Grade 12 Physics (40S)

A Course for Independent Study

Field Validation Version

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2009

Manitoba Education, Citizenship and Youth

Manitoba Education, Citizenship and Youth Cataloguing in Publication Data

530 Grade 12 physics (40S) : a course for independent study.—
Field validation version

ISBN-13: 978-0-7711-4264-2

1. Physics—Study and teaching (Secondary).
2. Physics—Programmed instruction. 3. Physics—
Study and teaching (Secondary)—Manitoba. I. Manitoba.
Manitoba Education, Citizenship and Youth.

Manitoba Education, Citizenship and Youth
School Programs Division
Winnipeg, Manitoba, Canada

Any websites referenced in this document are subject to change. Educators are advised to preview and evaluate websites and online resources before recommending them for student use.

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ACKNOWLEDGEMENTS

Manitoba Education, Citizenship and Youth gratefully acknowledges the contributions of the following individuals in the development of *Grade 12 Physics (40S): A Course for Independent Study, Field Validation Version*.

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Grade 12 Physics (40S)

Module 1: Kinematics

This module contains the following:

- Introduction to Module 1
- Lesson 1: Grade 12 Physics: A Course for Independent Study
- Lesson 2: Kinematics—Bringing You Up To Date
- Lesson 3: Deriving Equations for Motion Involving Uniformly Accelerated Motion
- Lesson 4: Using Kinematics Equations for Constant Acceleration to Solve Problems
- Lesson 5: A Review of Working with Vectors
- Lesson 6: Relative Motion
- Module 1 Summary

Module 1: Kinematics

Introduction to Module 1

Welcome to the first module of Grade 12 Physics.

This first module introduces this Independent Study Option (ISO) course and provides some of the information you will require to complete it successfully. The study of kinematics will tap into your prior knowledge by linking concepts you have already studied to some new ideas and applications. Kinematics refers to the study of motion. You will be building on the knowledge of motion you acquired from previous science courses.

Lesson 1: Grade 12 Physics: A Course for Independent Study provides information about how an ISO course works. This lesson describes what you must do in order to complete the course and receive your credit.

Lesson 2: Kinematics—Bringing You Up To Date is a review of the concepts of position, displacement, velocity, and acceleration, as well as the four different ways of representing motion (physical/conceptual, numerical, graphical, and symbolic).

Lesson 3: Deriving Equations for Motion Involving Uniformly Accelerated Motion involves the derivation of the special equations for constant acceleration. Basically, you will relate the graphical representation of motion to some new symbolic relationships.

Lesson 4: Using Kinematics Equations for Constant Acceleration to Solve Problems introduces a method of solving problems called the "GUESS" method. You will employ this method to solve problems for accelerated motion along a straight line.

Lesson 5: A Review of Working with Vectors is a review of vectors. Here, you work with parallel, antiparallel, and perpendicular vectors.

Lesson 6: Relative Motion deals with relative motion, an application of vectors to the motion of objects in a frame of reference that is also moving.

Assignments in Module 1

You will be completing the following two assignments, which you will send to your tutor/marker when you have completed Module 2. Assignments from Modules 1 and 2 will be submitted together.

Lesson	Assignment Number	Assignment Title
4	Assignment 1.1	Equations of Motion
6	Assignment 1.2	Relative Motion

Lesson 1: Grade 12 Physics: A Course For Independent Study (1 hour)

Overview

Welcome to Grade 12 Physics!

Grade 12 Physics continues the study of basic concepts that will form the foundation for you to study physics in the future. You have already studied many concepts in physics. For example, in Grade 9 Science you studied electricity. In Grade 10 Science you studied the motion of vehicles and passengers, specifically how and why they move. In Grade 11 Physics you studied kinematics and dynamics in more detail, plus you investigated waves, sound, and light. We will be referring to concepts that you have studied in the past as necessary prior knowledge for the new concepts you will learn in this course. Grade 12 Physics will expand upon, and more fully complete, the investigation of some ideas already considered, as well as introduce many new topics. Many topics studied later in the course require that you understand and are able to apply knowledge from earlier in the course.

This course is divided into four major topics. Each topic contains two or three modules, organized as follows:

Topic 1: Mechanics

- Module 1: Kinematics
- Module 2: Dynamics
- Module 3: Projectiles and Circular Motion
- Module 4: Work, Energy
- Module 5: Momentum

Topic 2: Fields

- Module 6: Exploration of Space and Low Earth Orbit
- Module 7: Electric Fields and Magnetic Fields

Topic 3: Electricity

- Module 8: Electric Currents
- Module 9: Electromagnetic Induction

Topic 4: Medical Physics

- Module 10: Medical Physics

What Will You Need?

In order to complete this course, you should have access to:

- **A computer with Internet access (optional):** If you do not have a computer with Internet access, you will still be able to complete the course, but you need to use alternative ways of accessing the required information.
- **A computer with a spreadsheet program (such as Microsoft Excel):** This is not a requirement, but would be a useful resource.
- **A computer with Graphical Analysis:** Graphical Analysis is software that helps you produce and analyze graphs. If you do not already have access to this software and you are attending school, ask your school's ISO Facilitator how you can obtain access. If you are not attending school, you would have received the software with the course.
- **A calculator:** We recommend that you use a non-programmable, non-graphing calculator as you work on this course because this is the kind of calculator you will be allowed to use while you complete your exams.

Please note that you do not need a textbook to complete this course. All of the content is in this package.

If you do not have access to one or more of these resources, contact your tutor/marker.

How Will You Know How You're Doing?

You will know how well you are learning by how well you complete the following things:

Midterm and Final Exams

The course contains a midterm exam and a final exam. You will write them both under supervision. The midterm exam is based on Modules 1 to 5 and is worth 20% of the final mark of the course. You will write it when you have completed Module 5.

The final exam is worth a total of 30% of your final mark. Most of it (25% of your final mark) is based on Modules 6 to 10. A small portion of it (5% of your final mark) is based on Modules 1 to 5. You will complete it when you have completed Module 10.

You will be allowed to use a calculator to write your exam. The calculator that you bring with you should be a **non-programmable, non-graphing calculator**.

In order to write your exams, you will need to apply for them. Here is how you can do that.

If you are attending school, ask your school's ISO Facilitator to add your name to the ISO exam eligibility list. Do this at least three weeks prior to the next scheduled exam week.

If you are not attending school, check the **Examination Request Form** for options available to you. The Examination Request Form was mailed to you with this course. Fill in this form and mail or fax it three weeks before you are ready to write your exam. The address is:

ISO Registration
555 Main St.
Winkler, MB R6W 1C4
Fax: 204-325-1719
Phone: 1-800-465-9915

Midterm and Final Practice Exams and Their Answer Keys

To be successful on your midterm and final exams, you need to complete the practice exams found at: http://www.edu.gov.mb.ca/k12/dl/downloads/index.html.

These exams are very similar to the actual exams that you will be writing. They also include answer keys, so that when you have finished writing them you can check your answers. This will give you the confidence that you need to do well on your exams. If you do not have access to the Internet, contact the Independent Study Option at 1-800-465-9915 to get a copy of the practice exams.

Assignments

Every module contains assignments that you will be sending to your tutor/marker for assessment. They are found in most lessons and are worth a total of 50% of your final mark.

What is a Typical Lesson Like?

The lessons in this course contain the following parts:

- **Learning Outcomes:** These are the things you should have learned by the completion of the lesson.
- **Introduction:** The introduction sets the stage for the lesson. It may draw upon prior knowledge or briefly describe the organization of the lesson.
- **Key Words:** This section contains a list of the important words that will be used throughout the lesson.
- **Body of the Lesson:** The body of the lesson develops the concepts. It contains explanations, diagrams, and fully completed examples.
- **Learning Activity:** Most lessons have one or more learning activities. These include questions that you should complete in order to help you practice or review what you have just learned. Learning activities are not assessed. In other words, you complete them and check your answers yourself (the answer keys are found at the end of the module). **Do not email learning activities to your tutor/marker.**

  Make sure you complete each learning activity, as it will help you practice what you have learned and prepare you to successfully complete your assignments and exams.
- **Lesson Summary:** The summary briefly describes the concepts that were developed within the lesson.
- **Assignments:** Assignments are found near the end of most lessons. In total, all assignments will be worth a total of 50% of your final mark. You will send these to your tutor/marker at the end of every module or every second module.

What if You Need Help?

There are two people who can help you be successful in your course.

Your Tutor/Marker

The first person who can help you is your tutor/marker. Tutor/markers are experienced teachers who tutor ISO students and mark assignments and exams. If you are having difficulty at any time during this course, be sure to contact your tutor/marker. They are there to help you. If you are not sure how to contact your tutor/marker, phone the ISO office at 1-800-465-9915

Your Learning Partner

The next person who can help you with your course is your learning partner. A learning partner is someone you choose who will help you learn. It may be someone who knows something about physics, but it doesn't have to be. A learning partner could be someone else who is taking this course, a teacher, parent, sibling, or a friend, or anybody else who can help you. Most importantly, a learning partner should be someone you feel comfortable with and will support you as you work through this course.

Your learning partner can help you keep on schedule, check your work, help you make sense of assignments, read your course with you, or look at your learning activities and respond to them. You may even study for your exam with your study partner.

How Much Time Will You Need?

Learning through independent study has several advantages over learning in the classroom. You are in charge of how you learn and can choose how quickly you will complete the course. You don't have to wait for your teacher or classmates, and you can work as quickly as you want. You can also complete as many lessons at a time as you want. We really want you to succeed. Read the next few pages to get an idea of how to pace yourself.

Why is the Course so Large?

This course seems larger than it actually is. Remember that this course package includes all the things that you would find in a regular face-to-face physics course taught in a classroom, such as the following:

- all the information that is normally found in a textbook
- all the notes that a teacher would hand out in class
- all the assignments that a teacher would hand out in class
- all the learning activities that a teacher would hand out in class, along with their answer keys
- all the explanations and instructions that a teacher would either say or write on a blackboard or whiteboard

This course also contains many diagrams and graphs, which tend to take up more room than straight text. This makes the course seem larger than it actually is.

In other words, even though there are many pages to this course, it should not take you more time to complete than if you were learning Grade 12 Physics in a classroom. You will be spending at least 45 minutes per school day to complete the course in a regular school year, or at least at least 90 minutes daily in a semester. Look at the following three charts and decide which chart best describes the time of year when you want to cover the course. This will help you plan your course so that you can complete it when you want to.

Chart A: Semester 1

Here is a suggested timeline that you can follow if you start your course in September and need to complete it by the end of January.

Module	Completion Date
Module 1	September 15
Module 2	September 30
Module 3	October 10
Module 4	October 20
Module 5 and Midterm Exam	October 31
Module 6	November 12
Module 7	November 25
Module 8	December 5
Module 9	December 20
Module 10 and Final Exam	January 15

Chart B: Semester 2

Here is a suggested timeline that you can follow if you start your course in January and need to complete it by June.

Module	Completion Date
Module 1	February 10
Module 2	February 24
Module 3	March 10
Module 4	March 20
Module 5 and Midterm Exam	March 31
Module 6	April 15
Module 7	April 30
Module 8	May 15
Module 9	May 31
Module 10 and Final Exam	June 15

Chart C: Full School Year (Not Semestered)

Here is a suggested timeline that you can follow if you have registered for this course in September and would like to complete it by June.

Module	Completion Date
Module 1	September 30
Module 2	October 20
Module 3	November 10
Module 4	November 30
Module 5 and Midterm Exam	December 20
Module 6	January 30
Module 7	February 28
Module 8	March 30
Module 9	April 30
Module 10 and Final Exam	May 31

Do not wait until the last minute to complete your work, since your tutor/marker may not be available to mark it. Make sure that you leave enough time for your work to travel through the mail, as it might take over a week. It may also take a few weeks for your tutor/marker to mark everything and send the marks to your school.

When Do You Send in Your Assignments?

You'll be mailing your assignments to your tutor/marker as soon as you have completed them. Each time you mail something, you must include the Module Cover Sheet. Here is a chart showing exactly what you will be mailing in at the end of each module.

Module	Assignments To Be Handed In
Modules 1 and 2	All assignments for Modules 1 and 2 at the end of Module 2
Modules 3 and 4	All assignments for Modules 3 and 4 at the end of Module 4
Modules 5	All assignments for Module 5 at the end of Module 5
Modules 6 and 7	All assignments for Modules6 and 7 at the end of Module 7
Modules 8 and 9	All assignments for Modules 8 and 9 at the end of Module 9
Module 10	All assignments for Module 10 at the end of Module 10

What are the Guide Graphics For?

Graphics have been placed inside the margins of the course to identify a specific task. Each graphic has a specific purpose to guide you. A description of each graphic is described below:

- **Assignment:** This is an assignment that you complete and send to your tutor/marker. You will be sending in your assignments at the end of every module or every second module.
- **Internet:** If you have access to the Internet, you can use it to get more information. Internet access is optional.
- **Learning Activity:** Complete this learning activity to help you review or practice what you have learned and prepare for your assignment and exam. You will not send learning activities to your tutor/marker.
- **Learning Partner:** Ask your learning partner to help you with this task.
- **Mail-in:** It is now time to mail in your assignments.

- **Time:** This icon gives you an approximate idea of the amount of time that you will need to complete this lesson or assignment. The actual time that it takes to complete an assignment varies from student to student, so these are just rough guides. If you find that you have completed an assignment in much less time than is listed on the icon, then you may need to spend more time on it. If you find that you are spending much more time than indicated, it may be time to move on.
- **Exam Preparation:** This icon refers to content in the course that is likely to be found on either the midterm or final exam, so learn it well.

The Appendices

Included with this course is an appendix. The appendix contains some information that is required for the course and some other information that could be useful in helping you to complete the course.

Here is a list of the appendices found at the end of this course:

Appendix A: Equation Sheet contains a list of equations grouped according to the topics covered in the course. This list of equations will be provided along with the exams that you will be writing. It is imperative that you learn which concept the equation refers to, the quantity associated with each symbol, and its unit of measurement.

Appendix B: Rounding Off provides the rules for rounding off numbers correctly.

Appendix C: Significant Digits provides the rules and examples for determining where to round off your answer based on the information provided in the question and the type of calculation that is performed.

Appendix D: Space Exploration contains information about the planets and the sun, which is required to solve problems in Module 6.

Appendix E: Table of Isotopes contains information about the isotopes of the elements that is used to solve problems in Module 10.

Appendix F: Grade 12 Physics Websites contains a list of websites for each of the modules. These websites may contain small programs called applets, or they may contain animations, either of which will illustrate a specific concept discussed in the lessons of that module. Check this appendix when you reach the end of a lesson to see if there was an applet or animation on the web that would help you to better understand the concepts for that lesson.

Appendix G: Glossary

Appendix H: List of Specific Learning Outcomes—You will not be using this appendix. It has been placed here to help classroom teachers using this course as a resource.

Use of Significant Digits

When submitting any assignments or when writing the exams, you are expected to round off your answer to the correct number of significant digits. In all of the work you will do, the answers should be rounded off to either 2 or 3 significant digits, as determined by the information provided in the question.

Refer to Appendix B: Rounding Off and Appendix C: Significant Digits. Please read these over and practice using these rules. With the diligent application of the rules for significant digits, you should use significant digits as automatically as you use punctuation when you write a sentence.

A Note to Classroom Teachers Using this Course as a Resource

The SLOs for each lesson are listed in Appendix H, which is found at the end of this course.

Summary

In this lesson, you learned how this course is designed, and how you can complete it.

Lesson 2: Kinematics—Bringing You Up To Date (1 hour)

Learning Outcomes

When you have completed this lesson, you should be able to

- ❑ define terms such as position, distance, displacement, speed, velocity, and acceleration
- ❑ describe motion in words, using a table of data, on a graph, and using equations

Key Words

position	distance	displacement
speed	velocity	acceleration
time instant	time interval	scalar
vector	rise	run
slope	reference point	uniform motion

Introduction

This first module reviews some of the terms and concepts that you studied in Grade 10 Science and in Grade 11 Physics. In Grade 10 Science, you were asked to describe motion in words, using numbers from measurements in a data table, using a graph of the measurements, and finally by using equations. You will recall that the graphs were particularly useful. The graphs that you drew—that is, position-time graphs, velocity-time graphs, and acceleration-time graphs—were all just different versions of the same story of the motion of an object. They not only described a motion, but they also allowed you to calculate some other quantities useful in describing motion.

In Grade 11 Physics, these concepts were expanded upon. You were required to convert one type of graph into another, such as a position-time graph into a velocity-time graph, or a velocity-time graph into an acceleration-time graph, by taking the slope of the lines of the first graph. Then you discovered that you could go in the opposite direction. You could start with an acceleration-time graph and reconstruct a velocity-time graph, or start with a velocity-time graph and reconstruct an acceleration-time graph. This second set of conversions required that you find the area between the line on the graph and the horizontal axis.

Also, in Grade 11 Physics, equations for kinematics were derived from the graphs and used to solve problems. In Grade 11 Physics, you were not required to learn the derivations of these equations. The derivations were provided simply to demonstrate to you the origin of these equations. Your task was to be able to use the equations to solve kinematics problems.

In Grade 12 Physics, you will be going one step further. Not only should you be able to describe motion in words, using a data table, using a graph of position-time, velocity- time, or acceleration-time, and using the appropriate equations, you must also be able to derive the equations for kinematics from the appropriate graph. Physics is not only about having a list of equations into which you can plug numbers. The equations of physics are the symbolic summary of the concepts involved in a particular topic. The concepts must be understood first before you can successfully work with problem solving.

So here's a bit of advice to ensure that you will have some success in the problem-solving process in Grade 12 Physics. Try to understand the big picture about the phenomenon that you are studying. What is the phenomenon? Into which topic does it fit? What are the variables or names of the factors that affect the situation? What symbols are used to represent these variables? Are they vectors or scalars? What units do they have? If you can't answer these questions, then even though you will be given the equations for that situation, you will be unable to solve problems.

In this first lesson, then, let's put this method of studying physics into practice!

A Review of Kinematics

You have already seen that there are many terms that are associated with describing motion: time instant, time interval, position, displacement, speed, velocity, and acceleration. Before we begin to talk about kinematics, which is the study of motion, it would be wise to review all of these terms.

A **time instant** is just a clock reading, such as 3:14 PM.

A **time interval** is simply the time that elapses between two clock readings or two instants in time. For example, the time interval between 3:14:25 PM and 3:14:39 PM is 14 seconds.

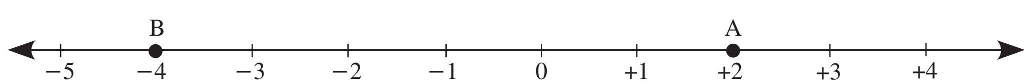
Time is a scalar quantity, meaning we can specify time using only magnitude. In SI, the unit we use for time is the second or s.

In order to talk about motion, we must be able to indicate where an object is located. An object moves when it changes its location.

The **reference point** is the zero location in a coordinate system or frame of reference.

Position is the location of an object in relation to the location of a specific point called the reference point.

Since in this section we are dealing only with motion along a straight line or straight-line kinematics, you can think of positions as falling along a straight line. A classic example would be the number line. The position of each number (for example, each integer) is marked on the line relative to the position of 0, the reference point. Numbers to the right of zero are considered to be positive numbers, and numbers to left the zero are considered to be negative numbers. In the same way, we can mark positions along a line.



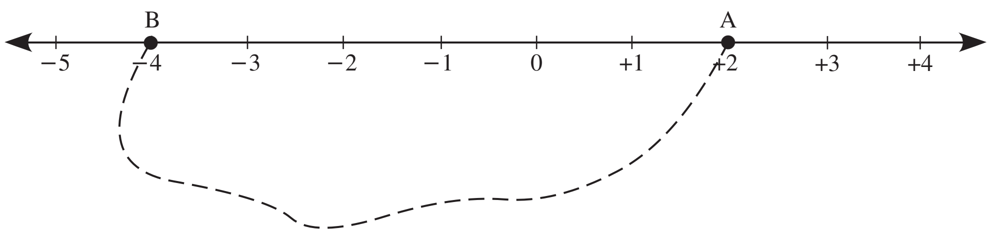
The reference point is zero, which we mark as 0 m.

The point A is located at a position of +2 m—that is, 2 m to the right of the reference point. Normally, we consider motion to the right or up as positive. In a given question, you should specify the directions for the motions.

The point B is located at a position of –4 m—that is, 4 m to the left of the reference point. Again, we consider motion to the left or down to be negative.

The points A and B represent two positions. A represents position 1 (pos_1) and B represents position 2 (pos_2). If the object moved from position A over to position B, then position A is called the initial position (pos_1) and position B is called the final position (pos_2).

Let's say a ladybug was to walk from position A to position B. Now, the ladybug is not likely to walk in a straight line, but rather to wander. A possible path is indicated below with the dashed line.



Along the path indicated by the dashed line, the ladybug travels a distance of 11 m during a time of 45 seconds.

> **Distance** (*d*) is the length of the path travelled by an object. It has no direction and is therefore a scalar quantity.

In this case, the distance travelled is 11 m, $d = 11$ m.

The time interval, Δt, is 45 s.

Speed

From these data, we can calculate how fast the ladybug was travelling. How fast an object travels is called its **speed**. Average speed is calculated by taking the total distance travelled over the total time interval.

Speed is a measure of how fast an object is travelling. Speed is calculated by the distance travelled over the time interval.

$$v = \frac{d}{\Delta t}$$

Quantity	**Symbol**	**Unit**
Speed	v	metres/second (m/s)
Distance	d	metres (m)
Time interval	Δt	seconds (s)

$$\text{Average speed} = \frac{\text{total distance travelled}}{\text{total time interval}}$$

$$v_{avg} = \frac{d_{total}}{\Delta t_{total}}$$

Here, the speed of the ladybug would be:

$$v_{avg} = \frac{d_{total}}{\Delta t_{total}}$$

$$v_{avg} = \frac{11 \text{ m}}{45 \text{ s}}$$

$$v_{avg} = 0.24 \text{ m/s}$$

Since speed has no direction associated with it, it is a scalar.

Displacement

Now, **displacement** represents the change in position—that is, the final position minus the initial position. The symbol for displacement is $\vec{d}$. Displacement represents not only how far the object has travelled, but also in which direction it has travelled. Both of these must be specified—that is, magnitude and direction—for displacement. Therefore, displacement is a **vector** quantity.

Displacement represents the change in position of an object. Disiplacement is calculated by subtracting as follows: final position – initial position.

$$\vec{d} = \text{pos}_2 - \text{pos}_1$$

Quantity	Symbol	Unit
Initial position	pos_1	metres (m)
Final position	pos_2	metres (m)
Displacement	$\vec{d}$	metres (m)

Displacement is a *vector* quantity.

The ladybug's initial position was +2 m and its final position was –4 m.

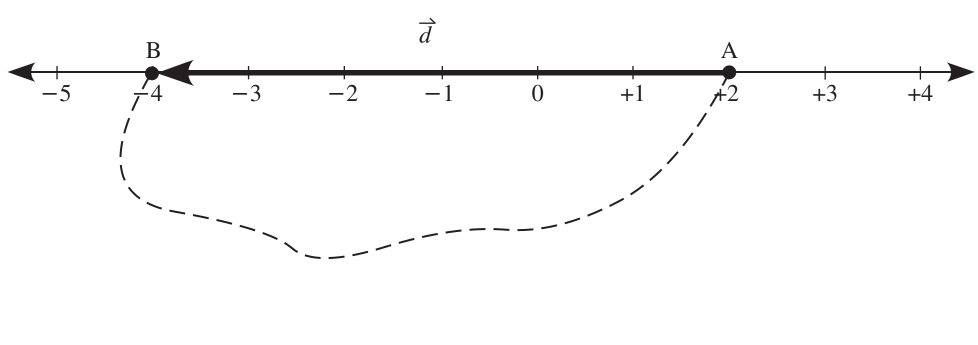
$\text{pos}_1 = +2$ m

$\text{pos}_2 = -4$ m

displacement = $\text{pos}_2 - \text{pos}_1$

$$\vec{d}_{\text{total}} = \text{pos}_2 - \text{pos}_1$$
$$\vec{d}_{\text{total}} = -4\text{ m} - (+2\text{ m})$$

The displacement of the ladybug is –6 m or 6 m to the left.



To represent a vector, we use a directed line segment—an arrow. The **tail** of the arrow (the end of the arrow without a head) is placed at the initial position (point A). The **head** (the end of the arrow where the arrowhead is) is placed at the final position (point B).

The displacement vector $\vec{d}$ is drawn in the diagram above.

Velocity

Once you understand displacement and are able to determine displacement, you can move on to finding velocity. Velocity is defined as the rate of change of position. It is calculated by taking the displacement over the time interval.

Velocity is the rate of change of position. Velocity is calculated by the displacement over the time interval.

$$\vec{v} = \frac{\vec{d}}{\Delta t} = \frac{\text{pos}_2 - \text{pos}_1}{\Delta t}$$

Quantity	Symbol	Unit
Initial position	pos_1	metres (m)
Final position	pos_2	metres (m)
Displacement	$\vec{d}$	metres (m)
Velocity	$\vec{v}$	metres/second (m/s)
Time interval	Δt	seconds (s)

Velocity is a *vector* quantity.

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time interval}}$$

$$\vec{v}_{\text{avg}} = \frac{\vec{d}_{\text{total}}}{\Delta t_{\text{total}}}$$

Velocity is a vector quantity. Its direction will be the same as the direction of the displacement.

Velocity will have units of metres over seconds (m/s) in SI units. You may be familiar with other velocity units like kilometres per hour (km/h). Units like these should be converted to m/s before doing calculations.

You can think of velocity as speed plus direction.

Getting back to the ladybug, you can see that the displacement was –6 m during a time of 45 s.

Using, $\vec{v}_{avg} = \dfrac{\vec{d}_{total}}{\Delta t_{total}}$

. $\vec{v}_{avg} = \dfrac{-6\text{ m}}{45\text{ s}} = -0.13\text{ m/s}$

The velocity of –0.13m/s indicates that the ladybug would have travelled from A to B and during 45 seconds if it had maintained a constant speed of 0.13 m/s in the negative direction or to the left. Since the ladybug had wandered from the straight-line path, this velocity represents the average velocity for this journey.

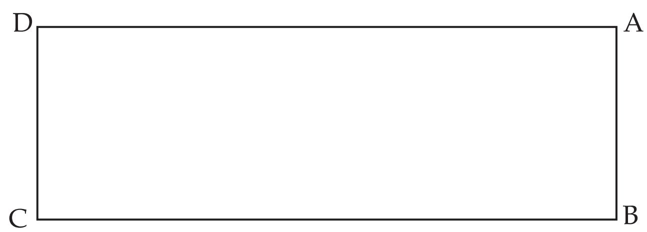
Learning Activity 1.1

Working with Distance, Displacement, Speed, and Velocity

Test your understanding of these ideas that you are reviewing by trying the questions below. Remember, you do not submit learning activities for assessment. Instead, you complete them in order to prepare yourself to complete the assignments, which **are** submitted for assessment. Once you have completed this learning activity, check your answers in the answer key at the end of this module.

To answer questions #1–3, 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 travelled?
   b) displacement?
3. If the journey in #2 took 55.0 s, calculate
   a) your average speed.
   b) your average velocity.

Acceleration

Some motions occur with the speed and the direction of motion always being the same. In other words, the velocity is constant.

The motion of an object with constant velocity is called **uniform motion**.

Not all motion is uniform motion. Objects may speed up, slow down, or change direction. In these cases, we say that the object is accelerating.

Acceleration is defined as the rate of change of velocity. Think of it as how the velocity changes with time. For example, an acceleration of +2 ms/s indicates that an object is changing its velocity by 2 m/s, every second, in the positive direction.

Acceleration can be calculated as the change in velocity over the time interval.

Acceleration is defined as the rate of change of velocity. Acceleration is calculated by taking the change in velocity and dividing it by the time interval.

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} \text{ or } \vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$$

Quantity	**Symbol**	**Unit**
Acceleration	$\vec{a}$	metres/second squared (m/s^2)
Change in velocity	$\Delta\vec{v}$	metres/second (m/s)
Time interval	Δt	seconds(s)
Initial velocity	$\vec{v}_1$	metres/second (m/s)
Final velocity	$\vec{v}_2$	metres/second (m/s)

Acceleration is a *vector* quantity.

The equation would look like:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{change in time}}$$

$$= \frac{\text{final velocity minus initial velocity}}{\text{final time minus initial time}}$$

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

This brings us up-to-date as far as a review of terms for kinematics is concerned.

Learning Activity 1.2

Acceleration Calculations

Test your understanding of these ideas that you are reviewing by trying the questions below. Remember, you do not submit learning activities for assessment. Instead, you complete them in order to prepare yourself to complete the assignments, which are submitted for assessment. Once you have completed this learning activity, check your answers in the answer key at the end of this module.

1. 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?
2. 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?

Describing Motion

In studying physics, we have four different ways of representing or describing any given phenomenon. These are visual, numerical, graphical, and symbolic. The following example will illustrate these different modes of representation.

Visual Representation

This first description deals with the visual (that is, what you see happening).

In this description, we will start with our everyday terms. We will deal only with motion along a straight line.

You are walking down the hallway from English class to geography class. It is 50 metres east from the door of the English room to the door of the geography room. It takes 25 seconds to walk this distance at a steady pace.

The steady pace tells us that this is uniform motion.

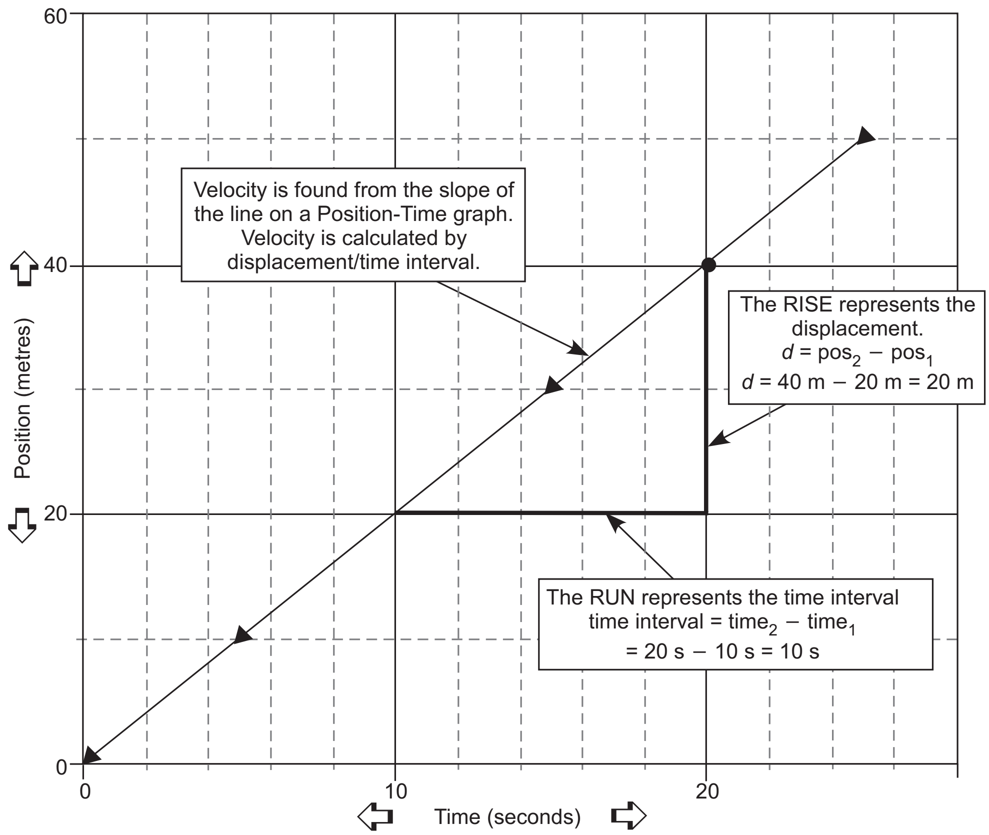
Numerical Representation

The description above can also be represented in a data table of time and position. We must indicate from where all the positions are measured—that is, the reference point. In this case, the reference point will be the door to the English room. From the description, we see that you would travel 50 metres east in 25 seconds or 10 metres east for every five seconds.

Time (seconds)	Position (metres east)
0	0
5	10
10	20
15	30
20	40
25	50

Graphical Representation

The information above can be plotted on a graph. Time would be plotted on the **horizontal axis**. Position will be plotted on the **vertical axis**.



You can see on the graph that the line is straight. A straight line on a position-time graph represents uniform motion.

If you have a position-time graph, there is some information that you can read directly from the graph. A position-time graph tells the story of where an object is at an instant in time.

For example, from the position-time graph above, the position at 12 seconds would be 24 metres east. The object is at 35 metres east at about 17.5 seconds.

Symbolic Form (Equations)

You can write a mathematical equation to describe this motion.

From a graph, you can read information directly. However, you can also calculate quantities—that is, find indirect information. There are only two things that can be found from a graph indirectly. One is the slope of the line (slope = rise/run); the second is the area beneath the curve or line, between the line and the horizontal axis.

You can see from the data table that the position in metres east is always twice as large as the time in seconds. The position measures how far you are located from the origin. Travelling from the origin to this position is a change in position or **displacement**. The time it took you to walk is a **time interval**.

Your equation would be:

Displacement = (2.0 m/s east) (time interval).

The 2.0 m/s east is a speed with direction. This is **velocity**.

But what does this mean on the graph? Is this direct or indirect information? If it is indirect, is it the slope or the area?

Displacement is calculated by the change in position, $\vec{d}_{\text{total}} = \text{pos}_2 - \text{pos}_1$.

On the graph this represents the **RISE**.

Time interval is $\Delta t_{\text{total}} = t_2 - t_1$.

On the graph, this represents the **RUN**.

Together, the equation relating these three quantities is written as:

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$

$$\bar{v}_{\text{avg}} = \frac{\text{pos}_2 - \text{pos}_1}{t_2 - t_1} \text{ or } \bar{v}_{\text{avg}} = \frac{\vec{d}_{\text{total}}}{\Delta t_{\text{total}}}$$

In conclusion, **velocity** is just the **slope** of a position-time graph!

All four of these modes of representation are equal. If you are given one of these, the other three modes of representation can be obtained. Normally, when you begin the study of the new concept, it is best to begin with the visual representation. You know the old saying, "A picture is worth a thousand words." In this course, it is wise to use diagrams as a starting point for explanations for problem solving. The visual clues provided by diagrams help to clarify the situation and avoid confusion.

For problem solving, of which there will be a great deal in this course, the focus is on the symbolic mode of representation—that is, the equation. Again, while using the equation is an efficient way to deal with problems, a proper understanding of the situation is required. This is where the visual representation, the diagram, plays its very important role.

Learning Activity 1.3

Modes of Analyzing Motion

Check your understanding of the concepts in this lesson by completing the following questions. You may check your work against the answer key provided at the end of Module 1.

1. Consider the following situation. You are jogging at a constant pace around a track. This is the typical track that might be found around the perimeter of a football field. The distance around the track is 360 m.
   a) Draw a diagram of the situation.
   b) It takes you 90.0 seconds to jog completely around the track and return to your starting point. Calculate your average speed and your average velocity.
   c) On a straight section of the track, it takes you 25 seconds to jog 100 m. What is your average velocity? Hint: Refer to your diagram.
   d) Are you accelerating while you are jogging along one of the straight sections of the track? Explain.
   e) Are you accelerating while you are jogging along one of the curved sections of the track? Explain.
2. The car is travelling along a section of the road that forms one-half of a circle with a radius of 176 m. The car requires 22.0 seconds to travel around the curve.
   a) Draw a diagram of the situation.
   b) What is the average speed of the car while it travels around this half-circle?
   c) What is the average velocity of the car while it travels around this half-circle?

Lesson Summary

In this lesson, you reviewed some ideas on kinematics.

Assignment

Most lessons will have an assignment at this point in the lesson. This lesson does not have an assignment.

Assignments are to be completed and submitted for evaluation. Assignments are part of your evaluation. Together they represent 50% of your total mark in this course. After completing a particular section of the course, you will be instructed to submit all of the assignments from a particular module. Submit assignments to your tutor-marker when you are instructed to do so.

Released 2009

Printed in Canada
Imprimé au Canada