TOPIC 1.4: PROJECTILE MOTION

S4P-1-15 Solve simple free-fall problems using the special equations for constant acceleration.

Include: horizontal and vertical components of motion of the curved path of a projectile (without air resistance)

S4P-1-16 Draw free-body diagrams for a projectile at various points along its path (with and without air resistance).

S4P-1-17 Calculate the horizontal and vertical components with respect to velocity and position of a projectile at various points along its path.

S4P-1-18 Solve problems for projectiles launched horizontally and at various angles to the horizontal to calculate maximum height, range, and overall time of flight of the projectile.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

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

SPECIFIC LEARNING OUTCOME

S4P-1-15: Solve simple free-fall problems using the special equations for constant acceleration.

Include: horizontal and vertical components of motion of the curved path of a projectile (with or without air resistance)

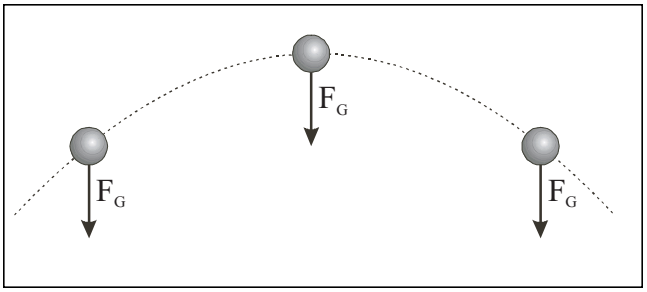
SUGGESTIONS FOR INSTRUCTION

Entry Level Knowledge

The special equations for constant acceleration are covered in Topic 1 and students are familiar with free fall from Senior 3 Physics.

Notes to the Teacher

Solve various problems using the derived kinematic equations, given the $a = g = -9.8\ m/s^2$. The problems should include when the initial velocity is zero (dropped object), the initial velocity is positive, and the initial velocity is negative. A common student difficulty is recognizing that an object at its maximum height still has an acceleration of $-9.8 m/s^2$ although its instantaneous velocity is zero.



The Force of Gravity Is Always Constant

Another student difficulty is when an object is in a system that is moving at a constant velocity (i.e., rising) and the object is released. Students tend to believe the initial velocity of the object is zero, but it actually is the velocity of the moving system. Additionally, when an object is thrown upward and returns to its original position, the displacement of the object would be zero when applying the kinematics equations.

Collaborative Teamwork

Students are given a simple free-fall problem to resolve in a group and then present the solution to the rest of the class.

SKILLS AND ATTITUDES OUTCOME

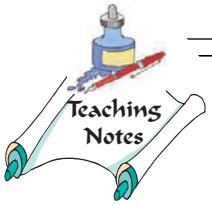
S4P-0-2g: Develop mathematical models involving linear, power, and/or inverse relationships among variables.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved (GLO E3)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

Pencil-and-Paper Tasks

Students solve problems for free fall using the special equations of motion.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOMES

S4P-1-16: Draw free-body diagrams for a projectile at various points along its path (with or without air resistance).

S4P-1-17: Calculate the horizontal and vertical components with respect to velocity and position of a projectile at various points along its path.

SUGGESTIONS FOR INSTRUCTION

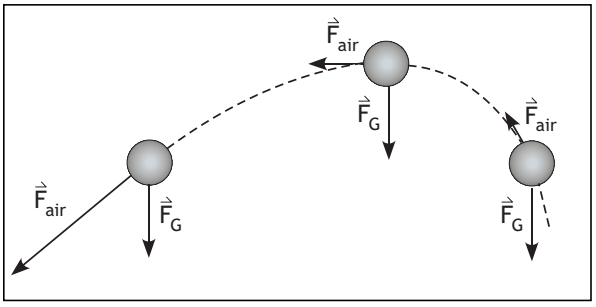
Entry Level Knowledge

Vector components are addressed in the Topic 1.2 (Dynamics) and simple free-body diagrams are covered in Senior 3 Physics.

Notes to the Teacher

Students must be aware that the horizontal and vertical motions are independent of each other. To reinforce these concepts, it is useful to draw free-body diagrams. The horizontal motion is a uniform (constant) motion and the vertical motion is a uniformly accelerated motion ($a = -9.8\ m/s^2$). The net force (F_g) acting on the projectile is constant (neglecting air resistance).

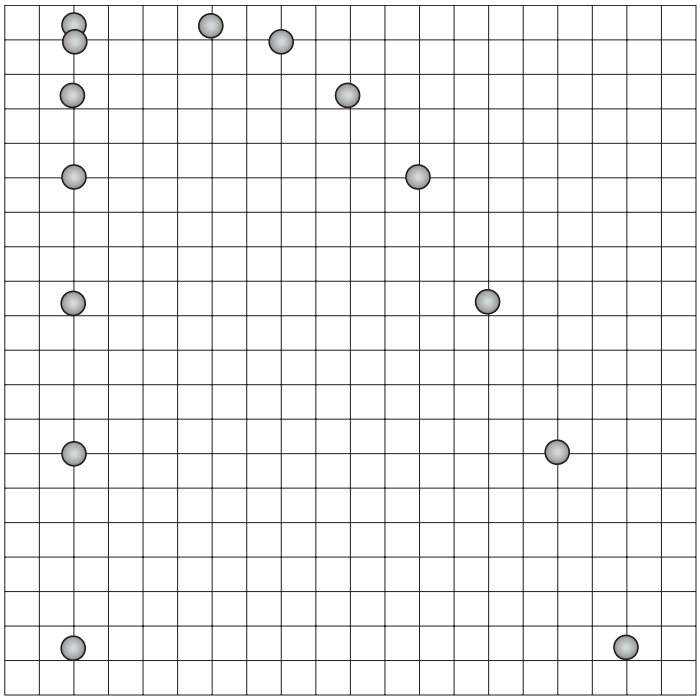
If air resistance is taken into consideration, the frictional force will always be in the opposite direction to the velocity (tangential to the path). The frictional force will decrease the horizontal as well as the vertical components of velocity. The resulting path will be asymmetrical. Students should only analyze this type of projection qualitatively, not quantitatively.



Projectile with Air Resistance

Class Activities

Review qualitatively, with the aid of diagrams, the horizontal and vertical velocities, and acceleration. Observe a projectile with a stroboscope and record on a video camera to analyze with computer software or VCR. Show Vertical and Horizontal Motion from the videodisc *Physics: Cinema Classics*. This gives an excellent demonstration of the independence of these two motions.



Strobe of free fall and projectile

SKILLS AND ATTITUDES OUTCOME

S4P-0-2f: Record, organize, and display data using an appropriate format.

Include: labelled diagrams, tables, graphs

GENERAL LEARNING OUTCOME CONNECTION

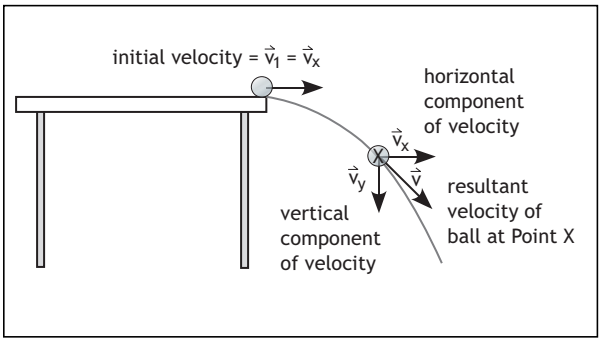
Students will…

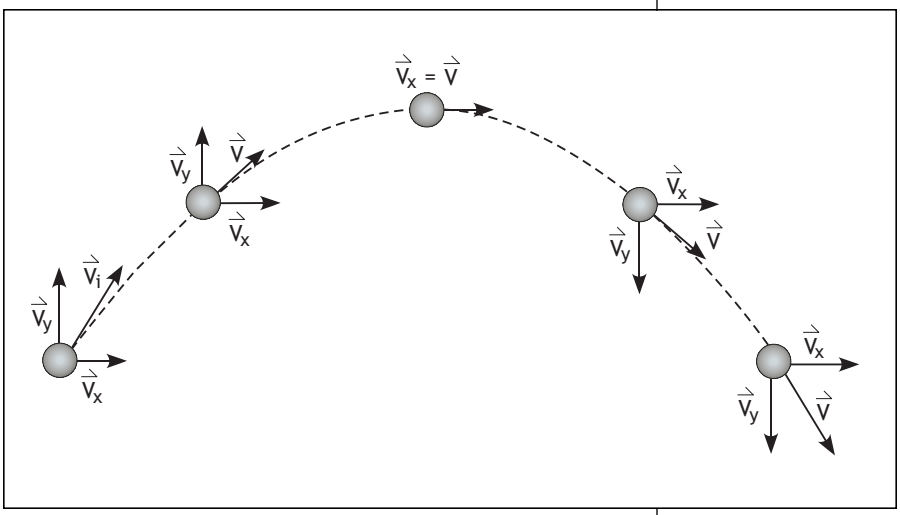
Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

Demonstrate appropriate problem-solving skills while seeking solutions to technological challenges (GLO C3)

SUGGESTIONS FOR INSTRUCTION

Students should be careful to differentiate between force and velocity vectors. A blackline master of the strobe photo is included in Appendix 1.7 for copying.





SUGGESTIONS FOR ASSESSMENT

Pencil-and-Paper Tasks

Draw free-body diagrams of a projectile at various points on its path, using vectors to represent the horizontal and vertical velocities.

Calculate the horizontal and vertical components of position and velocity.

Determine the net force, position, and velocity vectors.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOMES

S4P-1-16: Draw free-body diagrams for a projectile at various points along its path (with or without air resistance).

S4P-1-17: Calculate the horizontal and vertical components with respect to velocity and position of a projectile at various points along its path.

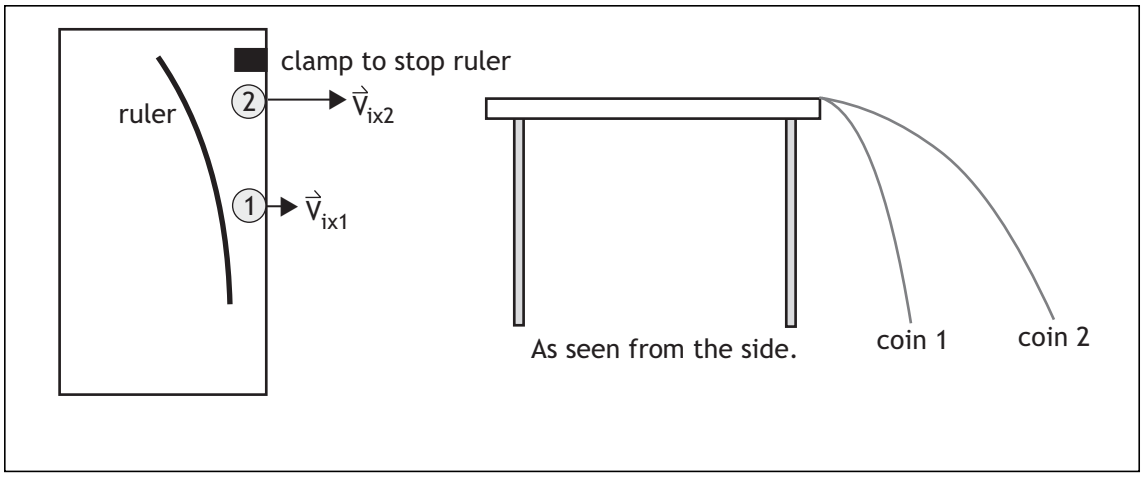
SUGGESTIONS FOR INSTRUCTION

Demonstrations

An air table, inclined at an angle, can demonstrate the motion of a projectile. A stream of water can also demonstrate trajectories associated with initial angles of launch.

Place two coins on the edge of a table, with one placed above the other (see diagram). Launch objects simultaneously off the edge of a table using a flexible ruler. The coin further out will have a greater velocity and therefore a greater range, but both coins will land on the floor at the same time.

Have students observe this demonstration visually and by listening to the sound of the ruler striking the coins and the coins striking the ground. Using the diagrams provided, students measure the horizontal and vertical displacement for each time interval. Students reach the conclusion that the horizontal velocity component is constant and the vertical component of velocity increases/decreases the same as an object in free-fall motion.



SKILLS AND ATTITUDES OUTCOME

S4P-0-2f: Record, organize, and display data using an appropriate format.

Include: labelled diagrams, tables, graphs

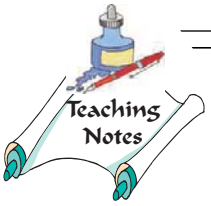
GENERAL LEARNING OUTCOME CONNECTION

Students will…

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

Demonstrate appropriate problem-solving skills while seeking solutions to technological challenges (GLO C3)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

GENERAL LEARNING OUTCOME CONNECTION	SPECIFIC LEARNING OUTCOME	SKILLS AND ATTITUDES OUTCOMES
Students will… Demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information (GLO C4)	**S4P-1-18: Solve problems for projectiles launched horizontally and at various angles to the horizontal to calculate maximum height, range, and overall time of flight of the projectile.**	**S4P-0-2b:** Propose problems, state hypotheses, and plan, implement, adapt, or extend procedures to carry out an investigation where required. **S4P-0-2d:** Estimate and measure accurately using SI units.

SUGGESTIONS FOR INSTRUCTION

Entry Level Knowledge

Equations for constant acceleration are covered in Topic 1 and uniform motion is treated in both Senior 2 Science and Senior 3 Physics.

Notes to the Teacher

The calculations of the horizontal and vertical components should involve situations when the projectile is rising and when the projectile is on its way back down with respect to velocity and position. The velocity and position of a projectile coming to rest at the same height at which it was launched will be symmetrical with respect to the maximum height midpoint. The maximum range of a projectile will be obtained when launched at an angle of 45°. Any two complementary launch angles will have the same range, provided air resistance is ignored.

Class Activity

Illustrative examples with solutions are included in Appendix 1.7.

Laboratory Activities

Perform a lab of a projectile launched horizontally and/or at an angle (commonly referred to as a "monkey" or Gauss gun).

Construct and launch catapults (trebuchet or counterweight design).

Student Research/Report

Students research and report on the historical development of a catapult or trebuchet.

SKILLS AND ATTITUDES OUTCOMES

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

S4P-0-2i: Select and integrate information obtained from a variety of sources.

Include: print, electronic, specialists, or other resource people

S4P-0-3b: Describe examples of how technology has evolved in response to scientific advances, and how scientific knowledge has evolved as the result of new innovations in technology.

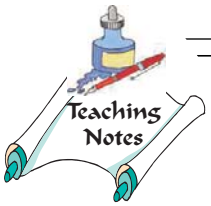
S4P-0-3e: Identify a problem, initiate research, and design a technological or other solution to address the problem.

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

Pencil-and-Paper Tasks

Students solve kinematics equations for projectile problems.

Problem-Based Learning

Catapult contest: Students use the design process to build a catapult or trebuchet to launch a marshmallow. Assessment is based on design, distance, and accuracy.

SUGGESTED LEARNING RESOURCES

Lab 3.1: Initial Velocity of a Projectile, p. 119, *Physics: Concepts and Connections*, Irwin Publishing Ltd., 2003

Lab 3.2: Projectile Motion, p. 120, *Physics: Concepts and Connections*, Irwin Publishing Ltd., 2003

NOTES