Unit 4
Physical Science: Motion

Unit Overview

Introduction

The concept of motion allows students to investigate and develop their interest in the sports that are part of their daily lives. Students will not only have opportunities to investigate the principles of kinematics but will also be encouraged to apply its development into areas of individual interest. Whether they choose Olympic sports events or personal leisure activities such as snowmobiling or biking, students will develop their understanding of the concepts of displacement, velocity, and acceleration.

Focus and Context

The unit on motion should have two principle focuses- inquiry and problem solving. Students will be able to examine questions which inquire into the relationships between and among observable variables that affect motion. Once these relationships are understood, design investigations can begin to address the problems associated with those questions. By applying mathematical and conceptual models to qualitative and quantitative data collected, motion can be graphically represented. This will provide a visual representation of aspects of velocity and acceleration. Mathematics and graphical analysis allow us to see basic similarities in the motion of all objects. In addition, the unit provides opportunities to explore decision making as the students investigate the developments in design technology.

Curriculum Links

Prior to Level I, the study of motion receives little depth of treatment. Indirect connections are found with “Forces and Simple Machines” and “Flight” in elementary science. “Force and Motion” and “Machines and Work” in the intermediate grades have more direct, foundational connections. In high school, those students who pursue studies in Physics will develop further connections in “Force, Motion, Work, Energy, and Momentum.” The study of motion will also develop a strong link to Mathematics in grades 9 and Level I where “Data Management” includes the collection, display, and analysis of data.

Curriculum Outcomes

(From the K-12 Pan Canadian Science Framework Document)

Students will be expected to

STSE

Nature of Science and Technology

114-3 evaluate the role of continued testing in the development and improvement of technologies

114-6 relate personal activities and various scientific and technological endeavors to specific science disciplines and interdisciplinary studies

115-1 distinguish between scientific questions and technological problems

115-4 describe the historical development of a technology

Relationships between Science and Technology

116-7 analyse natural and technological systems to interpret and explain their structure and dynamics

Social and Environmental Contexts of Science and Technology

117-8 identify possible areas of further study related to science and technology

117-10 describe examples of Canadian contributions to science and technology

118-3 evaluate the design of a technology and the way it functions on the basis of identified criteria such as safety, cost, availability, and impact on everyday life and the environment

SKILLS

Initiating and Planning

212-4 state a prediction and hypothesis based on available evidence and background information

212-6 design an experiment and identify specific variables

212-7 formulate operational definitions of major variables

212-9 develop appropriate sampling procedures Performing and Recording

213-3 use instruments for collecting data effectively and accurately

213-4 estimate quantities

Analysing and Interpreting

214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

214-10 identify and explain sources of errors and uncertainty in measurement, and express results in a form that acknowledges the degree of uncertainty

Communication and Teamwork

215-2 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

KNOWLEDGE

325-1 Describe quantitatively the relationship among displacement, time, and velocity

325-2 Analyze graphically and mathematically the relationship among displacement, time, and velocity

325-3 Distinguish between instantaneous and average velocity

325-4 Describe quantitatively the relationship among velocity, time, and acceleration

Physical Science: Motion

Investigating Velocity

Outcomes

Students will be expected to

- devise a method of representing the linear motion of two moving people or objects (215-2)
- develop appropriate sampling procedures for determining the speed of an object's linear motion (212-9)
- use instruments such as ticker timers, photogates, or motion sensors effectively and accurately for collecting data (213-3)
  - demonstrate the proper use of SI units
  - describe the role of instruments in experimental physics.

Elaboration – Strategies for Learning and Teaching

Throughout this unit, it is important that the differences between speed-velocity, distance-displacement, and average velocity-constant velocity be recognized and the names consistently used. Also, if students are provided with various examples of motion to investigate, they will begin to develop a thorough understanding of the concepts of displacement and velocity. The suggested way to introduce this cluster of outcomes is to investigate the linear motion of an Olympic runner. However, the study of motion can easily be applied to many Olympic events, personal interests such as skiing, swimming, snowmobiling, bicycling or orienteering, or the motion of objects. Note, in grade 9 mathematics, students have been exposed to data collection, graphing and its analysis.

In small groups, students should identify a type of motion that can be investigated, with the provision that it must include two moving objects. As they develop their method, students should address key questions such as, What kind of data will we collect? How will we represent the motion?

Given measuring tapes and stopwatches, students will work in groups to collect data on the forward motion of a group member. Students should use equal time intervals and collect at least five distance data points, for example, the distance travelled by a runner at the end of two-second intervals for a total of ten seconds.

It is important to review the expected process of establishing sampling procedures for collecting data and formatting data charts. A brief review of metric units may be necessary as it relates to the context of the problem being discussed.

The student will make a list similar to the following:

(i) thermometers to measure temperature

(ii) microscopes/telescopes to see things very small/very far

(iii) stop clocks to measure time

(iv) computers to collect, store and analyze data.

Physical Science: Motion

Investigating Velocity

Suggested Assessment Strategies

Performance

Students could construct a data table of collected values. Data points are to be plotted on a distance/ time (d/t) graph (m/s) and joined by a line representing the motion. (212-9)

Students could measure and record time and distance, using the proper measuring instrument or device. Measurements should reflect the precision of the measuring instrument. (213-3)

Students could measure and record time and displacement, using the proper measuring instrument or device. Measurements should reflect the precision of the measuring instrument. They should plot a displacement-time graph and use it to find the acceleration. (213-3)

Presentation

Students could present a method of representing the linear motion of two moving people or objects. They should include how the data will be collected, organized and put in a format that will allow for analysis. (215-2)

Students could present a method of representing the linear accelerated motion of two moving objects. They should include how the data will be collected, organized, and put in a format that will allow for analysis, and suggest the kinds of qualitative and quantitative analysis that can be completed. (215-2)

Portfolio

Students could enter into their portfolio an operational definition for acceleration, and provide examples of acceleration in daily life. Leave space so that it can be updated as their study of acceleration continues. (212-7)

Students could prepare for their portfolio a formal write-up for the experiment designed and conducted to study the factors affecting acceleration. (212-6, 212-9)

Resources

Science 10

pages 362-365

pages 352-353

pages 369-373

pages 689-690

Physical Science: Motion

Investigating Velocity (Cont'd)

Outcomes

Students will be expected to

- evaluate the relevance, reliability, and adequacy of data and data collection methods (214-8)
  - distinguish between accuracy and precision of data
- identify and explain sources of errors and uncertainty in measurement, and express results in a form that acknowledges the degree of uncertainty (214-10)
  - record measurements using appropriate number of significant digits.
  - demonstrate the proper use of significant digits during calculations
  - express measurements in scientific notation when appropriate.
- describe quantitatively, and analyze both graphically and mathematically, the relationship among distance, time, and speed of an object's linear motion (212-7, 325-1, 325-2)
  - define average speed and calculate it, given information about distance moved and time taken
  - explain what is meant by uniform motion
  - explain what is meant by instantaneous speed

Elaboration – Strategies for Learning and Teaching

The outcomes concerning measurements, uncertainty and significant digits can be dealt with as the various kinematic concepts are dealt with. It should also be noted that these concepts are part of the Mathematics 1204 curriculum and a simple review should be sufficient at this time.

Students should identify and explain sources of error and degree of uncertainty. It is important to discuss accuracy of measurement and techniques that minimize errors. This outcome, and any others dealing with measurements and data analysis, should be addressed throughout the unit, especially in dealing with laboratory investigations.

It should be noted that this topic is part of the Mathematics 1204 course and all students should have a good grasp of this already.

The student will first define a measurement written with the correct number of significant digits as one for which all digits but the last one are certain. That is, the last digit will be an estimated value which lies between the graduations (marks) on the measuring device.

Previously collected data may be a good starting point in plotting speed/time graphs. The average speed for each time interval can be determined. Students should recognize that the average speed during a time interval can be calculated by determining the slope of the line between time intervals, or by a mathematical equation.

The mathematical formula relating distance, time, and average speed should be introduced here:

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

Physical Science: Motion

Investigating Velocity (Cont'd)

Suggested Assessment Strategies

Performanace

While collecting and recording data in a chart, students could write all values in a form that recognizes the precision of the measurements. Calculations using collected data should recognize significant digits. (214-10)

Interview

In a group, students could identify potential sources of error in data collection. A member(s) from each group should be asked to name the sources of error and how each affected the data collected. (214-10)

Presentation

In a group, students could present suggestions on ways to improve the method by which data is collected and recorded. Possible presentation formats may include video, role-playing or demonstration. (214-8)

Students could illustrate graphically the motion sequence for an object. This should include stop (no motion), motion forward and away from the original starting point. (325-2)

Students could use data to construct a distance/ time (d/t) graph from which two methods may be used to determine quantitatively, the average speed of a student's or object's motion. (325-1, 212-7)

Journal

Students could enter into their portfolio an operational definition for velocity. They could provide examples that affect their daily life. (212-7)

Resources

Science 10

page 344

pages 344-349

pages 702-703

page 698

pages 340-341; 354-357; 362-364

Physical Science: Motion

Investigating Velocity (Cont'd)

Outcomes

Students will be expected to

- describe quantitatively, and analyze both graphically and mathematically, the relationship among distance, time, and speed of an object's linear motion (212-7, 325-1, 325-2) Cont'd
  - carry out an experiment to measure the speed of an object at various points along its path, making use of ticker timers or micro-computer based laboratories, and analyze the data graphically
  - given the distance-time data, plot a d/t graph, appropriately labeled with the dependent and independent variables correctly placed
  - determine the slope of a d/t graph and state the physical significance of the slope
  - for a uniformly moving object, plot a speed-time graph and explain the physical significance of the y-intercept and the area under the graph
  - determine speed from a distance/time graph, and determine distance from a speed/time graph
- predict the time taken for a moving object to complete a course on the basis of initial measurements, estimated values, and an understanding of the displacement, time, and, velocity relationship (212-4, 213-4)

Elaboration – Strategies for Learning and Teaching

The student will show that the best-fit graph is a straight, horizontal line with the y-intercept equal to the constant speed and the area under the graph equal to the distance traveled.

Students can apply their understanding of motion to compare two runners in a 5000 metre race. Given the time at various displacement intervals early in the race, and calculating the average velocities, students can predict the final results of the race. Knowing the remaining displacement for the slower runner, students can calculate the time required to complete the race.

Physical Science: Motion

Investigating Velocity (Cont'd)

Suggested Assessment Strategies

Paper and Pencil

Students could predict finishing times for both runners to complete a 5000 metre race, using data representing the initial displacements. This can be done graphically on a d/t graph and verified mathematically. (212-4, 213-4)

What is the distance remaining for Sally when Mary crosses the finish line? How long does it take Sally to cross the finish line after Mary? Develop a chart so that individual time values are given for distances of 1000 metre increments. What assumptions are made? (212-4, 213-4)

Resources

Science 10

Core Lab: *"Determining an Average Speed"*, pp. 372-373, or Appendix A

Physical Science: Motion

Investigate the Relationship Between Velocity, Time and Acceleration

Outcomes

Students will be expected to

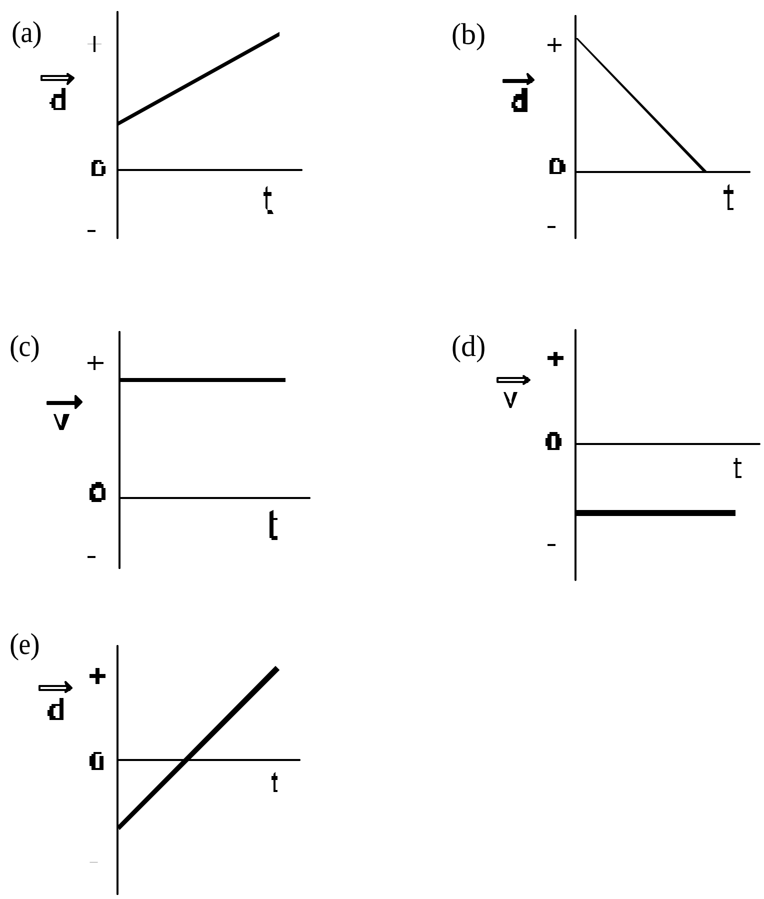
- describe quantitatively, and analyze both graphically and mathematically, the relationship among displacement, time, and velocity of an object's uniform motion (212-7, 325-1, 325-2)
  - distinguish between scalar and vector quantities, using distance and displacement, and speed and velocity, respectively, as examples.
  - define average velocity, and explain why it is a vector quantity
  - given two (or a means of finding two) of average velocity, displacement and elapsed time, calculate the third quantity
  - determine velocity from a position-time graph, and determine displacement from a velocity-time graph
  - determine the direction of motion (positive or negative) of a uniformly moving object from its position-time graph, and its velocity-time graph

Elaboration – Strategies for Learning and Teaching

The mathematical formula relating displacement, time, and average velocity should be introduced here:

$$\overline{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$$

The student will be able to deal with graphs such as the following, giving answers as provided on the following page.



a) Positive slope of a d-t graph means object has fixed speed to the right.

b) Negative slope of a d-t graph means object has fixed speed to the left.

c) Object has fixed speed to the right. (same as (a))

d) Object has fixed speed to the left. (same a (b))

e) Positive slope of a d-t graph means object has fixed speed to the right. However, it did begin its motion to the left of the zero metre reference point.

Physical Science: Motion

Investigate the Relationship Between Velocity, Time and Acceleration

Suggested Assessment Strategies

Interview

Students could analyse graphically and mathematically the relationships among displacement, time, and velocity for a motion sequence. What assumptions have to be made? (325-2)

Resources

Science 10 TR

pages 446-449; 452-455

pages 414-416; 432

page 433

pages 434-435

Physical Science: Motion

Investigate the Relationship Between Velocity, Time and Acceleration (Cont'd)

Outcomes

Students will be expected to

- distinguish between average velocity and instantaneous velocity (325-3)

Elaboration – Strategies for Learning and Teaching

The average velocity represents motion over a time period, whereas instantaneous velocity represents the velocity at a particular time

Teachers could introduce accelerated motion by discussing the motion of a student sprinting over 50 metres. Note, unlike constant velocity, the runner will travel a greater distance in each succeeding time interval until maximum velocity is reached. This non-uniform velocity results from acceleration (or, if slowing down, deceleration). Students should be aware of the effect of forces on the velocity; however, the concept of an unbalanced force causing acceleration should be limited in its development to only its resultant effect.

- use instruments for collecting data on uniformly accelerated linear motion effectively and accurately (213-3)
  - from the data obtained in the core lab, plot a position-time graph
  - given one of position or time, determine the other from a graph
  - determine the instantaneous velocity by taking the slope of a tangent drawn to the curve at a selected position or time on the graph and use velocities obtained in this way to plot a velocity-time graph

Students should produce both displacement/time and velocity/time graphs for the data from the core lab. Students should recognize that a smooth curve through the points on the displacement/time graph is a more accurate representation than straight lines. Students should draw tangents (representing instantaneous velocity) at various times. Acceleration can be introduced as the rate of change of velocity per unit time. Students should be able to translate this quantitatively by examining the slope of each tangent line and its relative change at each time interval.

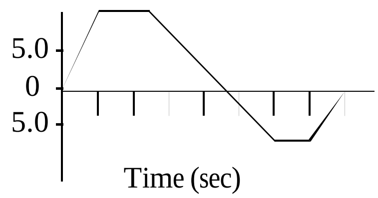
Physical Science: Motion

Investigate the Relationship Between Velocity, Time and Acceleration (Cont'd)

Suggested Assessment Strategies

Paper and Pencil

Using displacement/time (d/t) graphs representing different motion sequence, students could identify and distinguish between average and instantaneous velocities. (325-3)



Resources

Science 10

page 433

Core Lab: *"Speeding and Slowing Down"*, pages 460-461, or

Appendix A.

pages 446-449

page 349

Physical Science: Motion

Investigate the Relationship Between Velocity, Time and Acceleration (Cont'd)

Outcomes

Students will be expected to

- describe quantitatively, and analyze both graphically and mathematically, the relationship among velocity, time, and acceleration (212-7, 214-5, 325-4)
  - distinguish between uniform and non-uniform motion
  - explain what is meant by uniform or constant acceleration and explain why it is a vector quantity
  - define acceleration as the rate of change of velocity per unit time
  - use the definition of acceleration to determine acceleration, initial velocity, final velocity, or time, given the other three
  - relate the slope of a linear velocity-time graph to the acceleration
  - calculate the area of a velocity-time graph and relate it to the object's displacement
  - given the velocity-time graph for a uniformly accelerating object, determine its initial velocity and its acceleration
  - explain how one can tell from the position-time graph whether the magnitude of an object's velocity is increasing, decreasing, or constant
  - determine, at any time, the instantaneous velocity from a displacement/time graph for an object with zero acceleration or uniform acceleration.

Elaboration – Strategies for Learning and Teaching

Students should only deal with uniform acceleration.

The mathematical formula relating acceleration, time, and velocity should be introduced here:

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

It is not intended for students to either derive or use the formula

$$\vec{d} = v_i t + \tfrac{1}{2}\vec{a}t^2$$

Develop the concept that the slope of a velocity/time graph represents acceleration ((m/s)/s) or m/s^2) and that it can be represented by the mathematical formula given above.

Since the slope of a position-time graph is the velocity, the student will have to determine by looking at the graph if it is (i) curving with an ever increasing slope, (ii) an ever decreasing slope, (iii) not curving at all, i.e. a straight line means constant velocity, or (iv) a horizontal line —that is, not moving at all.

Physical Science: Motion

Investigate the Relationship Between Velocity, Time and Acceleration (Cont'd)

Suggested Assessment Strategies

Presentation

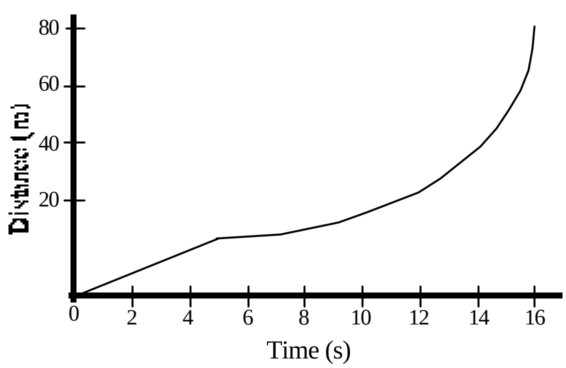
Students could use data to construct a displacement/time (d/t) and velocity/time (v/t) graphs. They could describe quantitatively two methods to determine acceleration. The should also calculate the acceleration and compare the results. (325-4)

Time (s)	John : Total Displacement (m)[A]	Joel : Total Displacement (m)[A]
0	0	0
2	3.0	1.6
4	6.0	6.4
6	9.0	14.4
8	12.0	25.6
10	15.0	40.0

[A] Represents total displacement from start during the time interval

Paper and Pencil

Given a series of graphs, students could identify the patterns that indicate uniform and non-uniform (accelerated) motion. E.g., for the graph below, they could describe the motion represented by the graph and calculate the velocity at t= 2, 6, 10, 12, 14 s (214-5)



Resources

Science 10

pages 384-388; 390-392; 398-400; 446-449; 452-455; 462-465; 466-472

Physical Science: Motion

Technological Improvements Based on Design Testing and Analysis

Outcomes

Students will be expected to

- distinguish between scientific questions and technological problems related to a motion research topic (115-1)
- describe the historic development of a motion technology (115-4)
- evaluate the design of a motion technology and the way it functions with relation to safety, construction, and cost (118-3)
- evaluate the role of continued testing in the development and improvement of a motion technology (114-3)

Elaboration – Strategies for Learning and Teaching

This cluster of outcomes can be introduced by examining the relationship between science and technology. Teachers could discuss with students the need to have a scientific question "What is the effect of the track surface on the performance of a runner's footwear?" is restated into a technological problem "How can the design of a runner's footwear be modified to take into account the track's surface?"

Using teams, students could research the development of various designs of footwear that have been used by runners. They should categorize and describe those designs now available and analyse each category for design features and function (that is, track event, track surface, indoor-outdoor). Students should evaluate the design of the footwear on the basis of safety (preventing injury), overall construction, reliability, and cost.

Students should identify the features of footwear design that would be considered important to develop improvements. They should evaluate the role of continued testing in their development and improvement.

Physical Science: Motion

Technological Improvements Based on Design Testing and Analysis

Suggested Assessment Strategies

Although the following strategies use the context of athletic footwear, they provide a model which can be applied to other topics.

Observation
Students are asked to wear athletic footwear to class and are divided to form heterogeneous groups. They could find and record similarities and differences among the footwear.

Students are then asked to regroup homogeneously on the basis of similar footwear (for example, basketball).

In this research group, students could identify how technology has modified the footwear design to suit its intended purpose. Participation in this investigation will be based on a 5-step rating scale. (115-1)

Journal
Students could respond to a self-developed question regarding the role of continued testing in the development and improvement of footwear (e.g., as design tries to meet a sport's changing need, what role will continued testing play?) (114-3)

Presentation
Research groups could collectively present findings on their type of footwear based on function and design, safety, construction, and cost. The presentation must address the question of whether function determines design or design determines function. (118-3)

Resources

Science 10
pages 430-431

pages 458-459

page 396

Science 10 TR
pages 176-177

Science 10
page 134

Physical Science: Motion

Present and Future Development

Outcomes

Students will be expected to

- relate a research project on motion to studies in specific science disciplines and interdisciplinary studies (114-6)
- identify areas of further study related to science and technology of motion (117-8)
- describe examples of Canadian contributions to science and technology in the area of motion (117-10)

Elaboration – Strategies for Learning and Teaching

This can easily be applied to other interest areas. Similar investigations might be made into the technology of ice skates, snowboards, bicycles, skis, skateboards, or cars.

Students can develop a Venn diagram or Concept Map to detail each of the following:

1 Relationship of a particular interest to specific science disciplines and interdisciplinary studies. For example, the motion of running can be related to studies in kinematics, aerodynamics, and mathematics.

2 Identification of possible areas of future study related to science and technology. For example, factors that affect the motion of a runner can be related to sports training, computer technology, mechnical engineering, and aerodynamics.

Students may require teacher direction with the format expected for the Venn diagram or Concept Map and the detail or reference expected.

Students can present examples of Canadian contributions in a specific area of interest. A specific company can be researched with their contribution (e.g., Bombardier designs in snowmobiles, trains, and airplanes), or a particular topic researched (e.g., Canadian contributions in the area of track surface or bicycle design). The report should include such details as design contributions, recent developments, and global impact.

Physical Science: Motion
Present and Future Development

Suggested Assessment Strategies

Performance
Students could present to the research group (based on similar footwear type) findings on the evolution of a specific type of athletic footwear. Peers should evaluate the presentation using a 5-step rating scale. (115-4)

Journal
Students could develop a Venn diagram (or Concept Map) to present various science disciplines and interdisciplinary studies for a particular interest in motion. (114-6)

Presentation
In a research group, students could develop and present a Venn diagram (or Concept Map) which links the study of motion to science and technology. (117-8)

Portfolio
Students could research and write a report on a specific Canadian contribution to science and technology in the area of motion. The report should include such details as design contributions, recent developments and global impact (e.g., Bombardier, SPAR Aerospace, Rupert W. Turnbull). (117-10)

Resources

Science 10

page 408, 430, 458