Range of a Horizontal Projectile — Teacher's Notes

Main Topic	Motion
Subtopic	Projectile Motion
Learning Level	High
Technology Level	High
Activity Type	Student

Description: To measure the launch velocity of a horizontal projectile and predict its range.

Required Equipment	Marble Projectile Ramp, Datalogger, Photogate, Meterstick, Clamp
Optional Equipment	

Educational Objectives

- To predict the range of a horizontal projectile after measuring its launch velocity.

Key Question

- How can we predict the range of a projectile?

Concept Overview

Students will use a photogate to measure the launch velocity of a horizontal projectile. That velocity will be used to predict the projectile's range, or horizontal displacement. To make these predictions, students use the following kinematics formula:

$$d = v_i t + \frac{1}{2}at^2$$

The projectile's time of flight can be found by considering its vertical motion. The vertical initial velocity is zero, and the vertical acceleration is g, -9.8 m/s^2. The vertical displacement is the distance from the ramp end to the floor. Simplified, and solved for t:

$$t = \sqrt{\frac{2d_y}{g}}$$

To find the range, consider the horizontal component of the motion. The initial velocity will be that measured by the photogate. Horizontally, acceleration is zero. The time is that found in the equation above. Simplified, and solved for d_x:

$$d_x = v_{ix}t = v_{ix}\sqrt{\frac{2d_y}{g}}$$

Note that students need not solve explicitly for t before finding the range.

In the second part of the lab, students will use energy conversion to predict the ball's velocity at the end of the ramp. If the marble's gravitational potential energy is completely converted into kinetic energy:

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$

Students will find, however, that the marble's real velocity is quite a bit slower than what they predict using this formula. In fact, a large part of the marble's initial potential energy is converted into rolling energy. If the marble could slide down the ramp without rolling, the energy prediction would be more accurate.

Lab Tips

The Marble Projectile Ramp is used to launch a marble horizontally from a table or desk. The included screws can be moved to provide up to four different starting points and velocities. You can use a photogate to measure the marble's velocity as it exits the ramp and predict where it will land using projectile motion equations.

The Marble Projectile Ramp consists of an aluminum ramp with mounting plate (base). The ramp comes with two screws and one ¾" (1.9 cm) diameter chrome steel ball. The screws are inserted into holes in the ramp to give a consistent starting point. A C-clamp (not included, # PX-1209) is required to attach the ramp to a table or desk.

The procedure directs students to mark their predicted range with tape. You can instead ask them to place a cup so that the marble will land in it. In this case, they must account for the height of the cup in their calculations.

The exact range of the marble, when it hits the floor, can be measured by placing a piece of paper on the floor with a piece of carbon paper on top of it. The falling marble will make a mark on the paper at the exact point where it lands.

Range of a Horizontal Projectile Name: ___________________
Class: ____________________

Pre-Lab Questions:

1. You will measure the vertical displacement and initial velocity of a horizontally launched projectile. Derive a formula to find the horizontal displacement of the projectile. (Hint: First derive a formula to find the time it will take for the projectile to reach the floor.)

2. Write an equation relating an object's gravitational potential energy at the top of a ramp to its kinetic energy after it goes down the ramp.

Goal:

Predict the horizontal range of a projectile.

Materials:

Marble Projectile Ramp, Datalogger, Photogate, Meterstick, Clamp

Procedure:

Using Velocity to Predict Range:

1. Screw one of the screws through one of the holes in the ramp. Hold a marble against the screw with your finger then quickly let go. Releasing the ball from a different hole will result in a different velocity at the bottom of the ramp.
2. Clamp a photogate in place so that the light beam can pass through the hole in the base of the ramp. Using the diameter of the marble and the time measured by the photogate, you can calculate the velocity of the marble at the bottom of the ramp.
3. Release the marble, catching it before it hits the floor. Record the launch velocity here: ________________
4. Measure the vertical distance from the end of the ramp to the floor. _____________
5. Using the velocity and the vertical distance the ball falls, calculate how far the marble will go horizontally when it hits the floor.

6. Mark the distance with tape.
7. Launch the marble as you did before, this time letting it hit the floor. How accurate was your prediction?
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   ____
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Using Energy to Predict Velocity:

8. Measure the marble's initial height above the table, on the ramp, and calculate its potential energy.

9. Predict the ball's kinetic energy at the bottom of the ramp. Assume that all of the potential energy becomes translational motion, and calculate the marble's velocity at the end of the ramp.

10. Your prediction is probably going to be about 30% too fast, which means that some of the energy is unaccounted for. Where is the "missing" energy?
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    ____
    ____