Projectile Motion

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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 roll a ball down a ramp and determine the ball's velocity using a photogate. 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 velocity of a ball using a photogate and computer software for timing.
- 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 velocity measurement when calculating the impact point.

Materials

Macintosh or Windows PC	plumb bob
LabPro	ramp
Logger *Pro*	meter stick or metric measuring tape
Vernier Photogate	Target
ball (1- to 5-cm diameter)	
masking tape	Carbon paper, clean white sheet paper

Preliminary questions

1. If you were to drop a ball, releasing it from rest, what information would be needed to predict how much time it would take for the ball to hit the floor? What assumptions must you make?
2. If the ball in Question 1 is traveling at a known horizontal velocity when it starts to fall, explain how you would calculate how far it will travel before it hits the ground.
3. A computer-interfaced photogate can be used to accurately measure the time interval for an object to break the beam of a photogate.. If you wanted to know the velocity of the object, what additional information do you need?

Procedure

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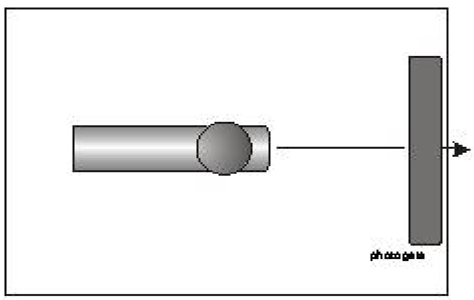
1. Assemble the projectile launch ramp at the edge of the lab table so that a ball can roll down the ramp and off the table edge horizontally as shown in Figure 1.

2. Position the photogate so the ball rolls through the photogate just as it leaves the ramp and begins to fall. To the best of your ability center the detection line of the Photogate on the middle of the ball, across its diameter. Connect the photogate to DIG/SONIC 1 of the LabPro. To prevent accidental movement of the photogate, use tape to secure its support stand in place.

3. Mark a starting position on the ramp so that you can repeatedly roll the ball from the same place. Roll the ball down the ramp through the photogate and off the table. Catch the ball as soon as it leaves the ramp. **Note**: Do not let the ball hit the floor during these trials or during the following velocity measurements. Make sure that the ball does not strike the sides of the Photogates. Reposition the Photogate if necessary.

4. Open the "Logger Pro 3" folder on the bottom pull-up toolbar and open the "37mm.cmbl" file.



5. Click Collect. Check to see that the photogate is responding properly by moving your finger through the photogate . Logger *Pro* will plot a time interval (Δt) value and a velocity for each instance you run your finger through the photogate Click Stop, then click Collect again, to clear the trial data and prepare for data collection.

7. Roll the ball from the mark on the ramp, through the photogate, and catch the ball immediately after it leaves the table. Repeat nine times. Take care not to bump the photogate, or your velocity data will not be precise. After the last trial, click Stop to end data collection. Record the velocity for each trial number in the data table.

8. Inspect your velocity data. Did you get the same value every time? Determine the average, maximum, and minimum values by clicking once on the velocity *vs*. time graph and then clicking the Statistics button, . What one value would be most representative of all ten measurements?

9. Carefully measure the distance from the table top to the floor and record it as the table height *h* in the data table. Use a plumb bob to locate the point on the floor just beneath the point where the ball will leave the table. Mark this point with tape; it will serve as your *floor origin*.

Figure 3

10. Use your velocity value to calculate the distance from the floor origin to the impact point where the ball will hit the floor. You will need to algebraically combine relationships for motion

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with constant acceleration

First, simplify the equations above. What is the value of the initial velocity in the vertical direction (v_{oy})? What is the acceleration in the horizontal direction (a_x)? What is the acceleration in the vertical direction (a_y)? Remember that the time the ball takes to fall is the same as the time the ball flies horizontally. Use this information and the simplified equations to calculate how far the ball should travel horizontally during the fall.

Mark your predicted impact point on the floor with tape and position a target at the predicted impact point. Be sure the impact point is along the line of the track.

11. To account for the variations you saw in the photogate velocity measurements, repeat the calculation in Step 10 for the minimum and maximum velocity. These two additional points show the limits of impact range that you might expect, considering the variation in your velocity measurement. Mark these points on the floor as well.

12. After your instructor gives you permission, release the ball from the marked starting point, and let the ball roll off the table and onto the floor. Mark the point of impact with tape. Measure the distance from the floor origin to the actual impact and enter the distance in the data table.

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Data Table

Trial	Velocity				
	(m/s)				
1			Maximum velocity		m/s
2			Minimum velocity		m/s
3			Average velocity		m/s
4			Table height		m
5			Predicted impact point		m
6			Minimum impact point distance		m
7			Maximum impact point distance		m
8			Actual impact point distance		m
9					
10					

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 velocity 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?