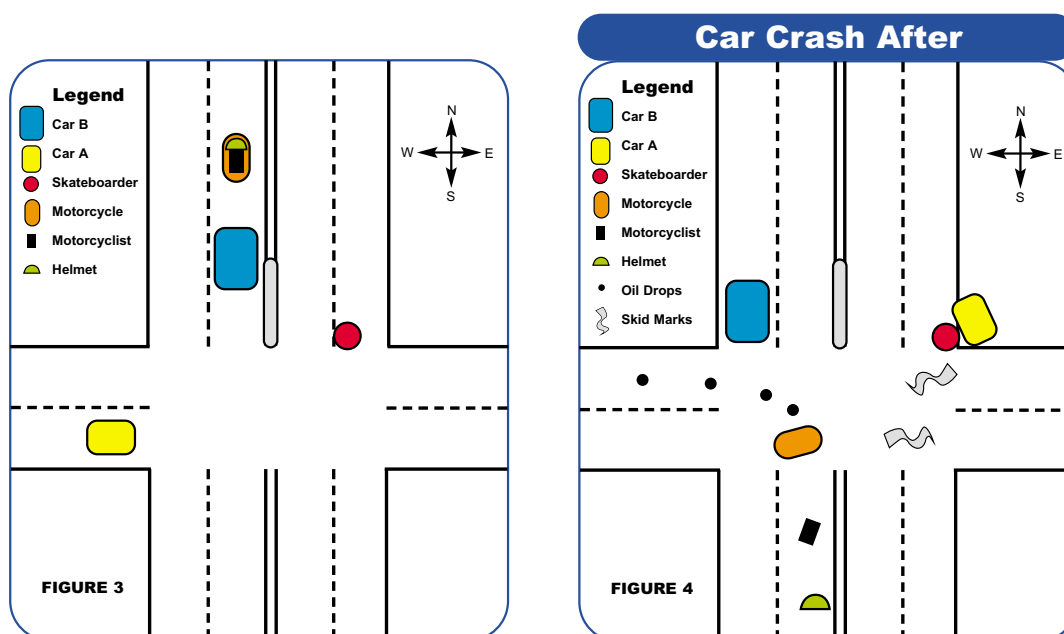
with concrete experiences of the student, then building toward the more abstract concepts. In a sense, this approach is a *scaffolding* for students, taking them in identifiable steps towards increased sophistication of treatment. These motion concepts could be applied in a variety of situations, and consequently a variety of student activity sheets, along with the answers, have been supplied.

Students often struggle somewhat with the concepts related to Newton’s Laws, momentum, impulse, and energy. These are treated more conceptually at Senior 2 than in an exclusively symbolic (mathematical) treatment common at advanced levels of the study of physics. Students may have some difficulty in applying the motion ideas conceptually to actual problems requiring explanations. Some differentiation of instruction is recommended for these topics, and suggestions and strategies are included.

Generally, the students will enjoy doing the activities. The Great Egg Drop Competition and the Rocket Car activities are often very well received. Most of the activities can be completed with equipment found in high school physics laboratories. Very little in the way of new equipment is required. CBL units and graphing calculators should be available from the mathematics department in your school, as these are used regularly in Senior 2 Applied Mathematics (20S).

Overall, *In Motion — A Student Learning Resource* was conceived to address the specific learning outcomes across all levels of student ability. It can be modified and enriched with ease to stimulate the gifted student, and it can also be adapted to meet the needs of those who may be struggling. Teachers are encouraged during the first years of implementation, as with any new course, to find out what works, what does not work, what needs to be changed, and how to adapt to the needs of those students in the local environment. Readily available science and physics textbooks, together with many resources on the Internet, can provide a wealth of supplementary aids for the Senior 2 classroom teacher.

Note: There are some errors in the reference. These have been acknowledged as errata in the appropriate chapter and section.



Chapter 1

Introduction

CLASS ACTIVITY:

Tapping into Prior Knowledge

The rotational graffiti activity will stimulate discussion about the concepts of motion that the students have already acquired. The context of vehicles and traffic provides an avenue for students to relate motion to their everyday personal experience.

Car Crash – Who Is to Blame?

This class activity provides a problem to which the students will return as their knowledge of motion increases. Terms such as speed, acceleration, force, friction, momentum, and energy will be discussed. At this time, there is no need to clarify the terms, as this will be done all in good time.

SUGGESTED ACTIVITY:

From their everyday experience, students should have some understanding of speed, distance, and time interval. Before vector quantities like velocity and displacement are studied, a class activity relating speed, distance, and time interval can be performed.

A battery-operated toy truck or tractor is allowed to move across the floor. In small groups, students are asked to describe the motion. Then they are to share their descriptions with the class. They are encouraged to use whatever words they can that are related to motion.

The students are asked how they would measure this motion. The procedure should involve measuring the time required for the toy to travel a certain distance. This information can be used to calculate speed using the speed-equals-distance-traveled-over-time interval.

This is a good place to introduce some symbolism. The relationship for speed is:
speed = distance traveled/time interval or $v = \Delta d/\Delta t$.

The fact that the speed remains constant indicates that the speed is uniform and we call this uniform motion.

Once speed has been measured, the speed equation can be used to predict the distance traveled in a given time. Also, the speed equation can be used to calculate the time required for the toy to travel a certain distance. Students should realize that equations are very useful tools that allow us to make predictions for the outcome of events based on the given information.

While the emphasis for the *In Motion* cluster is not mathematical calculations, it is useful to lay the groundwork for problem solving. Using the speed relationship, students can be instructed in a systematic method of problem solving. Links should be made to the students' mathematics knowledge. If a pattern is developed that the students can follow, it will ensure success in their endeavours.

Speed, Distance Traveled, Time

1. Jose rides his bicycle from his home to school. He travels 6.25 km in 0.550 hour. What is his average speed for the trip?
2. Kevin is warming up for the basketball game. He does three laps around the gym. Each lap is 75.0 metres. It takes Kevin 42.8 seconds to run the three laps.
 - a. What distance did Kevin run?
 - b. What was his average speed?
3. April and Ashleigh run a 100-m race. April finishes the race in 13.25 s and Ashleigh takes 13.50 s. What is the average speed with which April and Ashleigh each run the 100 m?
4. Matt skateboards at 3.25 m/s for 55.0 s. How far did he travel?
5. Edward rollerblades around Kildonan Park. He skates at 7.75 m/s for 12.5 minutes.
 - a. How many seconds was he skating?
 - b. How far did he skate?
6. Edgar travels to the mall at an average speed of 28.0 km/h. The mall is located 8.00 km from Edgar's home. How long in hours does it take Edgar to travel from his home to the mall?
7. A ladybug is crawling across the floor in a straight line at 1.25 cm/s. The ladybug crawls 3.25 m.
 - a. What distance in cm does the ladybug crawl?
 - b. How long does the ladybug take to crawl this distance?
8. You and your family are traveling from Winnipeg to Brandon. The distance from Winnipeg to Brandon is 200 km. If you travel at a speed of 105 km/h, how long will it take to travel from Winnipeg to Brandon?
9. When you get to Brandon, you stop for lunch. This takes one hour. You then travel from Brandon to Regina, a distance of 385 km, in 3.75 hours. What was your average speed?

10. a. How far is it from Winnipeg to Regina?
 b. How long did it take you and your family to travel from Winnipeg to Regina? (Hint: state the total time, including while you were eating.)
 c. What was your average speed for this whole trip from Winnipeg to Regina?

In Motion Worksheet—Speed, Distance, Time

Note: Three significant digits are used in the final answer.

1. $\Delta d = 6.25 \text{ km}$ $v = \Delta d / \Delta t$
 $\Delta t = 0.550 \text{ hours}$ $v = 6.25 \text{ km} / 0.550 \text{ h}$
 $v = \underline{\hspace{2cm}}$ $v = 11.36 = 11.4 \text{ km/h}$
2. 1 lap = 75.0 m **a.** $\Delta d = \underline{\hspace{2cm}}$
 Kevin runs 3 laps Kevin runs 3 laps \times 75.0 m/lap = 225 m
 $\Delta t = 42.8 \text{ s}$ **b.** $v = \underline{\hspace{2cm}}$
 $v = \Delta d / \Delta t = 225 \text{ m} / 42.8 \text{ s}$
 $v = 5.2570 = 5.26 \text{ m/s}$
3. $\Delta d = 100 \text{ m}$ $v_{\text{April}} = \Delta d / \Delta t_{\text{April}} = 100\text{m} / 13.25 \text{ s}$
 April's time = $\Delta t_{\text{April}} = 13.25 \text{ s}$ $v_{\text{April}} = 7.547 = 7.55 \text{ m/s}$
 Ashleigh's time = $\Delta t_{\text{Ashleigh}} = 13.50 \text{ s}$
 $v_{\text{April}} = \underline{\hspace{2cm}}$ $v_{\text{Ashleigh}} = \Delta d / \Delta t_{\text{Ashleigh}} = 100\text{m} / 13.50 \text{ s}$
 $v_{\text{Ashleigh}} = \underline{\hspace{2cm}}$ $v_{\text{Ashleigh}} = 7.4074 = 7.41 \text{ m/s}$
4. $v = 3.25 \text{ m/s}$ $v = \Delta d / \Delta t$
 $\Delta t = 55.0 \text{ s}$ $3.25 \text{ m/s} = \Delta d / 55.0\text{s}$
 $\Delta d = \underline{\hspace{2cm}}$ $3.25 \text{ m/s} \times 55.0 \text{ s} = \Delta d$
 $\Delta d = 178.75 = 179 \text{ m}$
5. $v = 7.75 \text{ m/s}$ **a.** 1 minute = 60 s
 $\Delta t = 12.5 \text{ minutes}$ 12.5 minutes = 12.5 min \times 60s/min = 750 s
 $\Delta d = \underline{\hspace{2cm}}$ **b.** $v = \Delta d / \Delta t$
 $7.75 \text{ m/s} = \Delta d / 750 \text{ s}$
 $7.75 \text{ m/s} \times 750 \text{ s} = \Delta d$
 $\Delta d = 5812.5 = 5810 \text{ m}$

6. $v = 28.0 \text{ km/h}$

$\Delta d = 8.00 \text{ km}$

$\Delta t = \underline{\hspace{2cm}}$

$v = \Delta d / \Delta t$

$28.0 \text{ km/h} = 8.00 \text{ km} / \Delta t$

$28.0 \text{ km/h} \times \Delta t = 8.00 \text{ km}$

$\Delta t = 8.00 \text{ km} / 28.0 \text{ km/h}$

$\Delta t = 0.28571 = 0.286 \text{ h}$

7. $v = 1.25 \text{ cm/s}$

$\Delta d = 3.25 \text{ m}$

$\Delta t = \underline{\hspace{2cm}}$

a. Δd in metres

$1 \text{ m} = 100 \text{ cm}$

$3.25 \text{ m} = 3.25 \text{ m} \times 100 \text{ cm/m} = 325 \text{ cm}$

b. $v = \Delta d / \Delta t$

$1.25 \text{ cm/s} = 325 \text{ cm} / \Delta t$

$1.25 \text{ cm/s} \times \Delta t = 325 \text{ cm}$

$\Delta t = 325 \text{ cm} / 1.25 \text{ cm/s} = 260 \text{ s}$

8. $\Delta d_{W-B} = 200 \text{ km}$

$v_{W-B} = 105 \text{ km/h}$

$\Delta t_{W-B} = \underline{\hspace{2cm}}$

$v_{W-B} = \Delta d_{W-B} / \Delta t_{W-B}$

$105 \text{ km/h} = 200 \text{ km} / \Delta t_{W-B}$

$105 \text{ km} \times \Delta t_{W-B} = 200 \text{ km}$

$\Delta t_{W-B} = 200 \text{ km} / 105 \text{ km/h}$

$\Delta t_{W-B} = 1.90476 = 1.90 \text{ h}$

9. $\Delta d_{B-R} = 385 \text{ km}$

$\Delta t_{B-R} = 3.75 \text{ h}$

$v_{B-R} = \underline{\hspace{2cm}}$

$v_{B-R} = \Delta d_{B-R} / \Delta t_{B-R}$

$v_{B-R} = 385 \text{ km} / 3.75 \text{ h} = 102.666 = 103 \text{ km/h}$

10. a. $\Delta d_{W-B} = 200 \text{ km}$

$\Delta d_{B-R} = 385 \text{ km}$

$\Delta d_{W-R} = \underline{\hspace{2cm}}$

$\Delta d_{W-R} = \Delta d_{W-B} + \Delta d_{B-R}$

$\Delta d_{W-R} = 200 \text{ km} + 385 \text{ km} = 585 \text{ km}$

b. $\Delta t_{W-B} = 1.90 \text{ h}$

$\Delta t_{\text{lunch}} = 1.00 \text{ h}$

$\Delta t_{B-R} = 3.75 \text{ h}$

$\Delta t_{\text{total}} = \Delta t_{W-B} + \Delta t_{\text{lunch}} + \Delta t_{B-R}$

$\Delta t_{\text{total}} = 1.90 \text{ h} + 1.00 \text{ h} + 3.75 \text{ h} = 6.65 \text{ h}$

c. $v_{\text{ave}} = \Delta d_{W-R} / \Delta t_{\text{total}} = 585 \text{ km} / 6.65 \text{ h} = 87.9699$

$v_{\text{ave}} = 88.0 \text{ km/h}$

Chapter 2

Analyzing Motion

Position and Displacement

Answers to Questions

The calculations will be done using significant digit rules. If changes are made to the number of significant digits, they will be noted.

PRACTICE—PAGE 8

1. The positions of the cars are as follows:

Car A = -5.10 cm or 5.10 cm to the left of the origin.

Car B = 0 cm. Car B is at the origin.

Car C = $+4.05$ cm or 4.05 cm to the right of the origin.

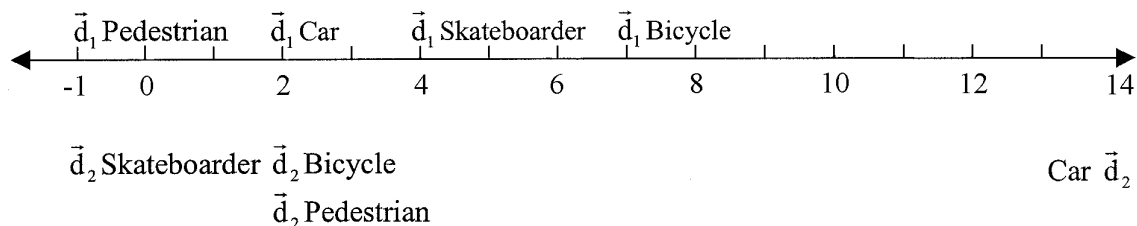
Car D = $+9.62$ cm or 9.62 cm to the right of the origin.

PRACTICE—PAGE 9

1.

	Car	Bicycle	Pedestrian	Skateboarder
d_1	+2 m	+7 m	-1 m	+4 m
d_2	+14 m	+2 m	+2 m	-1 m

a. and b.



c. Displacement = final position – initial position

$$\Delta \vec{d} = \vec{d}_2 - \vec{d}_1$$

$$\text{For the car, } \Delta \vec{d} = +14 \text{ m} - +2 \text{ m} = +12 \text{ m}$$

$$\text{For the bicycle, } \Delta \vec{d} = +2 \text{ m} - +7 \text{ m} = -5 \text{ m}$$

$$\text{For the pedestrian, } \Delta \vec{d} = +2 \text{ m} - -1 \text{ m} = +3 \text{ m}$$

$$\text{For the skateboarder, } \Delta \vec{d} = -1 \text{ m} - +4 \text{ m} = -5 \text{ m}$$

d. If the displacements all occur in the same time period, the motion can be described.

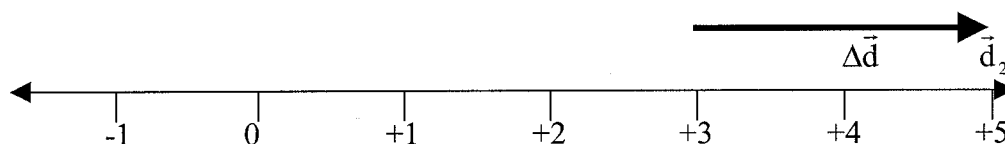
The car traveled a distance of 12 m to the right. The bicycle traveled 5 m to the left.

The pedestrian traveled 3 m to the right. The skateboarder also traveled 5 m to the left.

The bicycle and the skateboarder traveled at the same rate and kept the same distance apart. The car passed by the skateboarder first, then the bicycle. The pedestrian passed the skateboarder and ended up at the same position as the bicycle.

The car was traveling the fastest. The pedestrian was traveling the slowest. The bicycle and the skateboarder traveled at the same speed in the same direction.

2.



The truck had a final position of +5 after a displacement of +2. The arrow on the diagram shows the displacement of +2 had to start at +3 so that the final position was +5.

$$\Delta \vec{d} = +2 \text{ and } \vec{d}_2 = +5$$

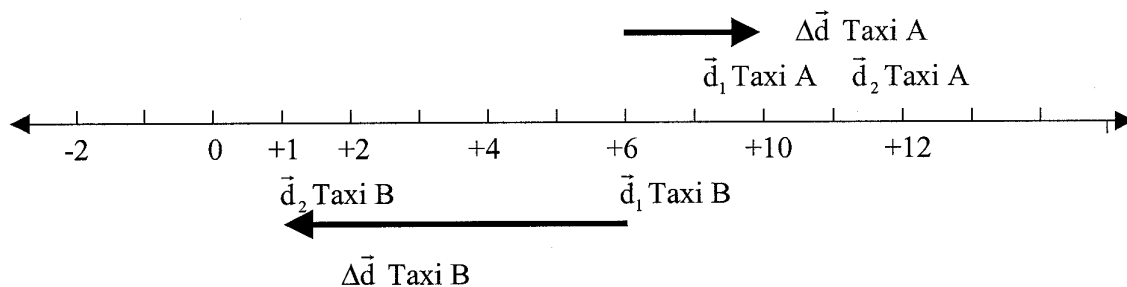
$$\text{Using } \Delta \vec{d} = \vec{d}_2 - \vec{d}_1$$

$$+2 = +5 - \vec{d}_1$$

$$\vec{d}_1 = +5 - +2 = +3$$

The initial position was +3.

3.

4. Taxi A $\vec{d}_1 = +6$ and $\vec{d}_2 = +10$

$$\begin{aligned} \Delta \vec{d} &= \vec{d}_2 - \vec{d}_1 \\ &= +10 - +6 = +4 \end{aligned}$$

Taxi B $\vec{d}_1 = +6$ and $\vec{d}_2 = +1$

$$\begin{aligned} \Delta \vec{d} &= \vec{d}_2 - \vec{d}_1 \\ &= +1 - +6 = -5 \end{aligned}$$

5. The displacement of Taxi A is +4 and the displacement of Taxi B is -5. Since the time of travel for both taxis was the same, the taxi that traveled farther had the larger speed.
6. If the origin was moved, the positions of the taxis would be different. However, even though the positions may have been different, the displacements would still be the same.

Instants and Intervals of Time

Think About IT!

Think About IT!—Page 10

1. Examples of an interval of time include one year to measure age, one class of 55 minutes, one school year, et cetera.
2. To convert seconds to hours, divide the number of seconds by the number of seconds per hour.

$$10 \text{ s} / 3600 \text{ s/h} = 10 \text{ s} \times 1 \text{ h} / 3600 \text{ s} = 1/360 \text{ h}$$

The difficulty in this calculation was the odd conversion factor.

Investigation # 1 VEHICLES IN MOTION

Think About IT!

Think About IT!—Page 11

1. The car is moving slowest when it is at the top of the ramp. The car has just begun to speed up from rest and is traveling very slowly. Also, in the results, one can see that the dots marking the positions of the car are closest together at the top of the ramp.
2. The car is moving fastest on the level surface. This is shown by the fact the dots are spaced farthest apart on the level surface. The car traveled the farthest in equal time intervals.
3. The spaces do not change across the table because the car is not speeding up or slowing down, since it is traveling on a level surface.
4. On the ramp, the car speeds up as it rolls down the ramp. On the table, the car moves with the same speed.

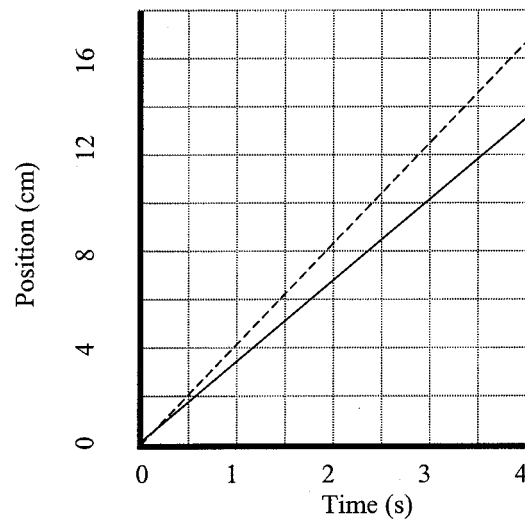
Uniform Motion

Since students are using rulers with millimetre calibration, an estimated digit in the 0.1 mm or 0.01 cm is used in the measurements. The distance is measured from the front tip of one car to the front tip of the next car.

Table A	
Position (cm)	Time (s)
0	0
3.36	1
6.63	2
9.95	3
13.27	4

Table B	
Position (cm)	Time (s)
0	0
4.10	1
8.20	2
12.30	3
16.40	4

Car A —
Car B - - -





**Think
About
IT!**

Think About IT!—Page 12

1. The slope of the line for Car B is steeper than the slope of the line for Car A.
2. Car A has a smaller space between successive images of the car. The points on the Position-Time graph do not rise as rapidly as those for Car B.

Car B has a larger space between successive images of the car. The points on the Position-Time graph rise more rapidly than those for Car A.

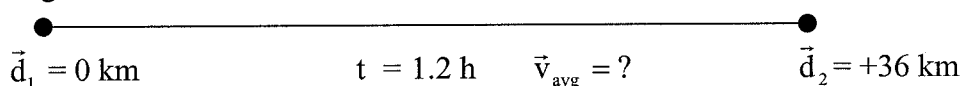
Think About IT!—Page 13

1. Concept map: The list of terms can also include direction, vector, and scalar.

Calculating Slope**PRACTICE—PAGE 14**

1. The positive direction will be to the right for all diagrams.

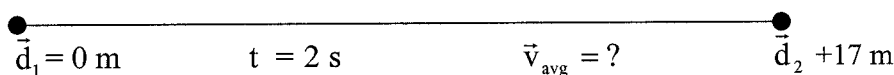
a. Origin



$$\bar{v}_{\text{avg}} = \frac{\Delta \bar{d}}{\Delta t} = \frac{+36 \text{ km} - 0 \text{ km}}{1.2 \text{ h}} = +30 \text{ km/h}$$

The average velocity of the bicycle is +30 km/h.

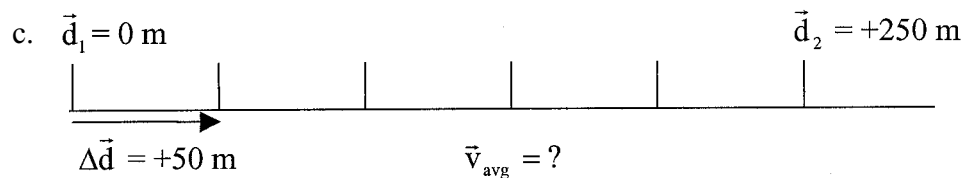
b. Origin



$$\bar{v}_{\text{avg}} = \frac{\Delta \bar{d}}{\Delta t} = \frac{+17 \text{ m} - 0 \text{ m}}{2 \text{ s}} = +8.5 \text{ m/s}$$

The average velocity of the person is +8.5 m/s.

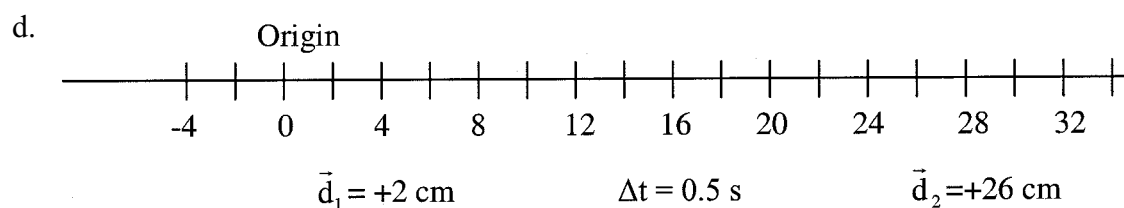
Using significant digits, the answer is +8 m/s.



$$\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt} = \frac{+250 \text{ m} - 0 \text{ m}}{18 \text{ s}} = +13.9 \text{ m/s}$$

The average velocity of the car is +13.9 m/s.

Using significant digits, the answer rounds to +14 m/s.



$$\vec{v}_{\text{avg}} =$$

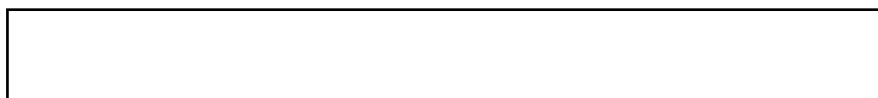
$$\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt} = \frac{+26 \text{ cm} - +2 \text{ cm}}{0.5 \text{ s}} = +48 \text{ cm/s}$$

The average velocity of the mini-V is +48 cm/s. With significant digits, use +50 m/s.

2. a. For a bicycle, 30 km/h would be fast.
- b. Running at 8.5 m/s is fast, bordering on unrealistic for the average person. Olympic calibre sprinters run at 10 m/s.
- c. The car is traveling at $13.9 \text{ m/s} \times 3.6 = 50 \text{ km/h}$. This would be a medium speed for a car.
- d. For a mini-V, 48 cm/s is a medium speed.

3. Assume that the skateboarder is coasting east, to the right or in the positive direction.

Corner = Origin



$$\vec{v}_{\text{avg}} = +2 \text{ m/s}; t = 3.5 \text{ s}$$

$$\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt}$$

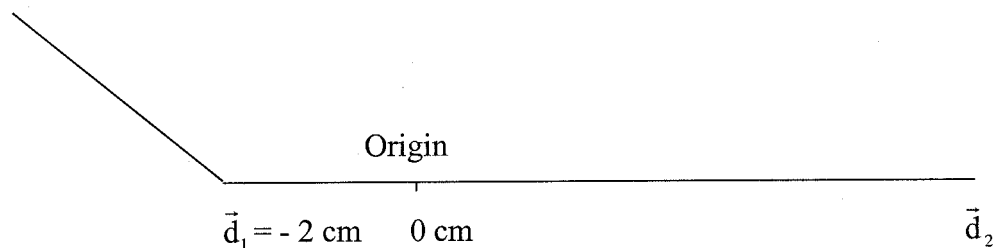
$$+2 \text{ m/s} = D\vec{d}/3.5 \text{ s}$$

$$D\vec{d} = (+2 \text{ m/s})(3.5 \text{ s}) = +7 \text{ m}$$

The displacement is +7 m or 7 m to the right.

4. When speeding, the displacement of a car in one unit of time is greater than that allowed by law. For example, a car traveling 35 km in one hour is speeding if the speed limit is 30 km in one hour.

5.



Since the positions are marked in cm, \vec{v}_{avg} should be expressed in cm/s.

$$\vec{v}_{\text{avg}} = +1.5 \text{ m/s} = +150 \text{ cm/s}; t = 0.4 \text{ s}$$

The unknown is the length of the track, $D\vec{d}$.

$$\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt}$$

$$+150 \text{ cm/s} = D\vec{d}/0.4 \text{ s}$$

$$D\vec{d} = (+150 \text{ cm/s})(0.4 \text{ s}) = +60 \text{ cm}$$

The track is 60 cm long. This answer has only one significant digit.

Uniform Motion

PRACTICE—PAGE 17

1. Since the object only traveled a distance of 70 m or so during a time of one hour, this Position-Time graph could represent the motion of an insect, such as a ladybug, along a straight-line path. The story might go like this.

The ladybug started at a position of 0 m at time 0 h. The ladybug moved in the positive direction, traveling at a constant low velocity. It reached a position of +3 m after 0.15 h. At 0.15 h, it began to move with a larger constant positive velocity, reaching a position of +20 m at 0.35 h. Then around 0.35 h, the ladybug began to crawl still more quickly in the positive direction at a constant velocity, reaching a position of +30 m shortly before 0.4 h. Around 0.4 h the ladybug slowed down, then traveled to a position of +40 m, reaching it at 0.5 h. At 0.5 h, it slowed down again, traveling with a low constant positive velocity until 0.8 h, reaching a position of +50 m at that time.

At 0.8 h, the ladybug stopped, turned around, sped up, and traveled with a large negative constant velocity to a position of +35 m at 0.93 h. At that time the ladybug sped up once more and traveled at a still larger constant negative velocity, reaching a position of +20 at 1.0 h.

2. The average velocity is found by taking the slope of the line on the Position-Time graph for that time interval.

The instantaneous velocity is found by locating the position on the curve of the Position-Time graph for the instant in question. Draw a line on the graph that runs in the same direction as the curve at that point in time. The slope of this line segment represents the instantaneous velocity. Note that since this line is estimated to run in the same direction as the curve, this can lead to wide variations in the slope.

In Question 2, the times have an additional 0 added on, giving each reading two significant digits.

a. $t_1 = 0 \text{ h}$, $\vec{d}_1 = 0 \text{ m}$

$$t_2 = 0.10 \text{ h}, d_2 = +15 \text{ m}$$

$$\vec{v}_{\text{avg}} = ?$$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+15 \text{ m} - 0 \text{ m}}{0.10 \text{ h} - 0 \text{ h}} = \frac{+15 \text{ m}}{0.10 \text{ h}} = +150 \text{ m/h}$$

Instantaneous velocity: From the line drawn on the graph at 0.05 h, the following points are taken.

$$t_1 = 0 \text{ h}, \vec{d}_1 = 0 \text{ m}$$

$$t_2 = 0.40 \text{ h}, d_2 = +60 \text{ m}$$

$$\vec{v}_{0.05} = ?$$

$$\vec{v}_{0.05} = \frac{D\vec{d}}{Dt} = \frac{+60 \text{ m} - 0 \text{ m}}{0.40 \text{ h} - 0 \text{ h}} = \frac{+60 \text{ m}}{0.40 \text{ h}} = +150 \text{ m/h}$$

The two velocities are equal.

b. $t_1 = 0.20 \text{ h}, \vec{d}_1 = +20 \text{ m}$

$$t_2 = 0.40 \text{ h}, d_2 = +26 \text{ m}$$

$$\vec{v}_{\text{avg}} = ?$$

$$\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt} = \frac{+26 \text{ m} - +20 \text{ m}}{0.40 \text{ h} - 0.20 \text{ h}} = \frac{+6 \text{ m}}{0.20 \text{ h}} = +30 \text{ m/h}$$

Instantaneous velocity: From the line drawn on the graph at 0.3 h, the following points are taken.

$$t_1 = 0 \text{ h}, \vec{d}_1 = +14 \text{ m}$$

$$t_2 = 1.0 \text{ h}, d_2 = +48 \text{ m}$$

$$\vec{v}_{0.3} = ?$$

$$\vec{v}_{0.3} = \frac{D\vec{d}}{Dt} = \frac{+46 \text{ m} - +14 \text{ m}}{1.0 \text{ h} - 0 \text{ h}} = \frac{+32 \text{ m}}{1.0 \text{ h}} = +32 \text{ m/h}$$

The two velocities are almost equal.

c. $t_1 = 0.60 \text{ h}, \vec{d}_1 = +32 \text{ m}$

$$t_2 = 0.08 \text{ h}, d_2 = +60 \text{ m}$$

$$\vec{v}_{\text{avg}} = ?$$

$$\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt} = \frac{+60 \text{ m} - +32 \text{ m}}{0.08 \text{ h} - 0.60 \text{ h}} = \frac{+28 \text{ m}}{0.20 \text{ h}} = +140 \text{ m/h}$$

Instantaneous velocity: From the line drawn on the graph at 0.05 h, the following points are taken.

$$t_1 = 0 \text{ h}, \vec{d}_1 = 0 \text{ m}$$

$$t_2 = 1.0 \text{ h}, d_2 = +54 \text{ m}$$

$$\vec{v}_{0.7} = ?$$

$$\vec{v}_{0.7} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+54 \text{ m} - 0 \text{ m}}{1.0 \text{ h} - 0 \text{ h}} = \frac{+54 \text{ m}}{1.0 \text{ h}} = +54 \text{ m/h}$$

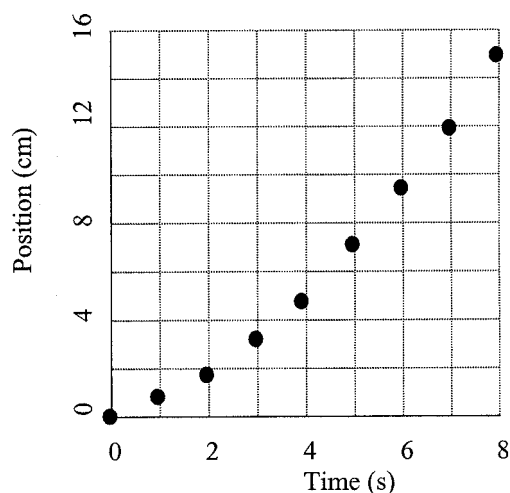
The two velocities are not equal.

Accelerated Motion

Note to Teacher: The instructions on page 18 indicate students are to measure the displacement between successive dots, but Table C asks for the **position** of the dots.

Have the students measure the position of each dot from the origin and record these in Table C. Also, since the dots are so large, students should pick one edge of the dot as the origin and measure the positions to the same edge of each of the remaining dots.

Position (cm)	Time (s)
0	0
0.8	1
1.9	2
3.3	3
5.0	4
7.1	5
9.4	6
12.0	7
14.9	8



The points on the graph should be joined with a smooth curve.

Erratum: The units for Column 1 in Table C should read as “cm” only.



**Think
About
IT!**

Think About IT!—Page 18

1. The Position-Time graph for uniform motion would be a straight line. The slope of this line would yield the average velocity. The slope is constant; therefore, the velocity is constant or uniform.

In this case, the slope of the line on the Position-Time graph is not constant, but is always changing. Therefore, the velocity cannot be constant and the motion is non-uniform.

2. As the car's velocity increases, the spacing of the dots becomes greater. The car will travel a farther distance in the same time when the velocity is greater.
3. The spacing of the dots increases uniformly. This indicates that the velocity of the car is increasing uniformly also. The acceleration must be uniform.

Table D—Page 19

A better format for this table would include a displacement column.

Table D

Time (s)	Position (cm)	Displacement During Time Interval (cm)	Average Velocity (cm/s)
0	0		
1	0.8	$0.8 - 0 = 0.8$	$0.8/1 = 0.8$
2	1.9	$1.9 - 0.8 = 1.1$	1.1
3	3.3	$3.3 - 1.9 = 1.4$	1.4
4	5.0	$5.0 - 3.3 = 1.7$	1.7
5	7.1	$7.1 - 5.5 = 2.1$	2.1
6	9.4	$9.4 - 7.1 = 2.3$	2.3
7	12.0	$12.0 - 9.4 = 2.6$	2.6
8	14.9	$14.9 - 12.0 = 2.9$	2.9

The average velocity for a time interval closely represents instantaneous velocity at the midpoint of each time interval. This leads us to Table E.

Erratum: The units for Column 2 in Table D should read as "cm" only.

**Think
About
IT!**

Think About IT!—Page 20

- The velocity changes at a regular rate, about 0.3 cm/s.
- As time increases, so does the velocity. They are directly related.
- The acceleration was uniform or constant at +0.3 cm/s/s.

PRACTICE—PAGE 21

- The first object is accelerating in the positive direction at $+16.0 \text{ m/s} / 4 \text{ s} = +4.0 \text{ m/s}$. It is traveling in the positive direction and speeding up.

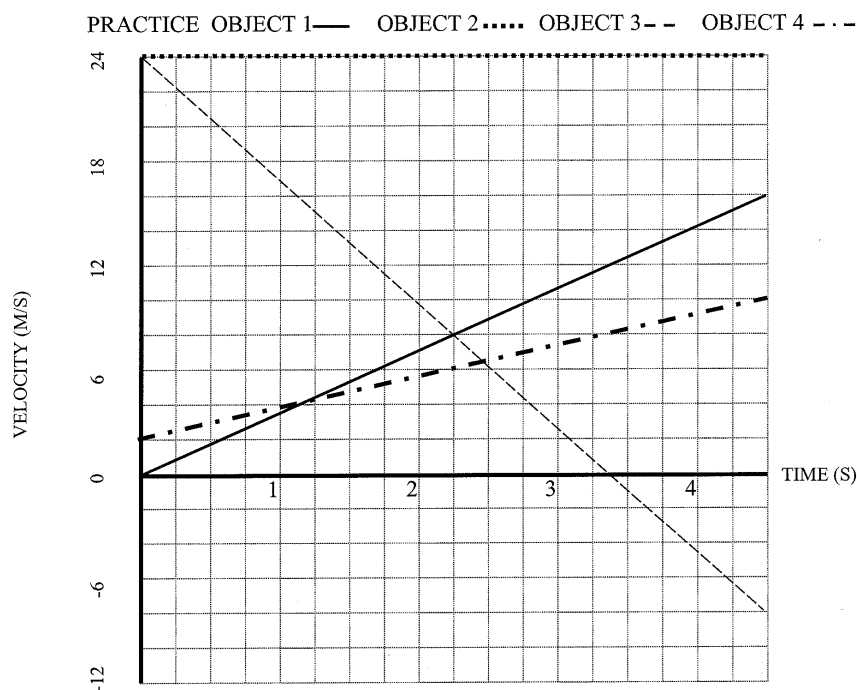
The second object has a constant velocity of $+24.0 \text{ m/s}$. The acceleration is 0 m/s/s . It is traveling in the positive direction.

The third object is moving initially with a large positive velocity of $+24 \text{ m/s}$. The velocity decreases from 0 s to 3 s. The object is slowing down. At 3 s the object momentarily stops and begins to move in the negative direction, speeding up until 4 s. The acceleration is always a negative acceleration. The acceleration is constant at -8 m/s/s .

The fourth object is initially moving at $+2 \text{ m/s}$ and speeds up in the positive direction. The object is always moving in the positive direction with a constant acceleration of $+2.0 \text{ m/s/s}$.

Table E

Velocity (cm/s)	Time (s)
0.8	0.5
1.1	1.5
1.4	2.5
1.7	3.5
2.1	4.5
2.3	5.5
2.6	6.5
2.9	7.5



2. Uniform motion and non-uniform motion:

Compare:

Both can be described using a Position-Time graph to indicate the position of the object at given points in time.

The slope of the Position-Time graph in both cases yields the velocity of the object.

Both can be described using a Velocity-Time graph to indicate the velocity of the object at given points in time.

The slope of the Velocity-Time graph in both cases yields the acceleration of the object.

Contrast:

The Position-Time graph for uniform motion is a straight line, a line of constant slope. The velocity of the object is uniform or constant. The Velocity-Time graph will be a straight, horizontal line. The acceleration is 0 m/s/s.

The Position-Time graph for non-uniform motion is a curved line, a line of changing slope. The velocity is always changing in time from instant to instant.

If the Velocity-Time graph is a straight line of constant slope (non-zero), then the acceleration is constant.

If the Velocity-Time graph is a curved line, then the acceleration is non-uniform, changing in time from instant to instant.

3. All the calculations of acceleration will use the following equation:

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{initial}} - t_{\text{initial}}}$$

The units used will be those given in the question.

a. $\vec{v}_1 = 0 \text{ km/h}$; $\vec{v}_2 = +20 \text{ km/h}$; $t = 6 \text{ s}$; $\vec{a}_{\text{avg}} = ?$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{initial}} - t_{\text{initial}}} = \frac{+20 \text{ km/h} - 0 \text{ km/h}}{6 \text{ s}} = +3.3 \text{ km/h/s}$$

Use one significant digit in the answer: +3 km/h/s.

b. $\vec{v}_1 = +10 \text{ km/h}$; $\vec{v}_2 = +60 \text{ km/h}$; $t = 30 \text{ min}$; $\vec{a}_{\text{avg}} = ?$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{initial}} - t_{\text{initial}}} = \frac{+60 \text{ km/h} - +10 \text{ km/h}}{30 \text{ min}} = +1.67 \text{ km/h/min}$$

Using significant digits, round off to +2 km/h/min.

c. $\vec{v}_1 = +50 \text{ km/h}$; $\vec{v}_2 = +60 \text{ km/h}$; $t = 6 \text{ s}$; $\vec{a}_{\text{avg}} = ?$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{initial}} - t_{\text{initial}}} = \frac{+60 \text{ km/h} - +50 \text{ km/h}}{6 \text{ s}} = +1.67 \text{ km/h/s}$$

Using significant digits, round off to +2 km/h/s.

d. $\vec{v}_1 = 0 \text{ m/s}$; $\vec{v}_2 = +7 \text{ m/s}$; $t = 3 \text{ s}$; $\vec{a}_{\text{avg}} = ?$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{initial}} - t_{\text{initial}}} = \frac{+7 \text{ m/s} - 0 \text{ m/s}}{3 \text{ s}} = +2.33 \text{ m/s/s}$$

Using significant digits, round off to +2 m/s/s.

Note to Teacher: Question 4 requires students to determine the displacement by taking the area beneath the curve of a Velocity-Time graph. This is beyond the scope of Senior 2 Science (20F). These concepts should be used only with the most capable students and should be considered as **enrichment material**.

4. In all cases, the origin will be the position of the initial velocity. Because the motion is non-uniform velocity with constant acceleration, all the Velocity-Time graphs will be straight-line graphs. However, the Position-Time graphs will all be curves. Since, in all cases, the acceleration is positive, the curves on the Position-Time will have an increasing slope, upwards to the right.

The displacement can be found by rearranging $\vec{v}_{\text{avg}} = \frac{D\vec{d}}{Dt}$ to solve for $D\vec{d}$. The

rearranged equation is $D\vec{d} = \vec{v}_{\text{avg}} Dt$. On a Velocity-Time graph, this represents the area beneath the line on the graph.

In our cases here, the average velocity can be found from the two given velocities as a simple average—add them up and divide by 2. So we use $\vec{v}_{\text{avg}} = \frac{\vec{v}_1 + \vec{v}_2}{2}$ and the

final equation becomes $D\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} Dt$. The displacement will give the final position

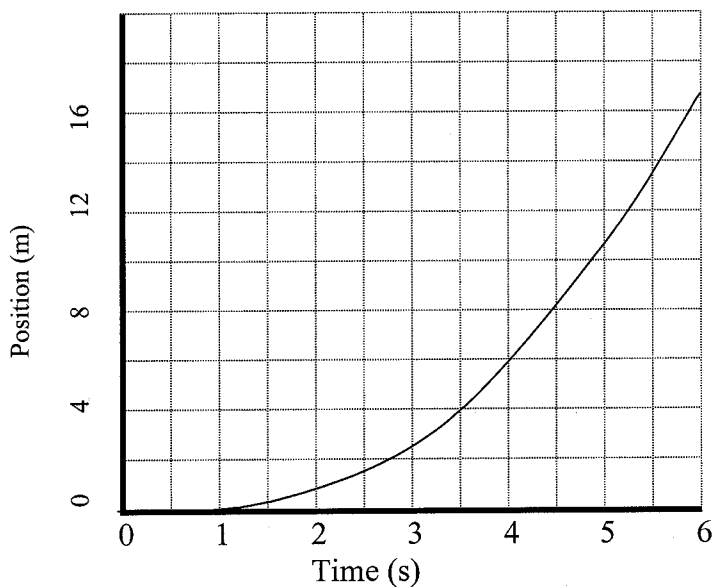
of the object for all the graphs. The line on the Position-Time graph will be a curve joining the initial position to the final position.

Finally, in some cases, the velocities will be changed to m/s from km/h to facilitate the comprehension of the displacement.

4. a. $\vec{v}_1 = 0 \text{ km/h} = 0 \text{ m/s}$; $\vec{v}_2 = +20 \text{ km/h} / 3.6 = +5.5 \text{ m/s}$; $t = 6 \text{ s}$; $D\vec{d} = ?$

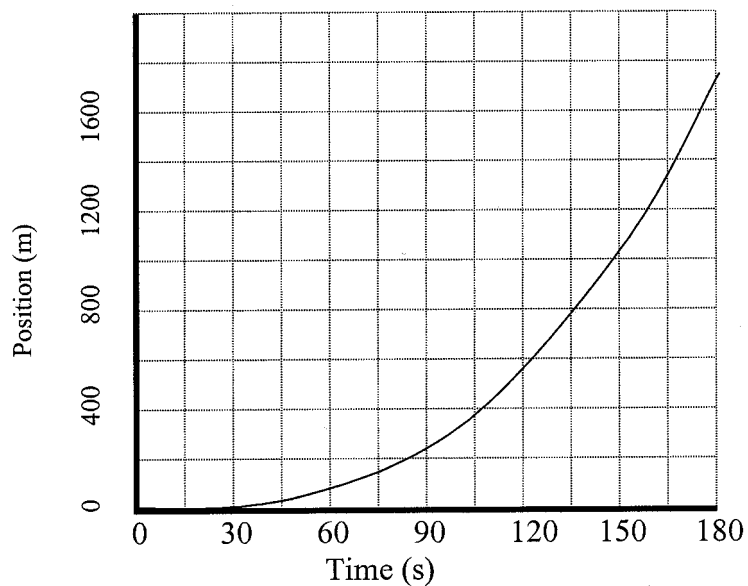
$$D\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} Dt = \frac{(0 \text{ m/s} + 5.5 \text{ m/s})}{2} (6 \text{ s}) = +16.5 \text{ m}$$

Therefore, \vec{d}_2 is +16.5 m. A curved line is drawn on the Position-Time graph starting at 0 m and ending at +16.5 m. The remaining questions are done in a similar fashion.



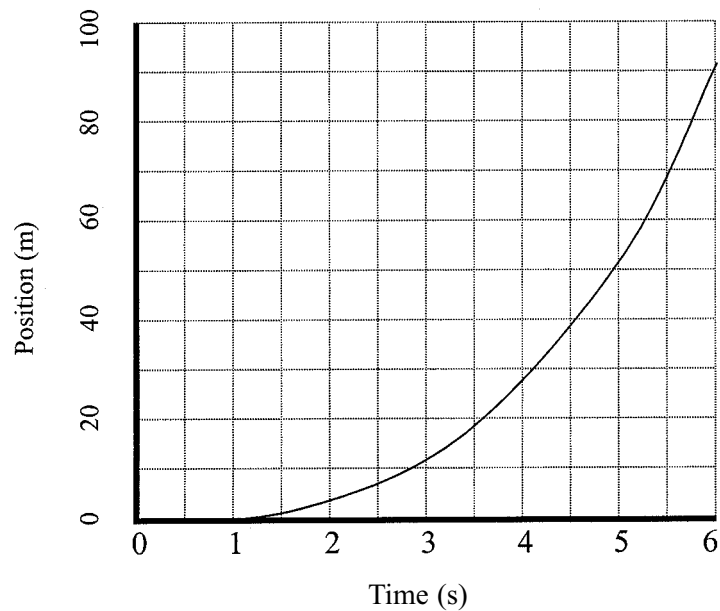
- b. $\vec{v}_1 = +10 \text{ km/h} / 3.6 = +2.8 \text{ m/s}$; $\vec{v}_2 = +60 \text{ km/h} / 3.6 = +16.7 \text{ m/s}$;
 $t = 30 \text{ min} = 180 \text{ s}$; $D\vec{d} = ?$

$$D\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} Dt = \frac{(+2.8 \text{ m/s} + 16.7 \text{ m/s})}{2} (180 \text{ s}) = +1750 \text{ m}$$



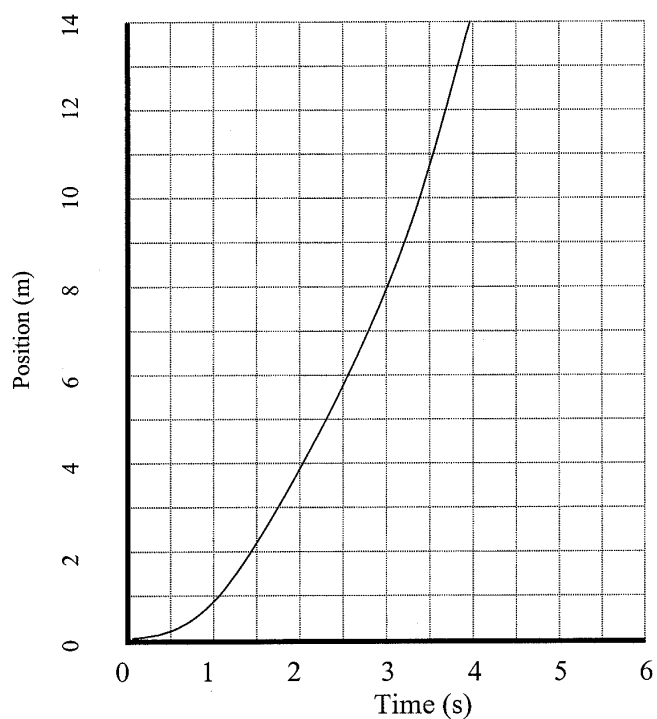
- c. $\vec{v}_1 = +50 \text{ km/h} / 3.6 = +13.9 \text{ m/s}$; $\vec{v}_2 = +60 \text{ km/h} / 3.6 = +16.7 \text{ m/s}$; $t = 6 \text{ s}$; $D\vec{d} = ?$

$$D\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} Dt = \frac{(+13.9 \text{ m/s} + 16.7 \text{ m/s})}{2} (6 \text{ s}) = +91.8 \text{ m}$$



- d. $\vec{v}_1 = 0 \text{ m/s}$; $\vec{v}_2 = +7 \text{ m/s}$; $t = 4 \text{ s}$; $D\vec{d} = ?$

$$D\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} Dt = \frac{(0 \text{ m/s} + 7 \text{ m/s})}{2} (4 \text{ s}) = +14 \text{ m}$$



**Think
About
IT!****Think About IT!—Page 22**

It appears that there are two sets of footprints: those of a wolf and those of a rabbit.

In the diagram, to the right represents the east or an easterly direction.

The wolf is traveling in a direction slightly south of east. By the spacing of the tracks, the wolf appears to be walking or running slowly. The rabbit is hopping along slowly in a direction slightly north of east. The paths of the wolf and the rabbit intersect. At this point, there are many wolf tracks in the same area. This indicates that the wolf remained there for a time while it killed and ate the rabbit. Once the meal was finished, the wolf moved away more slowly in a southeasterly direction.

Analyzing Motion: Enrichment

Note to Teachers:

The concepts involved in motion—position, velocity, acceleration, and time—should be developed using the four modes of representation: visual, numeric, graphical, and symbolic. Students need concrete experiences with these concepts. Some additional activities are provided, along with typical results.

To reinforce the concepts of motion, some extended student activities are supplied, along with answers. Many of these activities can be done by students working collaboratively in groups. Students helping other students has benefit for all involved.

Students are required to perform calculations. At this time, you may wish to introduce the concept of significant digits and the rules for significant digits in calculations. Some information is provided, with a very simple mnemonic device to aid students in determining which digits are significant.

Position and Displacement

SUGGESTED ACTIVITY:

Mark off a reference system on the board or on the wall. The origin is clearly marked as 0 m. The positions of +1 m, -1 m, +2 m, -2 m, et cetera, are marked off. A student stands at one of these positions, marked as \vec{d}_1 . The student then moves to a second position, marked as \vec{d}_2 .

Ask students to determine the distance traveled.

Ask students to determine the displacement.

The displacement, $\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$, can be calculated. Here, displacement can be seen as distance traveled with a direction.

The importance of direction can be illustrated as follows. If a student starts at +1 m and has a displacement of +2 m, the final position is +3 m. However, if the student starts at +1 m and the displacement is -2 m, the final position is -1 m. The direction is important because the student, while starting at the same spot, has different final positions.

Ask students to start at a given position and to predict the final position, given the displacement. Students can determine the initial position, given the final position and the displacement. The use of the number line is very helpful for the students to visualize the situation.

Vectors and Scalars

Once students are introduced to the concepts of vectors and scalars, they should include direction with all vector quantities.

Instruct students in recognizing quantities from the units attached. For example, 5 m indicates distance. A value such as +5 m or 5 m east or 5 m [E] indicates displacement. Students also need to practise using the name that accompanies a symbol. Many times an equation is memorized without any understanding of the meaning of the symbols.

As students encounter new quantities, they should be encouraged to keep track of them—name, symbol, unit, vector, or scalar.

When measuring quantities in science, it is necessary to specify the direction for some quantities. Most quantities we measure are scalars. These are measured with a size or magnitude but without regard to direction. For example, temperature is a scalar. While it can be positive or negative, it does not have a direction like right or left, or east or west associated with it.

Other quantities require that a direction be given along with the size or magnitude. Force is a vector. You can pull on a door handle with a force of 25 newtons east or you can push on the door handle with a force of 25 newtons west. Although these two forces have the same magnitude, they act in different directions. One force will open the door; the other force will not.

In the study of motion, two similar quantities, speed and velocity, are often confused. Speed describes how fast an object is moving, regardless of direction. The speedometer of a car measures speed. It indicates how fast the car is moving, but does not include the direction. For example, 100 km/h is a typical speed for a car on the highway.

Velocity, though, is a vector. If we start at a point and travel at 100 km/h east for one hour, we will end up 100 km east of our starting point. If we travel at 100 km/h west, starting from the same point, we will end up 100 km west of the starting point. These two velocities, 100 km/h east and 100 km/h west, are definitely different velocities. It is the direction that makes them different.

In summary, **scalars are quantities with size or magnitude only.** We give the value of such a quantity with a number for its size and a unit to tell us the type of quantity.

A vector is a quantity with both magnitude and direction. We describe the value of a vector with a number for its size, a unit to tell us the type of quantity, and a direction.

For each quantity, give the unit and state whether it is a vector or scalar quantity.

Table 1

Quantity	Symbol of the Quantity	Unit	Vector or Scalar
Time Instant			
Time Interval			
Distance Traveled			
Displacement			
Mass			
Length			
Speed			
Acceleration			
Velocity			
Force			
Energy			

Significant Digits

The Purpose of Significant Digits

Systems of measurement were invented in order to compare quantities. Only the size of the object used to define a unit of measure is known exactly. The metre was once defined as the distance between two scratches on a bar of platinum-iridium alloy at 0°C. All other measurements of distance are estimated. Not all measurements, however, are known to the same accuracy, which refers to how close the measurement is to the true value. A micrometer, for example, will yield a more accurate measurement of a hair's diameter than will a metrestick.

Recording a Measurement Using Significant Digits

When recording a measurement, include every digit that is absolutely certain plus the first digit that must be estimated. This is the definition of a significant digit. Significant digits are part of the measurement.

For example, suppose the length of a table is measured with a ruler calibrated to 10 centimetres. A proper measurement would be recorded as 2.64 metres. This indicates the table has a length of 2 metres plus 60 centimetres plus a little bit more. The table is definitely less than 2.7 metres but greater than 2.6 metres. The first two digits are known exactly and the third digit is estimated (a guess). The measurement has three significant digits. A measurement of the same table with a ruler calibrated to centimetres could yield 2.642 metres.

The final significant digit will always be one unit smaller than the calibration of the measuring instrument. For example, the first measurement above was recorded to the nearest centimetre, and the ruler was calibrated to only the nearest 10 centimetres. The second measurement was recorded to the nearest tenth of a centimetre, and the ruler was calibrated to the nearest centimetre.

Zeros are to be recorded if they are significant. If a table was measured and the end of the table coincided with a mark on the ruler (e.g., 2.6 metres), a zero must be recorded. If the ruler is calibrated in 10 centimetres, record zeros until the next smaller unit, one centimetre, is recorded. In this case, the measurement would be 2.60 metres. If the metrestick was calibrated in centimetre units, then zeros are recorded until one millimetre is recorded. Here, the measurement would be 2.600 metres.

Rules for Significant Digits

The following rules are used to determine the number of significant digits in a given measurement.

1. All non-zero digits are significant.
E.g., 374 (3 sig digs), 8.1 (2 sig digs)
2. All zeros between non-zero digits are significant.
E.g., 50407 (5 sig digs), 8.001 (4 sig digs)
3. Leading zeros in a decimal are not significant.
E.g., 0.54 (2 sig digs), 0.0098 (2 sig digs)
4. Trailing zeros are significant if they are to the right of a decimal point.
E.g., 2370 (3 sig digs), 16000 (2 sig digs), 160.0 (4 sig digs)
5. In numbers greater than 1, trailing zeros are not significant unless stated so.
E.g., 37000 (2 sig digs)

The last three zeros may or may not be part of the measurement. To show that they are, we use scientific notation. All the zeros written in the number in scientific notation are significant.

37000 with 3 sig. digits would be 3.70×10^4

37000 with 4 sig. digits would be 3.700×10^4

37000 with 5 sig. digits would be 3.7000×10^4

37000.0 has 6 sig. digits

ACTIVITY 1

Determine the number of significant digits in each of the following numbers

- | | | |
|-----------|-----------|-------------|
| 1) 5.897 | 2) 8.000 | 3) 10001 |
| 4) 0.333 | 5) 8.001 | 6) 0.008000 |
| 7) 7 | 8) 0.009 | 9) 947.000 |
| 10) 10000 | 11) 12000 | 12) 10000.0 |
| 13) 10321 | 14) 55040 | 15) 375000 |

ACTIVITY 2

State the number of significant digits in each measurement.

- | | | |
|--------------|--------------------------|------------------------------|
| 1) 2509 m | 2) 7.62 km | 3) 0.00055 m |
| 4) 0.0670 m | 5) 5.060×10^5 m | 6) 9.0000×10^{-5} m |
| 7) 240 m | 8) 2.4 m | 9) 2400 m |
| 10) 2400.0 m | 11) 0.005050 m | 12) 50 m |

ANSWERS—ACTIVITY 1

- | | | |
|-------|-------|-------|
| 1) 4 | 2) 4 | 3) 5 |
| 4) 3 | 5) 4 | 6) 4 |
| 7) 1 | 8) 1 | 9) 6 |
| 10) 1 | 11) 2 | 12) 6 |
| 13) 5 | 14) 4 | 15) 3 |

ANSWERS—ACTIVITY 2

- | | | |
|-------|-------|-------|
| 1) 4 | 2) 3 | 3) 2 |
| 4) 3 | 5) 4 | 6) 5 |
| 7) 2 | 8) 2 | 9) 2 |
| 10) 5 | 11) 4 | 12) 1 |

Alternate Rule for Significant Digits

Here is an alternate rule for determining significant digits. The rule is really a mnemonic device. Students are easily confused about the number of significant digits, especially if zeros are present. This rule will allow students to achieve success in working with significant digits, which should, in turn, encourage them to keep using them.

This method is called the “Atlantic-Pacific” method.

If the number in question does not contain a decimal, think “A” for Absent. If the number in question does contain a decimal, think “P” for Present.

Next, imagine a map of North America with north pointing to the top of the page. The “A” now stands for Atlantic and the “P” now stands for Pacific. Imagine an arrow starting from the correct coast being drawn towards the number. Once the arrow hits a non-zero digit, that digit and all digits after it are significant.

EXAMPLE 1

How many significant digits are shown in the number 37 500?

There is no decimal, so we think of “A” for “Absent.” Therefore, an arrow must come in from the Atlantic Ocean (i.e., the right side), as shown below.

37 500 <

The first non-zero digit that the arrow hits would be the 5. The 5 and all digits after it, in this case to the left of the 5, are significant.

ANSWER—EXAMPLE 1

There are three significant digits in the number 37 500, the 3, 7, and the 5.

EXAMPLE 2

How many significant digits are shown in the number 0.040500?

There is a decimal, so we think of “P” for “Present.” Therefore, an arrow must come in from the Pacific Ocean (i.e., the right side), as shown below.

fi 0.040500

The first non-zero digit that the arrow hits would be the 4. The 4 and all digits after it, in this case to the right of the 4, are significant.

ANSWER—EXAMPLE 2

There are five significant digits in the number 0.040500: the 4, 0, 5, 0, and 0.

Example 2 employs three separate rules for significant digits and zeros.

Uniform Motion

The following activity is an alternative to the activity with the toy vehicle pulling the ticker tape to record its position. This activity involves the participation of the whole class and produces velocities of various sizes and directions. It also provides the students with an opportunity to describe motion in a variety of ways.

The activity is intended to establish two important types of information that can be obtained from a Position-Time graph. The first type of information is found by reading the Position-Time graph directly. This provides the position of a moving object at a given instant in time, or the instant in time at which the object is at a given position.

The second type of information is found indirectly from the graph: it involves a calculation or interpretation. This indirect information is the slope of the line on the Position-Time graph. The slope gives the velocity of the object. The steepness of the slope gives the speed or magnitude of the velocity, while the sign of the slope gives the direction of the velocity.

Students can work collaboratively on the analysis of the results of the following activity.

Introducing Motion: Position, Time, Distance and Speed, Displacement, and Velocity

Purpose:

To determine the position of a person moving in a straight line at different instants in time.

To interpret a Position-Time graph to obtain distance traveled, speed, displacement, and velocity.

Apparatus:

50 metres of hallway or field, stopwatches, measuring tape

Procedure:

PART A

- Using the measuring tape, mark off 5-m intervals along a crack in the floor tiles. Place a piece of masking tape at each 5-m mark. Mark these positions using small signs, like yardage markers along the sidelines of a football field.
- Have students with stopwatches stand at each of the markers.
- Have one student begin at the 0-m mark. When the student begins to move, all timers start timing with the stopwatches.
- The student walks the full length of the course at a constant rate. As the walking student passes each timer, the timer will stop the stopwatch.
- The timers then share their times and positions with the group.

Observations:

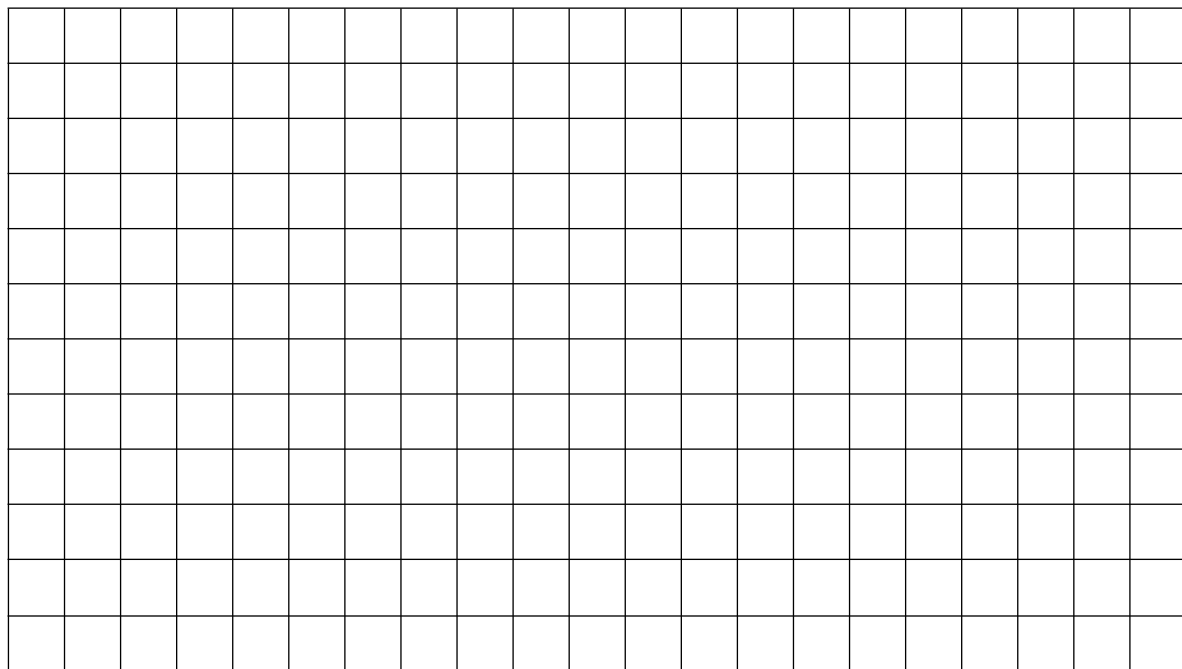
Description of motion:

Draw a picture of the motion:

Table 2A

Time (Sec)											
Position (Metres)											

On the following graph, label time on the horizontal axis and position on the vertical axis and plot the points from the data table. Draw in the line of best fit.



Procedure:**PART B**

The student starts from the 0-m mark this time and walks more quickly than before, but at a constant rate over the whole course. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

Table 2B

Time (Sec)										
Position (Metres)										

Plot this information on the previous graph, using a different colour for these points. Draw in the line of best fit.

Procedure:**PART C**

The student starts from the 0-m mark this time and runs at a constant rate over the whole course. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

Table 2C

Time (Sec)											
Position (Metres)											

Plot this information on the previous graph, using a third different colour for these points. Draw in the line of best fit.

1. Using the descriptions of the motion, how do the starting points compare for the three trials?
2. From the graph, determine the starting point for each of the three trials. Compare these to the answers in part (b).
3. From the description of the motions, what is the same about all three motions?
4. From the description of the motions, what is different about the three motions?
5. On the graph, what is different about the three lines?

Procedure:**PART D**

The student starts from the last mark this time and walks quickly but at a constant rate over the whole course, ending up at 0 m. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

Table 2D

Time (Sec)											
Position (Metres)											

Plot this information on the graph, using a fourth different colour for these points. Draw in the line of best fit.

Analysis:

1. How does this fourth line differ from the other three lines on the graph?
2. From the description of the motions, can you relate something about the line to the motion it represents?

Line 1:

Line 2:

Line 3:

Line 4:

Procedure:**PART E**

At the 10-m mark, station two timers. The student starts from the 0-m mark this time and walks quickly to the 10-m mark. The first timer stops the stopwatch. The student stays at the 10-m mark for a slow count of 5. At the count of 5, the second timer stops her stopwatch and the student resumes her journey, covering the whole course at a slower pace than before. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

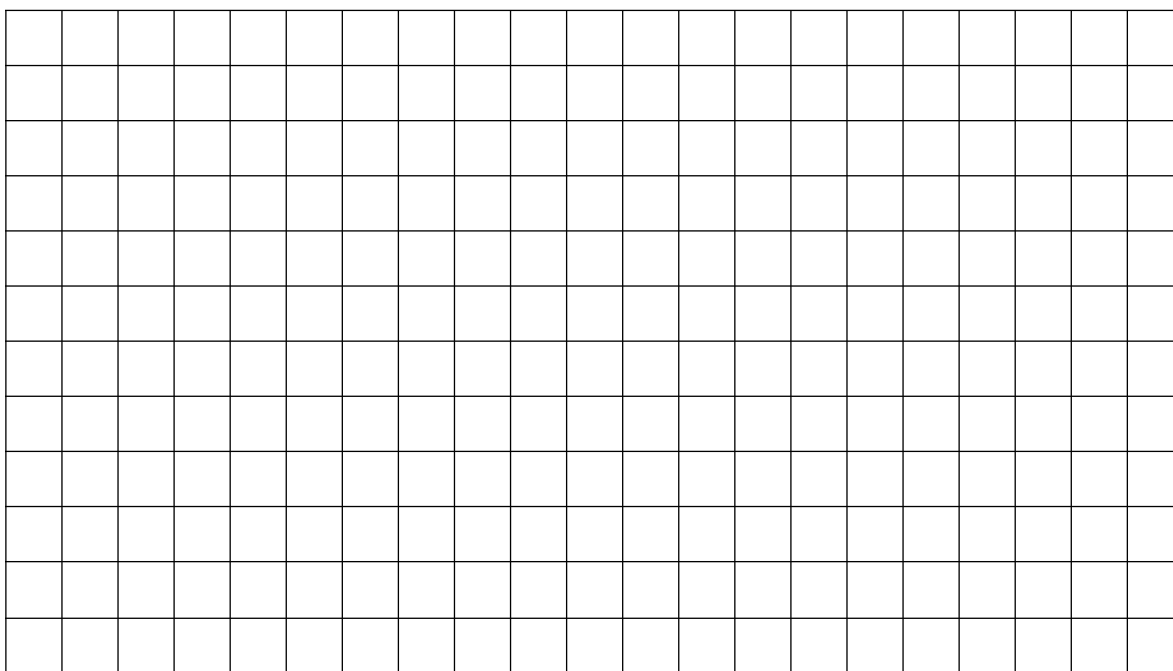
Description of motion:

Draw a picture of the motion:

Table 2E

Time (Sec)											
Position (Metres)											

Plot this information on the graph below. Plot position on the vertical axis and plot time on the horizontal axis. **Do not draw a line of best fit.** Instead, draw a line of best fit for each section.



Analysis:

1. What is different about each section of the graph?
2. Go back to the description of the motion. What does the graph look like when the student was moving quickly? Not moving? Moving slowly?

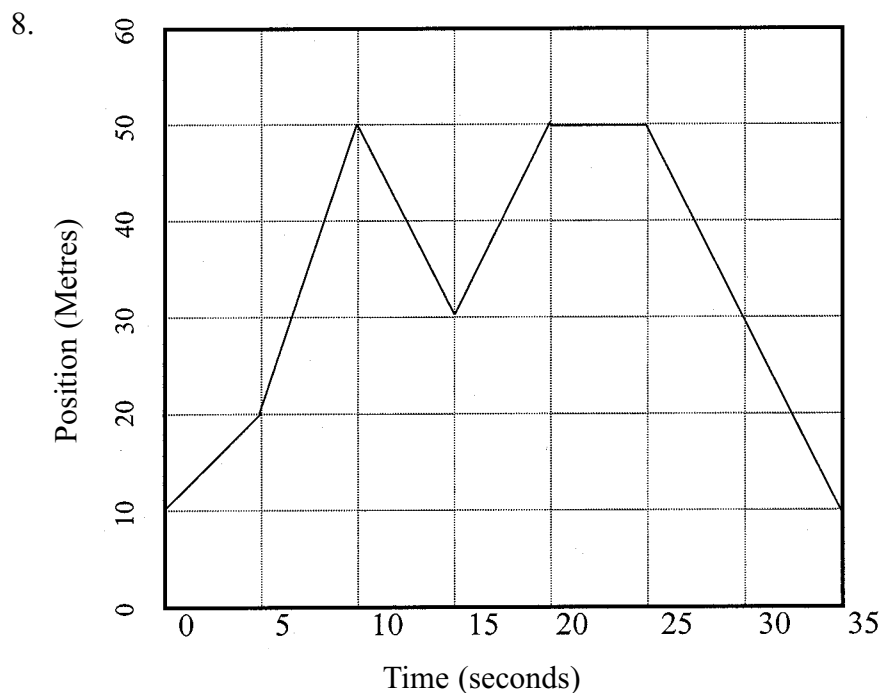
Conclusion:

Describe the information one is able to obtain **directly** from a Position-Time graph.

We can obtain more indirect information from a Position-Time graph by looking at the line. Describe the information we can obtain **indirectly** from a Position-Time graph.

Questions:

1. Distinguish between distance traveled and displacement.
2. Distinguish between average speed and average velocity.
3. For each trial (A through E), calculate the total distance traveled. Obtain the information from the graph.
4. For each trial (A through E), calculate the total time for the journey. Obtain the information from the graph
5. For each trial (A through E), calculate the average speed. Show the equation and the work for each calculation.
6. For each trial (A through E), calculate the **displacement** for the whole journey. Obtain the information from the graph.
7. For each trial (A through E), calculate the **average velocity** for the journey. Show the equation and the work for each calculation.



The graph of Position-Time above shows the position of a soccer linesman running along the sideline of a soccer field during a soccer game.

The 0-m mark is located at the goal line at the south end of the field. All the positions are marked north of that starting point.

- a. Where does the linesman start his journey?

- b. During which time intervals is the linesman moving to the north?

To the south?

Not moving?

- c. What is the distance traveled and the displacement for each interval listed below? Include direction with displacement.

Table 3

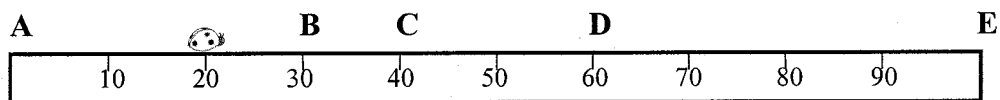
Time Interval	Distance Traveled	Displacement
0–5 seconds		
5–10 seconds		
10–15 seconds		
15–20 seconds		
20–25 seconds		
25–35 seconds		

- d. Calculate the average speed and the average velocity of the linesman for each time interval.

Table 4

Time Interval	Average Speed	Average Velocity
0–5 seconds		
5–10 seconds		
10–15 seconds		
15–20 seconds		
20–25 seconds		
25–35 seconds		

Describing Motion in Various Ways



1. A somewhat confused ladybug is moving back and forth along a meterstick. Determine both the displacement and distance traveled by the ladybug as it moves from:
 - a. A to B
 - b. C to B
 - c. C to D
 - d. C to E and then to D

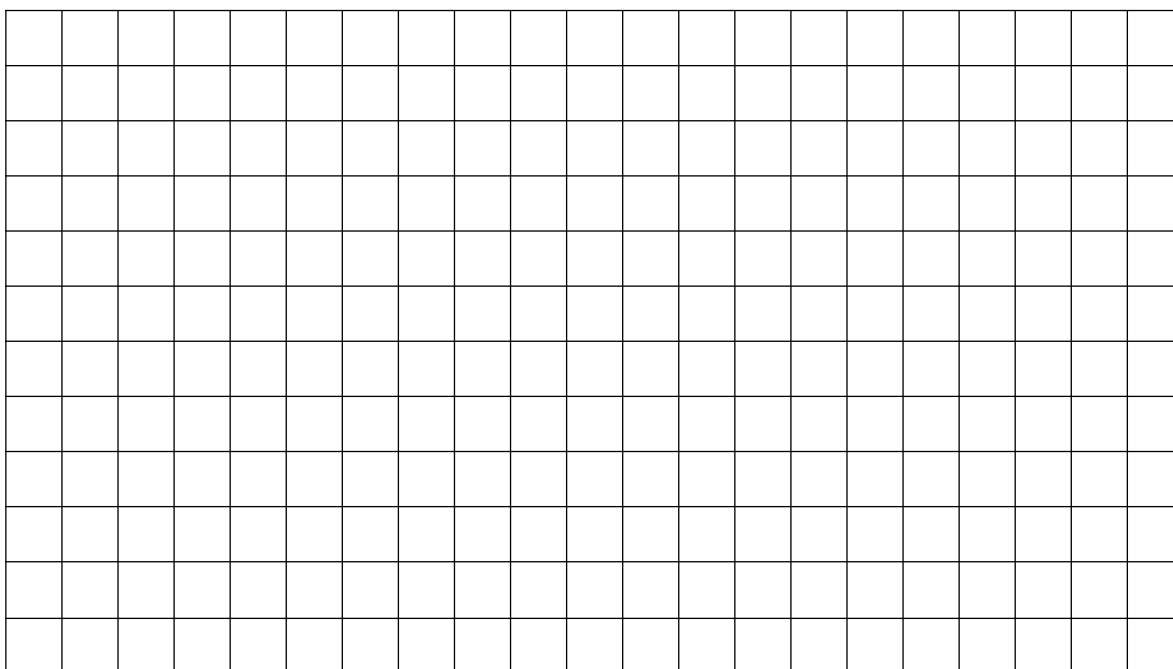
2. In the diagram above, **east** points to the **right**. During which of the intervals in #1 is the ladybug moving in the **easterly** direction?

In the **westerly** direction?

3. Below is a table showing the position above the ground floor of an elevator at various times. On the graph below the table, plot a graph of Position-Time.

Table 5

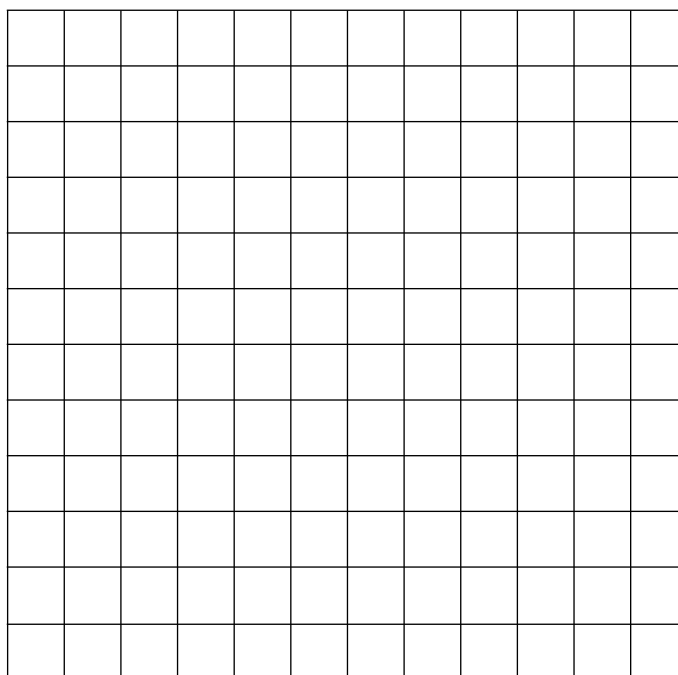
Time (Sec)	0	4	20	32	36	60	72
Position above the ground floor (m)	4.0	8.0	8.0	16	20	20	12



4. A troubled student is waiting to see the principal. He paces back and forth in the hallway in front of the principal's office. The hallway runs north and south. The door to the office is our origin, 0 m. Here is a description of the student's motion.

The student starts at 5.0 m N. He walks to the south for 7.0 m during 10.0 s. He stands still for 5.0 s. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s to reach the door.

- What is the total time the student spent in the hallway?
- What was the distance traveled by the student during his pacing?
- What was the average speed of the student during his pacing?
- On the graph below, plot time on the horizontal axis and position on the vertical axis. Use straight-line segments to join the points of Position-Time that you plot.

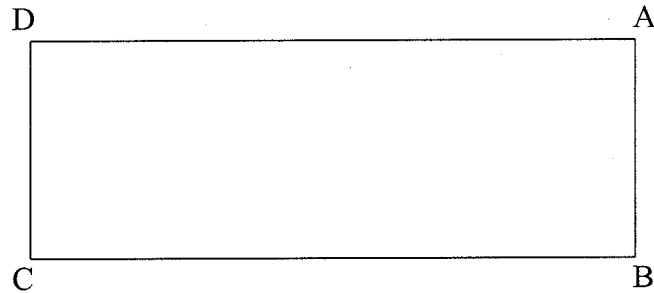


- What is the total displacement for the student's journey? Find this from the graph.
- What is the average velocity for the whole journey?

Velocity, Displacement, Time Problem Set

Questions 1–4 use the information below.

A city block is laid out in a grid running in the north-south and east-west directions. The blocks measure 135 m in length in the east-west direction, and 45.0 m in width in the north-south direction. A city block is drawn below.



1. On your bicycle, you travel from A to B during 9.00 s.
 - a. What is your average speed?
 - b. What is your average velocity?
2. If you travel from A to B to C to D, what is your
 - a. distance traveled?
 - b. displacement?
3. If the journey in #2 took 55.0 s, calculate
 - a. your average speed.
 - b. your average velocity.
4. You travel around the block in 90.0 s. Calculate your average speed and your average velocity.
5. Fargo is located 375 km south of Winnipeg. If it takes 4.00 h to travel from Winnipeg to Fargo, calculate your average velocity.
6. You make the return trip to Winnipeg from Fargo also in 4.00 h. What was your average velocity?
7. Jim lives on the same street as his school. The front of the school is located 1020 m [E] of Jim's house. If Jim walks at 3.00 m/s [E], calculate the time it takes Jim to walk from his house to the front of the school.
8. An airplane flies at a velocity of 215 km/h [W] for 2.75 hours. What is the displacement for this journey?

Relating Position-Time Graphs to Velocity-Time

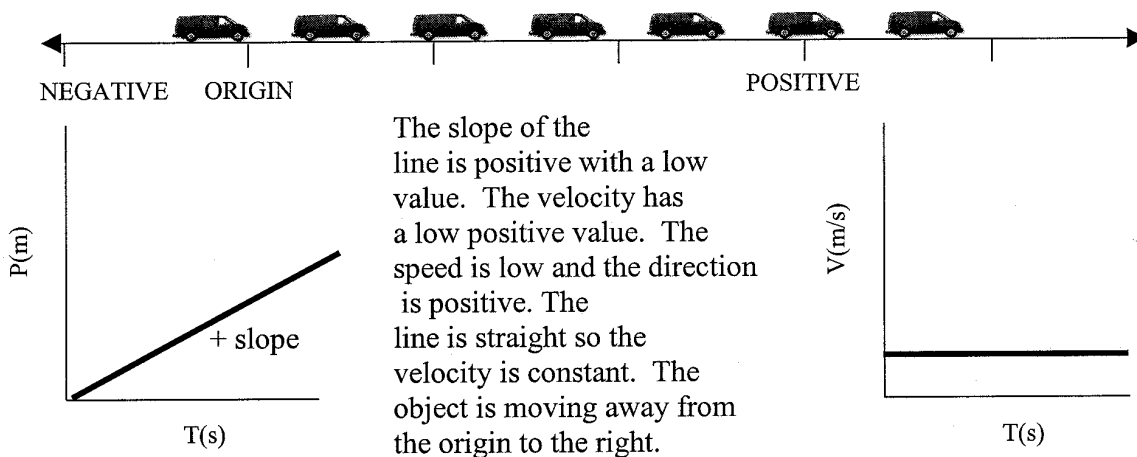
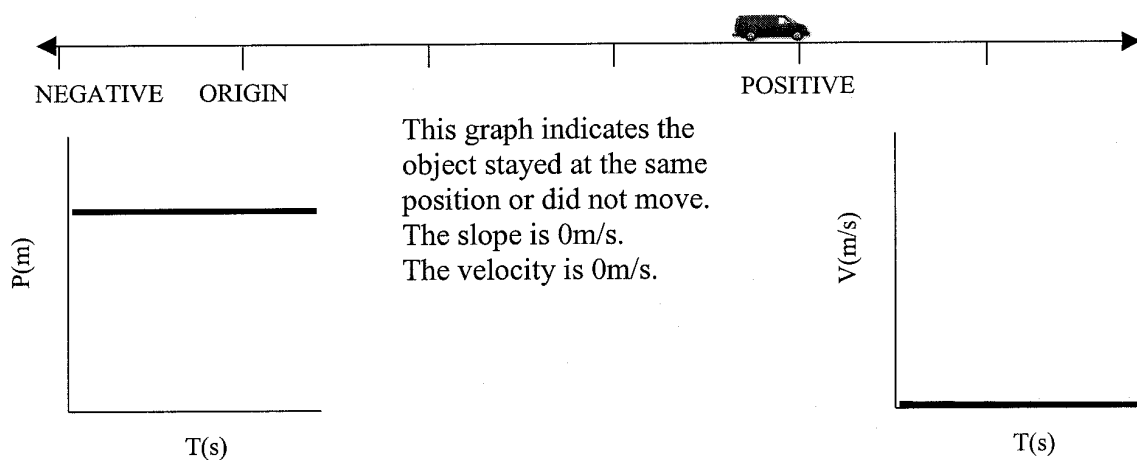
Position-Time graphs can be read directly to give the position of an object at an instant in time. This interpretation of a P-T graph tells us where an object is at a given time. This information generates the Position-Time version of the story of the motion.

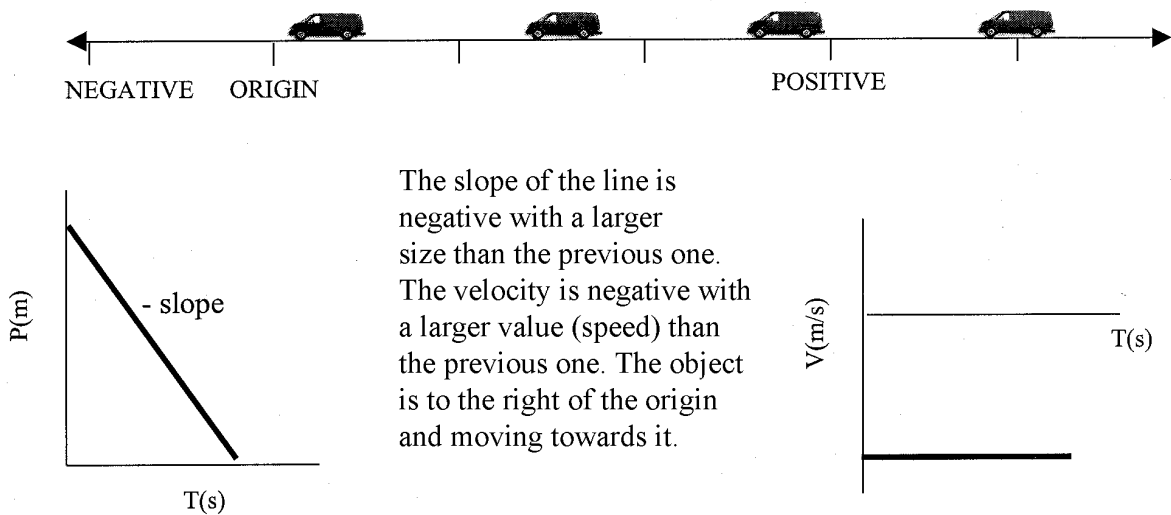
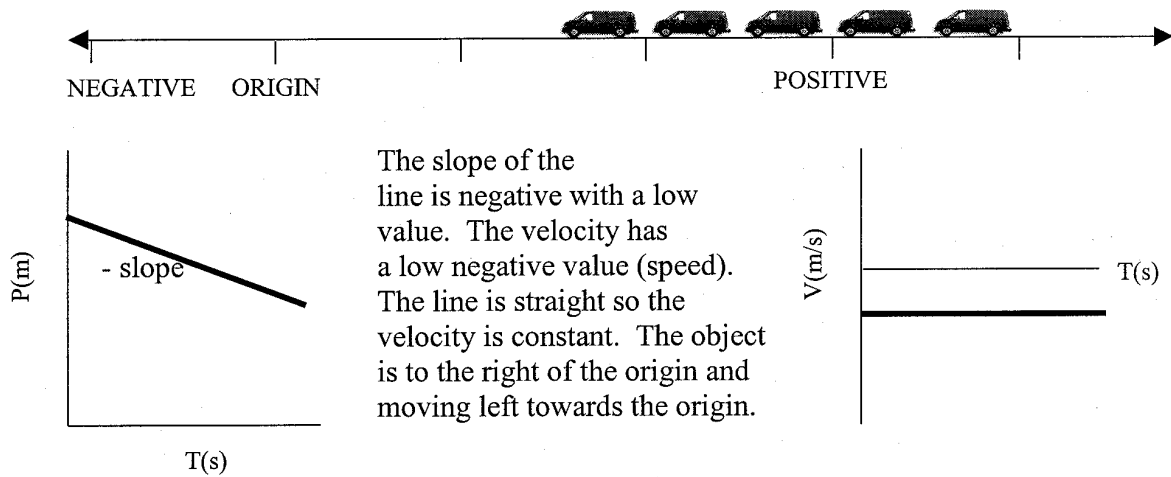
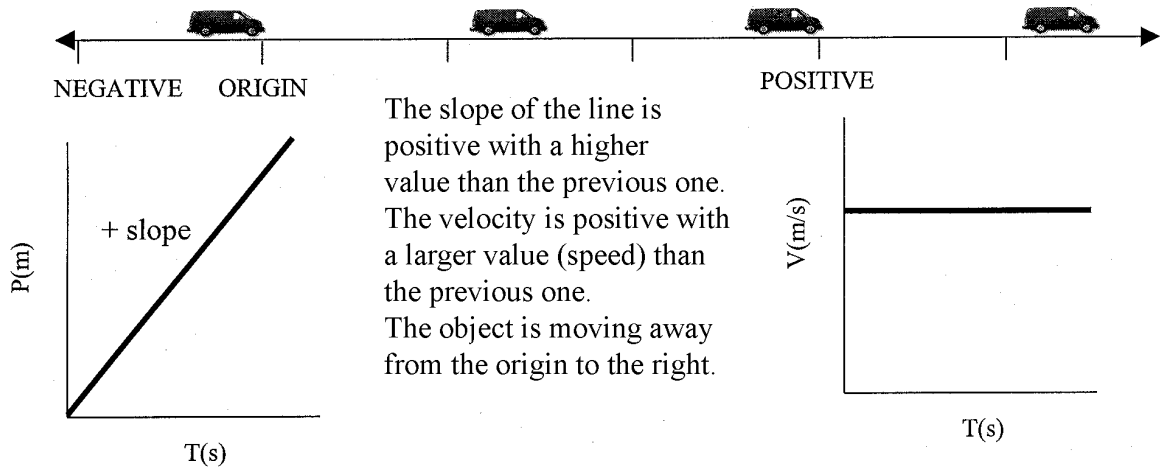
Slopes of P-T Graphs for Uniform Motion

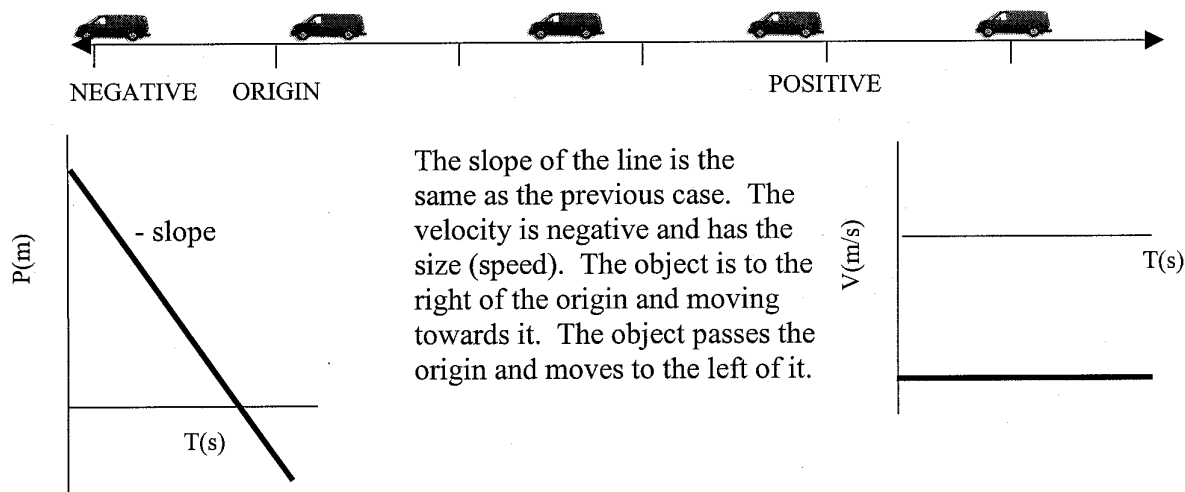
The slope of a P-T graph gives us the velocity of the object $\vec{v}_{\text{average}} = \vec{D}d / Dt$. This allows us to tell the Velocity-Time version of the story of the motion. Remember that slope refers to the steepness of a line. Therefore, the steeper the line on a P-T graph, the greater the magnitude or size (speed) of the velocity will be for that time interval or instant in time.

Since velocity is a **vector** quantity, it is important that the direction of the velocity is always included. Think of velocity as **speed with direction**.

Here are some typical examples of P-T graphs with various slopes. Straight lines on P-T graphs yield constant slopes, and constant velocities (speed and direction remain the same). All the time intervals are equal for the time between the positions of the van.





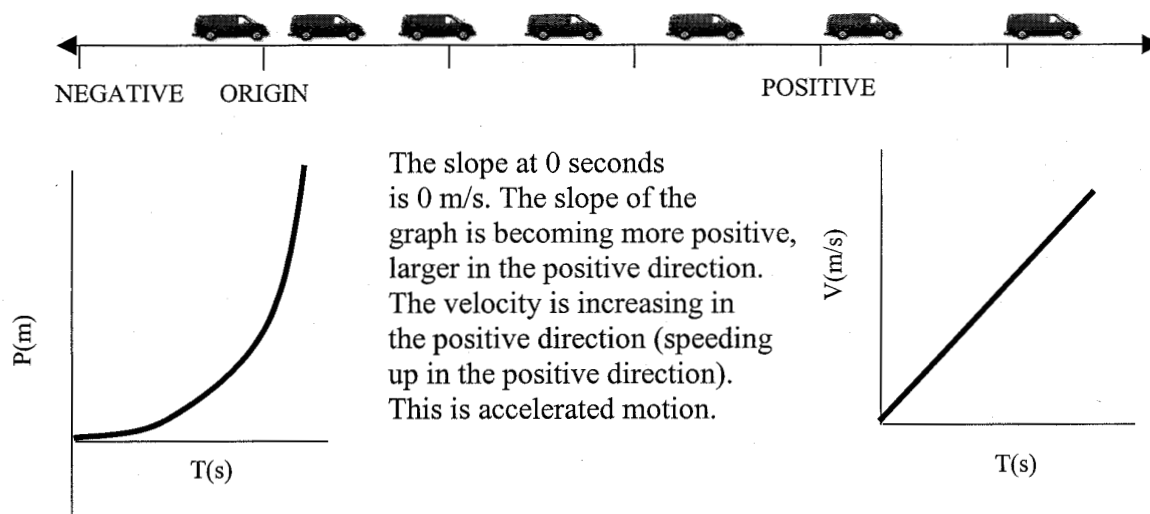


The slope of the line is the same as the previous case. The velocity is negative and has the size (speed). The object is to the right of the origin and moving towards it. The object passes the origin and moves to the left of it.

Position-Time Graphs for Non-Uniform Motion

In this type of motion, objects are speeding up or slowing down. Therefore, the velocity is not constant. Since the slope on a P-T graph gives the velocity, a changing velocity will mean that the slope on the P-T graph must also change. A line with a changing slope is a curve. The slope of the curve at a given moment will calculate the velocity at that instant, the instantaneous velocity.

So, if the slope on a P-T graph becomes more positive (the line becomes steeper), the instantaneous velocities are becoming more positive (larger speed in the positive direction).



The slope at 0 seconds is 0 m/s. The slope of the graph is becoming more positive, larger in the positive direction. The velocity is increasing in the positive direction (speeding up in the positive direction). This is accelerated motion.

Objects can also speed up traveling in the negative direction. If an object starts from rest (slope on P-T graph = 0 m/s) and speeds up in the negative direction, the slope on the P-T graph will become more and more negative.



Slope is 0.

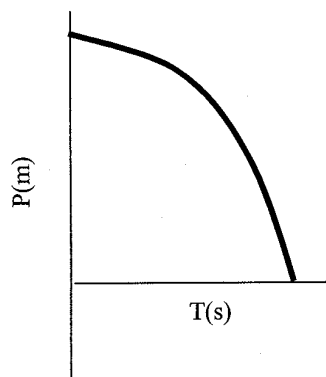
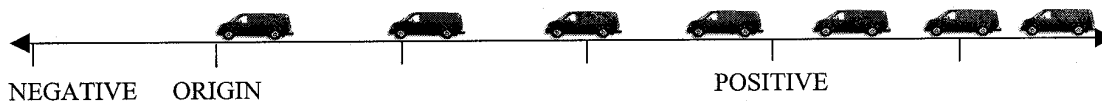


Slope is small negative.

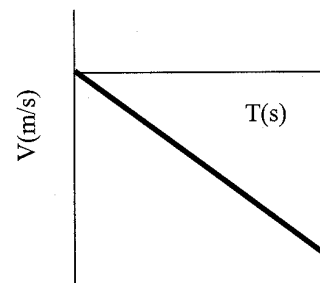


Slope is large negative.

Again, the P-T graph will be a curve for which you calculate the instantaneous velocity, using the slope of the line at that moment in time. Here, the velocity becomes more negative (larger speed in the negative direction).



The object starts at rest to the right of the origin and moves towards the origin. The slope becomes more negative. The velocity becomes more negative (speeding up in the negative direction). The object's last position is at the origin.



Accelerated Motion

For the class activity, students should be reminded to measure the distance between the dots from a position on one dot to the same point on the next dot.

Also, for the class activity, some information in the tables is incorrect.

Table C should have a heading of Position (cm).

Table D has the same unit error for Position as Table C. Also in Table D, the construction of the table does not lend itself to performing the required calculations. Two alternate arrangements are presented below.

Table 6

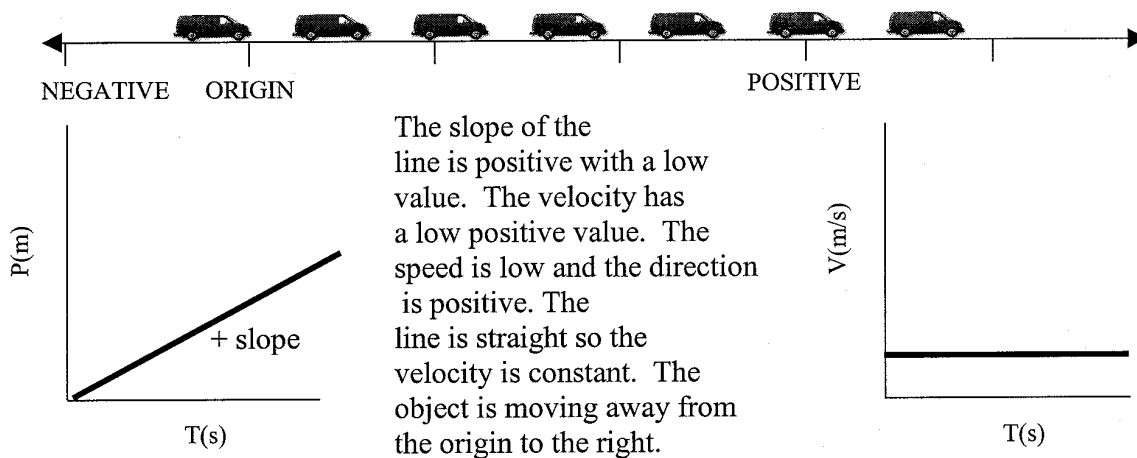
Time (s)	Displacement (cm)	Average Velocity (cm/s)
0–1		
1–2		
2–3		
3–4		
4–5		
5–6		
6–7		
7–8		

Table 7

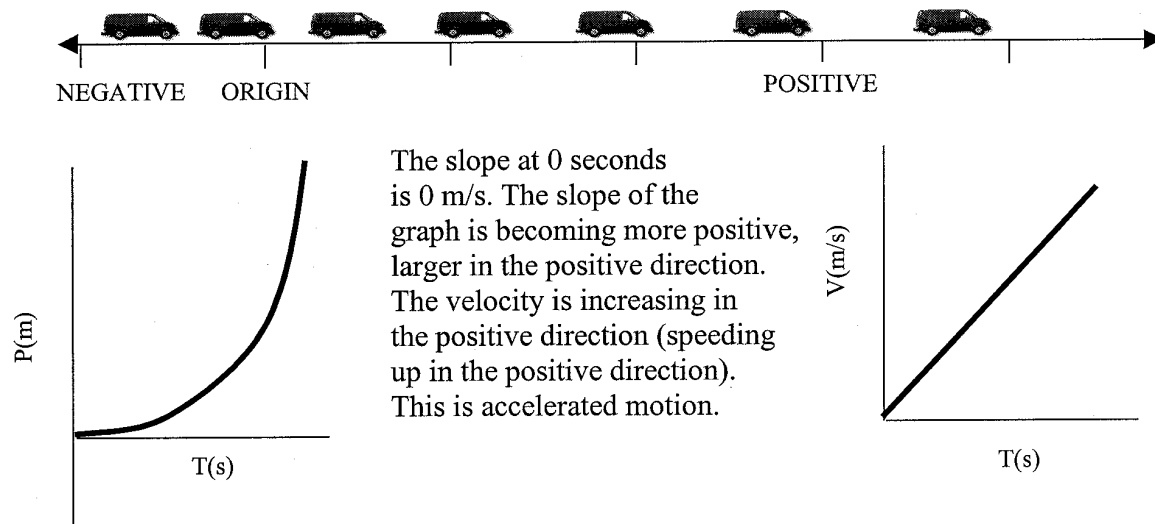
Time (s)	Position (cm)	Displacement During Time Interval (cm)	Average Velocity (cm/s)
0			
1			
2			
3			
4			
5			
6			
7			
8			

Acceleration—Non-Uniform Velocity

Up until now, most of the graphs of Position-Time have been straight-line graphs. The slope of a Position-Time graph gives the velocity. If the line is straight, the velocity is constant or uniform over that time interval. In these cases, since the velocity was uniform, there was no acceleration.



A few graphs of Position-Time were curves. On these graphs, the slope of the line still gave the velocity, but only the velocity at that instant (or instantaneous velocity). Since the slope of the curve on the Position-Time graph was always changing, so too was the instantaneous velocity always changing from one instant to the next. In these cases, the velocity was non-uniform or changing. There was an acceleration.



Acceleration involves an object speeding up or slowing down while moving in a straight-line path. Acceleration illustrates how velocity changes with time.

Acceleration is defined as the rate at which an object changes its velocity. It is a vector quantity, meaning that the direction in which acceleration acts is important.

The chart on the right shows that the velocity of an object is changing with time. For each second, the velocity changes by 3 m/s. The acceleration of this object is 3 m/s/s.

Since the acceleration is always 3 m/s/s, the acceleration is a uniform acceleration.

Table 8

Time (s)	Velocity (m/s)
0	0
1	3
2	6
3	9
4	12

Acceleration is calculated using the following relationship:

$$\begin{aligned} \text{Average acceleration} &= \frac{\text{change in velocity}}{\text{time interval}} \\ &= \frac{\text{final velocity} - \text{initial velocity}}{\text{time interval}} \end{aligned}$$

In symbols, the following equation is used to calculate acceleration:

$$\vec{a}_{\text{ave}} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

$$\vec{a}_{\text{ave}} = \frac{D\vec{v}}{Dt}$$

For example, the average acceleration for the time interval from 1 s when the velocity is 3 m/s, to 4 s when the velocity is 12 m/s, would be found as follows:

$$\text{Time}_{\text{initial}} = 1 \text{ s} \quad \text{velocity}_{\text{initial}} = 3 \text{ m/s}$$

$$\text{Time}_{\text{final}} = 4 \text{ s} \quad \text{velocity}_{\text{final}} = 12 \text{ m/s}$$

$$\begin{aligned} \vec{a}_{\text{ave}} &= \frac{D\vec{v}}{Dt} \\ &= \frac{12 \text{ m/s} - 3 \text{ m/s}}{4 \text{ s} - 1 \text{ s}} \\ &= \frac{+9 \text{ m/s}}{3 \text{ s}} = +3 \text{ m/s/s} \end{aligned}$$

Acceleration is expressed in units of velocity over time. The units of velocity and time determine the units of acceleration.

Typical units of acceleration are:

$$\frac{\text{velocity}}{\text{time}} = \frac{\text{m/s}}{\text{s}} = \text{m/s/s} \quad \text{or} \quad \frac{\text{velocity}}{\text{time}} = \frac{\text{km/h}}{\text{s}} = \text{km/h/s}$$

Remember, acceleration is a vector. Always include a direction with your answer.

The Meaning of the Sign of Acceleration

The sign of the acceleration gives the direction in which the acceleration acts. A positive acceleration acts to the right and a negative acceleration acts to the left. A positive acceleration does not always mean that an object is speeding up. Sometimes an object with a positive acceleration is slowing down.

Making sense of the sign of acceleration (and whether an object is speeding up or slowing down) requires that the sign of velocity also be considered. The following table summarizes the different situations that can occur.

Table 9

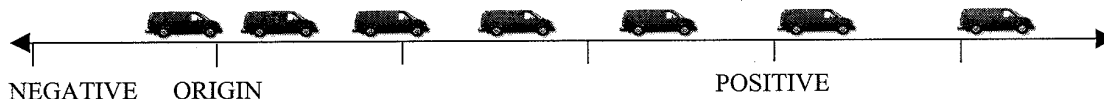
Sign (direction) of velocity	Sign (direction) of acceleration	What you see
+ (right)	+ (right)	Moving right, speeding up
+ (right)	– (left)	Moving right, slowing down
– (left)	– (left)	Moving left, speeding up
– (left)	+ (right)	Moving left, slowing down

The table may look very confusing. It is better to remember a simple rule. You will notice that if the velocity and acceleration have the **same** sign, the object will be **speeding up**. If velocity and acceleration have **opposite** signs, the object will be **slowing down**.

THE MEANING OF THE SIGN OF ACCELERATION—STUDENT ACTIVITY

In the following graphics, the time intervals between successive images of the van are all equal. For the directions, positive is to the right, and negative is to the left.

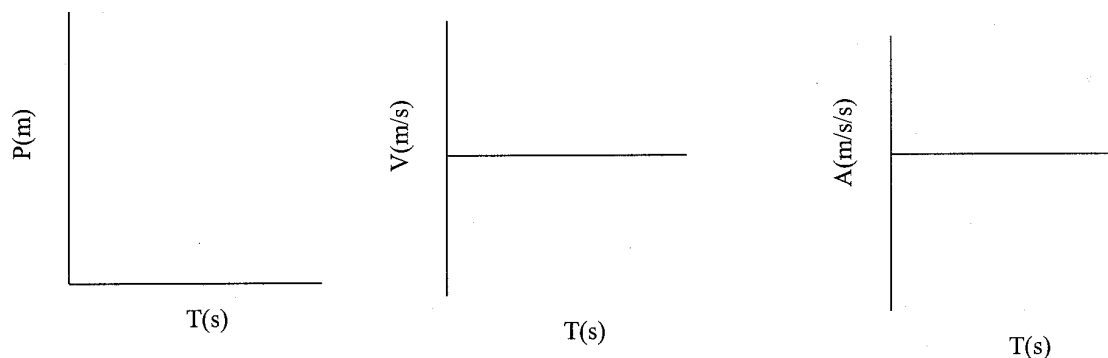
1. For the graphic below, describe the motion of the van.



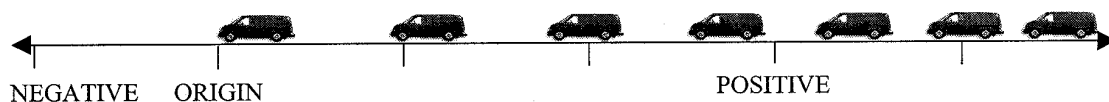
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



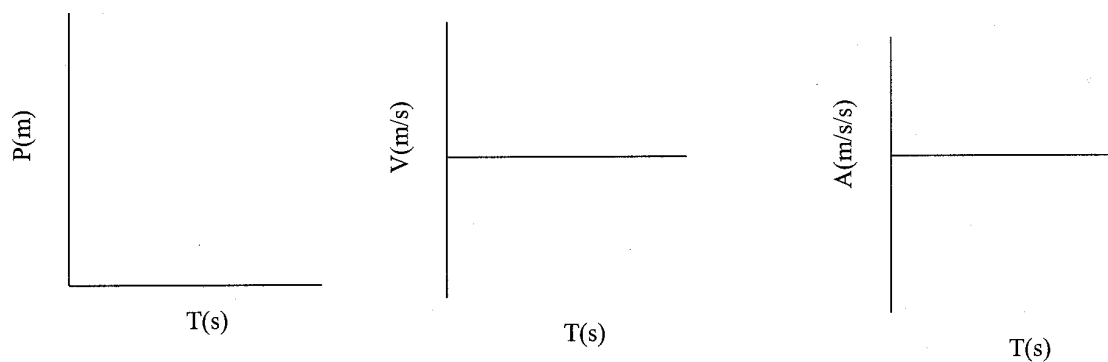
2. For the graphic below, describe the motion of the van.



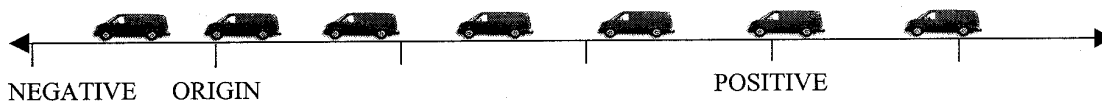
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



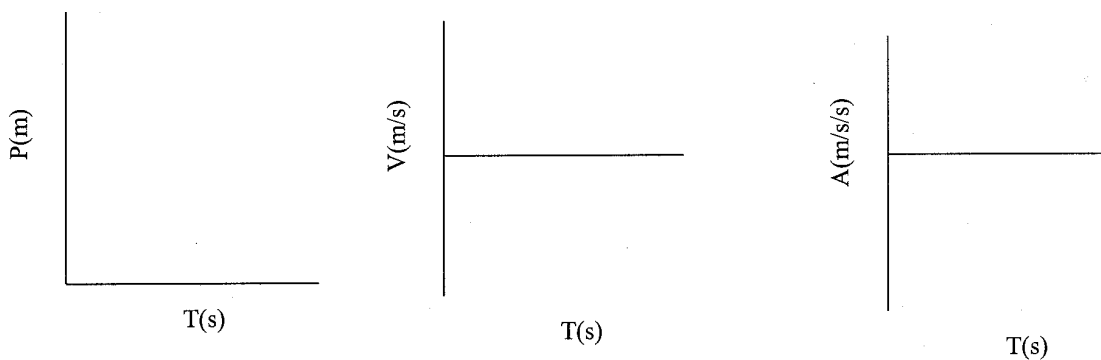
3. For the graphic below, describe the motion of the van.



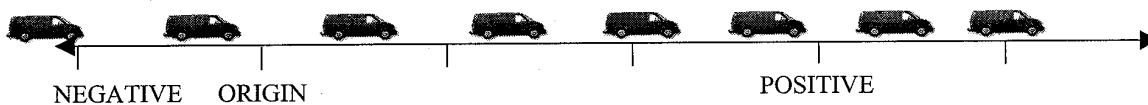
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



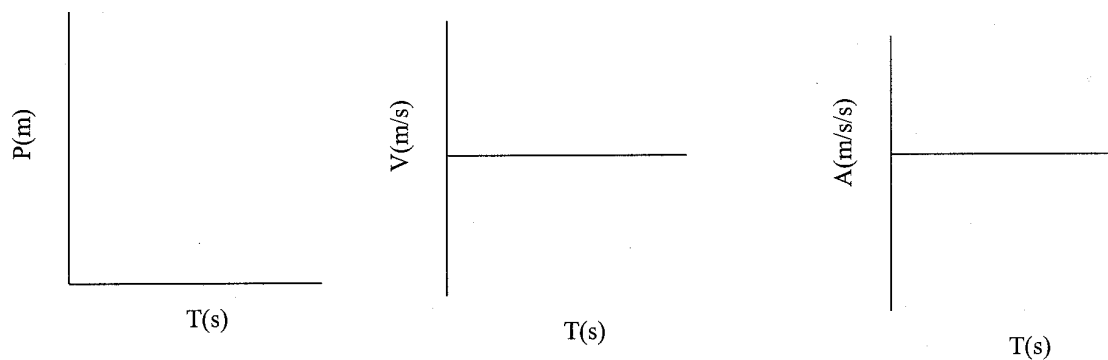
4. For the graphic below, describe the motion of the van.



What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



5. From the data in the table below, describe the motion of the object.

Table 10

Time (s)	Velocity (m/s)
0	10
1	9
2	8
3	7
4	6
5	5

What is the sign of the velocity?

What is the sign of the acceleration?

6. From the data in the table below, describe the motion of the object.

Table 11

Time (s)	Velocity (m/s)
0	-4
1	-8
2	-12
3	-16
4	-20
5	-24

What is the sign of the velocity?

What is the sign of the acceleration?

7. From the data in the table below, describe the motion of the object.

Table 12

Time (s)	Velocity (m/s)
0	-11
1	-9
2	-7
3	-5
4	-3
5	-1

What is the sign of the velocity?

What is the sign of the acceleration?

8. From the data in the table below, describe the motion of the object.

Table 13

Time (s)	Velocity (m/s)
0	0.25
1	0.50
2	0.75
3	1.00
4	1.25
5	1.50

What is the sign of the velocity?

What is the sign of the acceleration?

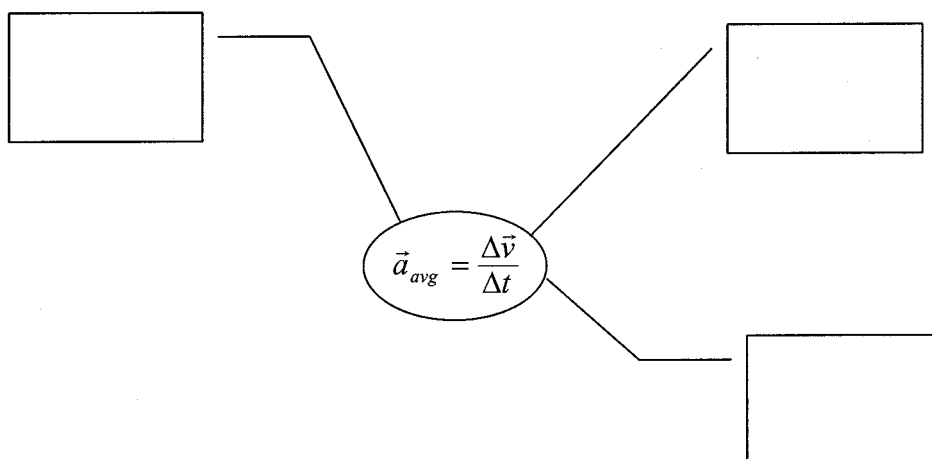
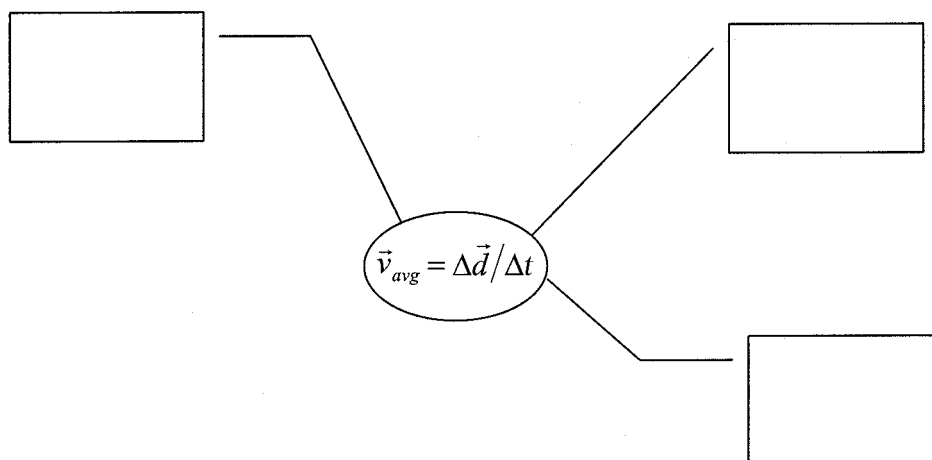
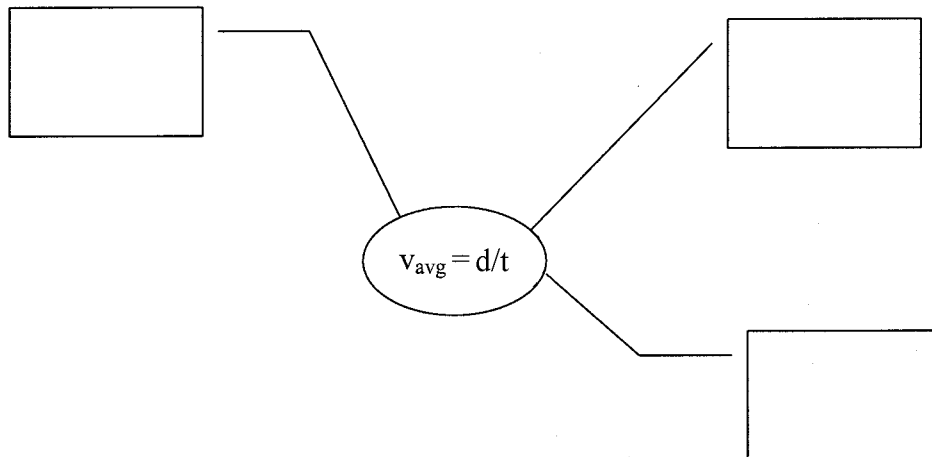
Acceleration, Velocity, Time Problem Set

1. A car can accelerate from a standstill to 100 km/h [E] in 9.60 s. Calculate the average acceleration.
2. An object is falling at -4.20 m/s. A downward motion has a negative direction. At a time 2.50 s later, the object is falling at -28.7 m/s. What was the average acceleration?
3. A curling stone is sliding at $+1.72$ m/s. After 2.25 s, the curling stone is sliding at $+1.00$ m/s. What was the average acceleration?
4. Albertine rides her bicycle on a hill with a downward slope. If Albertine coasts down the hill with an average acceleration of 1.68 m/s/s, what is her change in velocity during 5.25 s?
5. Albertine reaches the bottom of the hill coasting along at 9.25 m/s. She begins to coast up a second hill where the average acceleration is -1.20 m/s/s. What is the change in Albertine's velocity during 3.00 s of coasting up this hill? What is her final velocity?
6. A car traveling at 18.0 m/s [E] brakes for a red light and comes to a stop. The car accelerates at an average rate of -3.60 m/s/s. What is the length of the time interval over which the car is braking?
7. A dragster racing on a quarter-mile track (about 400 m) has an average acceleration of 11.2 m/s/s [E] reaching a velocity of 72.0 m/s [E]. What was the time needed to race this distance?

Concept Map: Speed, Velocity, and Acceleration

Give the name of each of the following equations.

For each symbol in the following equations, give the name the quantity, a definition, its unit, and whether it is a vector or scalar. Write the information around each rectangle.



Analyzing Motion: Enrichment Solutions

Vectors and Scalars

When measuring quantities in science, it is necessary to specify the direction for some quantities. Most quantities we measure are scalars. These are measured with a size or magnitude but without regard to direction. For example, temperature is a scalar. While it can be positive or negative, it does not have a direction like right or left, or east or west, associated with it.

Other quantities require that a direction be given along with the size or magnitude. Force is a vector. You can pull on a door handle with a force of 25 newtons east, or you can push on the door handle with a force of 25 newtons west. While these two forces have the same magnitude, they act in different directions. One force will open the door; the other force will not.

In the study of motion, two similar quantities, speed and velocity, are often confused. Speed describes how fast an object is moving, regardless of direction. The speedometer of a car measures speed. It indicates how fast the car is moving, but does not include the direction. For example, 100 km/h is a typical speed for a car on the highway.

Velocity, though, is a vector. If we start at a point and travel at 100 km/h east for one hour, we will end up 100 km east of our starting point. If we travel at 100 km/h west, starting from the same point, we will end up 100 km west of the starting point. These two velocities, 100 km/h east and 100 km/h west, are definitely different velocities. It is the direction that makes them different.

In summary, **scalars are quantities with size or magnitude only.** We give the value of such a quantity with a number for its size and a unit to tell us the type of quantity.

A vector is a quantity with both magnitude and direction. We give the value of a vector using a number for its size, a unit to tell us the type of quantity, and a direction.

For each quantity, give the unit and state whether it is a vector or scalar quantity.

Table 1

Quantity	Symbol of the Quantity	Unit	Vector or Scalar
Time Instant	t	second (s)	scalar
Time Interval	t	second (s)	scalar
Distance Traveled	d	metre (m)	scalar
Displacement	\vec{d}	metre (m)	vector
Mass	m	kilogram (kg)	scalar
Length	l	metre (m)	scalar
Speed	v	metres/second (m/s)	scalar
Acceleration	\vec{a}	metres/second/second (m/s/s or m/s ²)	vector
Velocity	\vec{v}	metres/second (m/s)	vector
Force	\vec{F}	newtons (N)	vector
Energy	E	joules (J)	scalar

Introducing Motion: Position, Time, Distance and Speed, Displacement, and Velocity

Purpose:

To determine the position of a person moving in a straight line at different instants in time.

To interpret a Position-Time graph to obtain distance traveled, speed, displacement, and velocity.

Apparatus:

50 metres of hallway or field, stopwatches, measuring tape

Procedure:

PART A

- Using the measuring tape, mark off 5-m intervals along a crack in the floor tiles. Place a piece of masking tape at each 5-m mark. Mark these positions using small signs, like yardage markers along the sidelines of a football field.
- A student stands at each of the markers with a stopwatch.
- Have one student begin at the 0-m mark. When the student begins to move, all timers start timing with the stopwatches.
- The student walks, at a constant rate, the full length of the course. As the walking student passes each timer, the timer stops the stopwatch.
- The timers then share their times and positions with the group.

Observations:

Description of motion:

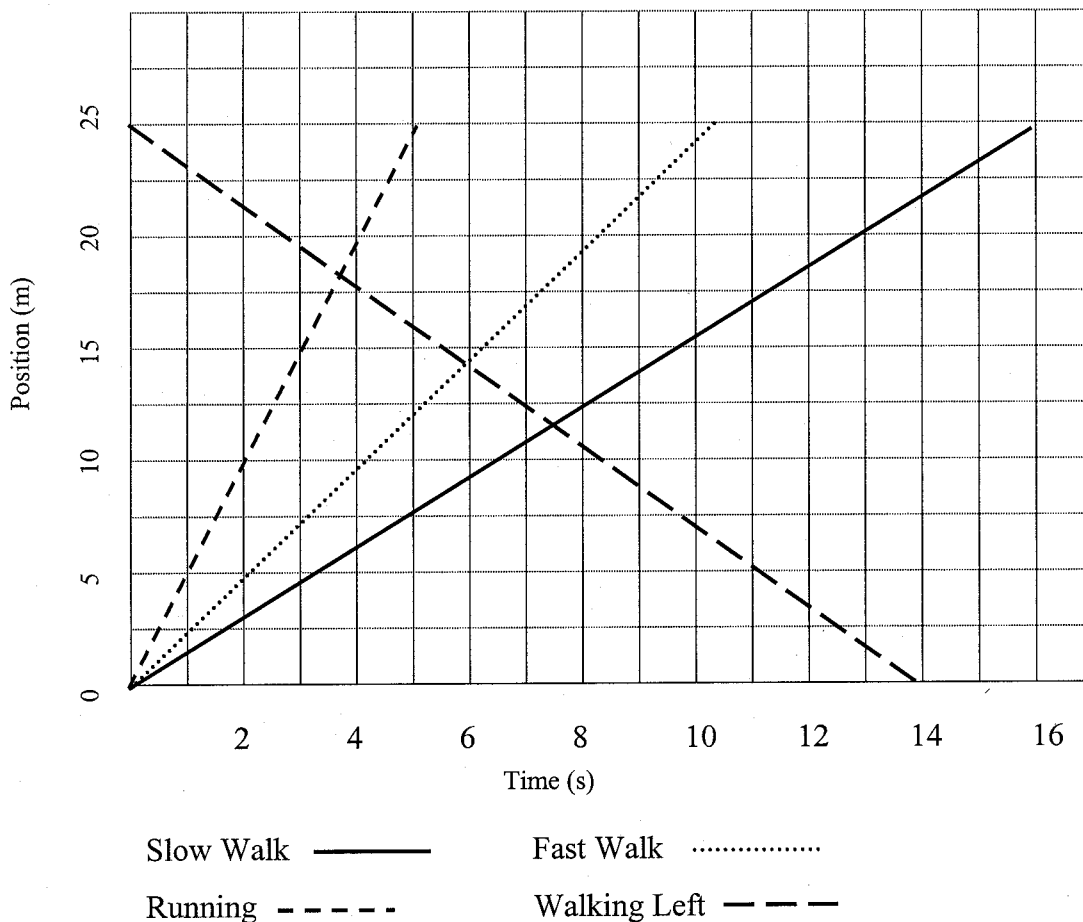
Draw a picture of the motion:

The student walks at a constant pace starting at the origin and ending at a position of 25 m to the right of the origin.

Table 2A

Time (Sec)	0	3	6	9	13	16					
Position (Metres)	0	5	10	15	20	25					

On the following graph, label time on the horizontal axis and position on the vertical axis and plot the points from the data table. Draw in the line of best fit.



Procedure:

PART B

The student will start from 0-m mark this time and walk more quickly than before but at a constant rate over the whole course. Again the timers will start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

The student started at the origin and walked at a faster but steady pace to the right, ending up at a point 25 m right of the origin.

Table 2B

Time (Sec)	0	2.0	4.0	6.5	8.3	10.4				
Position (Metres)	0	5	10	15	20	25				

Plot this information on the previous graph, using a different colour for these points. Draw in the line of best fit.

Procedure:**PART C**

The student starts from 0-m mark this time and runs at a constant rate over the whole course. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

The student started at the origin and ran at a steady pace to the right, ending up at a point 25 m right of the origin.

Table 2C

Time (Sec)	0	1.0	2.0	2.8	4.0	5.1				
Position (Metres)	0	5	10	15	20	25				

Plot this information on the previous graph, using a third different colour for these points. Draw in the line of best fit.

- Using the descriptions of the motion, how do the starting points compare for the three trials?

The starting points are all the same, at 0 m.

- From the graph, determine the starting point for each of the three trials. Compare these to the answers in part (b).

All the lines start at 0 m at 0 s. The starting points are all the same as in #1.

3. From the description of the motions, what is the same about all three motions?

All the motions start at the origin and end at 25 m to the right of the origin. The person moves to the right.

4. From the description of the motion, what is different about the three motions?

The speed is different in each case. In A, it is a walk. In B, it is a faster walk. In C, it is running.

5. On the graph, what is different about the three lines?

The slopes or steepness of the lines are all different.

Procedure:

PART D

The student will start from the last mark this time and walk quickly but at a constant rate over the whole course, ending up at 0 m. Again the timers will start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

The student begins at the 25 m mark and walks to the left, ending up at 0 m, the origin.

Table 2D

Time (Sec)	0	3	5	8	11	14					
Position (Metres)	25	20	15	10	5	0					

Plot this information on the graph, using a fourth different colour for these points. Draw in the line of best fit.

Analysis:

1. How does this fourth line differ from the other three lines on the graph?

The fourth line begins at +25 m instead of at the origin. The line slopes to the right and down (negative slope) instead of to the right and up (positive slope) like the others.

2. From the description of the motions, can you relate something about the line to the motion it represents?

Line 1: The student moves steadily but slowly to the right. The slope of the line is small and positive.

Line 2: The student moves steadily but more quickly to the right. The slope of the line is larger and positive.

Line 3: The student moves steadily but very quickly (running) to the right. The slope of the line is still larger and positive.

Line 4: The student moves steadily but slowly to the left. The slope of the line is small and negative.

Procedure:**PART E**

At the 10-m mark, station two timers. The student starts from the 0-m mark this time and walks quickly to the 10-m mark. The first timer stops the stopwatch. The student stays at the 10-m mark for a slow count of 5. At the count of 5, the second timer stops his stopwatch and the student resumes her journey, covering the whole course at a slower pace than before. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

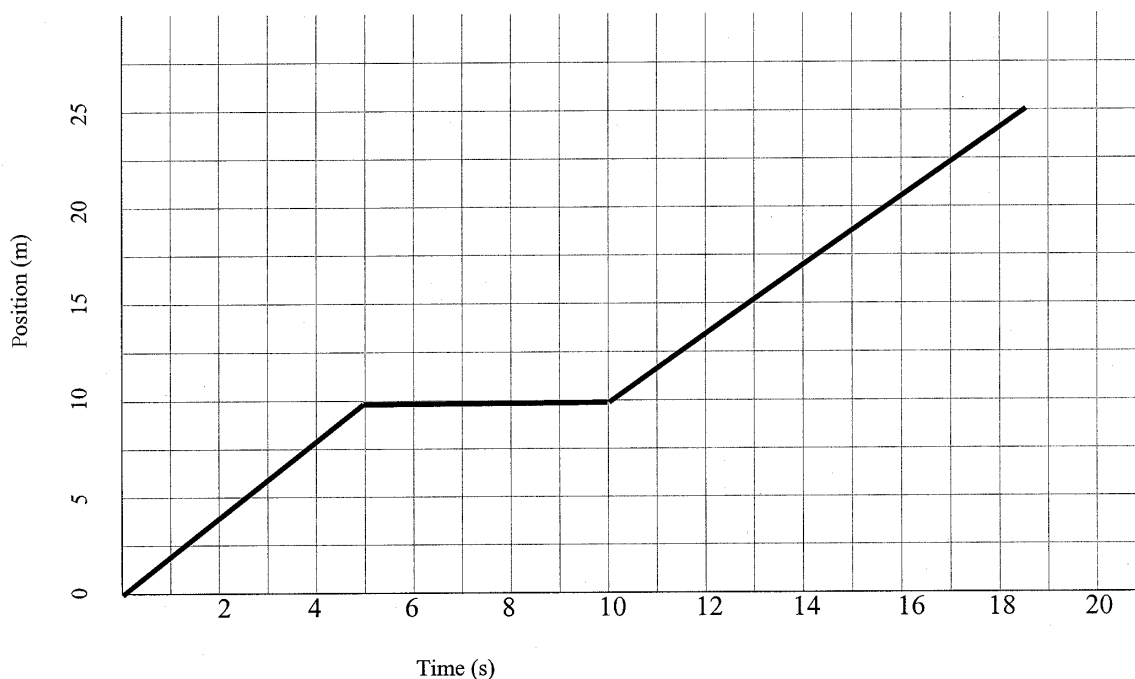
Draw a picture of the motion:

The student started at the origin, 0 m. She walked quickly to the right to the 10-m mark and stopped. She remained at the 10-m mark for a while, then walked more slowly, finishing at the 25-m mark.

Table 2E

Time (Sec)	0	2	4	10	13	16	19				
Position (Metres)	0	5	10	10	15	20	25				

Plot this information on the graph below. Plot position on the vertical axis and plot time on the horizontal axis. **Do not draw a line of best fit.** Instead, draw a line of best fit for each section.

**Analysis:**

1. What is different about each section of the graph drawn on page 5?

In each section, the slope of the line is different.

2. Go back to the description of the motion. What does the graph look like when the student was moving quickly? Not moving? Moving slowly?

In part 1, the student walked quickly. The graph is a straight line with a positive slope.

In part 2, the student stood still. The graph is a straight line with a slope of 0.

In part 3, the student walked more slowly than in part 1. The graph is a straight line with a positive slope, but not as steep as in part 1.

Conclusion:

Describe the information one is able to obtain **directly** from a Position-Time graph.

At a given time, the position of the object can be found directly from the graph.

We can obtain more indirect information from a Position-Time graph by looking at the line. Describe the information we can obtain **indirectly** from a Position-Time graph.

Indirectly, it seems that the speed with which the student moves gives a different slope to the line of the Position-Time graph.

When the student moves to the right, the slope is positive; and when she moves to the left, the slope is negative.

When the student moves quickly, the steepness of the line is greater.

Slope on a Position-Time graph determines the velocity of the object. The steepness gives the speed and the sign of the slope gives the direction.

Questions:

1. Distinguish between distance traveled and displacement.

Distance traveled refers to how far an object moves regardless of its direction of motion. For example, the student walked 10 m. It is a scalar.

Displacement refers to a change in position of an object. Displacement includes how far an object travels plus the direction of the motion. For example, the student walks 10 m to the right. Displacement is a vector.

2. Distinguish between average speed and average velocity.

Average speed indicates how fast an object is traveling. It is found by distance traveled over time. It is a scalar.

Average velocity is the rate of change of position with time. It is found by displacement over time interval. It is a vector.

3. For each trial (A through E), calculate the total distance traveled. Obtain the information from the graph.

In all trials except D, the student started at the origin and ended up at +25 m from the origin, traveling a distance of 25 m.

In trial D the student started at +25 m and finished at the origin, traveling a distance of 25 m.

4. For each trial (A through E), calculate the total time for the journey. Obtain the information from the graph

$$A: Dt = 16 \text{ s} \qquad D: Dt = 14 \text{ s}$$

$$B: Dt = 10.4 \text{ s} \qquad E: Dt = 19 \text{ s}$$

$$C: Dt = 5.1 \text{ s}$$

5. For each trial (A through E), calculate the average speed. Show the equation and the work for each calculation.

The equation used is $v_{avg} = Dd / Dt$

$$A: v_{avg} = 25 \text{ m} / 16 \text{ s} = 1.6 \text{ m/s}$$

$$B: v_{avg} = 25 \text{ m} / 10.4 \text{ s} = 2.4 \text{ m/s}$$

$$C: v_{avg} = 25 \text{ m} / 5.1 \text{ s} = 4.9 \text{ m/s}$$

$$D: v_{avg} = 25 \text{ m} / 14 \text{ s} = 1.8 \text{ m/s}$$

$$E: v_{avg} = 25 \text{ m} / 19 \text{ s} = 1.3 \text{ m/s}$$

6. For each trial (A through E), calculate the displacement for the whole journey. Obtain the information from the graph.

$$D\vec{d} = \vec{d}_2 - \vec{d}_1$$

This equation is used for all calculations. For A, B, C, and E, the work is the same.

$$D\vec{d} = \vec{d}_2 - \vec{d}_1 = +25 \text{ m} - 0 \text{ m} = +25 \text{ m}$$

For D, the calculation is

$$D\vec{d} = \vec{d}_2 - \vec{d}_1 = 0 \text{ m} - +25 \text{ m} = -25 \text{ m}$$

7. For each trial (A through E), calculate the **average velocity** for the journey. Show the equation and the work for each calculation.

$$\vec{v}_{avg} = \frac{D\vec{d}}{Dt}$$

This equation is used for all calculations.

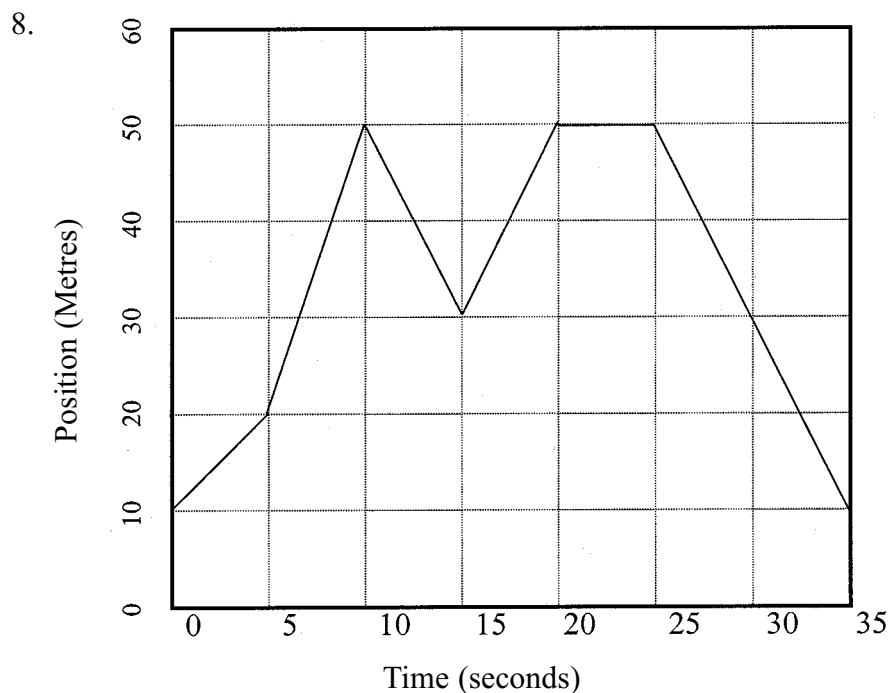
$$A: \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25 \text{ m} / 16 \text{ s} = +1.6 \text{ m/s}$$

$$B: \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25 \text{ m} / 10.4 \text{ s} = +2.4 \text{ m/s}$$

$$C: \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25 \text{ m} / 5.1 \text{ s} = +4.9 \text{ m/s}$$

$$D: \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = -25 \text{ m} / 14 \text{ s} = -1.8 \text{ m/s}$$

$$E: \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25 \text{ m} / 19 \text{ s} = +1.3 \text{ m/s}$$



The graph of Position-Time above shows the position of a soccer linesman running along the sideline of a soccer field during a soccer game.

The 0-m mark is located at the goal line at the south end of the field. All the positions are marked north of that starting point.

a. Where does the linesman start his journey?

10 m north of the south goal line.

b. During which time intervals is the linesman moving to the north?

0–10 s and 15–20 s

To the south?

10–15 s and 25–35 s

Not moving?

20–25 s

- c. What is the distance traveled and the displacement for each interval listed below? Include direction with displacement.

Table 3

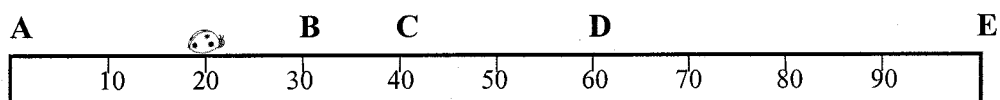
Time Interval	Distance Traveled d (m)	Displacement $\Delta \vec{d} = \vec{d}_2 - \vec{d}_1$ (m)
0–5 seconds	10	+20 m – +10 m = +10 m = 10 m [N]
5–10 seconds	30	+50 m – +20 m = +30 m = 30 m [N]
10–15 seconds	20	+30 m – +50 m = –20 m = 20 m [S]
15–20 seconds	20	+50 m – +30 m = +20 m = 20 m [N]
20–25 seconds	0	+50 m – +50 m = 0 m
25–35 seconds	40	+10 m – +50 m = –40 m = 40 m [S]

- d. Calculate the average speed and the average velocity of the linesman for each time interval.

Table 4

Time Interval	Average Speed $v_{\text{avg}} = d/t$ (m/s)	Average Velocity $\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t}$ (m/s)
0–5 seconds	10m / 5 s = 2 m/s	10m [N] / 5s = 2 m/s [N]
5–10 seconds	30m / 5 s = 6 m/s	30m [N] / 5s = 6 m/s [N]
10–15 seconds	20m / 5 s = 4 m/s	20m [S] / 5s = 4 m/s [S]
15–20 seconds	20m / 5 s = 4 m/s	20m [N] / 5s = 4 m/s [N]
20–25 seconds	0m / 5 s = 0 m/s	0m / 5s = 0 m/s
25–35 seconds	40m / 10 s = 4 m/s	40m [N] / 10s = 4 m/s [N]

Describing Motion in Various Ways



1. A somewhat confused ladybug is moving back and forth along a meterstick. Determine both the displacement and distance traveled by the ladybug as it moves from:

- a. A to B

$$\vec{Dd} = \vec{d}_2 - \vec{d}_1 = +30 \text{ cm} - 0 \text{ cm} = +30 \text{ cm}$$

$$d = 30 \text{ cm}$$

- b. C to B

$$\vec{Dd} = \vec{d}_2 - \vec{d}_1 = +30 \text{ cm} - +40 \text{ cm} = -10 \text{ cm}$$

$$d = 10 \text{ cm}$$

- c. C to D

$$\vec{Dd} = \vec{d}_2 - \vec{d}_1 = +60 \text{ cm} - +40 \text{ cm} = +20 \text{ cm}$$

$$d = 20 \text{ cm}$$

- d. C to E and then to D

$$\vec{Dd} = \vec{d}_2 - \vec{d}_1 = +60 \text{ cm} - +40 \text{ cm} = +20 \text{ cm}$$

$$d_{\text{CE}} = 60 \text{ cm}; d_{\text{ED}} = 40 \text{ cm}; d_{\text{total}} = 100 \text{ cm}$$

2. In the diagram above, **east** points to the **right**. During which of the intervals in #1 is the ladybug moving in the **easterly** direction?

A to B, C to D, and C to E

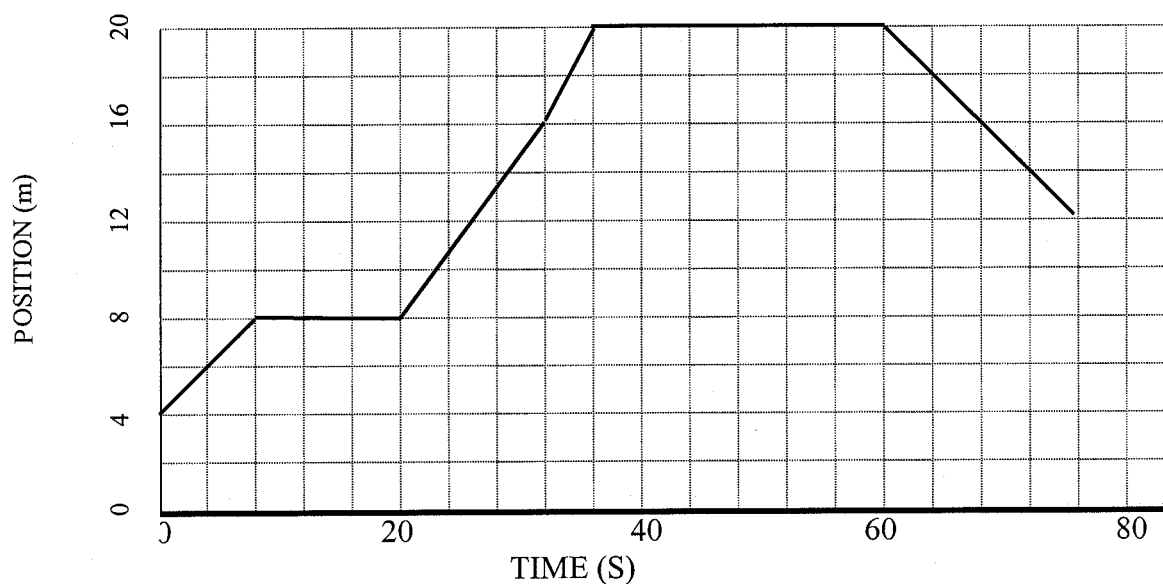
In the **westerly** direction?

C to B and E to D

3. Below is a table showing the position above the ground floor of an elevator at various times. On the graph below the table, plot a graph of Position-Time.

Table 5

Time (Sec)	0	4	20	32	36	60	72
Position above the ground floor (m)	4.0	8.0	8.0	16	20	20	12



4. A troubled student is waiting to see the principal. He paces back and forth in the hallway in front of the principal's office. The hallway runs north and south. The door to the office is our origin, 0 m. Here is a description of the student's motion.

The student starts at 5.0 m N. He walks to the south for 7.0 m during 10.0 s. He stands still for 5.0 seconds. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s to reach the door.

- a. What is the total time the student spent in the hallway?

$$t_{total} = 10.0 \text{ s} + 5.0 \text{ s} + 15.0 \text{ s} + 10.0 \text{ s} + 10.0 \text{ s} = 50.0 \text{ s}$$

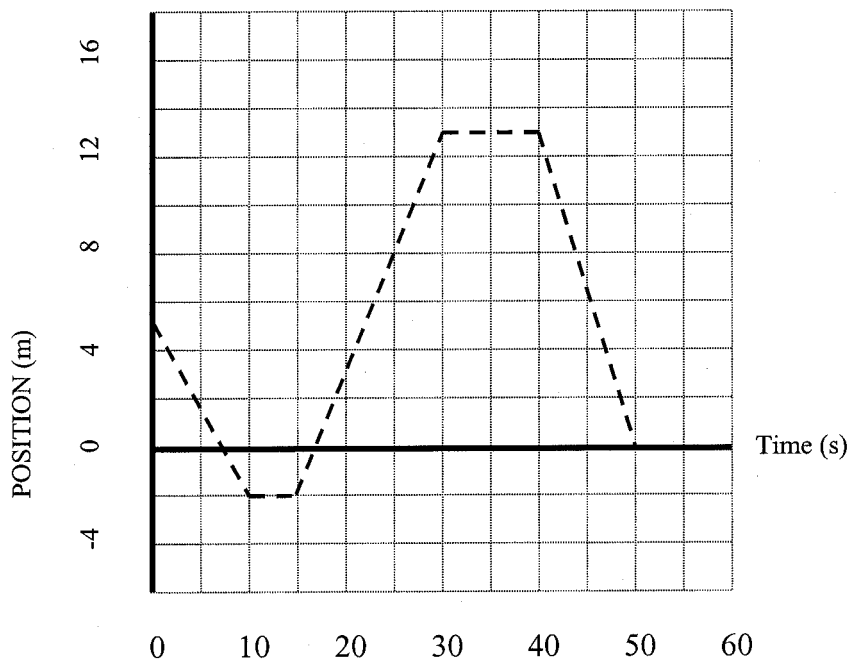
- b. What was the distance traveled by the student during his pacing?

$$d_{total} = d_1 + d_2 + d_3 = 7.0 \text{ m} + 15.0 \text{ m} + 13.0 \text{ m} = 35.0 \text{ m}$$

- c. What was the average speed of the student during his pacing?

$$v_{avg} = d / t = 35.0 \text{ m} / 50.0 \text{ s} = 0.700 \text{ m/s}$$

- d. On the graph below, plot time on the horizontal axis and position on the vertical axis. Use straight-line segments to join the points of Position-Time that you plot.



- e. What is the total displacement for the student's journey? Find this from the graph.

$$D\vec{d}_{total} = \vec{d}_{50} - \vec{d}_0 = 0\text{ m} - +5.00\text{ m} = -5.00\text{ m}$$

- f. What is the average velocity for the whole journey?

$$\vec{v}_{avg} = \frac{D\vec{d}}{Dt} = -5.00\text{ m} / 50.0\text{ s} = -0.100\text{ m/s}$$

Velocity, Displacement, and Time Problem Set

1. On your bicycle, you travel from A to B during 9.00 s.

$$D\vec{d} = 45.0 \text{ m[S]}; t = 9.00 \text{ s}$$

- a. What is your average speed?

$$v_{\text{avg}} = ?$$

$$v_{\text{avg}} = d / t = 45.0 \text{ m} / 9.00 \text{ s} = 5.00 \text{ m/s}$$

- b. What is your average velocity?

$$\vec{v}_{\text{avg}} = D\vec{d} / Dt = 45.0 \text{ m [S]} / 9.00 \text{ s} = 5.00 \text{ m/s [S]}$$

2. If you travel from A to B to C to D, what is your

- a. distance traveled?

$$d_{\text{AB}} = 45.0 \text{ m}; d_{\text{BC}} = 135 \text{ m}; d_{\text{CD}} = 45.0 \text{ m}$$

$$d_{\text{total}} = 45.0 \text{ m} + 135 \text{ m} + 45.0 \text{ m} = 225 \text{ m}$$

- b. displacement?

The displacement from A to B to C to D is the same as going directly from A to D, which is 135 m [W].

3. If the journey in #2 took 55.0 s, calculate

- a. your average speed.

$$d_{\text{total}} = 225 \text{ m}; t = 55.0 \text{ s}$$

$$v_{\text{avg}} = ?$$

$$v_{\text{avg}} = d / t = 225 \text{ m} / 55.0 \text{ s} = 4.09 \text{ m/s}$$

- b. your average velocity.

$$D\vec{d} = 135 \text{ m [W]}; t = 55.0 \text{ s}$$

$$\vec{v}_{\text{avg}} = D\vec{d} / Dt = 135 \text{ m [W]} / 55.0 \text{ s} = 4.09 \text{ m/s [S]}$$

4. You travel around the block in 90.0 s. Calculate your average speed and your average velocity.

- a. $d_{\text{total}} = \text{distance around the block} = 45.0 \text{ m} + 135 \text{ m} + 45.0 \text{ m} + 135 \text{ m} = 360 \text{ m}$

$$t = 90.0 \text{ s}$$

$$v_{\text{avg}} = d / t = 360 \text{ m} / 90.0 \text{ s} = 4.00 \text{ m/s}$$

- b. *The displacement for a trip around the block is 0 m. Therefore, the average velocity is 0 m/s.*

5. Fargo is located 375 km south of Winnipeg. If it takes 4.00 h to travel from Winnipeg to Fargo, calculate your average velocity.

$$D\vec{d} = 375 \text{ km [S]}; t = 4.00 \text{ h}$$

$$\vec{v}_{\text{avg}} = D\vec{d} / Dt = 375 \text{ km [S]} / 4.00 \text{ h} = 93.75 = 93.8 \text{ km/h [S]}$$

6. You make the return trip to Winnipeg from Fargo also in 4.00 h. What was your average velocity?

On the return trip, the velocity is in the opposite direction or 93.8 km/h [N].

7. Jim lives on the same street as his school. The front of the school is located 1020 m [E] of Jim's house. If Jim walks at 3.00 m/s [E], calculate the time it takes Jim to walk from his house to the front of the school.

$$\vec{v}_{\text{avg}} = 3.00 \text{ m/s [E]}; D\vec{d} = 1020 \text{ m [E]}$$

$$t = ?$$

$$\vec{v}_{\text{avg}} = D\vec{d} / Dt$$

$$3.00 \text{ m/s [E]} = 1020 \text{ m [E]} / t$$

$$t = 1020 \text{ m [E]} / 3.00 \text{ m/s [E]}$$

$$t = 340 \text{ s}$$

8. An airplane flies at a velocity of 215 km/h [W] for 2.75 hours. What is the displacement for this journey?

$$\vec{v}_{\text{avg}} = 215 \text{ km/h [W]}; t = 2.75 \text{ h}$$

$$D\vec{d} = ?$$

$$\vec{v}_{\text{avg}} = D\vec{d} / Dt$$

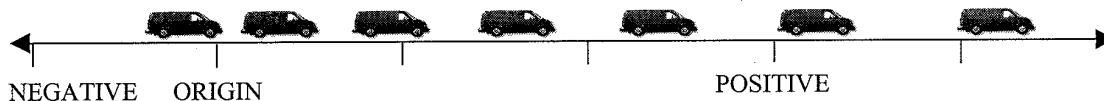
$$215 \text{ km/h [W]} = D\vec{d} / 2.75 \text{ h}$$

$$D\vec{d} = (215 \text{ km/h [W]})(2.75 \text{ h}) = 591.25 = 591 \text{ km [W]}$$

The Meaning of the Sign of Acceleration—Student Activity

In the following graphics, the time intervals between successive images of the van are all equal. For the directions, positive is to the right, and negative is to the left.

- For the graphic below, describe the motion of the van.



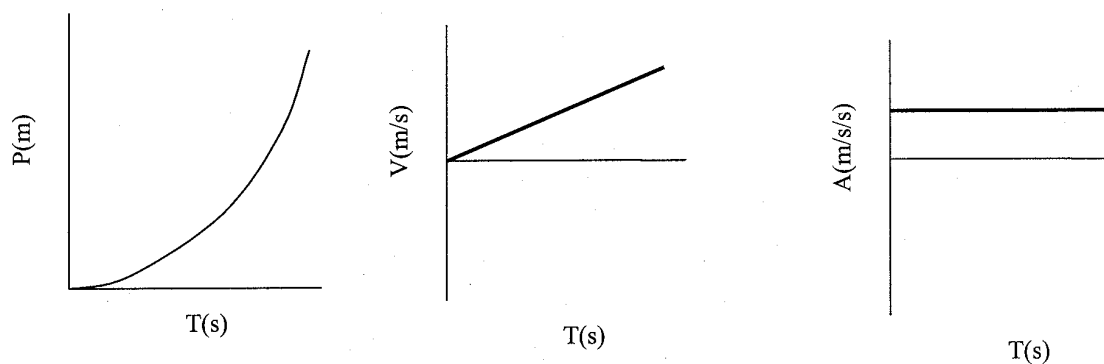
What is the sign of the velocity?

Positive

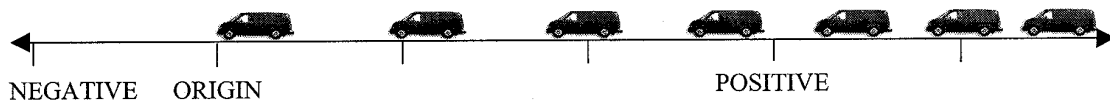
What is the sign of the acceleration?

Positive

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



- For the graphic below, describe the motion of the van.



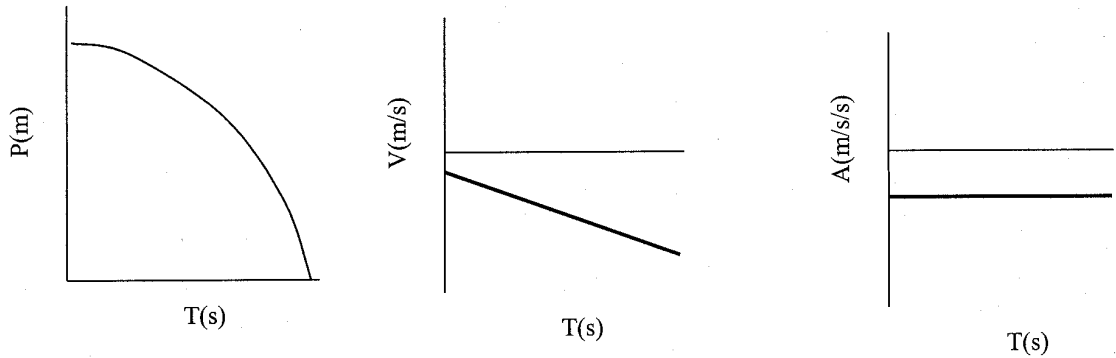
What is the sign of the velocity?

Negative

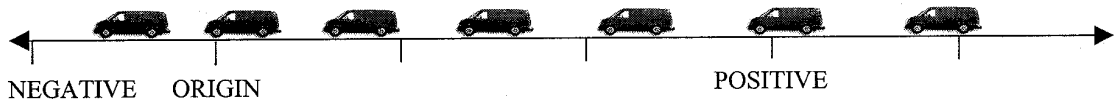
What is the sign of the acceleration?

Negative

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



3. For the graphic below, describe the motion of the van.



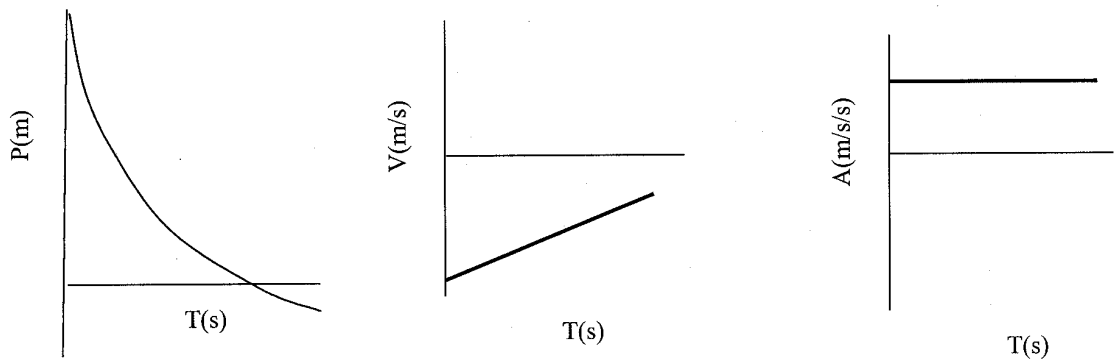
What is the sign of the velocity?

Negative

What is the sign of the acceleration?

Positive

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



4. For the graphic below, describe the motion of the van.



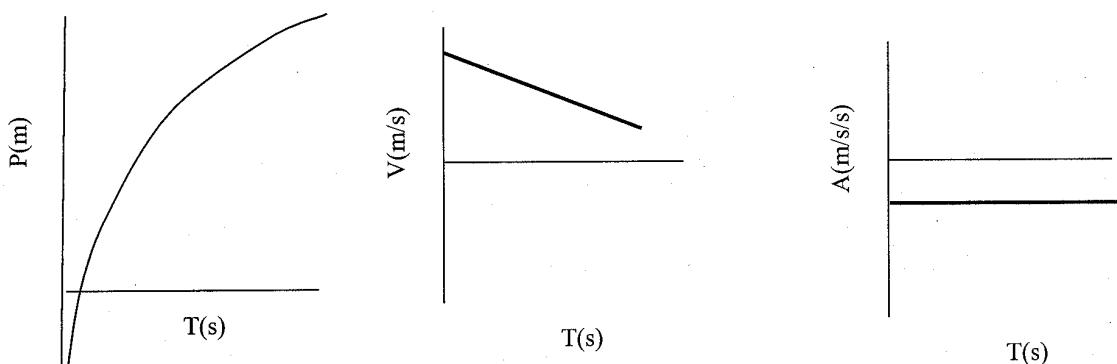
What is the sign of the velocity?

Positive

What is the sign of the acceleration?

Negative

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



5. From the data in the table below, describe the motion of the object.

The object is moving to the right but slowing down. There is an acceleration opposite to the direction of motion of the object.

Table 10

Time (s)	Velocity (m/s)
0	10
1	9
2	8
3	7
4	6
5	5

What is the sign of the velocity?

Positive

What is the sign of the acceleration?

Negative

6. From the data in the table below, describe the motion of the object.
The object is moving to the left and speeding up. The velocity is increasing in the negative direction, so the acceleration acts in the direction of motion.

Table 11

Time (s)	Velocity (m/s)
0	-4
1	-8
2	-12
3	-16
4	-20
5	-24

What is the sign of the velocity?

Negative

What is the sign of the acceleration?

Negative

7. From the data in the table below, describe the motion of the object.
The object is moving to the left but the velocity is decreasing. The acceleration acts in a direction opposite to the velocity.

Table 12

Time (s)	Velocity (m/s)
0	-11
1	-9
2	-7
3	-5
4	-3
5	-1

What is the sign of the velocity?

Negative

What is the sign of the acceleration?

Positive

8. From the data in the table below, describe the motion of the object.
The object is moving to the right and the velocity is increasing. The acceleration of the object is in the direction of motion.

Table 13

Time (s)	Velocity (m/s)
0	0.25
1	0.50
2	0.75
3	1.00
4	1.25
5	1.50

What is the sign of the velocity?

Positive

What is the sign of the acceleration?

Negative

Acceleration, Velocity, and Time Problem Set

1. A car can accelerate from a standstill to 100 km/h [E] in 9.60 s. Calculate the average acceleration.

$$\vec{v}_1 = 0 \text{ km/h}; \vec{v}_2 = 100 \text{ km/h [E]}; t = 9.60 \text{ s}$$

$$\vec{a}_{\text{avg}} = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{100 \text{ km/h [E]} - 0 \text{ km/h}}{9.60 \text{ s}} = 10.4 \text{ km/h/s [E]}$$

2. An object is falling at -4.20 m/s. A downward motion has a negative direction. At a time 2.50 s later, the object is falling at -28.7 m/s. What was the average acceleration?

$$\vec{v}_1 = -4.20 \text{ m/s}; \vec{v}_2 = -28.7 \text{ m/s}; t = 2.50 \text{ s}$$

$$\vec{a}_{\text{avg}} = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{-28.7 \text{ m/s} - (-4.20 \text{ m/s})}{2.50 \text{ s}} = \frac{-24.5 \text{ m/s}}{2.50 \text{ s}} = -9.80 \text{ m/s/s}$$

3. A curling stone is sliding at $+1.72$ m/s. After 2.25 s, the curling stone is sliding at $+1.00$ m/s. What was the average acceleration?

$$\vec{v}_1 = +1.72 \text{ m/s}; \vec{v}_2 = +1.00 \text{ m/s}; t = 2.25 \text{ s}$$

$$\vec{a}_{\text{avg}} = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = \frac{+1.00 \text{ m/s} - +1.72 \text{ m/s}}{2.25 \text{ s}} = \frac{-0.72 \text{ m/s}}{2.25 \text{ s}} = -0.32 \text{ m/s/s}$$

4. Alberto rides his bicycle on a hill with a downward slope. If Alberto coasts down the hill with an average acceleration of 1.68 m/s/s, what is his change in velocity during 5.25 s?

$$\vec{a}_{\text{avg}} = +1.68 \text{ m/s/s}; t = 5.25 \text{ s}$$

$$D\vec{v} = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = +1.68 \text{ m/s/s} = D\vec{v} / 5.25 \text{ s}$$

$$D\vec{v} = (+1.68 \text{ m/s/s})(5.25 \text{ s}) = +8.82 \text{ m/s}$$

5. Alberto reaches the bottom of the hill coasting along at 9.25 m/s. He begins to coast up a second hill where the average acceleration is -1.20 m/s/s. What is the change in Alberto's velocity during 3.00 s of coasting up this hill? What is his final velocity?

$$\vec{v}_1 = +9.25 \text{ m/s}; \vec{a}_{\text{avg}} = -1.20 \text{ m/s/s}; t = 3.00 \text{ s}$$

$$D\vec{v} = ? \text{ and } \vec{v}_2 = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt} = -1.20 \text{ m/s/s} = D\vec{v} / 3.00 \text{ s}$$

$$D\vec{v} = (-1.20 \text{ m/s/s})(3.00 \text{ s}) = -3.60 \text{ m/s}$$

$$\text{But, } D\vec{v} = \vec{v}_2 - \vec{v}_1$$

$$-3.60 \text{ m/s} = \vec{v}_2 - +9.25 \text{ m/s}$$

$$\vec{v}_2 = -3.60 \text{ m/s} + +9.25 \text{ m/s}$$

$$\vec{v}_2 = +5.65 \text{ m/s}$$

6. A car traveling at 18.0 m/s [E] brakes for a red light and comes to a stop. The car accelerates at an average rate of -3.60 m/s/s. What is the length of the time interval over which the car is braking?

$$\vec{v}_1 = 18.0 \text{ m/s [E] or } +18.0 \text{ m/s}; \vec{v}_2 = 0 \text{ m/s}; \vec{a}_{\text{avg}} = -3.60 \text{ m/s/s}$$

$$t = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt}$$

$$-3.60 \text{ m/s/s} = 0 \text{ m/s} - +18.0 \text{ m/s} / t$$

$$t = -18.0 \text{ m/s} / -3.60 \text{ m/s/s} = 5.00 \text{ s}$$

7. A dragster racing on a quarter-mile track (about 400 m) has an average acceleration of 11.2 m/s/s [E] reaching a velocity of 72.0 m/s [E]. What was the time needed to race this distance?

$$\vec{v}_1 = 0 \text{ m/s}; \vec{v}_2 = 72.0 \text{ m/s [E] or } +72.0 \text{ m/s}; \vec{a}_{\text{avg}} = 11.2 \text{ m/s/s [E] or } +11.2 \text{ m/s/s}$$

$$t = ?$$

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt}$$

$$+11.2 \text{ m/s/s} = +72.0 \text{ m/s} - 0 \text{ m/s} / t$$

$$t = +72.0 \text{ m/s} / +11.2 \text{ m/s/s} = 6.43 \text{ s}$$

Chapter 3

Inertia

Natural Motion – Galileo

CLASS ACTIVITY:

Galileo's Thought Experiment—Page 25

This activity was attempted with three different mini-Vs. The tracks for the mini-Vs were placed along two boards, one forming the downward sloping ramp, and the second forming the upward sloping ramp. The tracks were taped to the boards to limit their motion as the car passed. The cars were released from a point A, 100 cm from the lower end of the down ramp. The vertical height to the point A was 56 cm.

Point B was marked along the upward sloping ramp. It was the point at which the car stopped moving and reversed its direction. The angle of the upward sloping ramp was measured. The distance to point B from the bottom of the upward sloping ramp was measured. The vertical height from the table to point B was also measured.

Theoretically, the car should travel up the upward sloping ramp to point B and reach the same vertical height as the point of release, A. Due to friction and the loss of energy to other forms, the cars never reached the same height as point A (i.e., 56 cm). The best that could be achieved was about 35 cm in height to point B.

The three vehicles being used were slightly different in shape and mass. The lightest (vehicle A), a sports car, performed the worst. The one with the most mass (vehicle C), a van, performed the best.



Typical Results

- The point of release in all trials was 100 cm from the lower end of the downward sloping ramp and the vertical height was always 56 cm.

Table 1

Angle of upward sloping ramp	Vehicle	Average distance traveled up the upward sloping ramp (cm)	Average vertical distance vehicle to which the vehicle rose (cm)
30°	A	65	28
30°	B	68	30
30°	C	77	35
25°	A	79	30
25°	B	82	32
25°	C	89	34
17°	A	103	28
17°	B	118	31
17°	C	125	34
10°	A	141	25
10°	B	162	31
10°	C	169	33

- Ideally, the height from which you release the car above the floor and the height to which the car rises above the floor on the other ramp should be the same. However, due to friction and the loss of energy to other forms, the height to which the vehicle will rise is always less than the height from which it was released.

3. Distance from which car is released up the ramp = 90 cm.

Distance car travels up the up ramp will be less than 90 cm if the angles the ramps make with the floor are equal, or if the angle for the upward sloping ramp is greater than for the downward sloping ramp.

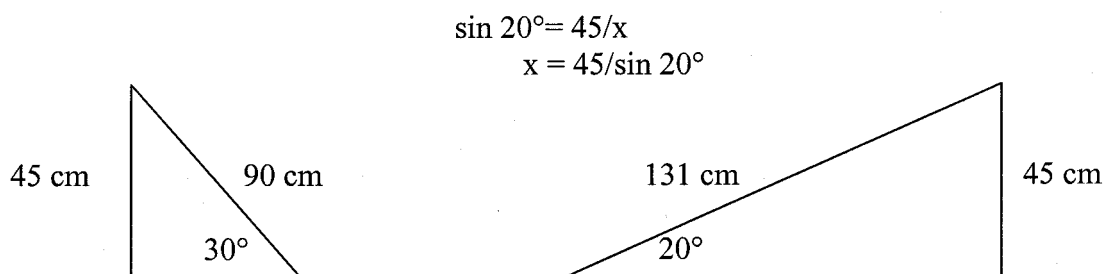
If the angle for the downward sloping ramp is less than for the upward sloping ramp, at a certain angle the vehicle will travel farther up the upward sloping ramp than 90 cm.

4. After decreasing the angle of the up ramp:

Distance from which car is released up the ramp = 90 cm.

Height above the floor to point of release = 45 cm.

Distance car moves up the up ramp = 131 cm.



Vertical distance car rises = 45 cm

The distances calculated above are for the ideal case, with no friction. The distances in real life will be less. The car will not rise to a height of 45 cm and will not travel up the slope to 131 cm.

Alternate Activity

If long movable lab tables are available, a similar activity can be done using these tables and a steel ball bearing. Butt the ends of two tables together. Raise the other ends by resting the legs on three or four textbooks. The ball bearing is released on one table from a point 1 m from the end that abuts the second table. Measure the height of the point of release above the floor. The ball then rolls down the first table and up the second table. Record the distance up the ramp the ball bearing rolls and the height it reaches above the floor.

Remove one set of textbooks from below the legs of the upward sloping table. Repeat the procedure. Repeat the procedure a third time. The ball bearing should roll almost to the end of the upward sloping table or completely off the table. If the final set of books is removed, the ball bearing rolls right off the table.

If the ball bearing is released onto a smooth, level floor as in a long hallway, the ball bearing will roll with a fairly constant velocity for a great distance. A ball released down a ramp elevated by 15 cm at one end rolled 40 m across a tiled floor and was still going when it hit the wall.

Typical Results

Table 2

Number of books under legs of upward sloping table	Point of release from end of table (cm)	Height of point of release above lowest point on the table (cm)	Distance ball travels up the upward sloping table (cm)	Height of point ball comes to rest above the lowest point on the table (cm)
3	100	3.5	89	3.0
2	100	3.5	134	3.2
1	100	3.5	>265	76.6
0	100	15 (see above)	>4000	


Think About IT!
Think About IT!—Page 25

- As the angle decreases for the up ramp, the car travels a further distance along the up ramp. The car must rise to the same height. Since the angle of the track is less, it takes a longer distance along the track to reach the same height.
- If the angle of inclination is 0° , the car would roll along forever.

PRACTICE—PAGE 26

- For initial motion, the object has uniform velocity.

Van with equal spacing at equal time intervals

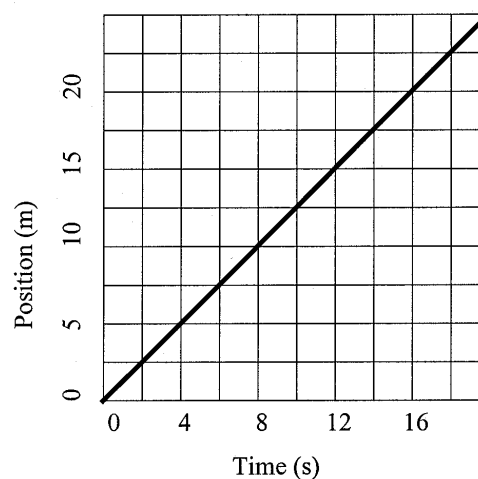
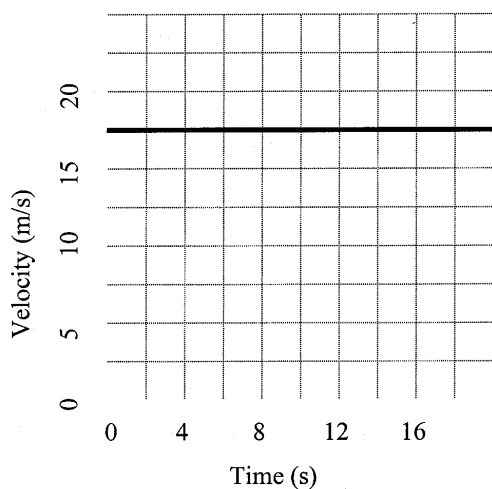


2. This table of data reflects inertial motion.

Table 3

Time (s)	Position (m)
0	0
1	2
2	4
3	6
4	8
5	10

3. This graph reflects inertial motion—motion with constant velocity.



4. An unbalanced force is any force that is acting on an object that is not cancelled out by another force of the same size acting in the opposite direction.
5. Aristotle did not use any kinds of measurements to verify his ideas about motion. He did not account for friction. To overcome friction, objects had to be pushed in order to continue to move.
6. Galileo reasoned things out in “thought experiments.” While his reasoning was correct, it was not verified by measurement.

The Velocity of a Car on an Inclined Plane

**Think
About
IT!**

Think About IT!—Page 30

- The calibration ratios should follow the pattern 1, 4, 9, 15, 25.

Sample Data

Table 4

Release point— distance up the ramp (cm)	Horizontal distance object travels before hitting the floor (cm)	Relative velocity	Actual calibration ratio	Ideal calibration ratios
5.0	17.4	1	1	1
18.5	34.8	2	4	4
34.0	52.2	3	7	9
61.5	69.6	4	12	16
100.0	87.0	5	20	25

Calibration ratio = Release point distance / First release point distance

Note to Teacher: The ramp was set at 30° from the horizontal. The track used was a plastic toy-car track nailed to the ramp. The track was quite bumpy. The object used was a marble. Better results could be obtained with a smoother track and a heavier object, such as a steel ball bearing.

The experiment was repeated using a smooth track consisting of a 1.5-m fenceboard with two smaller boards forming a channel wide enough for a Mini-V, and a steel ball bearing.

Table 5

Release point— distance up the ramp (cm)	Horizontal distance object travels before hitting the floor (cm)	Relative velocity	Actual calibration ratio	Ideal calibration ratios
5.0	21	1	1	1
22	42	2	4.4	4
45	63	3	9	9
82	84	4	16.4	16
121	105	5	24.2	25

These results closely match the ideal calibration ratios.

The angle for the calibration of the track does not matter as long as it is kept constant. In later activities, the calibrated track is used again. Be sure the students have the correct angle for the slope. A convenient way to do this is to put a mark at 100 cm from the end of the track and rest the track on three or four identical books.

2. The mathematical significance of the pattern 1, 4, 9, 16, 25 is that these numbers each represent the squares of a number.

$$1 = 1^2$$

$$4 = 2^2$$

$$9 = 3^2$$

$$16 = 4^2$$

$$25 = 5^2$$

Investigation # 2 INERTIA AND THE UNRESTRAINED OCCUPANT

Note to Teacher: Students using toy cars had difficulty with their passengers. If the passengers were too large or too lifelike (i.e., with arms and legs), they had difficulty remaining on the vehicle as it rode down the ramp. Also, the passengers with arms and legs tended to travel inconsistent distances after leaving the vehicle.

The car tended to skip over the barrier, a metrestick, when the velocity was 4 or 5. A good height for the barrier is about 1 cm. This barrier will stop the car at all speeds and allow the passenger to travel over it.

Typically, the results, when graphed, all followed the curve of an exponential relationship with an exponent of 2.

Distance traveled is proportional to velocity squared.

Some examples can reinforce this idea. For example, if a passenger is thrown a distance of 4 m at 20 km/h, then at 80 km/h, 4x the velocity, the passenger is thrown $4(4)^2 = 4(16) = 64$ m.

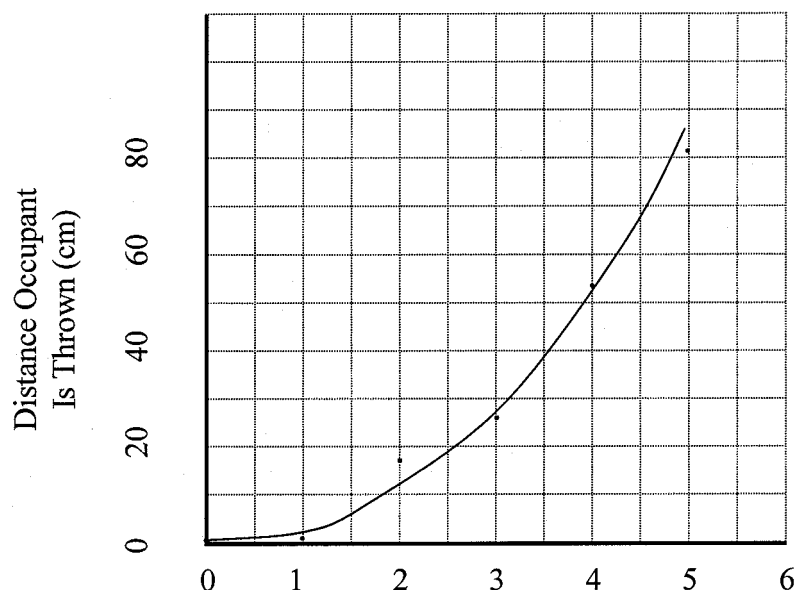
Table 6

Speed	Trial #1	Trial #2	Trial #3	Average distance occupant is thrown (cm)
0	0	0	0	0
1	0	2	0	0.7
2	19	15	18	17.3
3	30	19	29.5	26.2
4	37.5	76.5	46.5	53.5
5	86	63	94	81

Think
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1.



2. As the speed increases, the distance the occupant is thrown also increases.

The distance the occupant is thrown increases more rapidly than the velocity of the vehicle. This is an exponential relationship. The graph is a curve. This curve was mentioned in exponential population growth as a “J” curve.

3. Other factors that affect the distance the occupant is thrown are:

- the shape of the occupant (does it have arms? Legs? Is it round? Flat?)
- how it moves after landing (sliding, rolling)
- size of occupant
- angle of contact with the ground

Challenge—Page 32

“Idealize” the inertia and the unrestricted occupant activity.

1. How will the velocity be controlled?

Students can launch the vehicle at varying velocities, using different means. For example, elastics can be attached to a dynamics cart. The elastic can propel the cart. This would be done by attaching the elastic to the cart and to a fixed point. The cart would be pulled back, stretching the elastic. Once released, the cart would accelerate to a certain velocity before smashing into the barrier.

The elastic can be stretched to double the original distance. This will double the force and should result in a velocity that is twice as great as the original. This can be repeated for other amounts of stretch of the elastic.

2. How can the passenger be modified to come to rest in a regular fashion?

If solid objects are used, these should have a regular shape. The less sharp the corners, the better. A die could be used, but a dodecahedron might be better. Board games come with regularly shaped solid objects with many sides. The more sides the object has, the better.

If plasticine or clay is used, it can be moulded into a cube, then the corners can be flattened. This would make the object roll in a more regular fashion.



**Think
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Think About IT!—Page 32

1. The real relationship between the distance an unrestrained object is thrown and the speed of the car is an exponential relationship.

distance \propto velocity squared

$$d \propto v^2$$

If speed doubles, distance increases by 22 or 4 times.

If speed triples, then distance increases by 32 or 9 times.

Forces and Motion

*Think
About
IT!*

Think About IT!—Page 33

1. A car accelerates:

There is a force of friction between the tires and the road. The tires push backwards against the surface of the road. This pushes the car forward.

A car slows down:

Friction acting on the car opposes the motion. The car is slowed by friction.

The driver applies the brakes. Friction between the brake pads and rotors slow the movement of the wheels, slowing the car down.

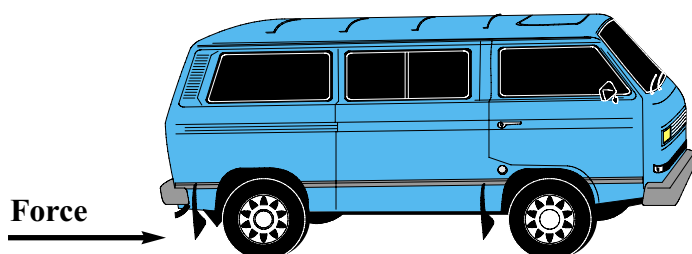
A car turns left:

A change in the direction of velocity is also **acceleration**. Any acceleration requires a force. The force of friction between the tires and the road pushes the car to the left, causing it to change the direction of motion.

A car brakes to stop:

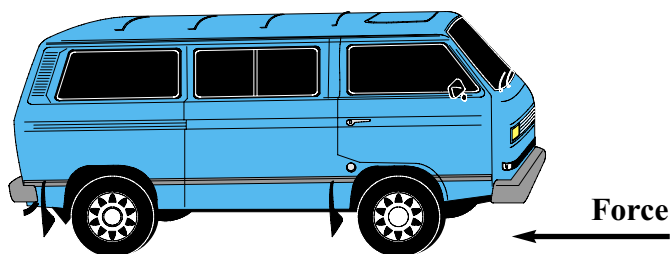
Again the force of friction between the brake pads and the rotors slows the movement of the wheels, slowing the car down.

2. Accelerates:



This is the force pushing the car forward as it accelerates.

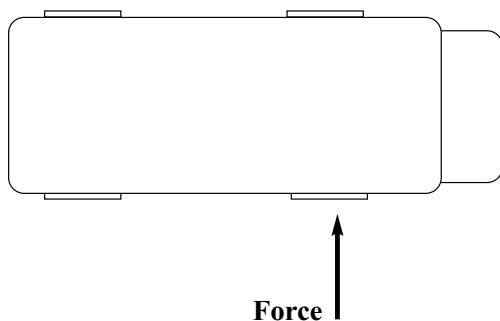
Slows down:



This is the braking force that slows the car down.

Turns left :

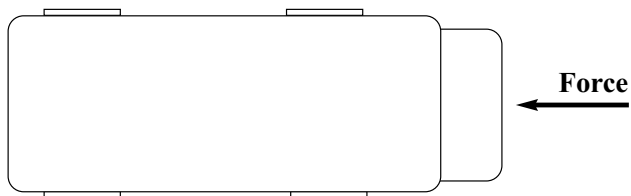
Top view:



This force turns the car left. The force does not speed up the car or slow it down, but changes the direction of the motion. This is also an acceleration.

Brakes:

Top view:



This force brings the vehicle to a stop. This force is due to the brake pads rubbing against the rotors, slowing down the rate of rotation of the wheels.

Investigation #3 FORCE AND ACCELERATION

Object:

How does the unbalanced force acting on an object affect its motion if the mass of the object is kept constant?

Independent variable = unbalanced force (weight of falling mass)

Dependent variable = motion of cart

Controls:

Mass being accelerated. Include both the mass of the cart and the falling mass.

Note to Teacher: Physics labs should have masses that would be convenient to use. An appropriate mass to use would be 100 g or 0.100 kg with a dynamics cart with a mass of about 1.00 kg. Have students label the carts they use. Later on, they must double the mass of their cart.

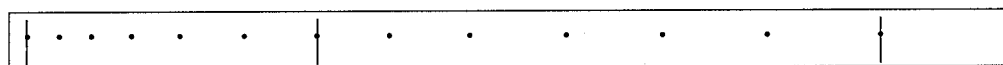
Forces are measured in newtons. Mass is measured in kilograms. The force of gravity on the hanging mass is about 1 N (Force of gravity = mass \times 9.8 N/kg).

The acceleration of a 1.0-kg cart plus the 0.1-kg hanging mass should be about $1\text{N}/1.1\text{ kg} = 0.9\text{ m/s}^2$. Due to friction, expect accelerations to be less than 0.9 m/s^2 .

The tables C, D, and E from pp. 18–20 have been combined into one. See the following page for a sample blank table.

Students should analyze the dots on the ticker tape using 6 dots = 0.10 s for a ticker timer with a frequency of 60 vibrations/second.

Be sure students do **not** count the first dot at the start of the time interval as one of the six dots. There should be six spaces visible between dots in a 6 dot = 0.10 s time interval.



Once the table is complete, students graph **time** at the midpoint of the interval and average velocity.

The graph should be a straight line with a positive slope.

The slope of a Velocity-Time graph yields **acceleration**.

Typical Results:

Table A

Unbalanced force due to weight of hanging mass (N)	Mass of cart and hanging mass (kg)	Acceleration (m/s/s)
1		
1		
1		
1		
1		

Conclusion:

A constant unbalanced force exerted on an object causes the object to accelerate at a constant rate.

Table B

Time (s)	Position (cm)	Time at midpoint of interval(s)	Displacement during time interval (cm)	Average velocity (cm/s)

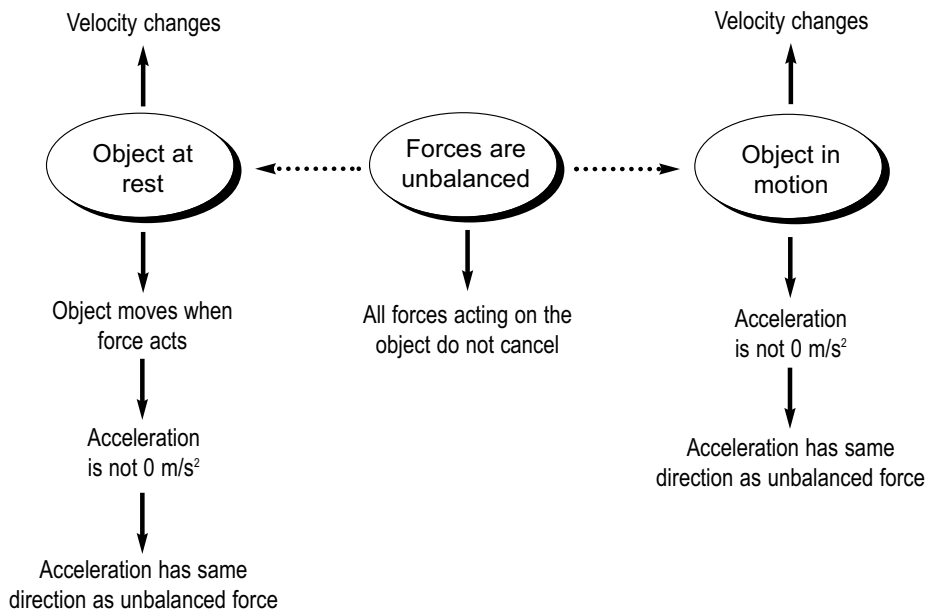
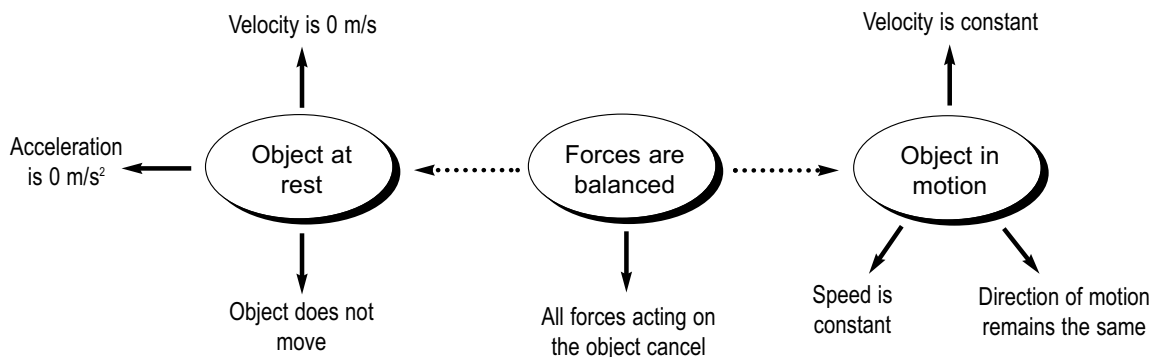


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1. The dots on the tape show that the displacement between adjacent dots increases. This indicates that the velocity is increasing (i.e., the object is speeding up). The change in velocity implies there is an acceleration. A constant, unbalanced force acting on an object produces a constant acceleration.

Think About IT!—Page 35

1.



Investigation #4 MASS AND ACCELERATION

Note to Teacher: Using ticker tapes to measure acceleration is a long process that needs reinforcement. Students must perform the necessary calculations many times to become proficient at them.

If the students understand these ideas conceptually without calculations, a good deal of time can be saved.

A suggested alternative to develop the inverse relationship between mass and acceleration for a constant force is to use dynamics carts, bricks for added mass, and scales or elastics to provide the unbalanced force. Students can pull a cart with a constant force measured on a scale. Students must accelerate with the scale and the cart in order to keep the force constant. As the mass increases, students can see and feel that the acceleration required becomes smaller. This develops the concept very effectively.

An elastic attached at one end to the cart and stretched at the other end by a metrestick can also be used to provide the force. The student must keep the elastic stretched a certain amount, say 40 cm, in order to maintain a constant force.

Object:

How does the mass of the cart affect the acceleration if the unbalanced force is kept constant?

Independent variable = mass of cart **plus** falling weight

Dependent variable = acceleration

Control: unbalanced force

Note to Teacher: The mass being accelerated is the mass of the cart **plus** the mass of the falling weight.

Students will already have one set of data for the acceleration of the cart.

Have each group add different masses to its cart and perform this one trial. Each group should keep the same falling weight as the previous trial. Once the group has determined the acceleration, the information can be shared with the other groups.

Weights or bricks or extra dynamics carts can be used to provide the extra mass on the carts.

Sample Data:

These trials used a falling mass of 100 g (force = 1 N). The students used dynamics carts, to which were added weights of 0.500 kg, 1.000 kg, 1.500 kg, and 2.000 kg. The total mass accelerated was the mass of the cart, the added mass, and the hanging mass.

Each group performed a trial for all the above added masses (four trials in all). This gave each member of the group one tape to analyze. The groups then shared their results with the class. Graphs of acceleration and total mass were plotted. The graph clearly shows the inverse relationship between the total mass and its acceleration.

The results given here represent the averages for five sets of data.

Table C

Mass on cart (kg)	Total mass (kg)	Falling mass (kg)	Acceleration (cm/s/s)
0	1.08	0.100	51
0.500	1.58	0.100	35
1.000	2.08	0.100	30
1.500	2.58	0.100	24
2.000	3.08	0.100	21

Conclusion:

If the unbalanced force acting on the cart is kept constant as the mass of the cart increases, the acceleration of the cart decreases.

Alternate Method:

If you have access to the Internet, an applet called Newton's Second Law by Walter Fendt can be used to do this experiment virtually. Students can adjust the masses of the cart and the falling mass, and the applet will calculate the acceleration. Again, remember that the mass being accelerated is not just the mass of the cart, but the combined mass of the cart and the falling mass.

<<http://www.walter-fendt.de/ph14e/n2law.htm>>

The applet is called Newton's Second Law.

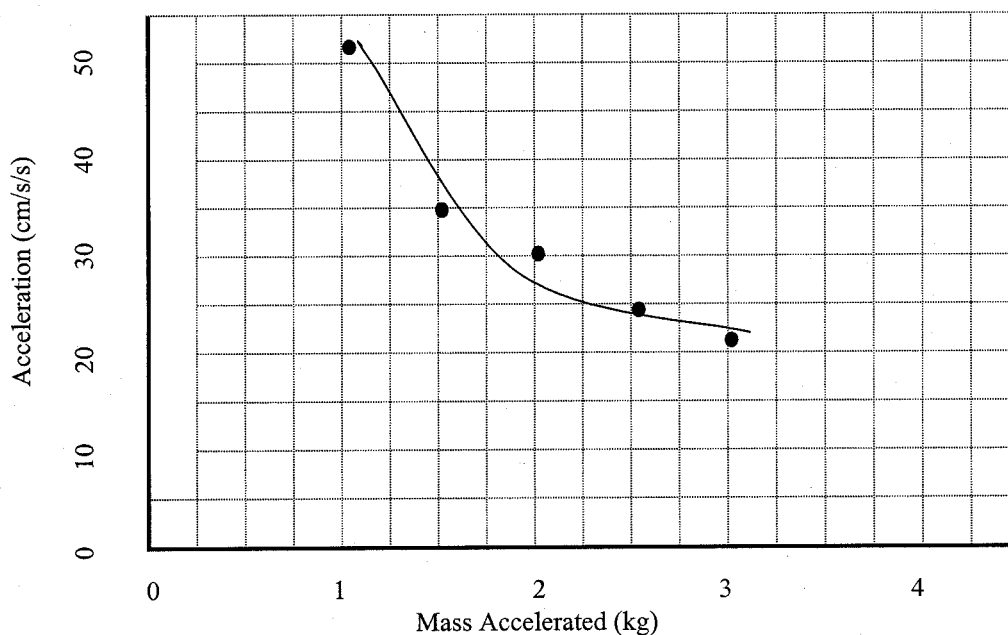
These applets can be downloaded if required, then utilized offline.

**Think
About
IT!****Think About IT!—Page 35**

1. As the mass of the cart increases, the acceleration decreases if the unbalanced force is kept constant.

Math Connection

The graph of mass accelerated and acceleration should yield a curve. The relationship is an inverse one (i.e., as mass increases), acceleration decreases for the same unbalanced force. A typical graph appears as follows.



Investigation # 5 FORCE AND MASS

Object:

How is the unbalanced force acting on the cart related to the mass of the cart if the acceleration is constant?

Independent Variable = mass of cart and hanging mass

Dependent Variable = hanging mass providing the unbalanced force

Controls = acceleration

Note to Teacher: It is expected, based on $\bar{F} = m\bar{a}$, that to maintain a constant acceleration, a doubling of the mass implies a doubling of the force. That is, $\bar{F} \propto m$ for constant acceleration.

Before the students actually perform the experiment, ask them to hypothesize about the force needed to accelerate double the mass. Then they can experiment to test the hypothesis.

Students can double the mass by accelerating two carts instead of one, provided they have equal masses. The students used 0.5-kg masses for the unbalanced force in previous investigations. This can easily be doubled or tripled.

In this case, doubling the mass of the cart and doubling the falling mass essentially doubles the total mass of the system. This system should show the same acceleration as the original cart and falling mass.

Sample Data:

Table D

Mass measured in carts	Falling mass providing unbalanced force (kg)	Acceleration (cm/s/s)	Average acceleration (cm/s/s)
1	0.100	77, 54, 57, 60, 60, 56, 47, 60	59
2	0.200	77, 63, 34, 37, 52, 62, 58, 58	55
3	0.300	48, 69, 50, 35, 68, 51, 60, 62	55

Analysis:

Students can analyze the ticker tapes to obtain the acceleration from a Velocity-Time graph. If CBLs are used, the graphing calculators can be used to calculate the acceleration.

Conclusion:

The unbalanced force required to provide a constant acceleration is related directly to the mass that is being accelerated. If the mass doubles, the force needed to provide a constant acceleration also doubles.

If the results do not show that $\bar{F} = a m$, students should critically analyze the experiment to suggest ways to improve the procedure.

Alternate Method:

This activity lends itself nicely to a virtual demonstration using the Newton's Second Law applet by Walter Fendt, which is available on the Internet.

<<http://www.walter-fendt.de/ph14e/n2law.htm>>

**Think
About
IT!**

Think About IT!—Page 36 (Top of Page)

1. As the mass increases, the unbalanced force needed to provide a constant acceleration increases directly in proportion to the increase in mass.

**Think
About
IT!**

Think About IT!—Page 36 (Bottom of Page)

1. The dots for the Car A grow increasingly farther apart. This indicates that the velocity of Car A is increasing (speeding up to the right). Car A is accelerating to the right. This acceleration is caused by a constant, unbalanced force acting to the right.

The dots for Car B also grow increasingly farther apart, but the separation of the dots increases more rapidly than Car A. This indicates that the velocity of Car B is increasing (speeding up to the right). Car B is accelerating to the right. However, the acceleration of Car B, the rate at which velocity changes, is larger than for Car A. This larger acceleration indicates the force acting on Car B is larger than on Car A if their masses are equal.

A ball rolling out into the street can be a warning that a child may dart out to retrieve the ball. At the point where the driver of Car A can see the ball, Car A will have reached a certain velocity. The driver of Car A must brake the car (i.e., give it a negative acceleration to bring it to a stop). The force to cause this braking is the force between the tires and the road.

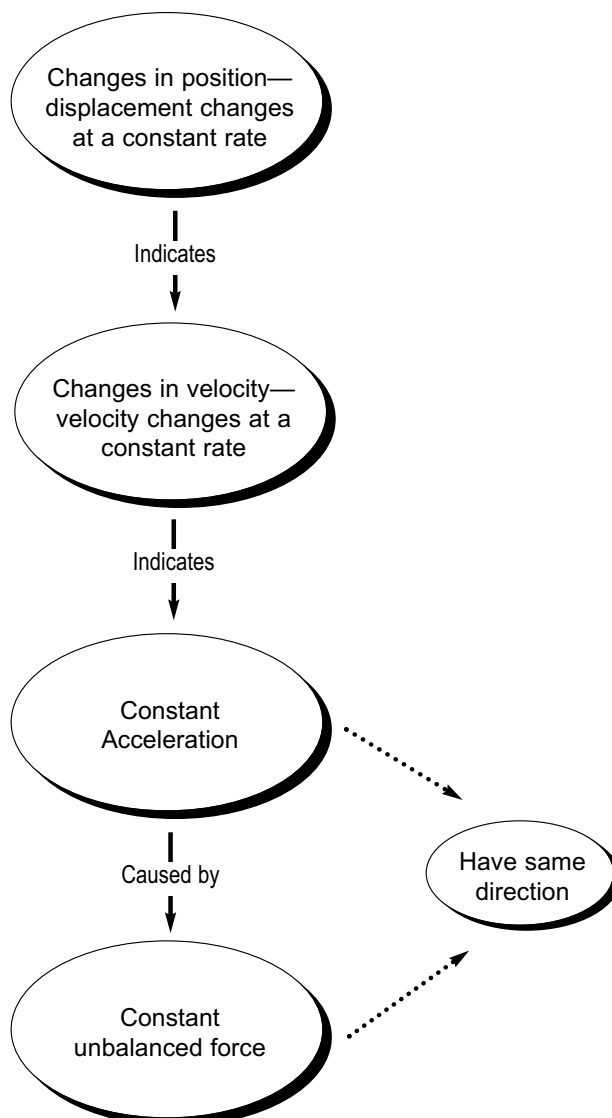
Car B reaches the point where the driver can see the ball, but it has a larger velocity than Car A. The driver of Car B applies the brakes and the force of friction between the tires and the road supply the unbalanced force needed to stop Car B. If the force of friction between the tires and the road is the same for both cars, Car B will take a longer time to brake to a stop and travel a larger distance than Car A. This larger stopping distance may carry Car B past the point where the ball, and a child trying to retrieve it, are located. The result could be a collision between Car B and the child.

Force and Direction

**Think
About
IT!**

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1.



- The racetrack is banked to maximize the turning force required to accelerate the object. This acceleration changes the direction of motion of the object, not its speed.

3. A fi B: Car accelerates

Second Law—An unbalanced force acting on an object (the car) causes the object (the car) to accelerate in the direction of the unbalanced force.

B fi C: Driver removes his foot from the pedal

First Law—An object in motion remains in motion with a constant velocity unless acted upon by an unbalanced force.

C: Black ice

Second Law—An unbalanced force is required to accelerate the car by changing the direction of its motion.

The force of friction between the tires and the road creates this force.

The ice reduces the friction between the tires and the road.

First Law—Since there is no unbalanced force, the rear wheels move in a straight line (skidding) outside the radius of the curvature of the road.

D: Car moves in a straight line

First Law—An object in motion, the car, continues in motion with a constant velocity because there is no unbalanced force acting on the object.

There is no force between the tires and the road to turn the car around the curve.

E: Car slams into the bank and stops

Second Law—The bank exerts an unbalanced force on the car, causing it to accelerate. The force acts in the opposite direction to the velocity of the car, so the acceleration is negative.

F: Windshield is cracked

First Law—An object in motion (passenger) remains in motion at a constant velocity when acted upon by an unbalanced force. The passenger continues moving when the car stops.

Second Law—The passenger striking the windshield exerts a force on the windshield, cracking it. The force of the windshield on the passenger accelerated the passenger in the opposite direction compared to the velocity.

- Water skiers or hockey players lean in order to turn so that the cornering forces (forces that change the direction of velocity) are maximized and properly balanced. Otherwise, they would topple over.

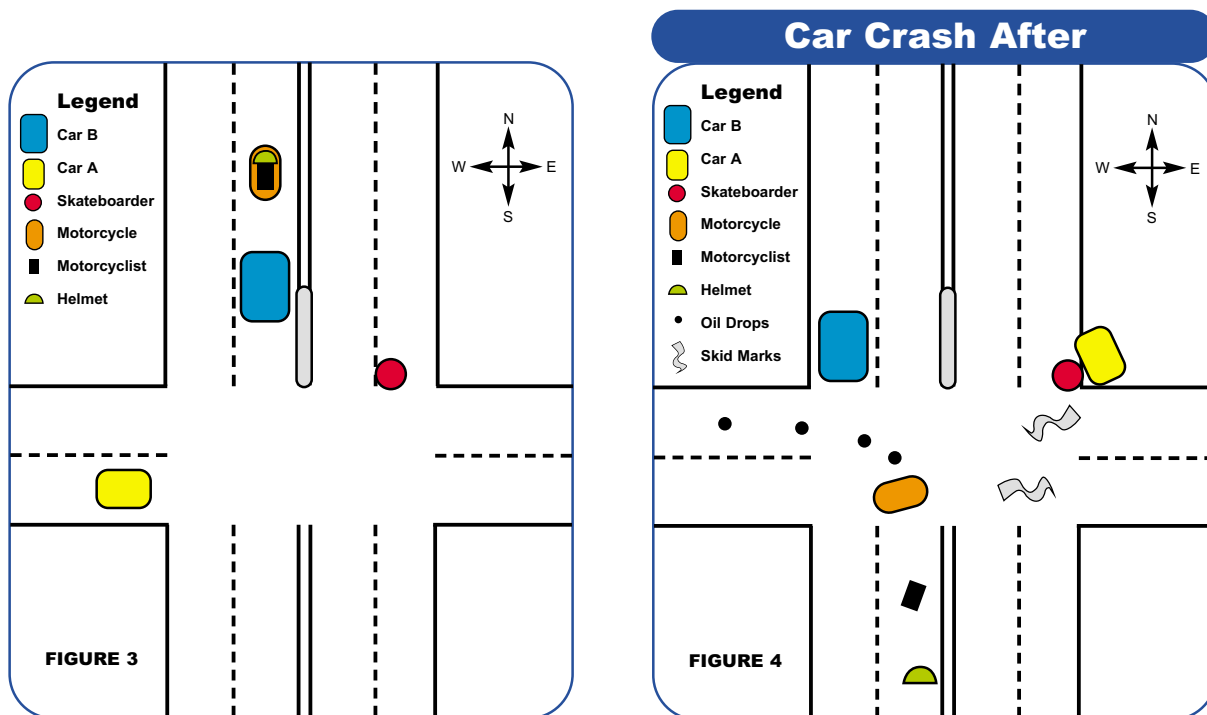
Car Crash

The motorcyclist was heading south. The motorcycle is in the intersection after the accident. This indicates the motorcycle hit an object, which stopped the motion of the motorcycle. A large force was needed to stop the motorcycle quickly. Such a force could be provided by the crash between the motorcycle and the car. This is Newton's Second Law.

The motorcyclist and her helmet are found south of the intersection and the motorcycle. Since the motorcycle was traveling south when it crashed into the car, the motorcyclist and her helmet, which were in motion, continued in motion until an unbalanced force acted on them. This is Newton's First Law.

When the motorcyclist landed on the ground, the force of friction between the road and the motorcyclist brought her to a stop. Again, this is Newton's Second Law.

If the motorcycle struck the front fender of Car A, the force of the collision would have pushed the front of Car A in a southerly direction. Car A would then have traveled in a more southeasterly direction. If the motorcyclist struck the rearmost portion of Car A, this would push the rear of Car A to the south. Car A was already turning north (we could assume), so the rear of Car A would slide to the east, and the direction Car A would take would then be more northerly and somewhat east of north. The skidmarks east of the intersection would be consistent with the rear tires sliding sideways in an easterly direction. Alternatively, the skidmarks may have nothing whatever to do with this particular incident. What about those oil drops?



Action - Reaction Forces

**Think
About
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The sprinkler head turns because an unbalanced force is exerted on it.

Water is forced out of the nozzle of the sprinkler. The sprinkler must exert a force on the water to cause the water to move (accelerate).

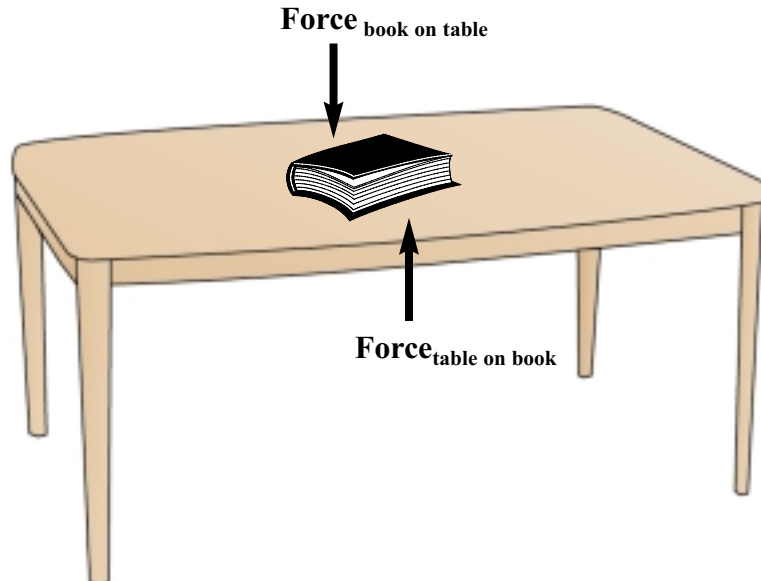
The water exerts an equal but opposite force on the sprinkler. The sprinkler accelerates due to this unbalanced force of the water acting on the sprinkler.

Note to Teacher:

- Action-reaction pairs of forces do not cancel each other out.
- Each force for two objects in contact acts on a different object.
- Therefore, they cannot cancel.

For example, a book rests on the table. The force of gravity pulls the book down, causing it to exert a force on the table. The table pushes the book upwards with the normal force, which is equal but opposite to the force of gravity on the book.

If we isolate the book and the table, we can show exactly the forces that act on each object.



**Try IT!—Page 39**

The scale reads 16 newtons.

The lighter student and heavier student are exerting forces to keep the spring scale motionless. Therefore, the net force on the scale is 0N.

The lighter student pulling on the scale can be thought of as the scale being attached to a rigid object like the wall. The heavier student must pull on the rope with a force of 16N to make the scale read 16N.

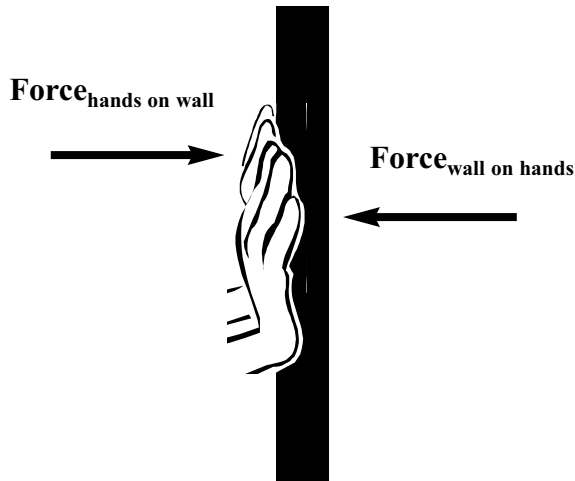
Conversely, the heavier student pulling on the scale can also be thought of as the scale being attached to a rigid object like a wall. The lighter student must pull on the rope with a force of 16N to make the scale read 16N.

Therefore, the students exert the same force. However, one student pulls to the right and the other student pulls to the left.

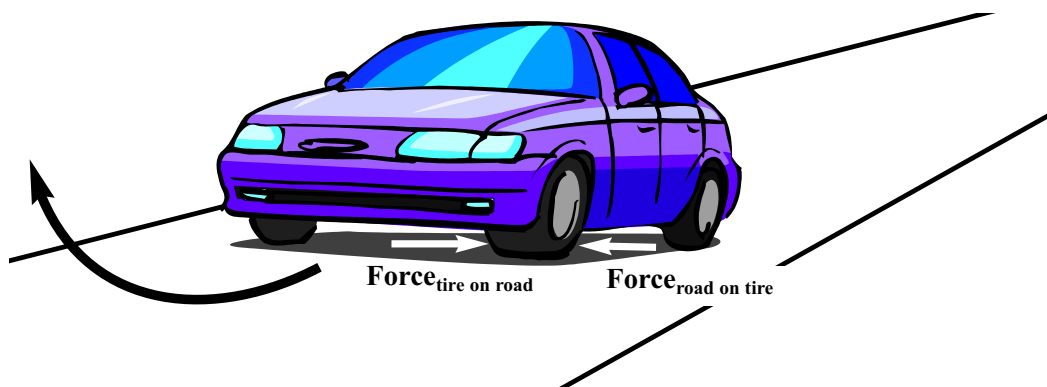
**Think About IT!—Page 40**

Note to Teacher: Question 3 is difficult. Break the situation down for the students into smaller interactions.

1. a. A person leans against a wall



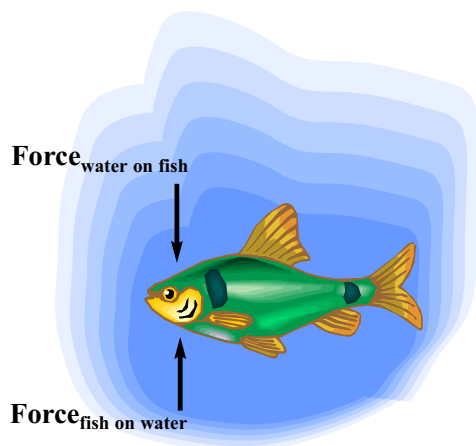
- b. A car rounds a corner with constant speed.



This is a top view of the tire in contact with the surface of the road. The car is accelerated in the direction of the unbalanced force acting on the car (i.e., the force the road exerts on the tire). The car turns to the right. This type of force that causes only the direction of velocity to change is called *centripetal force*.

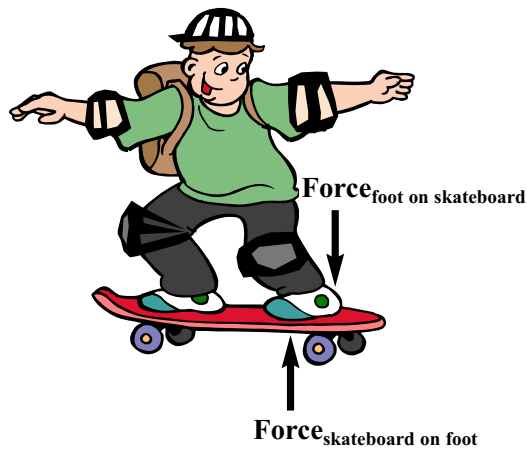
- c. Fish swims

The fish pushes water one way and is propelled in the opposite direction.

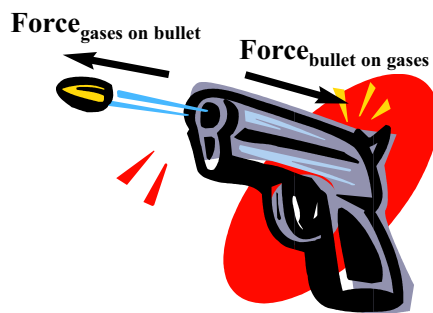
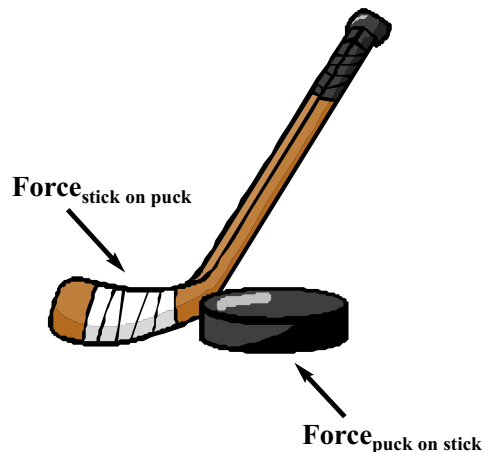


d. Skateboarder jumps

When jumping, the skateboarder pushes down on the skateboard with his foot. The skateboard pushes up on the skateboarder with an equal but opposite force.

**e. A gun recoils**

The expanding gases inside the barrel of the gun push on the bullet, propelling it in one direction. The gases also push on the end of the barrel of the gun in the opposite direction.

**f. A hockey player's slapshot**

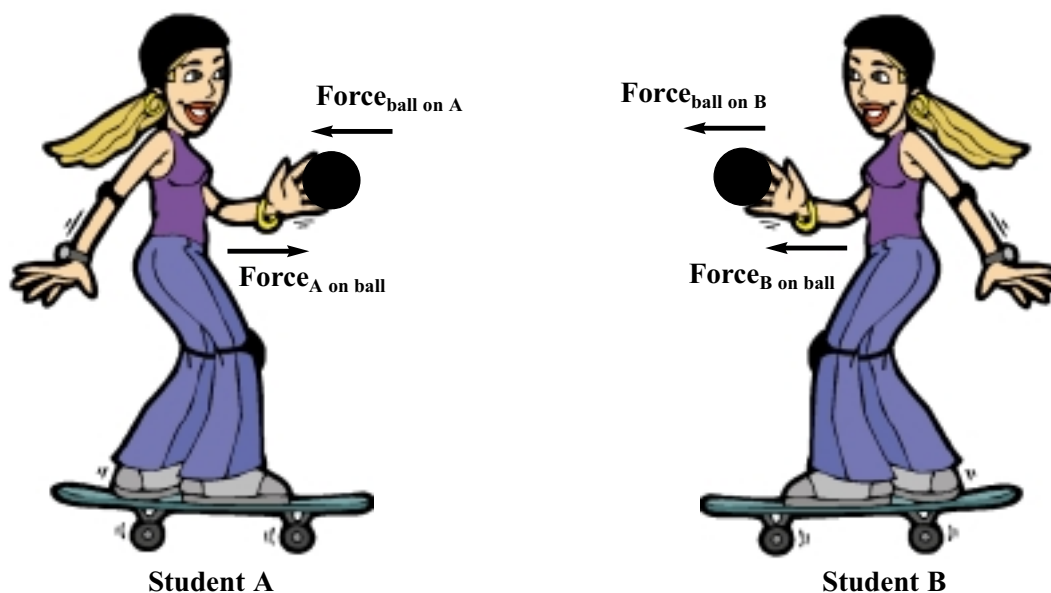
2. The two forces are equal, but opposite.

$$\text{Force}_{\text{car on mosquito}} = \text{Force}_{\text{mosquito on car}}$$

3. Separate this problem into parts: Student A throwing the ball; the ball flying through the air; Student B catching the ball; after Student B catches the ball.

Student A pushes the ball to the right (**action force**). This force accelerates the ball to the right. The student is pushed by the ball to the left (**action-reaction pair of forces**). This reaction force accelerates Student A to the left.

After the ball is released, the student rolls along at constant velocity to the left (no unbalanced force). The ball flies along to the right with constant velocity towards student B (no unbalanced force—Newton's First Law).



Student B catches the ball. The ball is moving to the right. The ball exerts a force on the student to the right as the student catches the ball (**action force**). This action force accelerates the student to the right. The student exerts a force to the left on the ball (**reaction force**). This causes the ball to accelerate to the left (slows down).

After the ball is caught, the ball and Student B roll along to the right at a constant velocity (no unbalanced force acting).

4. Whenever a part of your body collides with another object, like the surface of the road, your body part exerts a force on the road (**action force**).

By Newton's Third Law, the road must exert an equal but opposite force on your body part. This is the force that can damage you.

The protective equipment provides a cushion for these action-reaction forces so that the forces are decreased.

The smaller forces reduce the damage done to you.

Chapter 5

Momentum and Energy

Momentum

**Think
About
IT!**

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Order is small momentum to large momentum.

Table A

Object	Amount of Momentum (describe in your own words)	Comments
Statue	It has mass, but no velocity, momentum is 0.	
Building	It has mass, but no velocity, momentum is 0.	This has a larger mass than a statue, but momentum is still 0.
Football	It has a larger velocity, but little mass.	
Slapshot	The puck has mass and a larger velocity than the football.	The puck is moving faster than the football.
Marathon runner	It has both mass and velocity.	The velocity is smallest of sprinter, runner, and skateboarder.
Skateboarder	It has about the same mass as runner, but has a larger velocity.	
Sprinter	It has same mass as runner and skateboarder, but travels with a larger velocity.	
Transit bus	It has a large mass and small velocity.	
NASCAR stock car	It has a smaller mass than the bus, but a much larger velocity.	The car is moving much faster than the bus. This makes up for the smaller mass of the car.

Math Connection

The velocities used are realistic velocities.

Table B

Object	Mass (kg)	Velocity (km/h)	Momentum (kg-km/h)	Comments
Transit bus	8 000	50	400 000	
Football (thrown)	0.5	35	17.5	
Sprinter	75	35	2700	
Golden Boy statue	1 650	0	0	
NASCAR stock car	1 545	300	463 500	
Marathon runner	65	12	780	
Slapshot	0.15	150	22.5	
Building	1 000 000	0	0	
Skateboarder	68	20	1360	

The ranking of the smallest to largest momentum is:

- Statue
- Building
- Football
- Puck (slapshot)
- Marathon runner
- Skateboarder
- Sprinter
- Transit bus
- NASCAR stock car

Impulse and Momentum

Note to Teacher:

Impulse and momentum can be related through Newton's Second Law.

In symbolic form, the equation for Newton's Second Law is: $\vec{F}_{\text{net}} = m\vec{a}$

Where:

\vec{F} is the unbalanced force.

m is the mass of the object.

\vec{a} is the acceleration of the object.

Acceleration is found using the equation:

$$\vec{a}_{\text{avg}} = \frac{D\vec{v}}{Dt}$$

If we substitute for \vec{a} in Newton's Second Law, it becomes:

$$\vec{F} = m \cdot \frac{D\vec{v}}{Dt}$$

Cross-multiply with Dt and:

$$\vec{F}Dt = mD\vec{v}$$

The $\vec{F} Dt$ part is called *impulse*. It can be thought of as the **cause** of motion changes.

$$\text{Impulse} = \vec{F}Dt \quad \text{Units: N} \cdot \text{s}$$

The $m D\vec{v}$ is **change in momentum** not just momentum.

This is the **effect** or change in motion caused by applying an impulse to the object. If an impulse is applied, an object undergoes a change in velocity and, hence, a change in momentum.

Change in momentum = $m D\vec{v}$ (has units of kg-m/s)

Both quantities are **vectors**.

DEMONSTRATION:

A piece of paper is placed under a beaker at the edge of a table. The paper is quickly pulled out from under the beaker. The beaker does not move. Here, the force of friction between the beaker and the paper acts for a short time. The impulse applied and, hence, the change in momentum of the beaker, are small.

If the paper is pulled gently along the table, the beaker will move with the paper, acquiring a large velocity. Here, the same force of friction acts, but over a long time, allowing the beaker to acquire a large velocity.

**Think
About
IT!**

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1. **a.** large force—short time
 - hitting a baseball with a bat, hitting a golf ball
 - two cars crashing together
 - b.** small force for a long time
 - coasting to a stop while riding a bicycle
 - a sliding curling rock coming to a stop
 - c.** large force for a long time
 - a train speeding up or slowing down
 - a large boat or ship speeding up or slowing down
 - d.** small force over a short time
 - moving a pen or pencil while writing
2. **a.** Driving the golf ball

The large impulse can be obtained by swinging harder to increase the force, or using proper technique to increase the time of contact (i.e., follow-through). Both provide a large momentum to the ball.

Putting the golf ball

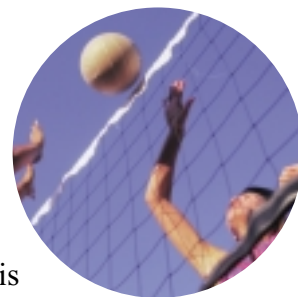
The small impulse can be obtained by exerting a small force with the putter on the ball. This decreases the momentum change the ball undergoes. Again, following through is important to maintain the correct direction.

**b.** Gymnast and reverse somersault

Before the dismount, the gymnast swings around the bar. As she falls, the force of gravity applies an impulse to her, increasing her speed and momentum, especially in the legs. The gymnast rises upwards on the other side. Once her hands release from the bar, the momentum is in the gymnast's body as she flies through the air.

c. Volleyball players “set up” a spike shot

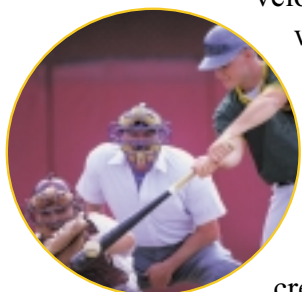
The setter must apply a force to the ball for a given length of time. If the setter can lengthen the time of contact with the ball, the force that must be applied to the ball can be reduced. This also allows for more control. The ball will have a momentum that will carry it in the correct direction and to the correct spot to be spiked. Good setters have “soft” hands. They can cushion the ball while it is in their hands and guide it with the right force in the right direction.

**d. Baseball players hitting a grand slam**

The player must swing the bat with a large force. This accelerates the bat to a high velocity. This requires strength on the batter’s part. Baseball players are seen warming up with weights on the bat. This strengthens the muscles needed to exert a large force on the bat and makes the bat feel very light once the rings are removed.

During the swing, the batter follows through, which lengthens the time of contact between the bat and the ball.

Both the large force and longer contact time increase the impulse applied and create a larger change in momentum. The ball is propelled with a larger velocity and travels farther, right out of the park.

**e. Car brakes for a yellow light**

The car must slow down and stop, decreasing its momentum to zero.

The braking force acting on the wheels can be small if the time to stop is large. This is the preferred method of stopping.

If the braking time must be small, then large braking forces are needed. The stop will be very abrupt and passengers and objects in the car will continue to move forward.

Drivers should “drive ahead.” As they approach an intersection, check the “Walk/Don’t walk” pedestrian signs. If the “Don’t walk” sign has been on for a long time, the green light is “stale” and the driver should be prepared to stop.

f. A catcher catches a fastball

The ball must undergo a change in momentum to bring it to zero. The catcher would attempt to catch the ball in the webbing of the catcher’s mitt.

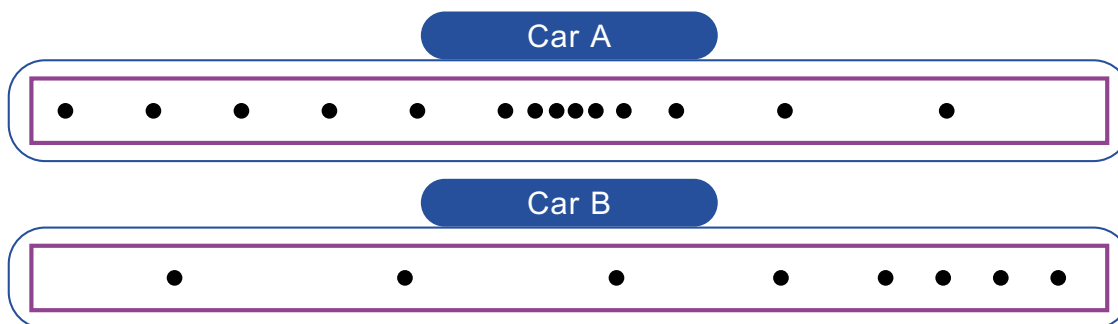
If the ball is caught flush on the palm of the hand, the ball stops in a very short time. To achieve the necessary change in momentum, a large force to stop the ball is required. The reaction force of the ball on the hand can damage the catcher’s hand.

If the ball is caught in the webbing, the length of time to stop the ball is increased, in turn decreasing the stopping force on the ball. Damage to the catcher’s hand is avoided.

The catcher can also lengthen the time of the catch by allowing her glove to move in the direction of motion of the ball as the catch is being made. This also decreases the stopping force and reduces the chances of injury to the catcher’s hand.

3. a. Car A experiences an impulse after six dots.

Car B experiences an impulse after one dot.



- b. Car A slowed to $1/3$ of its original velocity.

The change in momentum is a loss of $2/3$ of the original velocity.

Car B slowed to $1/4$ of its original velocity.

The change in momentum is a loss of $3/4$ of the original velocity.

Car B experiences the larger momentum change.

- c. Since Car B experienced the larger momentum change, it experienced the greater impulse.
- d. Car A experiences two impulses: one between six dots to seven dots; and after 10 dots, between 10 and 14 dots.

4. Mass halfback = 60 kg

Velocity of halfback = +3.2 m/s

Momentum of halfback = $m\vec{v} = 60 \text{ kg} * 3.2 \text{ m/s} = +192 \text{ kg}\cdot\text{m/s}$

Mass of lineman = 120 kg

Velocity of lineman = -1.8 m/s

Momentum of lineman = $m\vec{v} = -216 \text{ kg}\cdot\text{m/s}$

Since the lineman has the larger momentum, he will push the halfback backwards.

5. If the boulder and the boy have the same momentum, and we assume the boulder has a larger mass, the boy is currently running faster than the boulder is rolling down the hill.

We can assume the boy cannot run any faster. However, the force of gravity will apply an impulse to the boulder. As time goes on, the boulder will gain momentum and roll more quickly. The boulder will roll faster than the boy can run and catch up to him.

Eventually, the boy could be crushed.

or

The boy could simply step to the side, out of the boulder's path.

6. The person can throw the gold brick in one direction (e.g., east). This action force causes a reaction force of the brick on the fool pointing west.

So the fool applies an impulse to the brick in the easterly direction and the brick applies an impulse on the fool in the westerly direction.

The impulse applied to the fool appears as a change in momentum of the fool.

The fool slides across the ice to the shore with constant velocity, as there are no unbalanced forces acting on him.

He is not a fool. What good is gold when you are dead?

7. A spacecraft has a rocket, which is basically a chamber where fuel and oxygen are mixed and burn, producing heat and waste gases. The waste gases are forced out of a small opening at one end of the chamber. This rocket is at the side of the spacecraft.

The chamber walls exert a force (action force) on the gases, pushing them out the opening. The force of the chamber walls on the gases over a time interval gives an impulse to the gases.

By Newton's Third Law, the gases exert a reaction force on the chamber walls for the same length of time. This applies an impulse to the chamber walls, which are attached to the rocket. The rocket experiences a change in momentum. In this case, the resulting velocity change is due to the change in the direction of the velocity.

Challenge

Students may suggest cushioning devices, such as pillows, padded chairs/sofas, bubble wrap.

**Try
IT!**

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Be sure to try this activity. Students will be very impressed.

The principle behind it is to have the egg undergo its change in momentum over a long period of time. This reduces the stopping force required.

This is a natural lead-in to start discussing how passengers in vehicles can be protected when they must suddenly come to a stop (i.e., undergo a large momentum change).



Cushioning Devices

Think About IT!

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Fifty years ago, cars were built with very strong, rigid bumpers. In car crashes, the rigid bumpers would stop the car quickly, as they would not collapse. This caused passengers in the vehicle to be stopped with a large stopping force, causing injuries to the passengers.



Over the years, cars were redesigned to have shock-absorbing bumpers. In collisions at low speeds, the shock absorbers would collapse, lengthening the stopping time and distance, and reducing the damage to vehicles and the injuries to passengers.

Think About IT!

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1. Research Projects—Safety Devices
2. Design a car using modern safety features

The car should include a system to fasten the passengers in the car to prevent second collisions. This should include a shoulder harness/lap belt seat system. This keeps the passenger in place, including preventing the upper body from striking the steering wheel or dashboard. This also prevents a passenger from being thrown from the car and being injured by a second collision with the ground or some other object.

Objects inside the car, like the dashboard, should be padded so that body parts striking the padded surface will stop over a longer time and distance, reducing the stopping force. Objects like door handles should be recessed into the door. Knobs on the dashboard should be recessed and as flat as possible with a large radius so that the force of impact is spread out over a large area should a body part collide with the knob.

The car should include proper support of the back and head in case of a rear-end collision. The headrest should be high enough to be positioned properly behind the head.

The car should have crumple zones in the front and the rear of the car. In a collision, the crumple zones allow the car to stop over a longer period of time and a longer distance, decreasing the stopping force.

The car should have an impact-absorbing bumper. The bumper could be plastic, in which case it crumples during a collision. The bumper could also be attached to a shock absorber, which compresses and absorbs some of the energy of a collision.

The passenger compartment of the car should be strong enough not to flatten during a rollover. The cage of the car should remain intact, preventing the passengers from being crushed.

The passenger car should have air bags in the steering wheel and dashboard to cushion passengers as they continue to move forward when a car is stopped in a head-on collision. The air bags should be designed so that they do not injure the passengers. Injuries can result from the rapidly expanding air bag striking a passenger. The air bags should be designed to accommodate passengers of all sizes. Cars can also have side air bags built into the doors to cushion the passenger during side collisions.

Since children are often the passengers in a car, provisions for a child safety seat should be built into the seating in the car.

Windows should be laminated. This will prevent the glass from breaking up into shards that could then act as knives to cut the passengers. Laminating the glass (i.e., putting two layers of glass held together by a layer of adhesive) allows the glass to break into tiny pieces that are held in place by the adhesive. The windshield must be strong enough to prevent the passenger's head from poking through the windshield. If this happens, the hole in the glass closes and, as the passenger's momentum is reversed, the passenger could be decapitated.

3. Investigate NASCAR Regulations Online

Seat Belts:

<<http://www.evergreenspeedway.com/03brules.htm>>

<<http://www.speedbowl.com/speedpages/2002GeneralRules.html>>

<<http://www.phy6.org/stargaze/Sfall.htm>>

Roll Bar:

<http://www.google.ca/search?q=cache:r6H7FGQPDp4C:www.iceracingthunderbay.com/images/Rules_Regulations.pdf+NASCAR+safety+regulations+rollover+cages&hl=en&ie=UTF-8>

<<http://cc4w.org/favorite.htm>>

<<http://www.evergreenspeedway.com/03brules.htm>>

<<http://www.stockton99speedway.com/Division%20rules/WLM2003Rules.html>>

Head Restraints—HANS (Head and Neck Support):

<<http://auto.howstuffworks.com/nascar-safety4.htm>>

<<http://drive.fairfax.com.au/content/20000412/motorsport/motor3.html>>

<http://www.usatoday.com/sports/motor/nascar/2002-12-12-hans-side_x.htm>

Head Restraints—Hutchens Device:

<<http://www.stockcarproducts.com/safety9.htm>>

<<http://www.mascosafety.com/hutchens.html>>

Crumple Zones:

<<http://www.tennessean.com/sii/00/07/08/safety08.shtml>>

A good general information source on NASCAR safety.

<<http://www.autoracing1.com/MarkC/2001/0226CrumpleZones.htm>>

One Stop Site: This site provides links to a variety of physics sites dealing with “Moving About.”

<<http://www.phy.ntnu.edu.tw/java/carDistance/carAccident.html>>

4. Crumple Zone

The packaging of objects, such as TVs, computer monitors, et cetera, includes rigid foam to keep the object in place in the centre of a box. There is a space between the object and the box so that the box can crumple to absorb some of the energy in a collision without damaging the contents.

Padded Cushions:

Padded cushions spread out the force of contact between objects, lessening the force acting on one unit area. A smaller force results in less damage being done to the part of the body in that unit area. For example, padding in chairs, couches, and seats of all kinds function in this way. These are static situations where there is no motion.

For objects in motion, the same principle applies. Examples would be found in amusement-park rides. Here, the parts of the ride with which the riders come in contact, often violent contact, are padded. In the home, small children are constantly falling. Bumpers placed on corners and sharp edges can greatly reduce the injuries suffered by children. In industry, padded cushions are used where objects contact each other at low speed. For example, if a trailer is being backed into a loading dock, the padded cushion lengthens the stopping distance and prevents damage to the trailer and the dock.

Air Bags:

Hollywood stunt performers use large air bags to cushion their falls from a great height.

Air bags are used in packaging as bubble wrap.

Roll Bars:

Farm tractors use roll bars above the driver. Tractors tend to flip over backwards (i.e., the front end lifts up and swings up over the driver). The roll bar protects the driver from being crushed.

Tractors that are used on hillsides also use roll bars, as they may topple over on their sides.

Recreational vehicles, which are used in all sorts of uneven terrain, have roll bars to protect the driver.

Bumpers:

Bumpers are used on industrial equipment, such as moving platforms, conveyers, et cetera. The bumpers prevent damage to other equipment and to humans in case of collisions.

5. a. Dr. Claire Straith

He was a plastic surgeon. In the 1930s, he met many patients who were disfigured from car accidents. The disfigurements were caused by the second collision of the patient's face with the dashboard or the knobs on the dashboard in the car. Dr. Straith campaigned for the automobile makers to install padded dashboards and to redesign the knobs on the dashboard. Today, all cars have padded dashboards, and the knobs on the dashboard are recessed.

b. Bela Berenyi

He was an engineer at Mercedes during the 1950s. Until 1959, cars were built to be very strong. They could crash together without crumpling very much. The force of the collision was transmitted through the rigid car body to the passengers. The energy from the crash was dissipated as work was done on the passengers during second collisions, and this resulted in injuries.

Bela Berenyi designed a car body that would dissipate the force exerted on the passengers. The design includes two crumple zones: one at the front of the car and the other at the rear of the car, with a rigid passenger compartment. The crumple zones were designed to distort in a predictable way. The energy of the crash would go into the work done to crumple the crumple zones. During frontal collisions, the structure supporting the engine would slide under the passenger compartment rather than into it. Later, side-impact beams were placed in the side door to help absorb the force of a side collision. This completed the crumple zones on all sides of the car.

c. Nils Bohlin

He was an engineer who worked for Volvo. The first seat belts came out in 1949. These were two-point belts that were strapped across the hips. The hips were held in place by the belt during a crash, but the upper torso was not restrained. Drivers especially suffered injuries as the upper torso collided with the steering wheel. Passengers' upper torsos collided with the dashboard and windshield. Spinal injuries occurred as well.

The engineers at Volvo produced a two-point belt that went across the chest. However, in crashes, the hips, where the centre of gravity was found, would fly forward. The rest of the body would follow and the chin would be caught by the chest strap. This resulted in head and neck injuries and, sometimes, decapitation.

Nils Bohlin developed the three-point lap belt/shoulder harness style seat belt. This kept the hips in place and prevented the upper torso from striking the steering wheel, dashboard, or windshield. If properly adjusted, it also prevented the body from sliding under the belt.

d. John Hetrick

In 1952, John Hetrick was granted the patent for the mechanism that has evolved into the modern-day air bag. He noticed that compressed air could very quickly fill up a canvas bag. This is the basic design of an air bag. An air bag has a sensor that sends an electrical signal to an inflator mechanism when the air bag is needed. The inflator mechanism quickly inflates the air bag. The air bag cushions the passenger as he is stopped, spreading out the stopping force and lengthening the stopping time and distance. Once the passenger is stopped, the air bag deflates. This all occurs within about 0.5 seconds.

The advantage of the air bag is that it is user-independent. It works automatically when needed, unlike seat belts which must be done up by the driver and passengers. Around 1970, the National Highway Traffic Safety Administration (NHTSA) in the U.S. found that only 15 percent of people used seat belts. They put pressure on the automobile makers to develop the technology of the air bag. By 1980, Mercedes offered them. By 1988, the NHTSA forced all manufacturers to install them in their new models.

Problems arose where passengers were injured or killed from the force of the air bag as it was inflated. Children and small women who were improperly restrained also suffered injury and death. Late-model cars have two sensors. In low-speed collisions, one sensor fires and the air bag is inflated less and to a smaller size. This lessens the injuries to passengers. In high-speed collisions, both sensors fire and the air bag operates at full inflation and full size.

e. Ralph Nader

Ralph Nader is an American consumer activist fighting for the rights of the consumer against those corporations that build things as cheaply as possible so as to maximize profit.

In 1965, Nader wrote a book called *Unsafe at Any Speed: The Designed-in Dangers of the American Automobile* (Grossman). The book maintained that cars were built for style, cost, and performance, but not for passenger safety. He claimed that the Detroit automobile makers did not place a high priority on safety design in the cars they built. Senate hearings were held in the United States and the resulting publicity made the book a best-seller.

The upshot of all this was that the government of the United States formed the National Highway Traffic Safety Administration. This agency tells the automobile makers what to build into their cars to enhance passenger safety.

Protecting Occupants

A purple diamond-shaped icon with the text "Think About IT!" inside in white, slanted font.

Think About IT!—Page 50

1. The package should have a crumple zone to lengthen stopping distance and time.

If the package does collapse, it must not do so to such an extent that the egg is damaged.

2. The egg can move inside the package. This will lengthen the stopping distance and stopping time, reducing the force.

The egg should not be allowed to move so freely within the package that it will contact the outer package.

3. Cushioning materials like polystyrene, cotton batting, plastic bubble wraps, and packing chips can be used to absorb the shock.

Some students have used straws inside the compartment. Others have used straws on the outside of the compartment.

4. Student responses will vary.

Momentum and Energy in a Collision

Note to Teacher: In Newton’s Cradle, the total momentum is conserved. If sphere 1 receives some momentum, this momentum is transferred to sphere 6 during the collision. Sphere 1 loses its momentum but sphere 6 gains an equal amount of momentum.

The total momentum in the system is conserved.

Check with the physics teacher in your school for one of these devices.

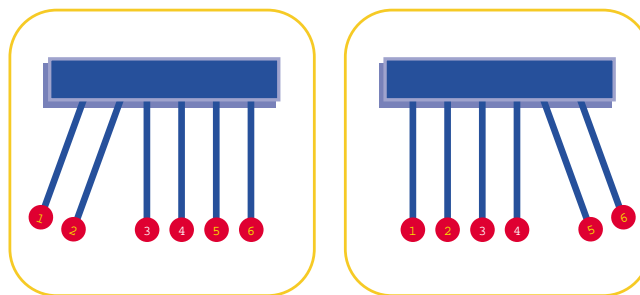
Again, Walter Fendt has an applet, appropriately named Newton’s Cradle, which will demonstrate how this device works.

<<http://www.walter-fendt.de/ph14e/ncradle.htm>>

Think About IT!

Think About IT!—Page 51

1. Pulling one sphere (sphere 1) and releasing it causes one sphere (sphere 6) to move away from the other end.
2. Pulling two spheres (spheres 1 and 2) away and releasing them causes two spheres (spheres 5 and 6) to move away from the other end.
3. Pulling three spheres (spheres 1, 2, and 3) away and releasing them causes three spheres (4, 5, and 6) to move away from the other end.
4. Pulling one sphere away from each end (spheres 1 and 6) and releasing them at the same time results in these two spheres striking the motionless spheres and rebounding with the same speed but in the opposite direction. The momentum of each sphere is reversed but the total momentum remains the same.



Think About IT!

Think About IT!—Page 53

1. If energy were not conserved but destroyed, the world would run out of energy.

Example: We eat food to supply chemical energy that our body uses to produce energy to keep us warm and to do work such as move other things and ourselves. If this energy was destroyed during conversion, the energy in the food could not be used to keep us warm or to move things.

If energy could be created, the world would be accumulating energy.

Example: A car could work with no fuel. The energy of motion would suddenly appear with no fuel as an energy source and no engine.

- The kinetic energy that appears where a car accelerates originates in the chemical potential energy stored in the fuel (gasoline) and oxygen, which react during combustion. The combustion reaction releases this energy as heat. The gas molecules move more quickly and push down on the piston, creating kinetic energy. The piston turns the crankshaft in the engine to the transmission, which turns the wheels. The turning wheels exert a force on the road, pushing the car forward. The kinetic energy is transferred along from the piston to the crankshaft to the transmission to the wheels to the car as a whole.

PRACTICE—PAGE 53



1. Roller Coaster

At the top of the ride, the roller coaster has a great deal of potential energy. As the roller coaster falls, it loses potential energy but picks up kinetic energy. At the bottom of the ride, the roller coaster has little potential energy but a great deal of kinetic energy.

2. Bungee Jumper

At the top the jump there is a lot of potential energy due to gravity and no kinetic energy. As the jumper falls, she loses gravitational potential energy and gains kinetic energy.

When the bungee cord starts to stretch, some gravitational potential energy and kinetic energy are converted into elastic potential energy, stored in the cord.

At the bottom, all the original gravitational potential energy is converted into elastic potential energy. There is no kinetic energy.



3. Car Crash

As the car accelerates, chemical potential energy is converted into (heat) kinetic energy in the particles of the combustion products of gasoline and oxygen. The kinetic energy is transferred into kinetic energy of the pistons in the engine, which turn the crankshaft, giving it kinetic energy. The transmission transfers this kinetic energy to the wheels. The wheels push the car forward.

While traveling at a constant speed, the chemical potential energy from the fuel is used to overcome friction. This energy is lost to heat and sound.

When the car brakes, the kinetic energy is converted into other forms. Heat is produced by the brake shoes rubbing against the rotors. The tires skid on the road, producing heat. Sound is also produced.

When the car hits the side panel of the truck, more kinetic energy is lost by the car. Some of this kinetic energy is converted into sound. Most of the kinetic energy is lost as the metal bodies of the car and truck are bent out of shape. The metal heats up.



4. Pole Vaulter

A pole vaulter runs. He has kinetic energy.

When the vaulter plants the pole, the pole bends. The kinetic energy of the vaulter is converted into potential energy in the bent pole.

The pole straightens, lifting the vaulter. The pole loses elastic potential energy. The vaulter gains gravitational potential energy.

At the top, the vaulter has gravitational potential energy and a little kinetic energy.

As the vaulter falls, he loses gravitational potential energy and gains kinetic energy.

5. Pogo Stick

At the top of the jump, the child has little kinetic energy. There is no elastic potential energy in the pogo stick. The child has gravitational potential energy.

As the child falls, she gains some kinetic energy, and she loses gravitational potential energy. This energy is used to do work to compress the spring, becoming potential energy as well, coming to a stop at the bottom of the jump.

The spring loses its potential energy as it expands, doing work to raise the child, giving her gravitational potential energy, and to move the child upwards, giving her kinetic energy.

As the child continues to rise, lifting the pogo stick off the ground, the kinetic energy is converted into gravitational potential energy. The child arrives at the top with no kinetic energy.



6. Cars with Spring-Loaded Bumpers

As the cars collide, their kinetic energy is used to do work to compress the springs. The kinetic energy becomes elastic potential energy.

When the cars approach as close as possible, they stop. The original kinetic energy is now all stored in the springs as elastic potential energy.

As the springs expand, the elastic potential energy is converted back into kinetic energy in the cars.

When the cars no longer have the bumpers in contact, the kinetic energy of the cars should be equal to their starting kinetic energy.

The occupants of the cars, if they are fastened to the car, will experience the same transformations as the car.

Chapter 6

Braking

Investigation # 6 BRAKING DISTANCE

Table A—Braking Distance

This trial was done using tracks made of old fenceboards, which were propped up by books. The pile of books was 27-cm high and was placed at 1.00 m from the end of the track that touched the floor. The angle of the track was about 15° .

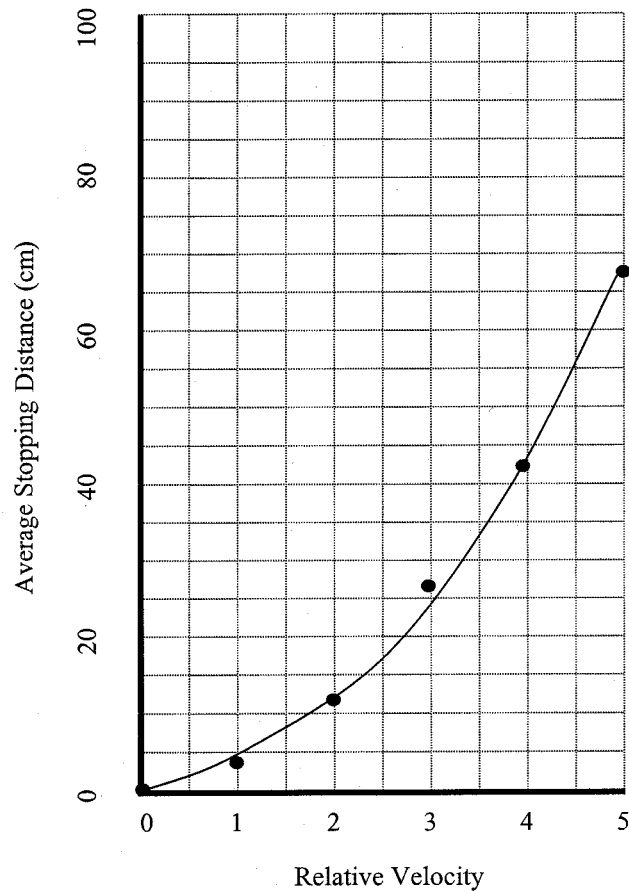
This trial was done with the slider sliding on the surface of a table.

Note: Be sure to position the car so that the middle of the car, the centre of mass, is at the calibrated release point. If the front of the car is used, the first sliding distance will be too large, making the ratios all too small.

Differences between group results can be attributed to the use of different cars.

Table A • Braking Distance

Relative Velocity	Group (cm)						Average Braking Distance (cm)
	#1	#2	#3	#4	#5	#6	
1	3.3	2.4	5.3	2.5	1.5	2.9	2.8
2	13.8	10.9	13.1	9.0	9.2	13.5	11.6
3	29.7	28.3	28.8	20.8	22.9	22.7	25.5
4	50.9	43.7	47.8	30.2	36.9	45.6	42.5
5	81.2	71.9	79.8	51.0	56.7	63.5	67.3

**Think About IT!—Page 55**

**Think
About
IT!**

1. The shape of the graph is a curve, curving upwards to the right.
The braking distance increases more than the velocity.
If the velocity doubles, the braking distance is 4X.
This is an **exponential relation**.
2. In terms of driving, one must realize that the braking distance increases more rapidly than velocity.
Larger velocities require much larger stopping distances.

Challenge—The effects of friction on braking

Students can adjust the surface on which the slider will be sliding.

To simulate gravel, a thin layer of sand, one grain thick, can be used on the table or floor. The following results were obtained.

Again, the different cars had an effect on the stopping distance.

The effect of stopping on the sand was to increase slightly the stopping distance, as a comparison of the average stopping distances from Tables A and B illustrates.

The results below in table B are for Group #1 from Table A.

Table B • Braking on Sand

Relative Velocity	Trial #1 (cm)	Trial #2 (cm)	Trial #3 (cm)	Average Braking Distance (cm)
1	2.5	3.5	3.5	3.2
2	16.5	16.0	15.0	15.5
3	33.0	36.0	34.0	34.3
4	48.0	58.0	53.0	53.0
5	78.0	89.0	80.0	82.3

**Think
About
IT!**

Think About IT!—Page 55

1. The effect of snow, rain, and ice is to lengthen braking distance.

These reduce the force of friction between the tires and the road.

With friction supplying the stopping power, and with friction decreased, it will take a longer distance to stop the car.

Math Connection

The ratio is calculated by dividing each stopping distance by the first stopping distance.

$$\text{Ratio} = (\text{Stopping distance}) / (\text{First stopping distance})$$

Table C

Ideal Ratio	Ratio: Table	Ratio: Table with Sand
1	$2.8 / 2.8 = 1$	$3.2 / 3.2 = 1$
2	$11.6 / 2.8 = 4.1$	$15.5 / 3.2 = 4.8$
3	$25.5 / 2.8 = 9.1$	$34.3 / 3.2 = 11$
4	$42.5 / 2.8 = 15$	$53.0 / 3.2 = 17$
5	$67.3 / 2.8 = 24$	$82.3 / 3.2 = 26$

Again, the result for the average stopping distance for the relative velocity of 1 is the critical measurement. If this value is inordinately small or inordinately large, the values of the ratios are skewed.

PRACTICE—PAGE 56

Note to Teacher: Calculation on page 56 should be $d = 0.06 \times (13.92 \text{ m/s})^2$.

- The value of K changes with the surface. It will make the effect of friction on stopping distance evident to the student if stopping distances are computed for all surfaces. (Three significant digits were used in these calculations.)

Table D • Braking Distance (m)

Velocity		Dry Pavement	Wet Concrete	Snow and Ice
km/h	m/s	$d = (.06)v^2$	$d = (.10)v^2$	$d = (.15)v^2$
10	2.78	0.46	0.77	1.15
20	5.56	1.85	3.09	4.63
30	8.33	4.16	6.93	10.4
60	16.7	16.7	27.8	41.7
90	25.0	37.5	62.5	93.8

- In all cases the braking distance at 60 km/h is 4 times the braking distance at 30 km/h.

Total Stopping Distance

Note To Teacher: To avoid some confusion, convert km/h to m/s first before using the velocity relationship.

It is important to point out to students that units must be the same on each side of the equation.

$$d = v t$$

$$m = ? s$$

v must have units of m/s in this case.

PRACTICE—PAGE 57

1. Car traveling at 60 km/h on a rain-soaked road. Reaction time is 1.5 s.

Reaction Distance:

$$t = 1.5 \text{ s}; v = 60 \text{ km/h} \div 3.6 = 16.67 \text{ m/s} = 17 \text{ m/s (rounded to 2 significant digits)}$$

$$d = ?$$

$$d = v t$$

$$= 17 \text{ m/s} \times 1.5 \text{ s} = 25 \text{ m}$$

Braking Distance:

$k = 0.10$ for wet concrete.

$$d = kv^2$$

$$= (0.10)(17)^2$$

$$= 29 \text{ m}$$

$$\begin{aligned} \text{Total stopping distance} &= \text{Reaction distance} + \text{Braking distance} \\ &= 25 \text{ m} + 29 \text{ m} = 54 \text{ m}. \end{aligned}$$

Reaction Time



**Try
IT!**

Try IT!—Page 58 and 60

Note to Teacher: Two classes performed this activity to determine their reaction times. The first group did the trials in the order given: no distractions, with impaired visibility, and distracted by talking. The reaction times were basically the same for each case. This can be attributed to the amount of practice the students had before performing each trial.

In the results given below, the students were asked to perform the trials in the reverse order of that given in the *In Motion* booklet. Here, the reaction times for “no distractions” are noticeably better than the times for “with distractions”.

Sample Data:

Table E

Student	Average Distance Metrestick Falls (m) No Distractions	Reaction Time (s)	Average Distance Metrestick Falls (m) Distraction— Impaired Visibility	Reaction Time (s)	Average Distance Metrestick Falls (m) Distraction— Talking	Reaction Time (s)
1	0.18	0.19	0.29	0.24	0.51	0.32
2	0.16	0.18	0.39	0.28	0.45	0.30
3	0.06	0.11	0.13	0.16	0.16	0.18
4	0.08	0.13	0.18	0.19	0.29	0.24
5	0.14	0.17	0.24	0.22	0.24	0.22
6	0.10	0.014	0.18	0.19	0.36	0.27
7	0.16	0.018	0.36	0.27	0.34	0.26
8	0.14	0.17	0.20	0.20	0.39	0.28
9	0.51	0.032	0.68	0.37	0.48	0.31
10	0.26	0.023	0.20	0.20	0.45	0.30
11	0.11	0.15	0.24	0.22	0.24	0.22
12	0.13	0.16	0.31	0.25	0.18	0.19
13	0.18	0.19	0.11	0.15	0.65	0.36
14	0.11	0.15	0.11	0.15	0.22	0.21
15	0.13	0.16	0.42	0.29	0.22	0.21
16	0.47	0.47	0.61	0.35	>1.00	>0.45
17	0.13	0.16	0.16	0.18	0.14	0.17
18	0.11	0.15	0.16	0.18	0.14	0.17

**Think
About
IT!**

Think About IT!—Page 60

1. If a car that is being tail-gated stops suddenly, the tail-gating car crashes into the car. The reason is the reaction distance. The tail-gater's car and the other car should have the same braking distance.

The problem is the distance the tail-gating car travels while the driver is reacting. That extra distance the tail-gating car travels is enough to cover the distance between the two cars. Hence, the two cars crash.

Note to Teacher: Students can test their reaction time and find the reaction distance, braking distance, and total stopping distance using a Java applet found at:

<<http://www.phy.ntnu.edu.tw/java/Reaction/reactionTime.html>>

This is an excellent activity that clearly demonstrates the factors that affect the total stopping distance of a vehicle. Students can change the speed of the vehicle to demonstrate the effect of increasing or decreasing speed on the total stopping distance.

<<http://www.javacommerce.com/cooljava/games-normal/reactiontime.html>>

This site allows students to test their reaction time.

PRACTICE—PAGE 60

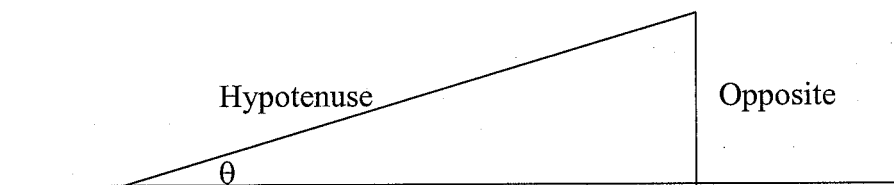
1. For the ideal case with no distractions, the reaction time of a typical student measured by catching a falling ruler is about 0.2 s. Using the applets above, a typical reaction time is about 0.4 s for depressing a mouse button.

The acceleration of the Mini-V down the ramp can be found with the following method. The acceleration of the Mini-V is given by the relationship

$$a = \sin \alpha (980 \text{ cm/s/s}),$$

where α = the angle the ramp makes with the horizontal.

$\sin \alpha$ is the ratio of the vertical height to a point on the ramp, divided by the distance that point is up the ramp from the end that touches the table (opposite/hypotenuse).



The formula $v^2 = 2aD$ can then be used to find the final velocity with which the Mini-V rolls off the ramp.

In this case, v = final velocity and D = the distance from the bottom of the ramp to the release point of the car.

Remember, the midpoint of the car should be positioned at each release point.

The trials used a vertical rise of 27 cm for a hypotenuse of 100 cm.

Thus, $\sin \alpha = 27/100 = 0.27$ and the acceleration if the Mini-V was $a = \sin \alpha (980 \text{ cm/s/s})$, $a = 0.27 (980 \text{ cm/s/s}) = 265 \text{ cm/s/s}$

The relative velocity for release point 1 (5.0 cm) can be calculated.

$a = 265 \text{ cm/s/s}$ and $Dd = 5.0 \text{ cm}$

$v^2 = 2aDd = 2 (265 \text{ cm/s/s}) (5.0 \text{ cm}) = 2650$

$v = 51.5 \text{ cm/s}$

The other velocities are just multiples of 51.5 cm/s.

The reaction distance is calculated using $Dd = vDt$.

The total braking (stopping) distance is the sum of the reaction distance and the braking distance (measured in the activity on page 55).

Table F

Relative Velocity	Actual Velocity (cm/s)	Braking Distance (cm)	Reaction Time (s)	Distance Traveled During Reaction Time (cm)	Total Braking Distance (cm)
1	51.5	2.83	0.200	$(51.5)(0.200) = 10.3$	11.1
2	103	11.6	0.200	$(103)(0.200) = 20.6$	32.2
3	154	25.5	0.200	$(154)(0.200) = 30.9$	56.4
4	206	42.5	0.200	$(206)(0.200) = 41.2$	83.7
5	258	67.3	0.200	$(258)(0.200) = 51.6$	118.9

If a reaction time of 0.400 s is used, the reaction distance will double, which will increase dramatically the total braking distance at high speeds.

Table F

Relative Velocity	Actual Velocity (cm/s)	Braking Distance (cm)	Reaction Time (s)	Distance Traveled During Reaction Time (cm)	Total Braking Distance (cm)
1	51.5	2.83	0.400	$(51.5)(0.400) = 20.6$	23.4
2	103	11.6	0.400	$(103)(0.400) = 41.2$	52.8
3	154	25.5	0.400	$(154)(0.400) = 61.8$	87.3
4	206	42.5	0.400	$(206)(0.400) = 82.4$	124.9
5	258	67.3	0.400	$(258)(0.400) = 103$	170

Again, the effect of reaction time and increased velocity can be illustrated by the applets mentioned earlier in this section.

2. When the first car begins to brake, the driver of the second car must perceive this action, process the information, and react by putting his foot on the brake. This reaction time results in the second car traveling the “reaction distance.”

If both cars are assumed to stop equally well when braking, the reaction distance will represent the minimum following distance that the second car can safely follow the first car.

<<http://www.visualexpert.com/Resources/reactiontime.html>>

The website above includes information on the factors that affect reaction time.

The reaction distance is calculated using a typical reaction time of 1.50 s. The speed of the car is 60 km/h, which must be converted to m/s by dividing by 3.6.

$$v = 60 / 3.6 = 16.7 \text{ m/s}$$

$$Dt = 1.50 \text{ s}$$

$$Dd = vDt$$

$$= (16.7 \text{ m/s})(1.50 \text{ s}) = 25.0 \text{ m}$$

Again, this is the absolute minimum following distance.

3. At 70 km/h, the speed is $70 / 3.6 = 19.4 \text{ m/s}$.
 The reaction distance is $(19.4 \text{ m/s})(1.50 \text{ s}) = 29.1 \text{ m}$.
 This is about seven car lengths with a bit of a cushion.
 At 80 km/h, the speed is $80/3.6 = 22.2 \text{ m/s}$.
 The reaction distance is $(22.2 \text{ m/s})(1.50 \text{ s}) = 33.3 \text{ m/s}$.
 This is about eight car lengths with a bit of a cushion.
 At 90 km/h, the speed is $90/3.6 = 25.0 \text{ m/s}$.
 The reaction distance is $(25.0 \text{ m/s})(1.50 \text{ s}) = 37.5 \text{ m}$.
 This is about nine car lengths with a bit of a cushion.
 The safe following distance for a car should be about one car length per 10 km/h.
 The recommended safe following distance has been replaced with a safe following time.
 This following time should be 3–4 s.
4. Using the answers to Practice #1, page 56, on dry pavement, the braking distance is 16.7 m at 60 km/h. A speed of 60 km/h would seem to be a good guess to be able to stop in 35 m.

The calculation of stopping distance requires the calculation of reaction distance, using $Dd = vDt$ plus the calculation of braking distance using $Dd = kv^2$. In both cases, v must be in m/s.

At 60 km/h:

$$v = 60 / 3.6 = 16.7 \text{ m/s and } Dt = 1.50 \text{ s}$$

$$\text{Reaction distance: } Dd = vDt = (16.7 \text{ m/s})(1.50 \text{ s}) = 25.0 \text{ m}$$

Braking distance is 16.7 m.

Total stopping distance is 41.7 m. The pedestrian would be struck by the car.

If we try a speed of 50 km/h, we get the following stopping distance.

$$V = 50 / 3.6 = 13.9 \text{ m/s and } Dt = 1.50 \text{ s}$$

$$\text{Reaction distance: } Dd = vDt = (13.9 \text{ m/s})(1.50 \text{ s}) = 20.8 \text{ m}$$

$$\text{Braking distance: } d = kv^2 = (0.06) (13.9 \text{ m/s})^2 = 11.6 \text{ m}$$

$$\text{Stopping distance} = 32.4 \text{ m.}$$

A car would have to be traveling at about 50 km/h in order to stop in time to avoid hitting the pedestrian.

5. The three-second rule for a safe following distance allows the driver of the second car to travel with a reaction time of 1.5 s without braking, then hit the brakes, and still stop in time to avoid a collision with the car ahead.

The braking distance varies with the square of the speed of the car. If the speed doubles, the braking distance increases by a factor of 4. However, since both cars are assumed to brake equally well, the braking distance will be the same for each vehicle.

If cars follow at a certain distance, say 10 m, this may be more than the reaction distance at a low speed. As the speed increases, the reaction distance increases in proportion to the speed of the vehicle. If the speed doubles, the reaction distance doubles. So the 10-m following distance would no longer be a safe following distance.

However, if the following time is used, the car will automatically increase the following distance to keep it safe. In 3 s, the car will travel twice as far if the speed is doubled. Since this is now the following distance, it will be a safe distance. The car will be able to stop in the reaction distance.

In inclement weather, the braking distance increases. The extra second provides a larger following distance, a cushion, which can be used up by the extra braking distance the second car may have.

The Final Challenge—Car Crash

Note to Teacher: This treatment of the crash scene is contingent upon using the revised crash scene map as outlined in the Preface, page A262.

The motorcyclist was heading south. The motorcycle is found in the intersection after the accident. This indicates the motorcycle hit an object, which stopped the motion of the motorcycle. A large force was needed to stop the motorcycle quickly. Such a force could be provided by the crash between the motorcycle and a car. This is an application of Newton's Second Law.

The motorcycle had significant kinetic energy (energy related to motion). This energy was transformed into other forms as the motorcycle came to a stop. Part of the energy was used to do work in damaging the motorcycle and the car's body. Other forms of energy, such as heat and sound, were also produced as a result of the collision event.

The motorcyclist and her helmet are found south of the intersection and the motorcycle itself. Since the motorcyclist was traveling south when the motorcycle crashed into the car, the motorcyclist and her helmet, which were in motion, continued in motion until an unbalanced force acted on them. That unbalanced force was provided by the road. This is an application of Newton's First Law. When the motorcyclist landed on the ground, the force of friction between the road and the motorcyclist brought her to a stop. Again, this is an instance of Newton's Second Law in operation.

Again, the motorcyclist possessed significant kinetic energy. This energy was converted into other forms, like heat as the motorcyclist slid along the road.

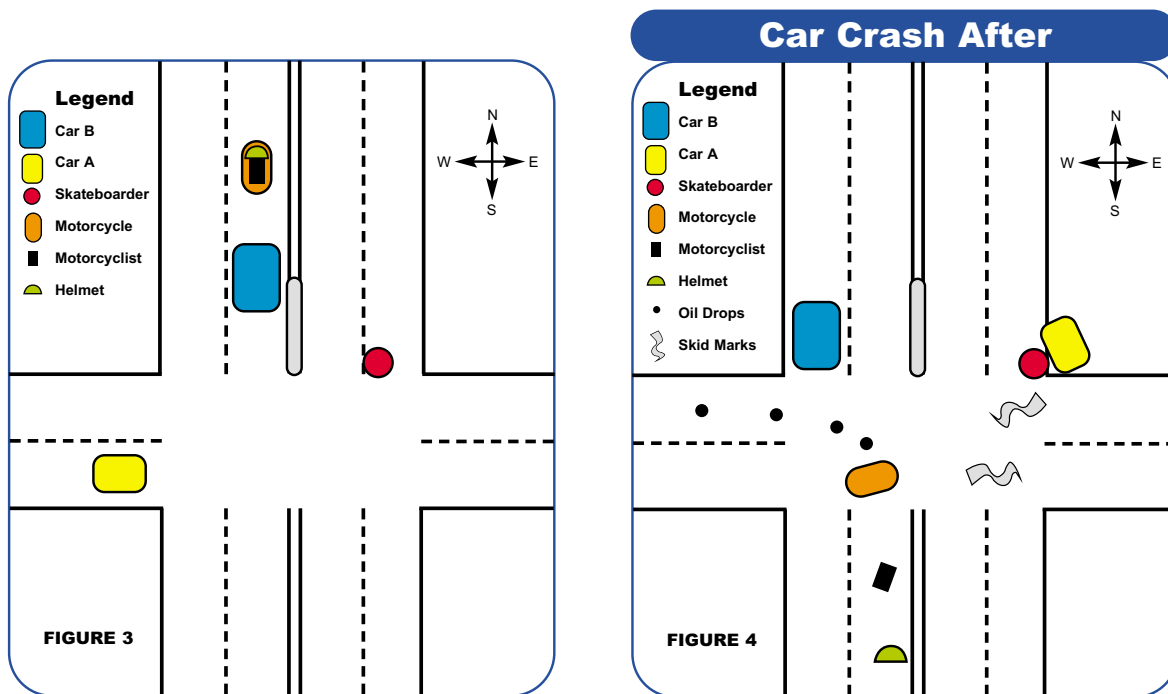
If the motorcycle struck the front fender of Car A, the force of the collision would have pushed the front of Car A in a southerly direction. Car A would then have traveled in a more southeasterly direction. If the motorcyclist struck the rearmost portion of Car A, this would push the rear of Car A to the south. Car A was already turning north (we could assume), so the rear of Car A would slide to the east, and the direction Car A would take would then be more northerly and somewhat east of north. The skidmarks east of the intersection would be consistent with the rear tires sliding sideways in an easterly direction. Alternatively, the skidmarks may have nothing whatever to do with this particular incident.

The skidding car would lose kinetic energy. The tires sliding on the road heated up enough to leave marks on the road. After Car A's rear tires stopped sliding, Car A continued in motion forward, ending up on the walkway where the skateboarder was located. When the skateboarder bailed (as we assume occurred), his skateboard, already in motion, stayed in motion until acted upon by an unbalanced force during its collision with the rear fender of Car A.

Oil Drops:

The oil drops are drawn in the incorrect position in the diagram as seen in *In Motion — A Student Resource*. They should be positioned, as indicated, in the intersection near the spot where the motorcycle came to rest. If this was the correct placement of these drops, then the drops act like the dots on a ticker timer. The dots trace out the path of some vehicle that may or may not have been involved in the incident. For instance, the skidmarks could have been from a driver who entered the intersection at the time of the accident, was struck, but then took evasive action and fled the scene altogether. Students should actively speculate on this or similar scenarios.

Another point in favour of the version of the story given by Car A’s driver is the fact that the skateboarder was crossing the intersection, moving to the east (or west), which meant that Car A, going east, should have had a green light. This final bit of information should demonstrate that the motorcyclist ran the red light. Or did she...?



Chapter 7

Driving Responsibly

Case Study #1

Note to Teacher: Depending on the time of the school year, students may already have taken Driver Education. Many of the responses reflect the messages of Driver Education. Teachers should be able to draw on the experiences of their students from their Driver Education classes or their in-car driving experience. The responses in this section are representative student samples.

In Case Study #1, students did poorly on the third part of the report: Evaluate available research. The point of this was for students to research the effect of moderate amounts of alcohol and distractions on reaction time and reaction distance. The effects of alcohol and distractions are to increase the reaction time and, hence, stopping distance. The message is that people should not drink and drive, even if their blood alcohol content is below 0.08. Secondly, drivers must give the task of driving their undivided attention.

Challenge — Sample #1

a. Assess and clarify the problem.

In this study, it seems that people are always getting away with irresponsible behaviour. For example, drinking but just slipping by with a lower blood alcohol level. This makes lots of people enraged, especially in this case where the driver hit the woman. It is confusing who caused the problem in this situation. The woman wasn't cautious and safe, and wore dark colours that blended her in with the night. On the other hand Mr. Smith was distracted by a hockey game at night and had drunk a few beers earlier. You don't know who to fault in this.

b. Review the police actions.

The police's actions in this were what they had to act according to the law. It is perfectly legal to drive under 0.08 blood alcohol level so they could not charge him for anything. To lots of people it may not seem right that he drink and drove, never mind hitting someone but the police did what they had to do. They had no other option because of the law.

c. Evaluate the available research.

The police investigated and questioned Mr. Smith in the normal basic way about what happened. They found the main things to lead onto: drinking beer, and not seeing Ms. Martin. They then took a Breathalyzer test and found out his blood alcohol level was only 0.06, below the limit. They didn't need to do any more research because what he did was obviously an accident from the evidence, and he was below the blood alcohol level.

d. Develop a course of action to reduce such incidents.

An extreme may be to just change the law, and lower the blood alcohol level to 0 as it is for some groups of people today. It would most likely be effective in reducing some of the incidents but people will also be angry with this. Another way may be to try and reduce distractions of people, such as banning cell phones in cars, or radios. People should be advised to wear visible bright clothes at night for their own safety. Have streetlights not only at crosswalks but so that the street is lit up everywhere, creating better visibility.

Challenge — Sample #2

1. “Assess and clarify the problem...”

There are several problems with situations like these. First of all, probably the most important, was that Mr. Smith was drinking. Although his blood-alcohol content was below the legal limit, alcohol still affects your alertness and visibility. Another problem is that Mr. Smith was listening to a hockey game on the radio. This would have provided a huge distraction to Mr. Smith. Add that to the fact that he already had a few beers clearly establishes that Mr. Smith was very distracted from assessing the road conditions and taking control of his car. The third problem is that Ms. Martin did not check both ways before crossing the street. Most of us are taught to look both ways before we cross the street but this must have slipped from Ms. Martin's mind. She should have taken extra care before stepping off the boulevard because it was fairly late at night. Finally, another problem is that Mr. Smith applied the brakes too late. If he had been going at a slightly lower speed he probably would have been able to stop in time. The time of day and his mental state are factors that add to the fact that he was driving too fast for his particular situation.

2. “Review the police actions...”

I think the police should have dealt with this situation a little more aggressively. Someone's life was at risk here and it seems that all they did was casually question Mr. Smith. The fact is that Mr. Smith ran over someone. In today's world, it doesn't seem right that you can just run over someone and not suffer any consequences. Mr. Smith had been drinking, and although he did not drink to the limit of 0.08, he did still have a few drinks which most likely affected his judgment. The police should have had a closer look at the situation. There are other options for punishment, such as taking away Mr. Smith's driver's license for a period of time.

3. “Evaluate the available research...”

The research into this situation is a little vague. Mr. Smith was apparently late to pick his wife up. When we're late and we're driving, our natural tendency is to pick up the pace. So why does the report say that Mr. Smith was running late, but he was driving at the speed limit? It doesn't make a lot of common sense. The report also does not mention the position of the car and if there was any physical evidence in the environment, such as skidmarks on the ground. Maybe Mr. Smith was lying and his judgment was too impaired that he never braked at all. Also, I find it a little strange that he never saw Ms. Martin. It would only make sense that he never saw her if the street corner was very dark, since she was wearing a dark blue coat. The report, overall, was just not thorough enough.

4. “Develop a course of action to reduce such incidents...”

There are a few things we can do to reduce such incidents. Ms. Martin was wearing a dark coat. Maybe if the street intersection was lit more brightly Mr. Smith would have seen Ms. Martin in time to prevent the accident. The main course of action we can take is to re-assess the legal limit of blood-alcohol content and the penalties for people who have been in an accident but are under the legal limit. In this particular situation, I think Mr. Smith should have been charged with at least some kind of offense. His offense was that he caused the accident. There's only so much authorities can do. The rest is up to the decisions of the public, such as Mr. Smith's decision to have a few beers before driving and Ms. Martin's decision to not look both ways before she crossed the street.

Challenge — Sample #3

The problem is that Mr. Smith hit Ms. Martin when driving at nighttime. Mr. Smith is partly to blame for the accident. Mr. Smith had a few drinks and was listening to the radio while he was looking for the street to turn on. Mr. Smith was being distracted by the radio while driving, and his reaction time is slower because of the alcohol in his body. Old age is also a cause of slow reaction time. He was also driving at the maximum speed limit. He was driving too fast for the conditions he was in. The accident was also Ms. Martin's fault. She was wearing dark colours at nighttime, and it is hard for drivers to see dark colours. Ms. Martin also crossed in the middle of the street without looking both ways for oncoming traffic.

The police didn't charge Mr. Smith with any offences because Mr. Smith's blood-alcohol content was 0.06 mL/L of blood and was below the legal limit of 0.08. He never got charged for hitting Ms. Martin because it was partly her fault that she got hit. She never checked before crossing the street and she was wearing dark clothes. The police couldn't charge anyone because no one was breaking the law. Mr. Smith's blood-alcohol level was below the limit, and he was driving the speed limit.

To reduce such incidents, people could drive a little slower at nighttime because they can't see as good. People could wear bright clothes when walking or biking at nighttime, so that drivers can see them better from a farther distance. Drivers can also put on their high beams when there are no oncoming cars. This will allow them to see farther ahead. People that have been drinking should never drive because even though their blood-alcohol is below the limit, it still affects their driving. Pedestrians can also check both ways before crossing the street.

Case Study #2

Anticipation Guide—Sample #1

1. Drivers who have serious accidents are likely to be the common troublemakers.

Before: No, I do not agree. People who have serious accidents are not always troublemakers. That is why they are called accidents. The person is not always trying to do it, it is an accident.

After: No, they are still not said to be “troublemakers.”

Comments: The driver in the newspaper article was said to be a good person, but he still had a serious accident and wasn’t labeled a troublemaker.

2. Criminal charges should be laid against young drivers who are involved in accidents.

Before: It depends on what the accident was, and how it was caused. If it was caused in an illegal way such as drinking, then it is the person’s own fault and they should be charged.

After: Once again, I think it depends on the degree that it happened.

Comments: In the article, yes, the driver was traveling way over the speed limit, and that is bad enough as it is, but it caused a death. In this case, though, I wouldn’t charge him. People make mistakes.

3. The laws of physics suggest cars that are out of control can be brought back into control.

Before: Yes, it does suggest that. They can be stopped by an unbalanced force and put back into control. Not always, but sometimes.

After: Yes, I still think it does.

Comments: It may be hard to get thing back into control, and sometimes impossible, but lots of times it may work. You just have to have the knowledge of how it works.

4. Most serious accidents caused by teenage drivers are the result of illegal narcotics or high blood-alcohol levels.

Before: Yes, from what I remember, that is the biggest cause of most serious accidents.

After: No, most serious accidents by teenage drivers are the result of speeding.

Comments: I think that if more people knew this (because I know I didn’t), it may help reduce the chances if the greatest are from speeding.

5. New driving laws, like Graduated Driver Licensing, drafted specifically for novice drivers, are intended to maintain unreasonable control over young adults.

Before: No, it is intended to help decrease accidents because it is proven that most accidents occur from teenage drivers.

After: No, they aren't.

Comments: The new driving laws are to try and get the kids comfortable with driving on the roads and not have to have peer pressure on them at the beginning.

Anticipation Guide—Sample #2

1. Drivers who have serious accidents are likely to be the common troublemakers.

Before: I think this statement is generally false. Your driving habits don't always reflect what you do outside of the vehicle. I definitely think that your attitude affects your driving, but if you get in a serious accident it may not be your fault and it may be because of other factors, like the weather or having a child in the car, etc.

After: After reading the article, it seems that the driver of the Mercury was obviously driving way over the speed limit and was out of school. The article didn't mention whether or not the driver was a "troublemaker" before, but I still agree with my BEFORE statement. Although alcohol and other factors affect your driving, I don't think that all people who have serious accidents will become common "troublemakers."

Comments: The driver of the vehicle will have to live with the guilt of killing a person for the rest of his life. His whole life is changed and if he was a "troublemaker" before the accident, I doubt he would be one after.

2. Criminal charges should be laid against young drivers who are involved in accidents.

Before: I don't entirely agree with this statement. As young drivers, we are still learning the "rules of the road" and the effects of our actions, such as driving at higher speeds, etc. We have to be given the chance to make mistakes because learning involves making mistakes. Although it's not always the case, I don't think young drivers deserve to be held with criminal charges when they've only grown accustomed to the road for a short time.

After: I still agree with my above statement. Now that I've read the article, I realize how personal it can get and that a boy my age lost his life because of someone else's actions.

Comments: Since the driver didn't have a previous record, I don't think he should be charged criminally at this point. He deserves severe consequences though. The biggest consequence is living with his guilt for the rest of his life.

3. The laws of physics suggest cars that are out of control can be brought back into control.

Before: I agree with this statement. In Driver's Ed they taught us what to do under certain situations where your car does lose control. Let's say that you hit a patch of ice and begin to swerve. If you concentrate and take full control of the wheel without speeding up (accelerating) you can bring your vehicle back under control.

After: In the article, the driver overcorrected and this resulted in the collision. By maintaining control over the wheel, he probably could have prevented this.

Comments: Since the driver was driving at such a high speed, the braking distance would be so much longer than if he was going the speed limit. At the higher speed, the driver found himself in a situation where it takes so much longer to brake.

4. Most serious accidents caused by teenage drivers are the result of illegal narcotics or high blood-alcohol levels.

Before: Right now, I'd say this is probably true although inexperience and speed are two other major causes.

After: The article mentioned that speed is statistically the greatest threat to young drivers.

Comments: Although the article's statement is true, illegal narcotics or high blood-alcohol levels also play a large factor in serious accidents with young drivers. Also, teenagers aren't the only ones who speed. Adults also speed and may be under the influence of drugs or alcohol when they drive.

5. New driving laws, like Graduated Driver Licencing, drafted specifically for novice drivers, are intended to maintain unreasonable control over young adults.

Before: I don't agree with this statement. Honestly, I'm in GDL and completing in-car training with a professional and after about three months with my learners permit, I still need a lot of practice. I think you need control or else a lot of young drivers would be very inexperienced. The rules aren't that harsh and it's not really unreasonable control.

After: I think the program in the article was a pretty good idea. That's only for about three months with only giving rides to family members. With our GDL program, we have to have nine months with a licenced driver for three years in the car at all times.

Comments: All the driver had to do was follow the simple law, and his friend would probably be alive today. Breaking the law cost his friend's life.

Anticipation Guide—Sample #3

1. Drivers who have serious accidents are likely to be the common troublemakers.

Before: I think that serious accidents are not all caused by common “troublemakers.” It depends who caused the accident. All people make mistakes while driving, not just troublemakers. The troublemakers are the ones who get into a lot of accidents and cause the accidents.

After: Young kids usually get into accidents more than mature adults. Young kids are usually the troublemakers on the streets because when they start driving, they drive fast because they think they’re superman and won’t get hurt in an accident. They think driving fast is cool and they don’t think about dying in an accident.

Comments: Serious accidents aren’t all caused by common “troublemakers.”

2. Criminal charges should be laid against young drivers who are involved in accidents.

Before: The accidents could’ve not been caused by the young drivers and they should not be charged. Young drivers should get charged if they are the ones who caused the accident and if they broke any laws.

After: I think that if young drivers speed and violate traffic signals/signs, then they should be charged. They should be charged if they caused the accident, especially if someone is killed.

Notes

Online Webquests

<<http://www.physicsclassroom.com/Default2.html>>

This site is the “motherlode” for this cluster. It has an excellent treatment of 1-D kinematics (distance, displacement, speed, velocity, and acceleration) in terms of conceptual development via a number of modes (descriptions of motion in words, tables, graphs, and symbols). “Newton’s Laws” and “Momentum and Its Conservation” are two other pertinent topics.

<<http://www.phy.ntnu.edu.tw/java/Reaction/reactionTime.html>>

Java applet—Reaction, time, and distance.

<<http://www.phy.ntnu.edu.tw/java/carDistance/carAccident.html>>

Java applet—Speed, following distance, coefficient of friction, and average reaction time can be adjusted to determine the following distance needed under certain speed and road conditions to stop successfully as the car ahead of you brakes.

<<http://www.sdt.com.au/STOPPINGDISTANCE.htm>>

Web page on stopping distances varying with speed. It also includes stopping distances of various types of cars. Plus, this site is in metric!

<<http://www.pbs.org/wgbh/nova/listseason/26.html>>

Escape: Because Accidents Happen: Car Crash—NOVA

Original broadcast date: 02/16/99

Topic: technology/engineering

This program explores the contributions of Dr. Claire Straith, Bel Berenyi, Nils Bohlin, and John Hetrick.

While today’s cars are safer than they’ve ever been, automobile safety has come slowly and at the expense of millions of lives. Car Crash focuses on the unheralded heroes of automobile safety: Dr. Claire Straith, a Detroit plastic surgeon who fought in the 1920s to get padded dashboards and recessed knobs installed in cars to protect motorists’ faces in an accident; Bela Berenyi, a Mercedes engineer who completely changed the way cars were designed and built with the invention of crumple zone and rigid cab construction; Nils Bohlin, the Volvo engineer who holds the patent for the single most effective safety device in any car—the seat belt; and John Hetrick, the unsung inventor of the air bag, whose work was 20 years too early.

<<http://www.pbs.org/wgbh/nova/transcripts/2605car.html>>

This site has the transcript of the program *Escape: Because Accidents Happen: Car Crash*.

<<http://www.pbs.org/wgbh/nova/escape/timecar.html>>

A great site for a description of the contributions of Dr. Claire Straith, Bela Berenyi, Hans Bohlin, and John Hetrick.

<<http://www.pbs.org/wgbh/nova/escape/resourcescar.html>>

A host of student resources and activities concerning car safety.

<<http://www.riccilegal.com/FSL5CS/articles/articles31.asp>>

A history lesson on the evolution of the seat belt and the resistance of the automobile manufacturers to adopt their installation in vehicles.

<http://www.nader.org/history_bollier.html>

This site contains a book outlining a history of Ralph Nader's contributions to the automobile safety and consumer movements in the United States.

<<http://www.womanmotorist.com/sfty/index-safety-airbags.shtml>>

This site is all about air bags.

<<http://www.nhtsa.dot.gov/>>

This is the United States government site for traffic safety. Check out the links to videos showing car crashes and the resulting second collisions of anthropometric dummies with the interior of the vehicle. It has videos of all sorts of situations. This site has it all: statistics, ratings of cars, research, and much more.

<<http://www.tc.gc.ca/road/menu.htm>>

This is the Transport Canada site for road transportation safety.

<<http://www.netsoc.dit.ie/~ncolgan/phe/n2law.htm>>

Newton's Second Law applet. Students can vary the mass of the car being accelerated or the mass of the hanging mass used to accelerate the cart. The mass under acceleration by the hanging mass is the mass of the cart PLUS the mass of the hanging mass.

<<http://www.netsoc.dit.ie/~ncolgan/>>

A site with a lot of applets, mostly those by W. Fendt.

<<http://www.cs.uleth.ca/students/berdine/>>

This site has Newton's Cradle demonstrating a number of different motions, including one sphere released from each side.

<<http://www.walter-fendt.de/ph14e/>>

This site has the latest updated applets from Walter Fendt. These can be downloaded and run from computers without an Internet connection simply by using the browser.

<<http://www.physics.gatech.edu/academics/Classes/summer2002/2211/main/demos/>>

This is a compilation of many applets from different sources. There is a particularly good one on distance versus displacement. This also has applets for *In Motion* with constant acceleration, Newton's Second Law, Newton's Cradle, and conservation of momentum with an astronaut tossing a ball in space.

<<http://www.visualexpert.com/Resources/reactiontime.html>>

This site (www.visualexpert.com) has a host of information on human perception, especially visual, and the factors that affect this. The information is applied to humans as drivers.

<<http://www.nhtsa.dot.gov/people/outreach/traftech/pub/tt201.html>>

The effect of the combination of alcohol and marijuana on the reaction time of drivers is detailed here. This would be a good site for the Chapter 7 case studies.

<<http://www.nsc.org/library/shelf/inincell.htm>>

The results of a study "Does Cell Phone Conversation Impair Driving Performance?"

Notes

Senior 2

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