TOPIC 3.1: KINEMATICS

The student will be able to:

S3P-3-01: Differentiate between, and give examples of, scalar and vector quantities.

Examples: distance, speed, mass, time, temperature, volume, weight, position, displacement, velocity, acceleration, force…

S3P-3-02: Differentiate among position, displacement, and distance.

S3P-3-03: Differentiate between the terms "an instant" and "an interval" of time.

S3P-3-04: Analyze the relationships among position, velocity, acceleration, and time for an object that is accelerating at a constant rate.

Include: transformations of position-time, velocity-time, and acceleration-time graphs using slopes and areas

S3P-3-05: Compare and contrast average and instantaneous velocity for non-uniform motion.

Include: slopes of chords and tangents

S3P-3-06: Illustrate, using velocity-time graphs of uniformly accelerated motion, that average velocity can be represented as $\vec{V}_{avg} = \frac{\Delta \vec{d}}{\Delta t}$ and that displacement can be calculated as $\Delta \vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} \Delta t$.

S3P-3-07: Solve problems, using combined forms of:

$\vec{v}_{avg} = \frac{\vec{v}_1 + \vec{v}_2}{2}$, $\vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t}$, $\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}$.

General Learning Outcome 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)

Specific Learning Outcomes

S3P-3-01: Differentiate between, and give examples of, scalar and vector quantities.

Examples: distance, speed, mass, time, temperature, volume, weight, position, displacement, velocity, acceleration, force…

S3P-3-02: Differentiate among position, displacement, and distance.

Suggestions for Instruction

Entry-Level Knowledge

In Senior 2 Science, students studied motion along a straight line. Vector directions were described only as forward and backward (S2-3-01, S2-3-02, S2-3-03).

Notes to the Teacher

The treatment of vectors is intentionally developmental, progressing from a qualitative approach in Senior 2 Science to more complex representations in Senior 3 and Senior 4 Physics. In Senior 3 Physics, students describe, add, and subtract vectors on a straight line and at right angles, using algebra and the Pythagorean theorem. The graphical method of adding and subtracting vectors is a useful introduction to the mathematical solution. In Senior 4 Physics, students will add and subtract vectors at any angle, using components.

A scalar is a quantity that represents magnitude only, whereas a vector is a quantity that has magnitude and direction.

Vectors can be introduced using position/distance/displacement examples. Position is the location of an object and requires a distance and direction from a known origin. The choice of the origin is arbitrary; however, the origin must be known by all. Distance is the length of the path travelled and displacement is the object's change in position.

Extend the vector concepts introduced in Senior 2 Science by using compass directions. First, use straight-line motion and then motion at right angles. Compare the concepts of position, distance, and displacement.

Illustrative Example 1

A woman begins at an origin and walks 4 m east, then 3 m west. What is her final position? (1 m east) What is her distance travelled? (7 m) What is the final displacement of the motion? (1 m east) Repeat the motion with the woman beginning at a position 2 m east of the chosen origin. What is her final position? (3 m east) What is her distance travelled? (7 m) What is the displacement of the motion? (1 m east)

SKILLS AND ATTITUDES OUTCOME

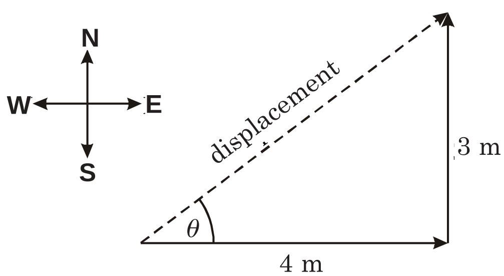
S3P-0-2h: Analyze problems, using vectors.

Include: adding and subtracting vectors in straight lines and at right angles, vector components

SUGGESTIONS FOR INSTRUCTION

Illustrative Example 2

A man begins at an origin, then walks 4 m east, then 3 m north. What is his final position? (5 m 37° north of east) What is his distance travelled? (7 m) What is the final displacement of the motion? (5 m, 37° north of east)



The direction for a vector may be described in a number of ways:

1. Common terms such as left/right, up/down, forward/backward
2. Compass directions (north/south/east/west)
3. Number line, using positive and negative signs (+/–)
4. Coordinate system, using angles of rotation from the horizontal axis

SUGGESTIONS FOR ASSESSMENT

Performance Assessment

Students engage in a scavenger hunt in the park, a field, or in the classroom, making use of vectors to locate an object or place.

Science Journal Entries

Students demonstrate results of a "vector journey" through labelled vector diagrams and a short story.

SUGGESTED LEARNING RESOURCES

Nelson, J. (1983) "Kinematics of a Student." *The Physics Teacher* 21.6: 386.

Appendix 3.2: A Vector Journey

Appendix 3.3: Journal Entry on Vectors

Appendix 3.4: A Vector Sampler

Appendix 3.6: Describing Motion in Various Ways

General Learning Outcome 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)

Specific Learning Outcomes

S3P-3-01: Differentiate between, and give examples of, scalar and vector quantities.

Examples: distance, speed, mass, time, temperature, volume, weight, position, displacement, velocity, acceleration, force…

S3P-3-02: Differentiate among position, displacement, and distance.

Suggestions for Instruction

Note: There are many different notations that are used to represent direction on direction finders. It is recommended that teachers refer to their physics and math texts to decide on a convenient strategy.

Teacher Demonstration

Attach a cone to the end of an elastic band, and fix the other end of the elastic band to something solid. The elastic can be stretched to imitate various lengths and directions of vectors.

Senior Years Science Teachers' Handbook Activities

Divide the class into groups. Each group prepares a list of situations in which knowledge of distance moved would be valuable, and a list of situations in which knowledge of displacement moved would be valuable. Students present their lists to the class. The following are possible examples: distance is valuable in determining fuel consumption for vehicles, wear and tear on vehicles, or the amount of exercise from jogging; displacement (distance and direction) is necessary to go from one location to another.

Students tell a vector story (your trek to school) that includes reference to an origin, magnitudes, and directions.

Students tell a vector story from a different frame of reference (e.g., a person walks 2.0 m/s backward on a bus moving past you at 10 m/s).

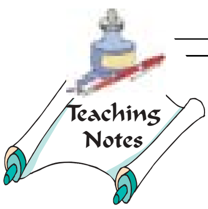
Using a Three-Point Approach Frame, students define and illustrate terminologies related to vectors (see Appendix 3.3: Journal Entry on Vectors).

SKILLS AND ATTITUDES OUTCOME

S3P-0-2h: Analyze problems, using vectors.

Include: adding and subtracting vectors in straight lines and at right angles, vector components

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

GENERAL LEARNING OUTCOME 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)

SPECIFIC LEARNING OUTCOME

S3P-3-03: Differentiate between the terms "an instant" and "an interval" of time.

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students may have some limited experience from mathematics.

Notes to the Teacher

The notion of time is important in physics. A common misconception is that an instant in time is a very short interval of time. However, an instant is considered to be a single clock reading (t). If time were plotted on an axis, an instant is just a single coordinate along that axis. An interval is a duration in time (i.e., the interval separating two instants on the time axis [Δt]). The combination of a clock reading and instantaneous position is called an event, a concept that later becomes useful when introducing relativity.

Note: Δ, pronounced "delta," is used to represent the phrase "change in," and is calculated as "final – initial."

e.g., Δt is read as: the change in time ($\Delta t = t_{final} - t_{initial}$)

Δv is read as: the change in velocity ($\Delta v = v_{final} - v_{initial}$)

Class Activity

Students time a runner at regular intervals and make a data table of the time "splits" (i.e., the time at 10-m intervals). From the table, note the instantaneous time and the time intervals.

Senior Years Science Teachers' Handbook Activities

Students use a Concept Frame for instant and interval of time.

SKILLS AND ATTITUDES OUTCOME

S3P-0-2c: Formulate operational definitions of major variables or concepts.

SUGGESTIONS FOR INSTRUCTION

Teaching Notes

SUGGESTIONS FOR ASSESSMENT

Asking and Answering Questions Based on Data

Students calculate Δt using $\Delta t = t_{final} - t_{initial}$ from the activity on the facing page.

Students differentiate, on a graph, between an instant and an interval of time.

SUGGESTED LEARNING RESOURCES

General Learning Outcome Connection

Students will...

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

Specific Learning Outcome

S3P-3-04: Analyze the relationships among position, velocity, acceleration, and time for an object that is accelerating at a constant rate.

Include: transformations of position-time, velocity-time, and acceleration-time graphs using slopes and areas

Skills and Attitudes Outcomes

S3P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-2d: Estimate and measure accurately, using Système International (SI) units.

Suggestions for Instruction

Entry-Level Knowledge

In Senior 2 Science, students were introduced to uniform motion (S2-3-01) and accelerated motion (S2-3-02 and S2-3-03). Senior 2 Science is intended to be a more qualitative treatment of motion developed within the context of the automobile. In Senior 3 Physics, the expectation is that a more sophisticated treatment of position, velocity, and acceleration will include a more complete graphical analysis with emphasis on the slope and area relationships, and an introduction to the mathematical relationships for motion.

Notes to the Teacher

The slope of a position-time graph represents velocity. The slope of a velocity-time graph represents acceleration. Alternatively, the area contained by an interval of time in a velocity-time graph represents the displacement during the time interval. The area contained under an interval of time in an acceleration-time graph represents change in velocity over the time interval. (See 3.14: Kinematics Graphs Transformation Organizer for a summary sheet.)

Begin this topic by interpreting the meaning of slope qualitatively, then by ratio. Given a graph of position versus time, an object moving faster will have a steeper slope. If the graph is a straight line, then $\Delta d \propto \Delta t$ and $\Delta d = k\Delta t$, where the constant k is the ratio of displacement to the time interval (the slope). Examination of the ratio leads to the conclusion that it is large when the object is moving fast and small when it is moving slow. The constant k represents the average velocity, and average velocity is defined as the rate of change of position with respect to time. In formula notation:

$$V_{avg} = \frac{\Delta d}{\Delta t}$$

The term “rate” refers to how much a quantity changes in one second. The quantity for a linear mechanical system is distance. Rate can be related to the equivalent for rotational (angle), fluid (volume or mass), electrical (charge), and thermal (heat) systems such that the concept of rate becomes intuitive. Fluid rates might include the output of an oil well in barrels per day. An example of electrical rate would be the amount of charge moving through the element of a toaster in C/s or amperes. Thermal rates, in joules per second or BTUs per second, can be used to describe the heating or cooling of our homes.

SKILLS AND ATTITUDES OUTCOMES

S3P-0-2e: Evaluate the relevance, reliability, and adequacy of data and data-collection methods.
Include: discrepancies in data and sources of error

S3P-0-2f: Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-2g: Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

S3P-0-4a: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

GENERAL LEARNING OUTCOME 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)

SUGGESTIONS FOR INSTRUCTION

Acceleration can be investigated graphically by referring to a straight-line graph of velocity versus time. From this graph, $\Delta d \propto \Delta t$ and $\Delta d = k\Delta t$, where the constant k is the ratio of velocity change to the time interval. Examination of the ratio leads to the conclusion that it is large when the object's velocity is changing rapidly and small when it is changing slowly. The constant k (slope) represents the average acceleration of the object denoted by the symbol a. We can now define average acceleration as the rate of change of velocity with respect to time. In formula notation:

$$a_{avg} = \frac{\Delta v}{\Delta t}$$

Galileo struggled with the definition of acceleration as a rate of change of velocity with respect to time ($\Delta v/\Delta t$) versus the rate of change of velocity with respect to position ($\Delta v/\Delta d$). Ultimately, Galileo chose $\Delta v/\Delta t$ because he was able to measure position and time, and establish this as a power relationship.

SUGGESTIONS FOR ASSESSMENT

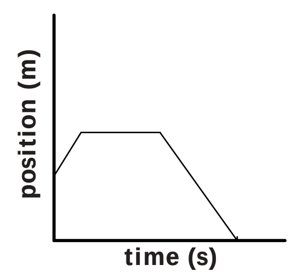
Observation

Students take a pre/post test to examine knowledge of graphs and their relationships for position, displacement, velocity, and acceleration.

Asking and Answering Questions Based on Data

Graphical Analysis: Students assess for an understanding of graphical representations in the real world. Include graphical descriptions of motion.

Illustrative Example: Students describe the motion of an object, given a position-time graph.



General Learning Outcome Connection

Students will…

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

Specific Learning Outcome

S3P-3-04: Analyze the relationships among position, velocity, acceleration, and time for an object that is accelerating at a constant rate.

Include: transformations of position-time, velocity-time, and acceleration-time graphs using slopes and areas

Skills and Attitudes Outcomes

S3P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-2d: Estimate and measure accurately, using Système International (SI) units.

Suggestions for Instruction

Prior Knowledge Activities

Research shows students are easily confused by the concepts of position and velocity, and velocity and acceleration. By investigating velocity change with respect to position as well as time, the student is forced to discriminate between the terms in the same exercise. The idea of negative acceleration is also often difficult to grasp. Students should work out all the possibilities for negative acceleration when the velocity changes are positive and when the velocity changes are negative. Review all combinations.

After introducing the relationships among position, velocity, acceleration, and time, have students apply these formulas to simple kinematics problems. Now is a good time for students to develop their skills for solving algebraic equations. Present several different types of problems to enhance these skills. See Appendix 3 for a complete list of problem types, solutions, and additional suggestions.

Laboratory Activities

Several types of activities may be used to study the relationships among position, velocity, acceleration, and time. Selection will depend on resources and the prior experience of the students.

Students complete a table of values for an object moving with a constant velocity of 5 m/s, and then plot the points onto a position time graph (t = 0, 1, 2, 3, 4, 5). Repeat, using a velocity of 10 m/s, 2 m/s, and 0 m/s. Compare the slope of each line with the velocity the slope represents.

Repeat the above exercise for velocity and time, using various accelerations.

A student walks back and forth in a straight line, stopping now and then. Other members of the class record the position of the student at regular intervals of time. They gather this information, using metre sticks and a stopwatch, or by using a motion sensor, then construct position-time, velocity-time, and acceleration-time graphs.

Other types of motion that could be investigated include walking away from the group at a steady pace, stopping momentarily, walking towards the group at a faster pace, rolling a ball down an incline, throwing a ball in the air, running 100 m, or any other suitable event.

Students can also investigate these kinds of motion by using microcomputers and motion detectors, and analyzing the data by using graphical analysis software.

SKILLS AND ATTITUDES OUTCOMES

S3P-0-2e: Evaluate the relevance, reliability, and adequacy of data and data-collection methods.
Include: discrepancies in data and sources of error

S3P-0-2f: Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-2g: Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

S3P-0-4a: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

GENERAL LEARNING OUTCOME 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)

SUGGESTIONS FOR INSTRUCTION

A tickertape lab can be used to describe the motion of your hand or an object falling or accelerating in some other manner.

Students examine the motion of an object rolling across a table. Use a video camera to record the motion with a scale (ruler) behind the object. Play the tape, stopping and observing the equal displacements in equal time intervals. Fairly accurate data can be collected by placing a transparency onto the TV screen (static electricity will hold it in place) and plotting position with a marker. Many VCRs allow frame-by-frame viewing for this type of analysis. You may also want to calibrate your video camera with a stopwatch to determine the interval of time between successive frames.

Demonstrations

Use a rolling ball or cart with a number scale in the background. Relate the scale to the concepts of position, displacement, and intervals. A VCR with frame-by-frame advance can be used to stop the motion.

Students can bring samples of children’s toys (either windup or electric) that will move at a constant speed (or very nearly constant).

SUGGESTIONS FOR ASSESSMENT

Research Report/Presentation

Students sketch a position-time graph of a real-world event (e.g., a runner, car, or rocket).

Lab Report

Students examine tickertape motion for position, velocity, and acceleration, taken from a lab activity.

Journal Report

Students collect samples of different types of motion from TV, movies, and cartoons. Students describe the motion and comment on the validity of the motion (e.g., the physics of the *Roadrunner* cartoons).

Visual Displays

Students describe the motion of a car from point A to point B, using position, velocity, and acceleration graphs.

Graphical Analysis

Students make measurements on a stroboscopic photograph, or sample tickertape, of a moving object.

General Learning Outcome Connection

Students will…

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

Specific Learning Outcome

S3P-3-04: Analyze the relationships among position, velocity, acceleration, and time for an object that is accelerating at a constant rate.

Include: transformations of position-time, velocity-time, and acceleration-time graphs using slopes and areas

Skills and Attitudes Outcomes

S3P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-2d: Estimate and measure accurately, using Système International (SI) units.

Suggestions for Instruction

Throw a ball into the air, roll a ball down an incline, up an incline, across a horizontal and up an incline, et cetera. Sketch a graph of velocity-time and acceleration for each case.

Senior Years Science Teachers' Handbook Activities

Students can complete a KWL/Knowledge chart (*Senior Years Science Teachers' Handbook*, page 9.13) to help assess their understanding of ideas from Senior 2 Science.

Journal Entry

Students construct a table of typical speeds for familiar moving objects (e.g., a baseball, car, or snail). Sketch two graphs of your trip to school: a position-time and velocity-time graph.

Students tell a story about motion (e.g., describe the motion of a car accelerating from rest at a stop sign to a constant speed). Include descriptions of the motion in the real world, including sample data, a graphic picture, and an algebraic representation.

Students make a list of objects that move at a constant speed (or very nearly constant).

Students identify other rates that they may know.

Students generate a list of objects that accelerate at a constant rate.

SKILLS AND ATTITUDES OUTCOMES

S3P-0-2e: Evaluate the relevance, reliability, and adequacy of data and data-collection methods.
Include: discrepancies in data and sources of error

S3P-0-2f: Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-2g: Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

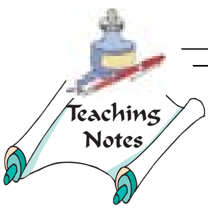
S3P-0-4a: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

GENERAL LEARNING OUTCOME 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)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

SUGGESTED LEARNING RESOURCES

Journals

Hestenes, David, and Malcolm Wells. (1992) “A Mechanics Baseline Test.” *The Physics Teacher* 30.3: 159–166.

Resources

Appendix 3.1: Working with the Modes of Representation

Appendix 3.5: Analysis of Data using *Microsoft Excel*

Appendix 3.6: Describing Motion in Various Ways

Appendix 3.7: Introducing Motion: Position, Time, Distance and Speed, Displacement, and Velocity

Appendix 3.8: Motion: Interpreting Position-Time Graphs

Appendix 3.9: Journal Entry: Kinematics (Position and Velocity)

Appendix 3.10: Kinematics: Position, Velocity, and Acceleration Graphs

Appendix 3.11: Kinematics and Graphing Skills Builder

Appendix 3.14: Kinematics Graphs Transformation Organizer

General Learning Outcome Connection

Students will...

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

Specific Learning Outcome

S3P-3-05: Compare and contrast average and instantaneous velocity for non-uniform motion.

Include: slopes of chords and tangents

Suggestions for Instruction

Entry-Level Knowledge

In Senior 2 Science, students are introduced to these ideas qualitatively.

Notes to the Teacher

A review of the graphical relationships for steady and accelerated motion is a good place to begin. Emphasis on the slope of a line as a rate of change facilitates a greater understanding of the meaning of velocity and acceleration. The meaning of an instant and an interval can lead into discussion to compare average and instantaneous velocity. The notion of a limit is difficult for students to understand. Consider the slope between two points on a curve as the points become closer together, and relate this to the average and instantaneous velocities. As the interval decreases, the line approaches the tangent to the curve at that point.

Examine Diagram 5. To find average velocity, we need a time interval (i.e., two times). Plot a point on the curve at time 1 and another point at time 2. Connect the two points and find the slope of the line. This will give you the average velocity between the two positions. To find the velocity at a given time, plot a point on the curve at that time. Then, draw a tangent to the curve at that point (see Diagram 6). The slope of this tangent is the instantaneous velocity of the object at that given moment.

Diagram 5

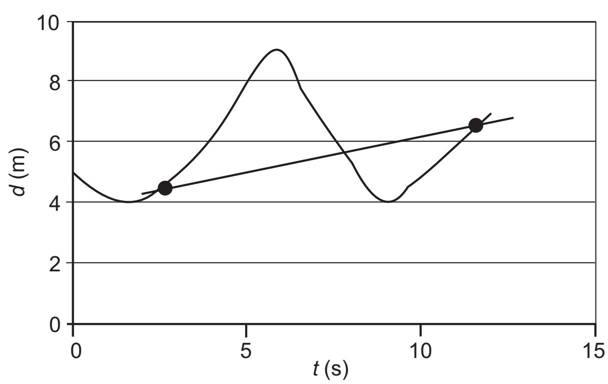
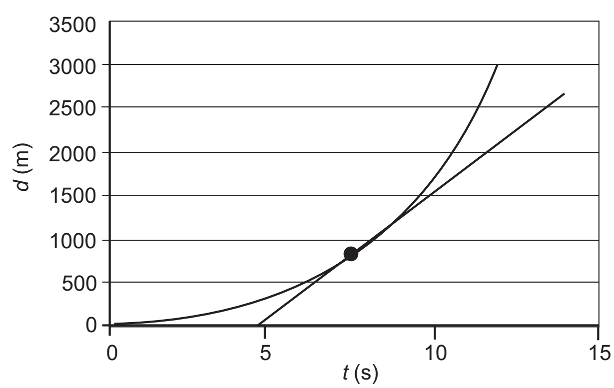


Diagram 6



SKILLS AND ATTITUDES OUTCOMES

S3P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-2f: Record, organize, and display data, using an appropriate format.

Include: labelled diagrams, tables, graphs

S3P-0-2g: Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them
(GLO D5)

SUGGESTIONS FOR INSTRUCTION

Class Activity

Videotape a ball falling under the influence of gravity. Play back the tape in slow motion or frame by frame and measure the position of the ball for equal intervals of time. The students can determine the average velocity of different time intervals by determining the distance the ball fell between two consecutive frames and knowing the time between two consecutive frames. The students can determine the instantaneous velocity of the ball by plotting a distance-versus-time graph, connecting the data points with a smooth curve, and finding the slope of the tangents to the curve at the desired times.

SUGGESTIONS FOR ASSESSMENT

Students find velocity by graphical methods:

a) Calculate average velocity

b) Calculate instantaneous velocity

SUGGESTED LEARNING RESOURCES

Appendix 3.8: Motion: Interpreting Position-Time Graphs

Appendix 3.9: Journal Entry: Kinematics (Position and Velocity)

General Learning Outcome Connection

Students will…

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

Specific Learning Outcome

S3P-3-06: Illustrate, using velocity-time graphs of uniformly accelerated motion, that average velocity can be represented as

$$\vec{V}_{avg} = \frac{\Delta \vec{d}}{\Delta t}$$

and that displacement can be calculated as

$$\Delta \vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} \Delta t.$$

Suggestions for Instruction

Notes to the Teacher

For a given time interval such that an object begins with velocity v_1 and accelerates uniformly to velocity v_2, the velocity-time graph will be a straight-line segment (Diagram 7). The midpoint of this segment will be $(v_1 + v_2)/2$ (Diagram 8). The area under the trapezoid in Diagram 7 can be shown to be the same as the area under the rectangle created in Diagram 8.

To find the area of the trapezoid, one could draw a line at the midpoint between v_1 and v_2. This creates two triangles of equal area below and above the line. If we shift the upper triangle's area into the lower triangle, a rectangle has been created (see Diagram 8). Mathematically, the midpoint of the two velocities is the average of v_1 and v_2 and:

$$\Delta d = \text{area} = \text{height} \times \text{base} = \left(\frac{v_1 + v_2}{2}\right)\Delta t$$

$$\Delta d = \left(\frac{v_1 + v_2}{2}\right)\Delta t$$

(Recall that area under a velocity-time graph results in displacement.)

Diagram 7

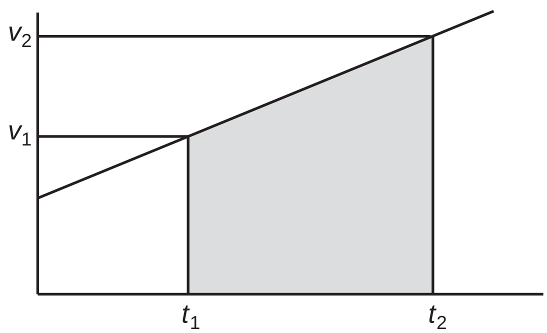
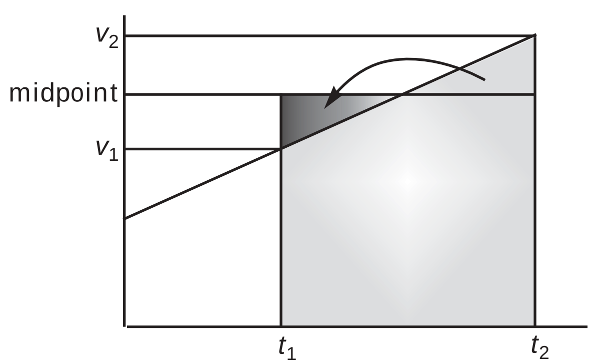


Diagram 8



GENERAL LEARNING OUTCOME CONNECTION

Students will…

Employ effective communication skills and utilize information technology to gather and share scientific and technological ideas and data (GLO C6)

SUGGESTIONS FOR INSTRUCTION

Teaching Notes

SUGGESTIONS FOR ASSESSMENT

Asking and Answering Questions Based on Data

Given an equation, students sketch the corresponding graph.

SUGGESTED LEARNING RESOURCES

Appendix 3.10: Kinematics: Position, Velocity, and Acceleration Graphs

Appendix 3.11: Kinematics and Graphing Skills Builder

Appendix 3.14: Kinematics Graphs Transformation Organizer

GENERAL LEARNING OUTCOME CONNECTION

Students will…

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

SPECIFIC LEARNING OUTCOME

S3P-3-07: Solve problems, using combined forms of:

$$\vec{V}_{avg} = \frac{\vec{v}_1 + \vec{v}_2}{2}, \quad \vec{V}_{avg} = \frac{\Delta \vec{d}}{\Delta t},$$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}.$$

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

Initially these formulas can be used to solve single-step problems to reinforce the representation for each variable, and to introduce students to the concept of solving problems algebraically. These formulas should then be applied to problems that require two and three steps to solve.

Illustrative Example

An object moving at 3 m/s accelerates for 4 s with uniform acceleration of 2 m/s^2. Find the displacement moved.

Solution: State the given information in symbolic form:

v_1 = +3 m/s

t = 4 s

a = +2 m/s^2

State the unknown:

Δd = ?

Enough information is given to find v_2 using:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t}$$

$$a\Delta t = v_2 - v_1$$

Solving for v_2, we get:

$v_2 = v_1 + a\Delta t$

v_2 = +3 + +2(4) = +11 m/s

Now, displacement can be found using:

$$\Delta d = \frac{(v_1 + v_2)}{2}\Delta t$$

$$\Delta d = \frac{(+11 + +3)}{2} \times 4$$

$$\Delta d = +28 \text{ m}$$

Illustrative Example

A car travelling at +10 m/s accelerates at a rate of +3.0 m/s^2 to a speed of +25 m/s. What distance does the car cover during the acceleration?

Δd =?

v_1 = +10 m/s

v_2 = +25 m/s

a = +3.0 m/s^2

Skills and Attitudes Outcomes

S3P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-2g: Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

General Learning Outcome 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)

Suggestions for Instruction

Since any available version of a displacement formula requires time, Δt will have to be found first:

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

$$\Delta t = \frac{\Delta v}{a} = \frac{v_2 - v_1}{a}$$

$$\Delta t = \frac{+25 \text{ m/s} - +10 \text{ m/s}}{3.0 \text{ m/s}^2} = 5.0 \text{ s}$$

Now that Δt, has been found, we can find Δd as follows:

$$v_{avg} = \frac{\Delta d}{\Delta t}$$

$$\Delta d = \left(\frac{v_1 + v_2}{2}\right)\Delta t$$

$$\Delta d = \left(\frac{+10 \text{ m/s} + +25 \text{ m/s}}{2}\right) \times 5.0 \text{ s}$$

$$\Delta d = +87.5 \text{ m} = +88 \text{ m}$$

Suggestions for Assessment

Performance Assessment

Student Assignments: It is recommended that students be given a significant amount of practice in the problem-solving area. Many are not used to this level of mathematical treatment applied to physical situations.

Written Assessment

While calculation problems may be used, it is important to assess in all modes of representation (i.e., the visual, numeric, graphical, symbolic, and linguistic).

Suggested Learning Resources

See <www.physicsweb.com> for concept development problems for kinematics, including graphical analysis and problem solving.

Appendix 3.12: Kinematics: Position, Velocity, and Acceleration Graphs, and Their Equations

Appendix 3.13: Kinematics Sampler: Graphs, Equations, and Problem Solving

General Learning Outcome Connection

Students will…

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

Specific Learning Outcome

S3P-3-07: Solve problems, using combined forms of:

$$\vec{v}_{avg} = \frac{\vec{v}_1 + \vec{v}_2}{2}, \quad \vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t},$$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}.$$

Suggestions for Instruction

Illustrative Example

If an object is accelerated at +5.0 m/s^2 and starts from rest, what is its velocity after it has travelled 20 m?

Solution: State the given information in symbolic form

Δd = +20.0 m	v_1 = +0 m/s
a = +5.0 m/s^2	v_2 = ?

No equation presented to date has enough information to provide a direct numerical answer in this scenario. Thus, two equations will have to be solved simultaneously. Algebraically, there are many ways to solve two equations simultaneously. Students should be challenged to reinforce the techniques they acquire in math class. A comparison method can be used as follows:

(Since Δt is not required for the final answer, set both equations equal to Δt to eliminate the time variable.)

Equation 1:

$$\Delta d = \left(\frac{v_1 + v_2}{2}\right)\Delta t$$

$$\Delta t = \left(\frac{2\Delta d}{v_1 + v_2}\right)$$

Equation 2:

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

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

$$\Delta t = \frac{v_2 - v_1}{a}$$

Since both equations are equal to Δt, they must be equal to each other.

$$\left(\frac{2\Delta d}{v_1 + v_2}\right) = \frac{v_2 - v_1}{a}$$

$$\left(\frac{2(20.0\text{ m})}{0 + v_2}\right) = \frac{v_2 - 0}{5.0\text{ m/s}^2}$$

$$\frac{40.0\text{ m}}{v_2} = \frac{v_2}{5.0\text{ m/s}^2}$$

$$v_2^2 = 200\,\tfrac{\text{m}^2}{\text{s}^2}$$

$$v_2 = +14\text{ m/s}$$

Senior Years Science Teachers' Handbook Activities

Students write Process Notes to aid their algebraic solutions.

SKILLS AND ATTITUDES OUTCOMES

S3P-0-2a: Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

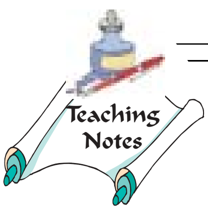
S3P-0-2g: Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

GENERAL LEARNING OUTCOME 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)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

NOTES