Projectile Motion

INTRODUCTION

You have probably watched a ball roll off a table and strike the floor. What determines where it will land? Could you predict where it will land? In this experiment, you will use a projectile launcher to fire a ball horizontally. A pair of photogates in the launcher will help you measure the initial speed. You will use this information and your knowledge of physics to predict where the ball will land when it hits the floor.

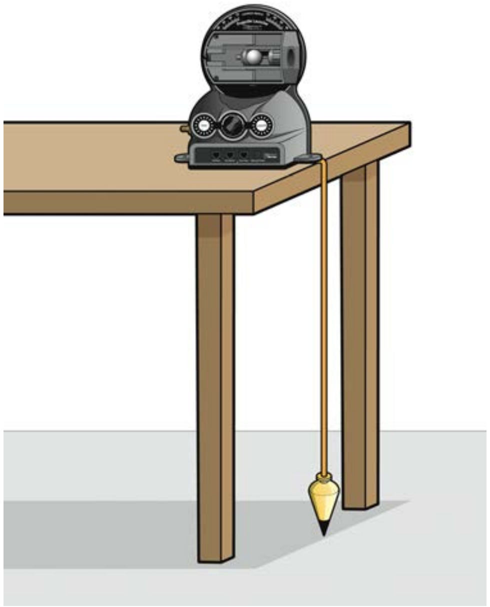

Figure 1

OBJECTIVES

- Measure the launch speed of a ball using a Vernier Projectile Launcher.
- Apply concepts from two-dimensional kinematics to predict the impact point of a ball in projectile motion.
- Take into account trial-to-trial variations in the speed measurement when calculating the impact point.

MATERIALS

Computer
Vernier computer interface
Logger *Pro*
Vernier Projectile Launcher
goggles
level
plumb bob
small cardboard box
meter stick **or** metric measuring tape
waxed paper
steel ball
Time of Flight Pad (optional, for Extension only)
Independence of Motion Accessory (optional, for Extension only)

PRELIMINARY QUESTIONS

Balance one 10c coin on the edge of a table. Place your index finger on a second 10c coin, then flick the second coin so that it travels off the table, while the first coin is gently nudged off the edge. It may take a few practice trials to be able to do this effectively.

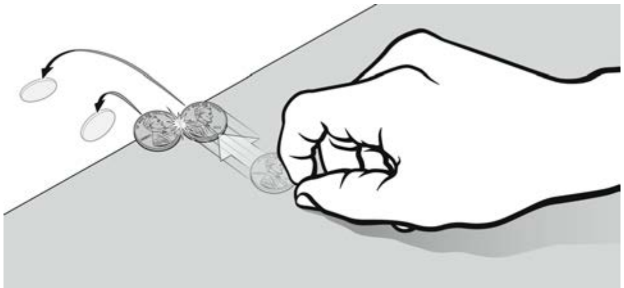

Figure 2

1. Predict which coin will land first, the coin moving horizontally, or the one that simply drops off the table. Explain.

2. Perform the investigation, listening for the sound of the coins as they land. Was your prediction supported or refuted?

3. You may believe the coins landed just a little bit apart from each other. Try it a few more times. Does one always land before the other?

4. What will happen if you increase the speed of the second coin? Predict and then give it a try.

5. What if you increase the height from which the coins are dropped? Your instructor may choose to stack two tables for you to test this.

6. Based on your observations, does the horizontal speed of the flicked coin affect the impact times of the coins?

7. What can you then say about the time to hit the floor for each coin?

INITIAL SET UP

1. Position the launcher next to the edge of your table. Eventually you will fire a ball horizontally that will travel several meters, so plan for this when choosing a location.

2. Place the level on top of the launch chamber. Use the lower knob on the back of the unit to adjust the orientation of the launch chamber until level. Tighten the knob to maintain this position.

3. Next, use the upper knob on the back of the launcher to set the scale to 0˚. Move the scale so that the notch of the launcher chamber is at 0˚. This setting accounts for deviation of the tabletop from horizontal.

4. Connect the Projectile Launcher to the interface. To do this, connect the clear, telephone-style end of the cable to the “Interface” port on the Projectile Launcher and the white, rectangular British Telecom end to the digital (DIG) port of the interface.

5. Open the file "08B Projectile Motion (Launcher)" in the *Physics with Vernier* folder. Logger *Pro* is set up to read the pulse time between the photogates and calculate the launch speed of the ball.

6. Connect the hand pump to the Projectile Launcher. Set the release pressure by adjusting the range knob. Turn clockwise for higher pressure and higher launch speed and counter-clockwise for lower pressure and lower launch speed.

   Note: Ask your teacher how to select an appropriate release pressure. When you pump the hand pump, you will hear a small release sound when the pressure is reached. Keep pumping until you hear at least three small release sounds, and then wait for five seconds so that the pressure is stabilized. Do not adjust the release pressure for the remainder of the activity or your prediction will be incorrect.

PROCEDURE

1. Obtain and wear goggles.

2. Insert a steel ball into the barrel. To do this, insert the ball into the launch chamber with your index finger and guide the ball into the barrel.

3. Pump the hand pump until the pressure stabilizes. Keep pumping until you hear at least three small release sounds and then wait for five seconds so that the pressure is fully stabilized.

4. Collect data using the following steps.
   a. Click ▶ Collect to start data collection.
   b. Hold the box in front of the opening of the launch chamber so you can catch the ball immediately after it leaves the Projectile Launcher. Do not let the ball strike the floor. This is important so as not to spoil the prediction.
   c. When you are ready to launch the ball, press and hold the Arm button, and then press the Launch button.
   d. Record the speed in the data table.

5. Repeat this process, catching the ball each time, so that you have a total of 10 launch speed measurements. Record the values in Table 1.

6. Inspect your speed data. Calculate the average speed value and identify the maximum and minimum values. Record the values in Table 2.

7. Determine the launch height.
   a. Measure the distance from the tabletop to the floor.
   b. The launch chamber of the Projectile Launcher is 0.146 m above the surface of the table. Determine the total distance the ball will fall.
   c. Record this total value as the launch height, *h*, in Table 2.

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8. Identify the floor origin and table offset.
   a. The launch point is clearly marked on the Projectile Launcher. Position the Projectile Launcher so that you can determine the distance from the launch point to the edge of the table, in line with the launch barrel. You will need this offset distance for later calculations. Record the offset value in Table 2.
   b. Use a plumb bob to locate the floor location just below the table edge. Mark this point with tape; it will serve as your floor origin.

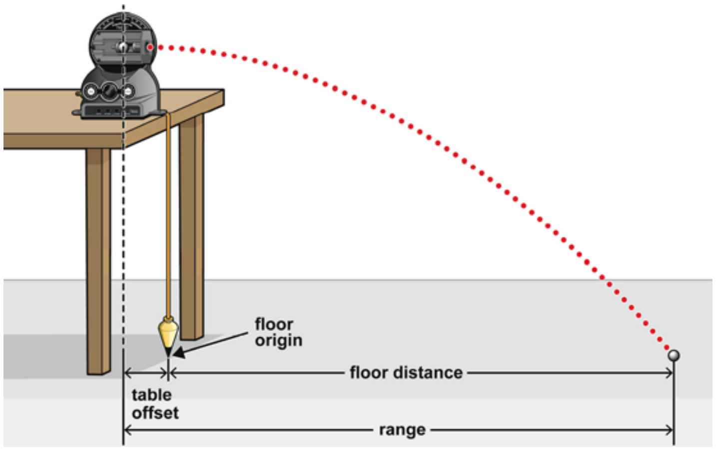

Figure 3

9. Determine the predicted impact point range.
   a. Use your average speed value to calculate your prediction for the *range*, that is, the horizontal distance the ball will travel. Record the value in Table 3 as the predicted range for the average speed.
   b. Subtract the table offset from the predicted range and record this value in Table 3 as the predicted floor distance for the average speed.
   c. To account for the variations you saw in the speed measurements, repeat the calculation for the minimum and maximum speed. These two additional points show the limits of impact range that you might expect, considering the variation in your speed measurement. Record the predicted ranges and floor distances for the maximum and minimum speeds in the data table.

10. Tape a piece of waxed paper to the floor that is long enough to account for the variation you have calculated. The waxed paper must be lined up with the launch chamber.

11. After your instructor gives you permission, launch the ball and allow it to strike the floor for the first time. Measure the distance from the floor origin to the actual impact and enter the floor distance in Table 4. Then, calculate the range for the actual impact.

$$range = floor\ distance + table\ offset$$

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DATA TABLE

Table 1	
Trial	Speed (m/s)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Table 2	
Maximum speed	m/s
Minimum speed	m/s
Average speed	m/s
Table height, h	m
Table offset, x_0	m

Table 3		
	Predicted range (m)	Predicted floor distance (m)
Average speed		
Maximum speed		
Minimum speed		

Table 4		
	Floor distance (m)	Range (m)
Actual impact		

ANALYSIS

1. Should you expect any numerical prediction based on experimental measurements to be exact? Would a *range* for the prediction be more appropriate? Explain.
2. Was your actual impact point between your minimum and maximum impact predictions? If so, your prediction was successful.
3. You accounted for variations in the speed measurement in your range prediction. Are there other measurements you used which affect the range prediction? What are they?
4. Did you account for air resistance in your prediction? If so, how? If not, how would air resistance change the distance the ball flies?

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EXTENDED EXPERIMENTAL INVESTIGATIONS

1. Investigate different launch angles.
   a. Derive a general formula for projectile motion when the object is launched at an angle.
   b. Predict the impact point based on the launch angle and speed. Repeat the experiment, launching the ball at a non-zero angle. Compare the impact point to your prediction. Repeat for additional launch angles.
2. Investigate the time of flight of the projectile and the factors that will affect this.
   a. How will the time to strike the floor vary with launch speed? Derive a general formula for the time of flight for an object launched horizontally.
   b. How will the time to strike the floor vary with angle? Derive a general formula for the time of flight for an object launched at an angle.
   c. Use the Time of Flight Pad to collect time of flight data for various launch speeds. Collect multiple trials for each speed to estimate the variations in the measurements.
3. Use the Independence of Motion Accessory (Optional) with the Projectile Launcher to investigate the motion of a dropped ball as another is projected horizontally. Examine one or more of the following phenomena.
   - **Independence of Motion** Do the two balls strike the floor simultaneously, even for different horizontal speeds or for differing horizontal distances travelled? Change the horizontal speed by changing the air pressure.
   - **Independence of Motion and Mass** Does the simultaneity depend on the mass of the balls? Try the experiment with the plastic balls.
   - **Vertical Fall Variation** Do the two balls strike the floor simultaneously, even if the drop height is much larger?
   - **Vertical Speed Variation** Set the Launcher barrel to an upward angle of about 20 degrees. Do the two balls now strike the floor simultaneously? Why or why not?

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