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

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

Required Equipment	Horizontal Projectile Lab, one ¾" steel marble, Meter Stick or Measuring Tape, Datalogger, Photogate, calculator, soup can or other small container.
Optional Equipment	

Educational Objectives

- To measure the launch velocity of a horizontal projectile and predict its range, using equations provided.

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:

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

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:

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

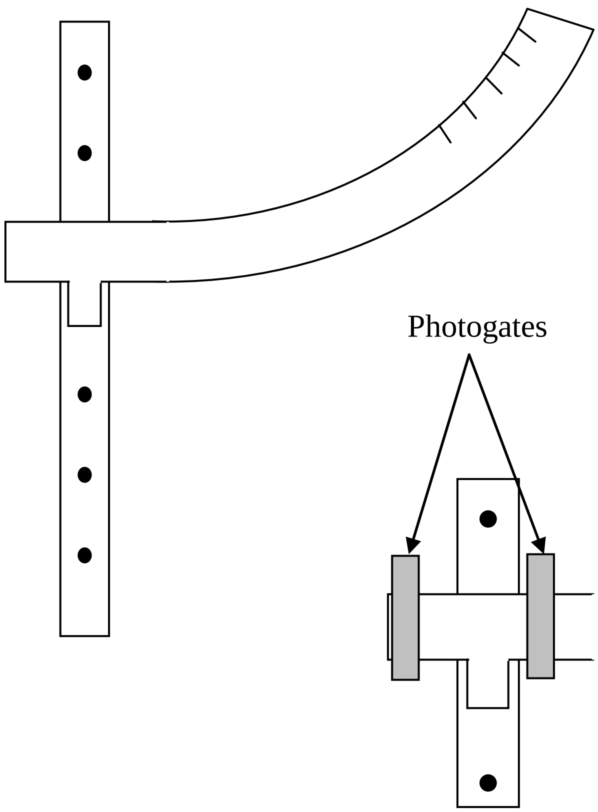
To find the range, consider the horizontal component of the motion. The initial velocity will be that measured by the photogate. Horizontally, acceleration is zero. The time is that found in the equation above. Simplified, and solved for d_x:

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

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

Lab Tips

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.



Assembly:

1. Push the two support pins into two holes on the Workshop Stand. Use the attachment bolt to secure the ramp in place.
2. Place the bubble level in the center of the end of the ramp. Adjust the feet of the Workshop Stand until the bubble is in the center, indicating that the end of the track is horizontal. (Leveling may be repeated during experimentation.)
3. To measure velocity, attach one or two photogates to the horizontal portion of the ramp. If only one photogate is used, it should be placed at the very end of the ramp.
4. To find velocity with one photogate, measure the time the gate is blocked. Divide the marble's diameter by that time to find its instantaneous velocity.
5. To find velocity with two photogates (preferred for datalogger systems other than EasySense), measure the time the marble travels between the two gates and the distance between the front edges of the gates. Divide the distance by the time to find the average velocity over the horizontal portion of the ramp.

Range of a Horizontal Projectile: Guided

Name: ___________________
Class: ____________________

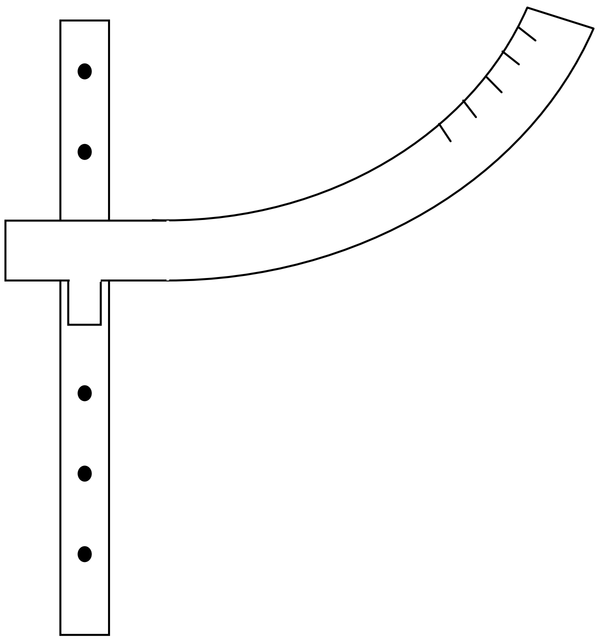
Goal:

To measure the launch velocity of a horizontal projectile and predict its range, using equations provided.

Materials:

Horizontal Projectile Lab, one ¾" steel marble, Meter Stick or Measuring Tape, Datalogger, Photogate, calculator, soup can or other small container.

Procedure:



1. Push the two support pins into two holes on the Workshop Stand. Use the attachment bolt to secure the ramp in place.
2. Place the bubble level in the center of the end of the ramp. Adjust the feet of the Workshop Stand until the bubble is in the center, indicating that the end of the track is horizontal.
3. Your teacher will assign you a starting point on the ramp for your experiment. Counting from the top, which mark is your release point? __________
4. If using one photogate to measure velocity, continue with #5. If using two photogates, skip to #18.

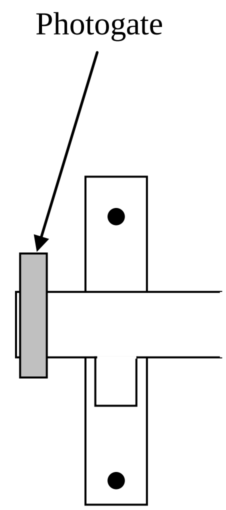
Range of a Horizontal Projectile: Guided

Name: ____________________

Class: ____________________

Finding Initial Velocity – 1 Photogate

5. Clamp a photogate to the end of the ramp, so that the steel marble will pass through the light beam.
6. Program the datalogger to measure the time that the single photogate is blocked.
7. Release the marble from your assigned point, and catch it before it hits the floor. Record the time in the table below.
8. Repeat, recording 4 more times.



Trial	Time (s)
1	
2	
3	
4	
5	
Average	

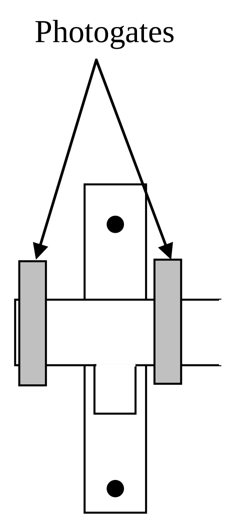
9. Calculate the average time.
10. The diameter of the marble is 1.9cm. Use this distance (don't forget to convert to meters) and the average time to calculate the marble's velocity as it goes through the gate.

$$v = \frac{d}{t}$$

11. Skip to #18.

Finding Initial Velocity – 2 Photogates

12. Clamp a photogate to the ramp just before the Workshop Stand. Clamp another photogate to the end of the ramp, so that the steel marble will pass through the light beam.
13. Program the datalogger to measure the time between when the two gates are blocked.
14. Release the marble from your assigned point, and catch it before it hits the floor. Record the time in the table below.
15. Repeat, recording 4 more times.



Trial	Time (s)
1	
2	
3	
4	
5	
Average	

16. Calculate the average time.

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Class: ______________________

17. Measure the distance between the front edges of the two photogates. Use this distance (don't forget to convert to meters) and the average time to calculate the marble's velocity as it goes through the two gates.

$$v = \frac{d}{t}$$

Predicting Projectile Range

Remember, you are analyzing the projectile path of the marble. <u>All of the following questions apply to the part of the motion between when the marble leaves the ramp and when it strikes the floor.</u>

A. Analyzing horizontal motion

18. After the marble leaves the ramp, what force(s) are acting on it <u>horizontally</u>?
____
19. Is the marble accelerating <u>horizontally</u>, or is its velocity constant?
____
20. Write an equation describing the relationship between the horizontal velocity of the marble, its horizontal range, and the time of flight.

21. Rearrange that equation to find the horizontal distance, or range, of the marble. (Use symbols only.)

B. Analyzing vertical motion

22. After the marble leaves the ramp, what force(s) are acting on it <u>vertically</u>?
____
23. Is the marble accelerating <u>vertically</u>, or is its velocity constant?
____
24. What is causing the vertical acceleration? __________
25. What symbol and value are used to represent that acceleration?
____
26. What is the marble's initial vertical velocity? __________

Range of a Horizontal Projectile: Guided

Name: ____________________

Class: ______________________

27. The general equation for the range of an accelerating object is

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

Simplify that equation as much as possible, using your answers from questions 24 and 25. (Use the symbol from #24, not the numerical value.)

28. Rearrange that equation to find the time that the object is in motion. (Use symbols only.)

Finding the Range

29. Substitute your answer to #28 for t in your answer to #21.

30. Self-check: The variables listed below should be in the equation. If known, record the values for each variable.

Horizontal velocity	
Vertical displacement (distance)	
Vertical acceleration (acceleration due to gravity)	

31. Place the soup can (or other container) on the table or floor. Measure the vertical distance from the end of the ramp to the top of the can. __________
32. Substitute your answers to #30 and #31 into the equation from #29. Calculate the predicted range of the projectile.

33. Find the point on the table or floor directly below the end of the ramp. Measure and mark your predicted range from that point. Place the container there.
34. Use the level to assure that the end of the ramp is still horizontal.

Name: ____________________

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35. Release the marble from your assigned point. Where did it land?

    ____

36. If it did not land in the container, repeat the launch (without moving the container or ramp). Describe the results.

    ____

37. Describe some possible sources of error in this experiment.

    ____
    ____
    ____