TOPIC 1.1: KINEMATICS

S4P-1-1 Derive the special equations for constant acceleration.

Include: $\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$; $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$; $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$

S4P-1-2 Solve problems for objects moving in a straight line with a constant acceleration.

Include: $\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$; $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$;

$v_2^2 = v_1^2 + 2a\Delta d$; $\Delta\vec{d} = \left(\frac{\vec{v}_1 + \vec{v}_2}{2}\right)\Delta t$

S4P-1-3 Solve relative motion problems for constant velocities using vectors.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena (GLO A1)

SPECIFIC LEARNING OUTCOME

S4P-1-1: Derive the special equations for constant acceleration.

Include: $\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$;

$$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2;$$

$$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$$

SUGGESTIONS FOR INSTRUCTION

Entry Level Knowledge

In Senior 2 Science, students were introduced to kinematics using the context of driving an automobile. The approach was mostly qualitative with an emphasis on the visual mode of representation. Students learned the definitions for average velocity and acceleration. In Senior 3 Physics, students extended this knowledge to focus on linear relations with an emphasis on graphical analysis using slope. Problem solving in Senior 3 Physics used the concept of average velocity.

Notes to the Teacher

In Senior 4 Physics, the spiral treatment of kinematics is completed by introducing the special equations for constant acceleration. In this way, students progress from a mostly qualitative understanding in Senior 2 Science to the introduction of a simple mathematical model in Senior 3 Physics and, finally, to a more complex mathematical approach in Senior 4 Physics. Students should gain experience solving several different types of kinematics problems, including using the quadratic formula. There exists many opportunities throughout the course to solve problems using these equations.

Prior Knowledge Activity

Students work collaboratively to complete a KWL chart (SYSTH) to review what they know from Senior 2 Science and Senior 3 Physics.

Class Discussion

Provide students with a list of descriptions of motion or have students create their own list. Various descriptions are possible: walking to school, riding a bicycle up a hill, rolling a ball across the table, and so on. Students will predict the position-time and velocity-time graphs for these motions. Students can then verify their results with motion sensors and graphing calculators. (See attached chart.)

Class Discussion

Consider the graphs from the student activity with the motion detector (or other similar graphs). Two of the graphs are straight-line graphs. (What kind of motion does this represent?) Mathematically speaking, straight-line graphs are useful since we can calculate the slope of the line. The slope of the straight-line position graph is average velocity (covered in Senior 3 Physics but a useful review here). Similarly, the slope of the straight-line velocity graph is average acceleration.

Representative sample graphs appear on pages 6 and 7.

SKILLS AND ATTITUDES OUTCOMES

S4P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S4P-0-2g: Develop mathematical models involving linear, power, and/or inverse relationships among variables.

GENERAL LEARNING OUTCOMES CONNECTION

Students will…

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

Describe and appreciate how the natural and constructed worlds are made up of systems and how interactions take place within and among these systems (GLO E2)

SUGGESTIONS FOR INSTRUCTION

At this point it is very easy for students to confuse these two types of motion. Therefore, continually encourage students to differentiate between the position- and velocity-time graphs. The derivations of the kinematics equations are rooted in the position-time, velocity-time, and acceleration-time graphs for an object moving with constant acceleration. The slope and the area between the line and the horizontal axis connect displacement, velocity, and acceleration graphically. Students should carefully differentiate among the terms position, velocity, and acceleration.

The special equations of motion can be derived from the slope and area of a velocity-time graph for an object moving with a constant acceleration. The derivations are included in the appendix for teacher reference (Appendix 1.1).

SUGGESTIONS FOR ASSESSMENT

Visual Display

Use a Category Concept Map to ensure students are able to identify each symbol in each equation and its characteristics. See Appendix 1.2 for the map.

Science Journal Entries

Students use process notes (SYSTH 13.14) to detail the derivations of the special equations.

Pencil-and-Paper Tasks

Given a graph of velocity-time, students will

derive $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$; $\Delta \vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}\,\Delta t$.

Students will algebraically derive

$v_2^2 = v_1^2 + 2a\Delta d$ from $\vec{a} = \frac{\Delta \vec{d}}{\Delta t}$ and $\Delta \vec{d} = \left(\frac{\vec{v}_1 + \vec{v}_2}{2}\right)\Delta t$.

SUGGESTED LEARNING RESOURCES

BLM 3-1: Kinematics Equations, *Physics 12*, McGraw-Hill Ryerson, 2003

QuickLab, Rocket Motion, p. 59, *Physics 12*, McGraw-Hill Ryerson, 2003

Conceptual Graphing, p. 17, Lab Manual, *Conceptual Physics*, Pearson, 2002

General Learning Outcome Connection

Students will…

Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena (GLO A1)

Specific Learning Outcome

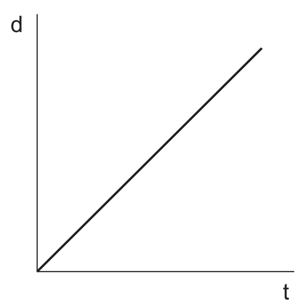
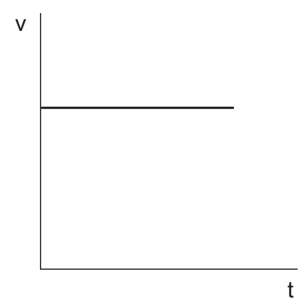
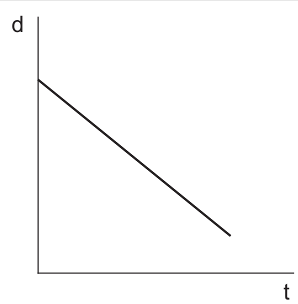
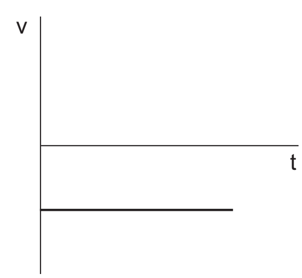
S4P-1-1: Derive the special equations for constant acceleration.

Include: $\vec{v}_2 = \vec{v}_1 + \vec{a}\,\Delta t;$

$$\Delta\vec{d} = \vec{v}_1\,\Delta t + \frac{1}{2}\vec{a}\,\Delta t^2;$$

$$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\,\vec{a}\,\Delta\vec{d}$$

Suggestions for Instruction

Action	Position-Time Graph	Velocity-Time Graph
A person walks away from the sensor at a constant velocity.		
A person walks towards the sensor at a constant velocity.		

SKILLS AND ATTITUDES OUTCOMES

S4P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S4P-0-2g: Develop mathematical models involving linear, power, and/or inverse relationships among variables.

GENERAL LEARNING OUTCOMES CONNECTION

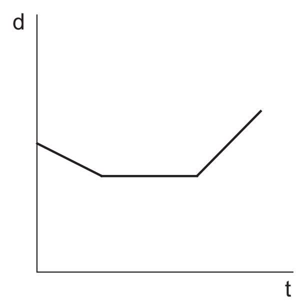
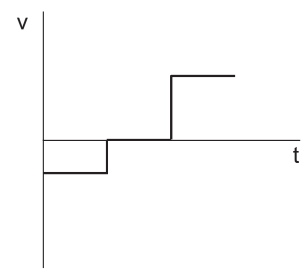
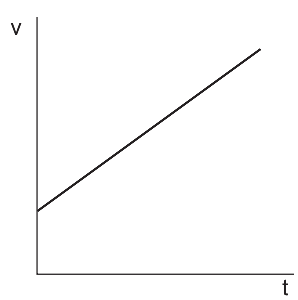
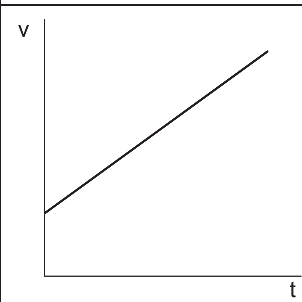
Students will…

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

Describe and appreciate how the natural and constructed worlds are made up of systems and how interactions take place within and among these systems (GLO E2)

SUGGESTIONS FOR INSTRUCTION

SUGGESTIONS FOR ASSESSMENT

Action	Position-Time Graph	Velocity-Time Graph
A person walks towards the sensor at a constant velocity, pauses, and then walks away from the sensor at a constant speed (can be the same as the initial speed or different).		
A person walks away from the sensor, slowly accelerating to a run.		

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena (GLO A1)

SPECIFIC LEARNING OUTCOME

S4P-1-2: Solve problems for objects moving in a straight line with a constant acceleration.

Include: $\vec{v}_2 = \vec{v}_1 + \vec{a}\,\Delta t$; $\Delta\vec{d} = \vec{v}_1\,\Delta t + \frac{1}{2}\vec{a}\,\Delta t^2$;

$$v_2^2 = v_1^2 + 2a\Delta d;\ \Delta\vec{d} = \left(\frac{\vec{v}_1 + \vec{v}_2}{2}\right)\Delta t$$

SUGGESTIONS FOR INSTRUCTION

Entry Level Knowledge

Students worked with the basic equations of motion in Senior 3 Physics. Problems were solved using multiple steps and the concept of average velocity.

Notes to the Teacher

The equations involving power relationships are new to the students. In many cases, problems that may have required two separate steps in Senior 3 Physics can now be solved using only one equation. Problem solving using the special equations can be spread throughout the course.

Instruct students in a systematic approach to solving word problems. A common approach includes the following steps:

- After reading the problem carefully, draw a diagram of the situation.
- Identify the given information.
- Identify the unknown quantities.
- Select the most convenient equation, substitute, and solve for the unknown.
- Check the final answer using different equations.
- Check units and directions for all vector quantities. Use unit analysis to reinforce the comprehension of the concepts of kinematics.

Students should experience a variety of problems. Illustrative examples can be found in Appendix 1.3. Students are always interested in problems that are framed in a familiar context such as flight, sports, or biomechanics.

A Three-Point Approach frame (SYSTH) can be used to define the terms in this section.

The IDEAL problem-solving frame can be used to aid students with solving kinematics problems.

SKILLS AND ATTITUDES OUTCOMES

S4P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S4P-0-2g: Develop mathematical models involving linear, power, and/or inverse relationships among variables.

GENERAL LEARNING OUTCOMES CONNECTION

Students will…

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

Describe and appreciate how the natural and constructed worlds are made up of systems and how interactions take place within and among these systems (GLO E2)

SUGGESTIONS FOR INSTRUCTION

Teaching Notes

SUGGESTIONS FOR ASSESSMENT

Pencil-and-Paper Tasks

Students solve a variety of problems using the special equations of constant acceleration.

Science Journal Entries

Students write process notes showing their reasoning for problem solutions.

Asking and Answering Questions Based on Data

Students use real-life situations to check their understanding of acceleration. Pictures of the situation can be interpreted into graphical representations of the motion, which can then be expressed mathematically through the kinematics equations.

General Learning Outcome Connection

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

Specific Learning Outcome

S4P-1-3: Solve relative motion problems for constant velocities using vectors.

Suggestions for Instruction

Entry Level Knowledge

In Senior 3 Physics, students added and subtracted collinear vectors and perpendicular vectors. Students also determined the components of vectors.

Notes to Teacher

At this time the vector case is extended to adding and subtracting vectors at any angle. The component method should be used.

Relative motion occurs when an object appears to have one motion to one observer and a different motion to a second observer, depending on how the two observers are moving with respect to one another. Examples include a boat crossing a river or an airplane flying through the air. The motion, as observed from the shore or the ground, is the vector sum of the two given motions.

Class Discussion

Introduce the concept of relative motion with simple examples of collinear motion. Encourage students to put themselves in each of the following situations and describe the velocity of the moving object with respect to their frame of reference.

Case One

The police are sitting in their car on the side of the road with a radar gun. A motorist is speeding toward the police car at a rate of 135 km/h [E]. If you are in the police car, what do you perceive the apparent velocity of the motorist to be? (135 km/h [E])

Case Two

A sports car is travelling east on Highway #1 at 140 km/h and a semi-trailer truck is travelling west on the same highway at 110 km/h. If you were in the sports car, what is the apparent velocity of the truck? (250 km/h [W])

If you were the truck driver, what is the apparent velocity of the sports car? (250 km/h [E])

Case Three

A delivery truck is travelling down Portage Avenue at 60 km/h [W]. A car is passing the delivery truck at a speed of 70 km/h [W]. If you were the truck driver, what is the apparent velocity of the car passing you? (10 km/h [W])

If you were a passenger in the car, what is the apparent velocity of the truck you are passing? (10 km/h [E])

Finally, if you are the police sitting on the side of Portage Avenue, what is the apparent velocity of the car? (70 km/h [W])

SKILLS AND ATTITUDES OUTCOME

S4P-0-2h: Analyze problems using vectors.

Include: Adding and subtracting vectors in straight lines, at right angles, and at non-orthogonal angles

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Understand the properties and structures of matter as well as various common manifestations and applications of the actions and interactions of matter (GLO D3)

SUGGESTIONS FOR INSTRUCTION

Another common example of collinear motion is a boat travelling on a river, heading straight upstream. Following this discussion, introduce students to motion that is not collinear. This example could then be extended to a boat heading straight across the river. In these cases, the vectors are at right angles. The next extension would be a boat heading across the river at some angle other than perpendicular to the shore. Remind students that the motion of the boat crossing a river remains constant irrespective of the motion of the river.

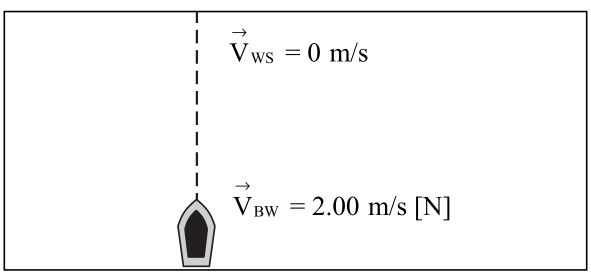


Diagram showing boat travelling in still water across a river.

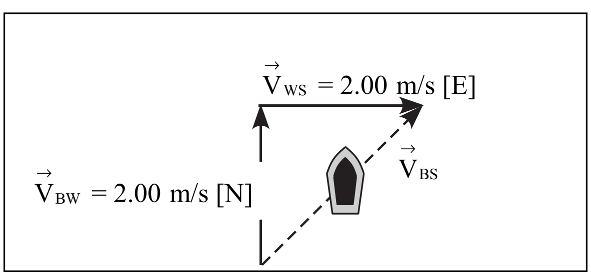


Diagram showing boat travelling across a river that has a current.

SUGGESTIONS FOR ASSESSMENT

Science Journal Entries

Students write about swimming across a river that has a current flowing. Students can determine under what conditions they can swim with a resultant velocity directly across the river. Compare the difference between swimming in a body of water with a current as opposed to a still body of water.

Students write process notes (SYSTH) to describe the steps followed to solve vector problems using the component method.

Students describe situations they have experienced that involve relative motion.

Students write process notes for solving a vector addition question using components.

Students make a concept map relating these terms from this vectors unit:

frames of reference	relative motion
position	velocity
acceleration	average velocity
components	addition

Performance Assessment

Students work in small groups to generate a series of relative motion problems, providing the questions and solutions to these problems. Students in the groups exchange problems and have their group solve the problems.

Students use a computer software simulation program, such as *Interactive Physics*, to demonstrate the concept of relative motion.

General Learning Outcome Connection

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

Specific Learning Outcome

S4P-1-3: Solve relative motion problems for constant velocities using vectors.

Suggestions for Instruction

Note that the boat has the same velocity in still water and when travelling in a river with a current. Use subscripts to help identify the variables. For example, if a boat is crossing the river, the boat's velocity relative to the water can be noted as vBW. Then the velocity of the current with respect to the ground is vWG. The addition of these two vectors will result in the velocity of the boat relative to the ground, vBG.

The common reference to the water is the link between the vectors.

Teacher Demonstration

Use the videodisc *Physics: Cinema Classics* to show the independent nature of vectors. Set up a demonstration where a toy bulldozer is travelling perpendicularly across a piece of rolled paper that is pulled along the floor at a constant velocity. This motion can be analyzed using a video camera suspended overhead.

The *Interactive Physics* software program can be used to show the vector components of relative motion for a boat crossing a river. The velocity of the boat can be changed to show the effect of the direction that the boat takes (its heading).

Many Java applets exist on the Internet to describe and interact with relative motion examples. Conduct an Internet search using "Relative, Motion, Java applets" as your search string for information.

SKILLS AND ATTITUDES OUTCOME

S4P-0-2h: Analyze problems using vectors.

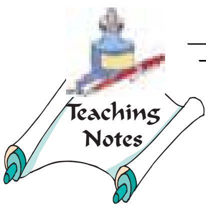
Include: Adding and subtracting vectors in straight lines, at right angles, and at non-orthogonal angles.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Understand the properties and structures of matter as well as various common manifestations and applications of the actions and interactions of matter (GLO D3)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Physics: Cinema Classics videotape

Disk 1/Side A, Chapter 15, Relative Position: Who's Upside Down?

Chapter 16, Relative Motion: Who's Moving?; Chapter 17, Relative Motion: Carts on a Table

Chapter 54, Boat and River

Interactive Physics software

BLM 3-3: Relative Velocity Vectors, McGraw-Hill Ryerson, 2003

BLM 2-1:Vector Components; BLM 2-2: Vector Addition by Components; BLM 3-1: Vectors in Two Dimensions; BLM 7-1: Relative Motion Problems, *Physics: Concepts and Connections*, Irwin Publishing Ltd., 2003

Investigation 3-B: Go with the Flow, *Physics 12*, McGraw-Hill Ryerson, 2003

Notes