Unit 1
Kinematics
Suggested Time: 25 Hours

Kinematics

Introduction

Motion is a common theme in our everyday lives: birds fly, babies crawl, and we, ourselves, seem to be in a constant state of movement, running, driving, and walking. Kinematics is the study of how objects move, and as such, makes up a large part of introductory physics.

Because students learn in a variety of ways, they must be given many different opportunities to explore kinematics. The experiences should include kinesthetic learning, where students will feel the effects of different speeds and accelerations and see the difference these make in the records of their own motion. Students need to have varied experiences and time to think, reflect, assimilate, and rethink so that they own their accumulated knowledge.

Students must be encouraged to develop the vocabulary of kinematics by discussing the concepts among themselves and with the teacher. They should be required to describe and explain the motion of objects both verbally and in written and mathematical forms. Students should use algebraic and graphical analytical techniques.

Focus and Context

Inquiry and problem solving are used throughout this unit in a variety of meaningful contexts. These contexts may include examples such as skateboarding, sports, automobile motion, or any other relevant context. Students learn best when they suggest the context. To foster connections, students must be given sufficient opportunities to observe, manipulate, discuss, predict, describe, and explain the motion of objects in various situations. Only then should problem solving in more abstract situations be undertaken.

Science Curriculum Links

Students are expected to review and extend their understanding of one-dimensional motion acquired in Science 1206, culminating in the use of one-dimensional vector representations of relative motion. The concepts developed in the study of kinematics in Physics 2204 will be applied to two-dimensional situations in Physics 3204.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Relationships Between Science and Technology** **116-2** analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of technology **116-6** describe and evaluate the design of technological solutions and the way they function, using scientific principles	*Students will be expected to* **Initiating and Planning** **212-1** identify questions to investigate that arise from practical problems and issues **212-3** design an experiment identifying and controlling major variables **212-8** evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **Performing and Recording** **213-2** carry out procedures controlling the major variables and adapting or extending procedures where required **213-3** use instruments effectively and accurately for collecting data **Analysing and Interpreting** **214-3** compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots **214-5** interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables	*Students will be expected to* **325-5** use vectors to represent force, velocity, and acceleration **325-2** analyse graphically and mathematically the relationship among displacement, velocity, and time **325-7** identify the frame of reference for a given motion

Vector Analysis

Outcomes

Students will be expected to

- use vectors to represent position, displacement, velocity and acceleration (325-5)
  - define scalar and vector quantities
  - distinguish between scalar and vector quantities, using distance and displacement, respectively, as examples
  - add and subtract linear and perpendicular vectors, algebraically and graphically

Elaborations—Strategies for Learning and Teaching

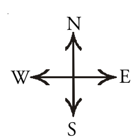
For kinematics vector treatment will be linear and perpendicular only

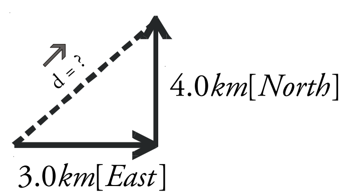
Students need to deal with formal expression of, and operations for, vector quantities. Students should realize that scalar quantities can be assigned an algebraic identifier (x, a, λ), and rules of operations as defined in algebra apply. However vector quantities must be assigned both a magnitude and direction. A line can be drawn on a Cartesian system whose length represents magnitude and orientation represents direction. There should also be a means to add, subtract and do other operations with these quantities.

Students could create “treasure” maps for each other in and around the school. On a city street map, it is possible to practice discriminating between distance and displacement.

The tip-to-tail nature of vector addition **must** be emphasized. Scale diagrams **and** algebraic methods (using rough sketches) should be used to do this.

Teachers should emphasize both magnitude and direction of resultant vector.





Solution: $\vec{d} = 5.0km[E\,35^o\,N]$

The following are other plausible ways of indicating directions.

$[35^o\ N\ of\ E]$

$[N\,55^o\,E]$

$[55^o\ East\ of\ North]$

Vector Analysis

Suggested Assessment Strategies

Paper and Pencil

- The sum of two vectors is zero. Students could answer questions such as; “What can you say about the magnitude and direction of the two vectors?? (325-5)
- Caroline and Erin planned to meet at the shopping mall. Caroline left her home and walked 4 blocks north, 2 blocks east, and 2 more blocks north to reach the mall. Erin left her house and walked 2 blocks south, 3 blocks west, and 3 more blocks south. Students could draw a careful vector diagram of both motions and answer the following questions:

  – What distance did each girl walk?

  – Which girl’s home is farthest in a straight line from the mall? (Direct in degrees)

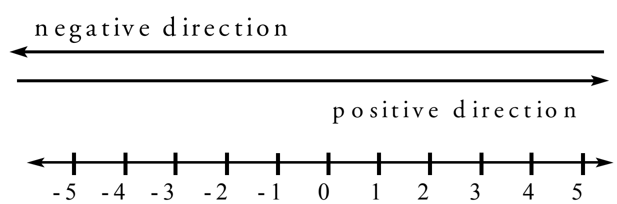
  – What is the straight line distance between Caroline’s home and Erin’s home?

  Note: *All distances may be expressed in blocks.* (325-5)

  - Using the diagram below, students could identify which pairs give a positive displacement:

  a. +5m, -2m   b. -3m, +6m   c. -4m, -2m

  (325-5)



Presentation

- Students could create a short narrative involving several of their friends using the following displacements. They should list three questions they could ask if the following were points on a test question.

  a. 10 km [E] b. 5.0 km [S] c. 8.0 km [W] d. 3.8 km [NW] (325-5)

Journal

- Students could answer, “What does the speedometer of a car measure: speed, velocity, or both?” They should explain their answer. (325-5)

Resources

www.gov.nl.ca/edu/science_ref/main.htm

Physics - *Its Methods and Meaning*, Taffel, Prentice-Hall, 1994. pp 43-46

Physics: C and C, p 7

Physics: C and C, pp 7-11

FP, pp 60-62

PMW, pp 43-45

Physics: C and C, pp 79-84

Outcomes

Students will be expected to

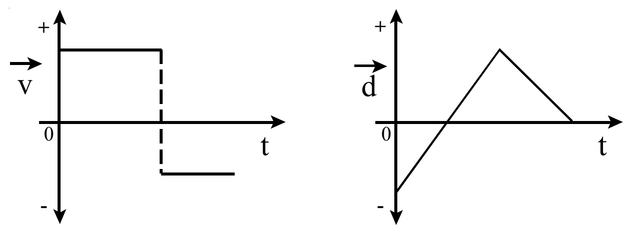
- analyze graphically and mathematically the relationship among displacement, velocity, and time (325-2)
  - explain how one can tell from the position-time graph whether the magitude of an object's velocity is increasing, decreasing, or constant
  - using the sign convention that motion to the right is positive and motion to the left is negative, determine the direction of motion of a uniformly accelerating object from its position-time graph and its velocity-time graph
  - given velocity-time graphs, tell if the velocity is increasing, decreasing or remaining constant
  - use a velocity-time graph for uniform acceleration to derive an equation
    - (i) for displacement in terms of initial velocity (or final velocity), acceleration, and elapsed time
    - (ii) relating final velocity, initial velocity, acceleration, and displacement

Elaborations—Strategies for Learning and Teaching

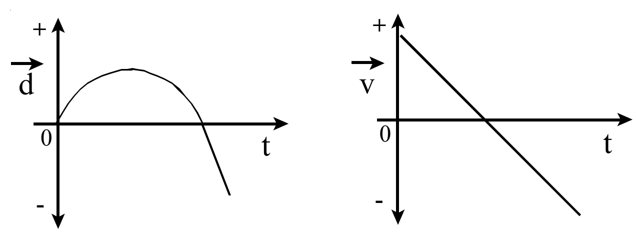
The graphical and mathematical analysis should apply to both uniform and accelerated motion. (Some of this will entail a review of concepts addressed in Science 1206.)

The students should be able to interpret and draw graphs such as the following:

(i) uniform motion

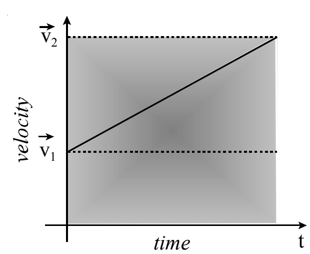


(ii) uniform acceleration



Algebraic formulae are nothing more than definitions and familiar relationships suitably rearranged for problem solving.

The students should be able to produce two derivations based on the graph shown below.



(i) $\vec{a} = \dfrac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

(ii) $\vec{d} = \dfrac{1}{2}\left(\vec{v}_2 = \vec{v}_1\right)$

Graphical and Mathematical Analysis

Suggested Assessment Strategies

Presentation

- With data collected from their motion trials at the beginning of this unit, students could make a table of their data and draw $\vec{d}-t$, $\vec{v}-t$ and $\vec{a}-t$ graphs from this information. They should explain what their graphs show. (325-2)
- In groups of two or more, students could draw some representative position-time and velocity-time graphs. They could then have another group describe the motion of the object for each graph. (325-2)
- In groups of two or more, students could analyse the motion of a dynamics cart launched up an incline using laboratory interface technology. This analysis of the cart throughout its motion up and down the incline with generated $\vec{d}-t$, $\vec{v}-t$ and $\vec{a}-t$ graphs will help students conceptualize the differences among displacement, velocity and acceleration. (325-2)

Resources

Physics: C and C, pp 56-64

Physics: C and C, pp 14-36

Physics: C and C, pp 19-22 and pp 38-52

Physics: C and C, pp 38-52

Physics: C and C, pp 53-55

Physics: C and C, pp 54-55

Physics: C and C, pp54-55

Graphical and Mathematical Analysis (continued)

Outcomes

Students will be expected to

- analyze graphically and mathematically the relationship among displacement, velocity, and time (325-2) **Cont'd**
  - solve kinematics problems using algebraic techniques including the manipulation of formulae (and including the special case of acceleration due to gravity)

Elaborations—Strategies for Learning and Teaching

Students can then use substitution to derive the following:

$$\vec{d} = \vec{v}_2\Delta t - \frac{1}{2}\vec{a}\Delta t^2 \qquad \vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2 \qquad \vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$$

$$\vec{V}_{avg} = \frac{\vec{V}_1 + \vec{V}_2}{2} \qquad \vec{a} = \frac{\vec{V}_2 - \vec{V}_1}{\Delta t}$$

$$\vec{d} = \vec{V}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2 \qquad \vec{d} = \vec{V}_2\Delta t - \frac{1}{2}\vec{a}\Delta t^2$$

$$\vec{V}_2^{\,2} = \vec{V}_1^{\,2} + 2\vec{a}\Delta\vec{d} \qquad \vec{d} = \left(\frac{\vec{V}_1 + \vec{V}_2}{2}\right)\Delta t$$

Problem solving is an integral part of the study of kinematics. Problems should be presented at various levels of difficulty, **but will not require the use of the quadratic formula**. Good problem solving strategies should be modelled consistently by the teacher. The first reading of a problem should give the student a general sense of what is given and required. A second reading should be done slowly for the purpose of gleaning all usable data from the text. Students often miss expressions such as "starting from rest" which give the information that v_1 is zero. When presenting solutions on the chalkboard, teachers should verbalize the thought process as completely as possible. Students should be encouraged to make a list of given data on the work sheet.

It is also a good practice to estimate the correct answer where possible, and to evaluate the solution according to common experience. For example, it is unreasonable to conclude in a solution that the final speed of an automobile is 350 m/s.

A further practice which is helpful in evaluating a solution is to carry the units throughout the work. If the answer for final velocity seems to be 35.0 m/s^2, the unit suggests something went wrong. Again, students will more likely accept what the teacher models.

Many students are uncomfortable starting a problem when they cannot clearly see the method that will lead to the answer. Since many physics problems have two or more steps, students should learn to solve what they can on the understanding that it may lead to something useful.

Graphical and Mathematical Analysis (continued)

Suggested Assessment Strategies

Paper and Pencil

- Students could solve problems similar to the following: Alex and Raj always try to outdo each other on their skateboards. They decide to have a "hang time" contest. They begin side by side and push their boards to a speed of 5 m/s. At the same time, they jump straight up as high as they can and land on the moving board. Alex's board goes 7.5 m before he lands, and Raj's board goes 6.0 m before he lands. How long was each boy in the air? How high did each jump? (325-2)
- Students could solve problems similar to the following: Two rocks are dropped simultaneously from windows in an office tower. Rock A is dropped from a height of 50.0 m and Rock B from a 25.0 m height. How long after Rock B strikes the ground will Rock A? (325-2)

Presentation

- In groups of two, students could prepare kinematics problems. They should write out the problem and solution(s) on a separate page. They could have another group try their problem(s). How is their understanding of the problem like or unlike that of their fellow students? (325-2)

Resources

Physics: C and C, pp 56-64

Graphical and Mathematical Analysis (continued)

Outcomes

Students will be expected to

- analyze graphically and mathematically the relationship among displacement, velocity, and time (325-2) **Cont'd**

Elaborations—Strategies for Learning and Teaching

Students should be encouraged to check given data against the basic kinematics formulae, until a formula is found for which all but one variable is known. They should then rearrange for the unknown. This should be solved, even if it does not give the required answer, since it adds another known variable to the list.

Students should use the kinematics acceleration formulae substituting "g" for "a".

- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of technology (116-2)

The CORE STSE component of this unit incorporates a broad range of Physics 2204 outcomes. More specifically it targets (in whole or in part) 116-2, 116-6, 212-1, 325-2. The STSE component, *The Physics of Tailgating*, can be found in Appendix A.

- identify questions to investigate that arise from practical problems and issues (212-1)
- carry out an experiment to investigate the motion of an object falling vertically near Earth (212-3, 213-2)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8, 213-3)
- compile and display evidence and information in a variety of formats (214-3)
- interpret trends in data, and infer or calculate relationships among variables (214-5)
- compare theoretical and empirical values and account for discrepancies (214-7)

The Laboratory outcomes (116-2, 212-1, 212-3, 212-8, 213-2, 213-3, 214-3, 214-5) and 325-2 are addressed by completing Acceleration Due to Gravity CORE LAB #1. (Lab 2.2, p 77)

Students should conduct a laboratory investigation involving the vertical acceleration of gravity. Possible apparatus might be a picket fence, ticker tape timers, motion sensors, and photogates. Teachers should expect a written lab report from their students. Percentage error should be calculated in this investigation and anywhere else an accepted value is known.

Graphical and Mathematical Analysis (continued)

Suggested Assessment Strategies

Journal

- Students could reflect on their understanding of kinematics now as compared to the beginning of this unit. What evidence do they have to support their understanding? (325-2)
- Students could discuss the following question; "In free fall, does the speed of an object affect the amount of air friction?" (116-2)

Presentation

- Students could draw a diagram of the picture of the activity they chose for motion. They should use coordinate axes where possible. Students should choose which direction is positive and which is negative. (116-2, 325-2)

Performance

- Students could conduct a lab and write a report on their investigation of the acceleration of gravity. (116-2)

Resources

Core STSE #1: *"The Physics of Tailgating"*, Appendix A

Core Lab #1: *"Acceleration Due to Gravity"* *Physics: C and C*, p 77
OR Computer Interface Alternative:
www.gov.nl.ca/edu/science_ref/main.htm

Relative Motion

Outcomes

Students will be expected to

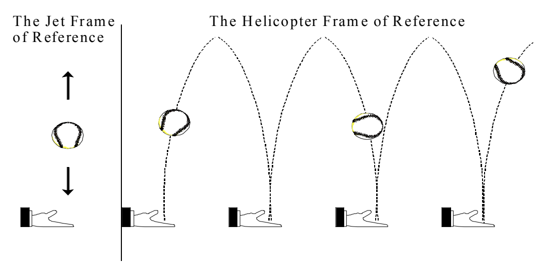
- explain what is meant by, and identify the frame of reference for, a given motion to distinguish fixed and moving frames (325-7)

Elaborations—Strategies for Learning and Teaching

Skateboard physics is a meaningful context for this concept. For example, if a skateboarder goes by, how does the motion appear against a fixed background? How does the background appear to the boarder?

The student will define a frame of reference as a place from which motion is observed. The description of any motion depends on the frame of reference of the observer.

For example, if you are on a jet plane travelling horizontally at a fixed speed while tossing a baseball up and down, catching it each time, you see the motion as straight up and down motion in **your frame of reference** (the cabin of the jet). However, if a helicopter is hovering in a stationary position (with respect to Earth), and the helicopter pilot can see through the windows of the jet, he will see the baseball tracing out great loops as the jet whizzes by.



Relative Motion

Suggested Assessment Strategies

Journal

- Students could use their knowledge of frames of reference to describe how a paperboy could toss a newspaper to a door step from a moving bicycle. Assuming he can only toss the paper direectly to his side (perpendicular to motion of his bike), should the paper be released directly in front of the door step? before reaching the door step? or after passing it? Students should explain their answer. (325-7)
- Students could explain everyday situations such as, when you sit in a car at a traffic light and observe a truck in the next lane, you may feel that you are moving backward although your vehicle is at rest with respect to the pavement." (325-7)

Resources

Physics: C and C, pp 95-97

Relative Motion (continued)

Outcomes

Students will be expected to

- explain what is meant by, and identify the frame of reference for, a given motion to distinguish fixed and moving frames (325-7) **Cont'd**
  - given two of the displacement of an object relative to a medium, the displacement of the medium relative to Earth, and the displacement of the object relative to Earth, calculate the third quantity
  - given two of the velocity of an object relative to a medium, the velocity of the medium relative to Earth, and the velocity of the object relative to Earth, with all velocities in the same direction, calculate the third quantity
  - given two of the velocity of an object relative to a medium, the velocity of the medium relative to Earth, where these are in opposite directions, and the velocity of the object relative to Earth, calculate the third quantity

Elaborations—Strategies for Learning and Teaching

It is useful for students to use the pneumonic device $\vec{V}_{ac} = \vec{V}_{ab} + \vec{V}_{bc}$ to determine the relative velocity of object A with respect to observer C in problems involving frames of reference.

Sample Problems Include:

1. An ant crawls a distance of 10 cm to the right on a plate (relative to the plate) as a disgusted picnicker pushes the plate a distance of 40 cm to the right (relative to Earth). Determine the displacement of the ant relative to the Earth.

2. An ant crawls a distance of 10 cm to the East on a plate (relative to the plate) as a disgusted picnicker pushes the plate a distance of 40 cm West (relative to Earth). Determine the displacement of the ant relative to the Earth.

3. An ant crawls a distance of 10 cm to the East on a plate (relative to the plate) as a disgusted picnicker pushes the plate a distance of 40 cm due North (relative to Earth). What is the displacement of the ant with respect to the Earth?

Familiar examples includes a boat in a stream (or plane in the air) travelling with the current (or wind).

Familiar examples includes a boat in a stream (or plane in the air) travelling against the current (or wind).

Relative Motion (continued)

Suggested Assessment Strategies

Journal

- Students could solve problems similar to the following: A parachute is designed such that air escaping from vents in the rear cause it to move at 20 km/h with respect to the air. If the wind is blowing at 20 km/h [Eastward], how could the parachutist reduce his/her relative velocity with respect to the ground to allow for the most safe landing? (325-7)
- Using the concept of relative motion, students could explain how a helicopter, in a gale which is blowing at 120 km/h toward the northwest, can remain positioned over an oil rig in the north atlantic. (325-7)

Resources

Physics: C and C, p 95

Physics: C and C, p 96

Physics: C and C, pp 97-98

Relative Motion (continued)

Outcomes

Students will be expected to

- explain what is meant by, and identify the frame of reference for, a given motion to distinguish fixed and moving frames (325-7) **Cont'd**
  - given two of the velocity of an object relative to a medium, the velocity of a medium relative to Earth, where these are perpendicular to one another, and the velocity of the object relative to Earth, calculate the third quantity
  - given the velocities of objects A and B in one dimension with respect to Earth, find their velocities with respect to each other
  - solve kinematics exercises/ problems involving relative motion

Elaborations—Strategies for Learning and Teaching

Familiar examples includes a boat in a stream (or plane in the air) travelling across the current (or wind).

The student should be able to solve problems like:

Car A is moving northward at 60 km/hr and Car B is moving northward at 50 km/hr along the same road (each with respect to the Earth). Determine the velocity of Car A with respect to Car B.

Sample Problems include:

1. A boat can travel at 4 m/s in still water. If a river current moves at 3 m/s, find the velocity of the boat relative to Earth if it goes

   a) downstream b) upstream c) across stream

2. A duck is flying due South at 30 km/hr with respect to the Earth. A photographer is driving due North at 60 km/hr with respect to the Earth. Determine:

   (a) the velocity of the duck with respect to the photographer

   (b) the velocity of the photographer with respect to the duck

3. A wild life crew spot a herd of moose 4.0 km due West and running directly away from the helicopter at 10 m/s West, with respect to Earth. The helicopter follows the herd at 42 m/s West with respect to Earth.

   a) What is the velocity of the helicopter relative to the moose?

   b) What is the velocity of the moose relative to the helicopter?

   c) How long will it take the helicopter to reach the herd's original location?

   d) How long from the time of first sighting will it take the helicopter to catch the herd?

Relative Motion (continued)

Suggested Assessment Strategies

Paper and Pencil

- Students could solve problems similar to the following: Mark rode his personal water craft at a constant speed of 30 km/h directly across a river running at 5 km/h downstream. What is Mark's velocity relative to the bank? (325-7)
- A section of the Humber river near Corner Brook flows at a rate of 3 km/h [W]. A triathlete can swim at a rate of 5 km/h in still water. She wishes to swim to a point that is directly across the river from where she is standing. Students could determine at what angle must this triathlete enter the water to accomplish this task? (325-7)

Resources

Physics: C and C, pp 99-100

Physics: C and C, p 96

Physics: C and C, pp 96-103

Unit 2
Dynamics
Suggested Time: 30 Hours

Dynamics

Introduction

From real life experiences, students know that objects speed up, slow down, and change direction, and they accept this as a matter of course. Dynamics is the study of the factors that cause such changes, that is, why an object moves the way it does. It is a logical extension of kinematics, and this unit should pick up with questions arising naturally from the motion of objects studied in the previous unit. Students could begin by investigating the effects of one-dimensional forces on themselves and on objects, and, through the application of Newton's laws, move on to an analysis of systems using their knowledge of dynamics. At the end of this unit students are introduced to situations where two or more objects are considered at once (a system is involved). These situations are dealt with using the concept of momentum and will be further developed in the next unit in a work and energy context.

Focus and Context

As in the kinematics unit, students should draw on their own experiences in attempting to describe and analyze forces. Familiar forces students feel acting on themselves in cars, on amusement park rides, and during sports activities should be discussed and analyzed. A simple activity such as measuring with a spring scale the force needed to start and continue to pull a student along the floor in a wagon or freight dolly can lead to discussion of the outcomes of applied force: acceleration and overcoming friction. Activities with dynamics carts would then allow students to investigate, measure, manipulate, and predict relationships among force, mass, and acceleration. This could lead to many opportunities for individual study and research projects involving the design and operation of such devices as seat belts, airbags, helmets, and sports equipment—all with a view to making connections among the design, principles of physics, and society's concern and influence (an STSE connection.)

Science Curriculum Links

This unit completes the study of motion begun in Science 1206. It provides students with an opportunity to reinforce their skills in using the graphing calculators. It leads students to the more sophisticated concepts of momentum and energy that are necessary for the study of interactions between masses. The concepts developed in the study of dynamics in Physics 2204 will be further developed in Physics 3204 with the treatment of two dimensional situations, uniform circular motion, and Kepler's Laws.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Nature of Science and Technology** **114-9** explain the importance of communicating the results of a scientific or technological endeavour using appropriate language and conventions **115-3** explain how a major scientific milestone revolutionized thinking in the scientific communities **Relationships Between Science and Technology** **116-5** describe the functioning of domestic and industrial technologies, using scientific principles **116-6** describe and evaluate the design of technological solutions and the way they function, using scientific principles **116-7** analyze natural and technological systems to interpret and explain their structure and dynamics **Social and Environmental Contexts of Science and Technology** **117-2** analyze society's influence on scientific and technological endeavours	*Students will be expected to* **Initiating and Planning** **212-3** design an experiment identifying and controlling major variables **212-8** evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **Performing and Recording** **213-2** carry out procedures controlling the major variables and adapting or extending procedures where required **213-3** use instruments effectively and accurately for collecting data **Analysing and Interpreting** **214-3** compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots **214-5** interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables **214-11** provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion	*Students will be expected to* **325-5** use vectors to represent force **325-8** apply Newton's laws of motion to explain inertia, the relationship among force, mass, and acceleration and the interaction of forces between two objects **326-3** apply quantitatively the laws of conservation of momentum to one-dimensional collisions and explosions

Dynamics Introduction

Outcomes

Students will be expected to

- use vectors to represent forces (325-5)
  - draw free - body diagrams
  - explain what is meant by net force and apply it to several situations
  - resolve a given force into two components
  - add two or more forces acting on an object to find the net or resultant force when:
    - (i) the forces are in the same direction
    - (ii) one or more of the forces are in the opposite direction to the others
    - (iii) one or more of the forces are perpendicular to the others
    - (iv) the forces make any angle in general with each other

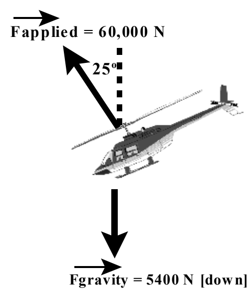
Elaborations—Strategies for Learning and Teaching

For dynamics, vector treatment will include vector components.

Students should investigate the use of vectors and vector diagrams to describe the forces which affect the linear motion of a variety of things such as air planes, birds, cars, and boats. The concept of free-body diagrams should be introduced. This analytical tool isolates an object in space and shows vectors representing all forces acting on it.

Students should solve exercises similar to those given below:

1. Given force $\vec{F}$ = 100 N, making an angle of 30º with the horizontal, determine its horizontal and vertical components.
2.



Sketch a free body diagram for the helicopter and determine the resultant force acting on it.

Cases (i) and (ii) are not challenging and do not require vector diagrams to solve.

Case (iii) involves a 90º angle. For example, find the net force of these three concurrent forces:

$\vec{F}$ = 16 N [W], $\vec{F}$ = 10 N [E], and $\vec{F}$ = 8 N [S]

Case (iv) find the net force of the following concurrent forces:

$\vec{F}$ = 60 N [W 50º S], $\vec{F}$ = 80 N [E 10º S], and

$\vec{F}$ = 40 N [W 70º N]

Use component method **only** for case (iv)

The Law of Sines and Law of Cosine methods not required.

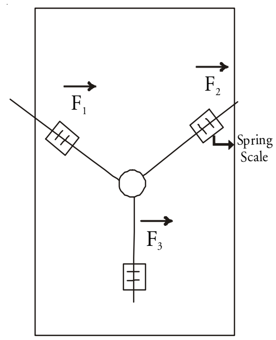
Dynamics Introduction

Suggested Assessment Strategies

Performance

- Students could demonstrate the use of the spring scale appropriately (zeroing and reading). (325-5, 116-6)
- Students could determine the resultant force acting on a washer suspended from 3 lines above a horizontal lab table, as shown. (325-5)

The angle of the strings and the scale reading will give direction and magnitude of each Force.



Resources

Physics: C and C, pp 131-136

Physics: C and C, pp 129-137

Physics: C and C, pp 139-141

Physics: C and C, pp 131-141

Physics: C and C, pp 131-136

Physics: C and C, pp 131-136

Physics: C and C, pp 137-138

Physics: C and C, pp 139-141

Newton's Laws

Outcomes

Students will be expected to

- apply Newton's laws of motion to explain inertia, the relationships among force, mass and acceleration, and the interaction of forces between two objects (325-8)
  – state Newton's first law of motion, and describe applications
  – explain, using Newton's first law of motion, what is meant by an inertial frame of reference
  – physically demonstrate the property of inertia
  – state Newton's second law of motion, and describe applications
  – explain how Newton's second law of motion may be used to define the Newton as a unit of force
  - given two of the net force, the mass, and the acceleration, or information from which they can be determined, calculate the third quantity
  - state Newton's third law of motion, and describe applications

Elaborations—Strategies for Learning and Teaching

An important corollary to Newton's First Law of motion which students must appreciate is this: if all forces on an object cancel each other, that is, if $\vec{F}_{net} = 0$, then there are two possibilities for the object's motion: the object is either stopped OR moving with a fixed velocity. There is no dynamic difference between these two conditions.

An inertial frame of reference is one in which Newton's first law of motion is valid. In general, any frame of reference that is not accelerating (i.e., not changing speed or direction) is an inertial frame. An example would be a bus which is travelling in a straight line at a fixed speed. The frame of reference of the bus is an inertial frame. (Assuming a silent engine, no vibrations, and a perfectly smooth road). If you lay a ball at your feet, it will stay there; if you push it, it will roll up the aisle until it bumps something (Newton's first law). But, suppose just after you lay the ball on the floor the driver just touches the brake ever so slightly. The ball will then roll forward. You will see it roll forward for no reason at all! After all, objects at rest should remain at rest. The frame of reference of the "accelerating" bus is no longer an inertial frame.

Demonstrations of inertia can include:
(i) pulling a table cloth from a table with objects on it
(ii) flicking a card from underneath a coin balancing on finger
(iii) banging the handle of a hammer against a hard surface to secure the hammer head

Newton's Laws

Suggested Assessment Strategies

Journal

- Teachers could ask students to comment on the following:

  The term "Newton" is merely a convenient shorthand for the actual dimension of inertially defined force. (325-8)
- Students could discuss the role of seat belts in conditions of both sudden stops and tight turns using Newton's First Law. (325-8)
- Students could explain, based on their knowledge of Newton Laws, why they should refuse to help a friend move, when they were asked to ride in the back of the van to hold a piano because there is no rope available. (325-8)

Paper and Pencil

- Students could calculate what force is necessary to accelerate a 1200 kg car along a horizontal surface from rest to 130 km/h in 8.0 s? (325-8)
- Students could calculate what mass would a sled on ice have if it requires a horizontal force of 100.0 N to change its velocity from 30.0 km/h to 120 km/h in 5.0 s? (325-8)
- Students could calculate what is the acceleration of a block having a mass of 0.5 kg which is being pulled in opposite directions by two children? Sean is pulling with a force of 3.0 N to the left, and Diane is pulling to the right with 5.0 N. They could calculate how far will it move in 3.0 s when these forces are exerted? (325-8)
- Students could calculate what would the tension be in a cable lifting an elevator and a person having a combined mass of 575 kg moving (a) upward at a rate of $5.0\ m/s^2$ and (b) downward at a rate of $5.0\ m/s^2$? (325-8)
- Students could design a problem that uses Newton's Second Law of motion. They should include an answer sheet and exchange their problem with that of another student. (325-8)
- Students could make an original puzzle that includes the following terms and their definitions: acceleration, inertia, applied force, net force, and normal force. Later in the unit they could add static friction, kinetic friction, and coefficient of friction. (325-8)

Resources

Physics: C and C, pp 125-129

Physics: C and C, pp 127-128

Physics: C and C, pp 129-130

Physics: C and C, p 130

Physics: C and C, p 130

Physics: C and C, pp 142-144 and pp 168-169

Newton's Laws

Outcomes

Students will be expected to

- apply Newton's laws of motion to explain inertia, the relationships among force, mass and acceleration, and the interaction of forces between two objects (325-8) **Cont'd**
  - state Newton's third law of motion, and describe applications
  - draw diagrams identifying the action-reaction pairs of forces in various interactions of particles or objects
  - distinguish between mass and weight
  - state, in words and in equation form, Newton's Law of universal gravitation
  - demonstrate that Newton's Law of universal gravitation is an inverse square law
  - describe how the force of gravity varies according to different locations on Earth
  - perform calculations using Newton's Law of universal gravitation
  - relate the Law of universal gravitation to Newton's 2nd Law using the acceleration of a free falling body of 9.8 m/s^2 or "g"
  - given two of an object's weight, its mass, and the acceleration due to gravity near Earth's surface, calculate the third quantity

Elaborations—Strategies for Learning and Teaching

Students should be able to, without doing a detailed calculation, determine the change in the gravitational force between 2 objects if their masses and/or the distance between the mass centres changes by a certain factor.

Students should be able to calculate the fifth quantity given four of the distance separating two particles or spheres, each of their masses, the force of gravitation attraction between them, and the universal gravitational constant.

$$\frac{Gm_{earth}\ m_{object}}{r^2_{earth}} = m_{object} \text{ x } g$$

$$g = \frac{G\ m_{earth}}{r^2_{earth}} = \text{gravitional field strength}$$

or

"Force per unit of mass"

Newton's Laws

Suggested Assessment Strategies

Performance

- Students could explain/research how the development of high speed photography has led to a better understanding of the forces involved in automobile collisions. (325-8)

Presentation

- Students could draw a cartoon that explains one of the concepts used in dynamics to this point. They should be sure that it is simple, specific, and short so the reader can learn from it. (325-8, 116-2, 115-3)

Resources

Physics: C and C, pp 142-144 and pp 168-169

Physics: C and C, p 127 and pp 158-159
Physics: C and C, pp 160-162

Physics: C and C, pp 162-163

Newton's Laws (continued)

Outcomes

Students will be expected to

- apply Newton's laws of motion to explain inertia, the relationships among force, mass and acceleration, and the interaction of forces between two objects (325-8) **Cont'd**
  - explain, qualitatively and quantitatively, what is meant by friction, and describe static and kinetic friction
  - solve exercises / problems involving Newton's laws of motion

Elaborations—Strategies for Learning and Teaching

Static and kinetic friction will be described both qualitatively and quantitatively. The following formulae should be used, as necessary, when friction is a factor: $f_k = \mu_k F_N$ and $f_s = \mu_s F_N$ (Max)

Teachers should note that f_s can be less than the Max value. For example, if f_s Max = 5.0N for a book on a table and someone applies a force of 3.0N, the force of static friction under Newton's 3rd law would be 3.0N. When the applied force is greater than f_s Max, Newton's 2nd law can be applied.

Over time, students should develop an understanding of the nature of friction and its effect on dynamic systems. They should understand the difference between static friction and kinetic (dynamic) friction.

Newton's Laws problems to be illustrated could include:

(i) pushing or pulling an object on a **horizontal surface**, with and without friction

(ii) vertical movement of objects (e.g., free fall, elevator problems, lifting an object on a string)

(iii) pushing or pulling two blocks on a **horizontal surface**

(iv) lifting or lowering two blocks

(v) Atwood's machine (loads on both sides of a single pulley)

(vi) hanging blocks off tables (No sloped surfaces)

(vii) hanging traffic light (Where $\vec{F}_{net}$ vertical is zero)

Newton's Laws (continued)

Suggested Assessment Strategies

Performance

- Students could measure various factors that could affect the size of the friction force. These should include normal force, surface area in contact, and types of surfaces in contact. (325-8)

Resources

Physics: C and C, pp 172-173

Physics: C and C, pp 140-141, 170, 197, 198

Newton's Laws (continued)

Outcomes

Students will be expected to

- investigate the relationship between acceleration and net force, for a constant mass of an object (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- investigate the relationship between acceleration and mass, for a constant net force (213-2)
- use instruments effectively and accurately for collecting data (213-3)
- compile and display evidence and information in a variety of formats (214-3)
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables (214-5)
- provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion (214-11)

Elaborations—Strategies for Learning and Teaching

These outcomes (212-3, 212-8, 213-2, 213-3, 214-3, 214-5, 214-11) and 325-8 are addressed by completing Newton's second law CORE LAB #2 and Kinetic Friction CORE LAB #3.

Whatever the method used for Newton's second law experiment, good results are obtained if care is taken in setting up the trials. If the gravitational force on a hung weight is used as a driving force, it is accelerating the combined mass that includes the cart and the hung mass. To do trials in which mass is kept constant, the combined mass must not change, and mass must be moved from the cart to the hanger to change the driving force. This is an excellent opportunity for students to learn to control variables and minimize errors. During the course of an investigation, student lab groups could be asked to make periodic progress reports and share ideas.
Students should write a thorough report on their lab. Students should analyse and interpret the data in raw form and graphically. From the raw data, it is possible to see whether the relationship is linear or exponential, direct or inverse. Graphs of $\vec{a} \alpha \vec{F}$ for trials where mass is kept constant, $\vec{a} \alpha 1/m$ for trials where applied force is kept constant, and $\vec{a} \alpha \vec{F}/m$ for all trials all lead to the equation $\vec{a} = \vec{F}/m$. Interpreting the numerical value and the dimensions (unit) of the slope on each graph, students realize that $\vec{F}_{Net} = m\vec{a}$ only if Newtons of force are dimensionally the same as $kg \cdot m/s^2$.

Students should distinguish between data collection and scientific inquiry. Data collection is a mechanical operation. Data could be collected by computerized systems or directly by a student. The interpretation of the data makes the science. Researchers consult with colleagues on an informal basis. The Internet is a technological development based on the desire to communicate globally. More formal peer review occurs when results are published in a journal and others attempt to duplicate the experiment.

Newton's Laws (continued)

Suggested Assessment Strategies

Performance

- Students could conduct a laboratory investigation of the relationships among force, mass, and acceleration. (325-8, 213-2, 213-3)

Informal Observation

- A checklist of laboratory skills is appropriate for the teacher to apply here. Possible skills might include using instruments correctly, doing enough trials for a good, average value, and recording the results in an appropriate table. (212-3)

Resources

Core Lab #2: *"Newton's Second Law"*
Physics: C and C, p 155
OR
Computer Interface Alternative:
www.gov.nl.ca/edu/science_ref/main.htm

Core Lab #3: *"Kinetic Friction"*
Physics: C and C, p 191

Momentum and Impulse

Outcomes

Students will be expected to

- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3)
  - define linear momentum, and explain why it is a vector quantity
  - given two of an object's mass, velocity, and momentum, calculate the third quantity
  - define impulse, and use Newton's second law to show how it is related to change in momentum
  - given the net force and time over which it acts, calculate the impulse
  - solve numerical and non-numerical exercises by using the concept of impulse equals change in momentum
  - state the law of conservation of linear momentum and test it in an experiment involving a one-dimensional collision of two carts, where one cart collides with a second cart that is initially at rest, and where the carts stick and move together with a common velocity after the collision
  - write an equation applying the law of conservation of momentum to a one-dimensional collision between two objects, in terms of two masses and the two velocities before and after the collision

Elaborations—Strategies for Learning and Teaching

A few appropriate questions will help the students conceptualize the idea of momentum. For example, the questions "would you rather be hit with a slow moving baseball or a fast moving baseball?" and "would you rather be hit with a ping pong ball or a bowling ball with the same speed?" will soon have the students identifying mass and velocity as two factors involved if a moving object is to do damage.

It might be possible to arrange for one of the police crash investigators to be a guest speaker. He/she could provide a realistic context for this study.

Impluse is to be identified by the symbol $\vec{\mathcal{J}}$ using the equation:

$$\vec{\mathcal{J}} = \Delta\vec{p} = \vec{F}\Delta t$$

The student will be able to solve exercises similar to the following:

1. A 100 g golf ball leaves the tee at 100 m/s. If the club was in contact with the ball for 0.04 s, determine the force exerted on it by the club.

   (The students should be provided with similar numerical exercises which require a solution for the other terms in the expression.)
2. Using the concept of impulse, explain why it is easier to drive a nail with a steel hammer, than with a rubber mallet

The Law of Conservation of Momentum can be stated as "The total momentum of all bodies in a system before they interact (e.g., collide, explode) is equal to the total momentum after they interact."

Put another way, (and using $\Delta\vec{p}=\vec{F}\Delta t$) we can say "The change in momentum in a system is zero when the net force on the system is zero."

Momentum and Impulse

Suggested Assessment Strategies

Journal

- Students could write a note explaining momentum, energy, and their transformations so a grade 8 student could understand them. (326-3)

Performance

- Students could conduct a lab and write a report. (326-3, 326-5, 214-7)

Paper and Pencil

- Students could solve problems such as; "A golf ball of mass 50.0 g is hit by a golf club at a speed of 35 m/s. If the effective mass of the club head is 0.32 kg, what velocity will the ball have just after the impact?" (326-3)

Resources

Physics: C and C, p 277

Physics: C and C, p 277

Physics: C and C, pp 278-281

Physics: C and C, p 282

Physics: C and C, p 286

Physics: C and C, pp 288 and 315

Physics: C and C, pp 288-291

Momentum and Impulse

Outcomes

Students will be expected to

- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3) **Cont'd**
  - given any five of: the two masses of objects involved in a one-dimensional collision, their velocities before and their velocities after the collision, calculate the sixth quantity
  - differentiate qualiatively between elastic and inelastic collisions
- use appropriate language and conventions when describing events related to momentum and energy (114-9)
- describe the functioning of a natural technology based on principles of momentum (116-5)
- analyze natural and technological systems to interpret and explain their structure and dynamics (116-7)
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (214-3)
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables (214-5)

Elaborations—Strategies for Learning and Teaching

The Laboratory outcomes (212-3, 212-8, 213-2, 213-3, 214-3, 214-5, 214-11) and 326-3 are addressed by completing Linear Momentum CORE LAB #4.

Such exercises will test the ability of the student to **use the sign convention**, to deal with objects that collide and stick, collide and rebound, objects that "explode", and in general to be able to solve momentum exercises involving objects moving in either direction in straight lines.

Students should be provided with a comprehensive set of exercises/ questions/problems.

Teachers should note that discussion of highly elastic and inelastic collisions should be made with the students. Collisions in which the bodies stick together after contact **or** are greatly deformed would be examples of inelastic collisions. Collisions in which objects bounce freely from each other would be examples of highly elastic collisions (A discussion of Kinetic Energy will be left for Unit 3.)

The CORE STSE component of this unit incorporates a broad range of Physics 2204 outcomes. More specifically it targets (in whole or in part) 114-9, 116-5, 116-7, 214-3, 214-5, 325-8, 326-3. The STSE component, *The Physics of Karate*, can be found in Appendix A.

Momentum and Impulse

Suggested Assessment Strategies

Paper and Pencil

- Students could write a report of their collision analysis lab. They are expected to look for patterns in their raw data. For example, they can investigate how Δv is related to mass ratio and account for the difference in total momentum from trial to trial. Some discussion of error (less than 100% conservation of momentum) is expected. (326-3)

Journal

- Students could write down their observations and questions that they have regarding the use of dynamics carts. They should organize them. How does writing the observations help students' understanding of their collision lab? (326-3)

Resources

Core Lab #4: *"Linear Momentum" Physics: C and C,* p 315
OR
Computer Interface Alternative:
www.gov.nl.ca/edu/science_ref/main.htm

Physics: C and C, p 291

Physics: C and C, p 349

Core STSE #2: *"The Physics of Karate",* Appendix A