TOPIC 3.2: DYNAMICS

The student will be able to:

S3P-3-08: Identify the four fundamental forces of nature.

S3P-3-09: Perform an experiment to demonstrate Newton's Second Law ($\vec{F}_{net} = ma$).

S3P-3-10: Define the unit of force as the newton.

S3P-3-11: Define $\vec{F}_{net}$ as the vector sum of all forces acting on a body.

Include: force of friction, normal force, gravitational force, applied forces

S3P-3-12: Construct free-body diagrams to determine the net force for objects in various situations.

Include: balanced and unbalanced forces, inclined planes

S3P-3-13: Solve problems, using Newton's Second Law and the kinematics equations from S3P-3-07.

Include: forces applied along a straight line and perpendicular forces

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Understand the composition of the universe, the interactions within it, and the impacts of humankind's continued attempts to understand and explore it (GLO D6)

SPECIFIC LEARNING OUTCOME

S3P-3-08: Identify the four fundamental forces of nature.

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

One of the primary goals in physics is to pursue an understanding of nature in terms of unifying principles. With respect to the unification of the fundamental forces, the greatest advances toward this goal include the unification of terrestrial and celestial mechanics by Newton; optics, electricity, and magnetism by James Clerk Maxwell; and space-time geometry with a theory of gravitation enunciated by Albert Einstein. The Standard Model of particle physics has achieved a unification of the Electromagnetic and Weak Nuclear Forces for very high energy levels. For an interesting description (and accompanying chart) of the nature of this model, consult the article by Steven Weinberg listed in the Suggested Learning Resources for this outcome.

The four fundamental forces in nature are the Strong Nuclear Force, the Weak Nuclear Force, the Gravitational Force, and the Electromagnetic Force.

- The **Strong Nuclear Force** is an attractive force that holds protons and neutrons in the nucleus of the atom. It is an extremely strong force necessary to overcome the repulsive force between two protons and only acts at short ranges of about 10^{-15} m.
- The **Weak Nuclear Force** is a force exerted between all subatomic particles. It enables the conversion of one type of quark into another, and is responsible for some types of nuclear decay.
- The **Gravitational Force** is an attractive force that all objects exert on each other and is dependent on the objects' masses.
- The **Electromagnetic Force** is the force that charged particles exert on each other.

Note: The Electromagnetic Force is responsible for most of the named forces that will be seen in high school physics (e.g., the coulomb and magnetic forces, the normal force, the tension force, frictional forces, and even applied forces).

SKILLS AND ATTITUDES OUTCOMES

S3P-0-1c: Relate the historical development of scientific ideas and technology to the form and function of scientific knowledge today.

S3P-0-1e: Differentiate between how scientific theories explain natural phenomena and how scientific laws identify regularities and patterns in nature.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world (GLO E1)

SUGGESTIONS FOR INSTRUCTION

Senior Years Science Teachers' Handbook Activities

Students use a jigsaw activity. Expert groups are formed for each fundamental force. The experts research and complete Concept Frames to describe the force with examples. Then groups of four are formed (with an expert on each force) to exchange information.

SUGGESTIONS FOR ASSESSMENT

Observation

Students use a Compare and Contrast Frame to distinguish among the various forces.

SUGGESTED LEARNING RESOURCES

Weinberg, Steven. (1999) "A Unified Physics by 2050?" *Scientific American*: 68-73.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

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

SPECIFIC LEARNING OUTCOMES

S3P-3-09: Perform an experiment to demonstrate Newton's Second Law ($\vec{F}_{net} = m\vec{a}$).

S3P-3-10: Define the unit of force as the newton.

S3P-3-11: Define $\vec{F}_{net}$ as the vector sum of all forces acting on a body.

Include: force of friction, normal force, gravitational force, applied forces

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

In Senior 2 Science, students investigated Newton's Second Law qualitatively in terms of the proportional relationships between force and acceleration and force and mass. In addition, students of Senior 2 Science were introduced to Newton's First and Third Laws.

Newton's Three Laws:

Newton's First Law: If no external or unbalanced force acts on an object, its state of rest or its constant speed are maintained.

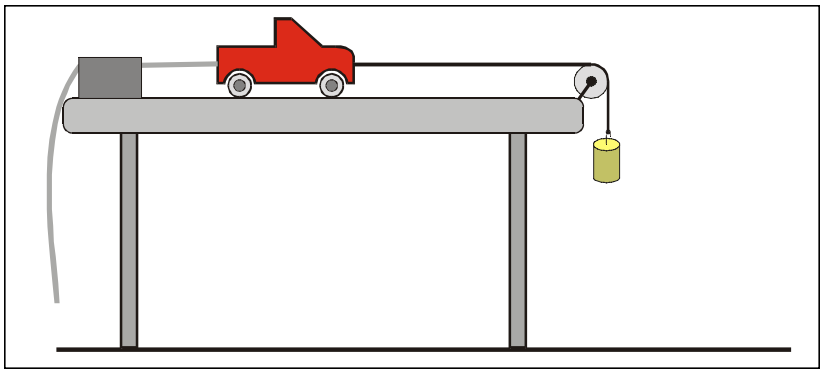
Newton's Second Law: $F_{net} = ma$.

Newton's Third Law: For every action force, there exists a reaction force that is equal in magnitude but opposite in direction.

Notes to the Teacher

Typically, an experiment to demonstrate Newton's Second Law involves a set-up in which a known net force acts on a known mass. The acceleration may be measured with a motion probe, tickertape timer device, or video analysis. The forces may be measured with a force probe, spring scale, or a known gravitational force (weight). One possible set-up is shown below.

A lab cart (m_1) on a horizontal surface is being pulled by a string that is connected to a falling mass through a pulley. If we increase the mass (force of gravity increases), we can measure acceleration and graph it. The force-versus-acceleration graph is a straight line and the slope is the ratio of force to acceleration. Ask students: Under what conditions will this ratio be large or small? It is large for objects that



SKILLS AND ATTITUDES OUTCOMES

S3P-0-2h: Analyze problems, using vectors.
Include: adding and subtracting vectors in straight lines and at right angles, vector components

S3P-0-2b: Propose problems, state hypotheses, and plan, implement, adapt, or extend procedures to carry out an investigation where required.

SS3P-0-4b: Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4c: Demonstrate confidence in carrying out scientific investigations and in addressing STSE issues.

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

are difficult to accelerate, and small for objects that are easy to accelerate. This resistance to acceleration is called the inertial mass of the object.

The relationship between F_{net} and acceleration can also be demonstrated in a lab, using dynamic carts on an inclined plane. As the angle of the incline increases, the force acting on the cart also increases according to $\sin\theta$.

$F = ma$ defines force. The SI units for force can be derived from this equation. Therefore, a unit of force is a kg•m/s^2, and is given the name newton (N).

Note: The F in $F = ma$ is the net force acting on the mass and should always be written as:

$F_{net} = ma$, where F_{net} = sum of the applied forces.

OR

$\sum \vec{F} = ma$, where $\sum \vec{F}$ = sum of the applied forces.

SUGGESTIONS FOR ASSESSMENT

Students submit a lab report that states the relationship among force, mass, and acceleration, and some systemic errors (specific to this lab) that could be redesigned to improve future trials.

SUGGESTED LEARNING RESOURCES

Appendix 3.15: Journal Entry: Dynamics and Diagrams

Appendix 3.16: Free-Body Diagrams: Linear Motion

Appendix 3.17: Free-Body Diagrams 2: Linear Motion

GENERAL LEARNING OUTCOME CONNECTION

Students will...

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

SPECIFIC LEARNING OUTCOMES

S3P-3-09: Perform an experiment to demonstrate Newton's Second Law ($\vec{F}_{net} = m\vec{a}$).

S3P-3-10: Define the unit of force as the newton.

S3P-3-11: Define $\vec{F}_{net}$ as the vector sum of all forces acting on a body.

Include: force of friction, normal force, gravitational force, applied forces

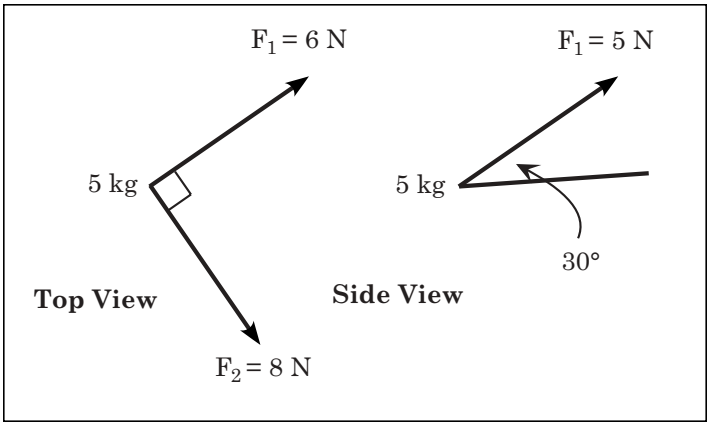
SUGGESTIONS FOR INSTRUCTION

The notion of a net force in the Second Law should be clearly stated as $\boldsymbol{F}_{net} = \boldsymbol{F}_{applied} + \boldsymbol{F}_{friction}$. The applied force is the vector sum of all forces acting on the mass in the direction of motion. Many textbooks gloss over this idea. In Senior 3 Physics, students should address problems using multiple forces under the following conditions:

a) forces acting on the same line (a single applied force and the force of friction);

b) forces acting at right angles to each other; and

c) as a component.



Journal Entry: Students describe various conditions that may result in zero acceleration.

SKILLS AND ATTITUDES OUTCOMES

S3P-0-2h: Analyze problems, using vectors.
Include: adding and subtracting vectors in straight lines and at right angles, vector components

S3P-0-2b: Propose problems, state hypotheses, and plan, implement, adapt, or extend procedures to carry out an investigation where required.

SS3P-0-4b: Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

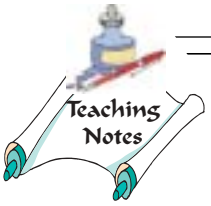
S3P-0-4c: Demonstrate confidence in carrying out scientific investigations and in addressing STSE issues.

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

GENERAL LEARNING OUTCOME CONNECTION

Students will...

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

SPECIFIC LEARNING OUTCOME

S3P-3-12: Construct free-body diagrams to determine the net force for objects in various situations.

Include: balanced and unbalanced forces, inclined planes

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Mass and weight are discussed qualitatively in Grade 8 Science as being distinct.

Notes to the Teacher

Introduce free-body diagrams (FBDs) here to illustrate that there can be multiple forces acting on an object even if it appears that there is only one force. The forces will all add together to a resultant force that is called *net force*. FBDs are vector diagrams of the forces acting on an object. Students should consider gravitational, normal, frictional, and applied forces as they practise drawing FBDs.

In a free-body diagram, the gravitational force (F_g) points downward. The normal force is always perpendicular to the surface with which a body is in contact and it stops objects from falling through the surface. For a body on an inclined plane, the normal force is perpendicular to the slope. The frictional force is always parallel to the surface of contact and usually opposes the motion of the object. Applied forces are any push or pull on the object. Applied forces through a string or rope are called tension forces and are directed along the string such that the force pulls equally on either end of the string.

Several references on FBDs are included in the Suggested Learning Resources for this outcome.

SKILLS AND ATTITUDES OUTCOME

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

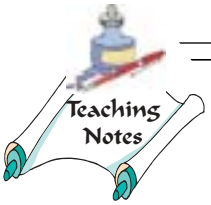
Include: adding and subtracting vectors in straight lines and at right angles, vector components

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



SUGGESTIONS FOR ASSESSMENT

Given an object (on a table, et cetera), students complete a free-body diagram according to a defined set of criteria.

SUGGESTED LEARNING RESOURCES

Court, J. (1993) "Free Body Diagrams." *The Physics Teacher* 31.2: 104.

Court, J. (1999) "Free Body Diagrams" *The Physics Teacher* 37.7: 427.

Fisher, K. (1999) "Exercise in Drawing and Utilizing Free-Body Diagrams." *The Physics Teacher* 37.7: 434.

Appendix 3.16: Free-Body Diagrams: Linear Motion

Appendix 3.17: Free-Body Diagrams 2: Linear Motion

GENERAL LEARNING OUTCOME CONNECTION

Students will...

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

SPECIFIC LEARNING OUTCOME

S3P-3-13: Solve problems, using Newton's Second Law and the kinematics equations from S3P-3-07.

Include: forces applied along a straight line and perpendicular forces

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

Many different kinds of motion can be used to illustrate Newton's Second Law, including:

- Biomechanics of human motion (muscles pulling on bones)
- Sports (downhill skiing, skateboarding)
- Pulleys
- Carts

Students address the following types of problems:

- Single and multiple forces acting on a straight line
- Two perpendicular forces acting on an object
- Single force acting at an angle on an object (resolved using components)

Senior Years Science Teachers' Handbook Activities

Students use process notes to aid their algebraic solutions.

SKILLS AND ATTITUDES OUTCOME

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

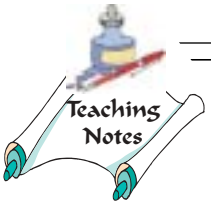
Include: adding and subtracting vectors in straight lines and at right angles, vector components

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 C6)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

Problem Construction

Students construct their own dynamics problems (including a solution).

SUGGESTED LEARNING RESOURCES

Court, J. (1993) “Free Body Diagrams.” *The Physics Teacher* 31.2: 104.

Court, J. (1999) “Free Body Diagrams.” *The Physics Teacher* 37.7: 427.

Fisher, K. (1999) “Exercise in Drawing and Utilizing Free-Body Diagrams.” *The Physics Teacher* 37.7: 434.

NOTES