

Projectile Motion

Purpose

Apply concepts from two-dimensional kinematics to predict the impact point of a ball in projectile motion, and compare the result with direct measurement.

Introduction and Theory

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 with a pair of photogates. You will use this information to predict where the ball will land on the floor, and compare with direct measurement.

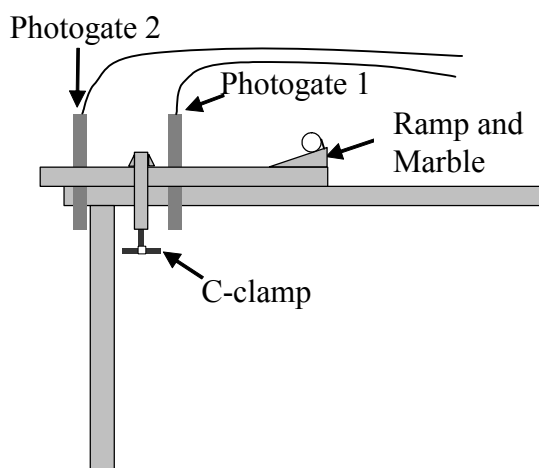


Figure 1

Apparatus Draw a labeled diagram of the setup and list all other equipment, with any identifying numbers.

LabPro interface box
1" diameter stainless steel marble
ramp and supports # (record the identifying number!)
2 Pasco Photogates
8½" × 11" sheet of paper
carbon paper
meter stick
plumb bob

Projectile Motion – Pre-lab

Print this page and finish the questions before coming to the lab. You will not be given a marble until this assignment is completed correctly.

1. If you were to drop a ball from rest, how long will it take for the ball to hit the ground? Write an equation in terms of the quantities you can measure in the lab, and gravitational acceleration g . What assumptions did you make?
2. If the ball in Question 1 starts with a horizontal velocity (v_{0x}), will your answer change? How far will it travel horizontally (x) before it hits the ground? Write an equation to calculate x in terms of the quantities you can measure in the lab, and g .
3. Using the formula for x from Question 2, find $\delta x/x$, the relative uncertainty of the horizontal distance the ball will travel.
4. To measure the initial horizontal velocity v_{0x} , two computer-interfaced photogates are used to measure the time interval for the ball to pass one photogate and then the other. To find the velocity of the ball, what additional information would you need?

Data

(Note: when you record any data, use the unit of the measuring device: don't do any unit conversion in the Data section.)

Set up the apparatus as in Figure 1, so that the marble can roll down the ramp, across a short section of table, and off the table edge.


Connect Photogate 1 to the DIG/SONIC 1 port of the LabPro interface box and Photogate 2 to DIG/SONIC 2. Turn on the computer and start the Logger Pro program. Click "OK" if the "Sensor Confirmation" window pops up.

For practice, release the marble from the nail at the top of the ramp and allow it to roll down the ramp, through the photogates and off the table. Catch the marble as soon as it leaves the table. The photogates should trigger when the marble rolls through their detectors, and the red LED on each gate should flash.

Open the file: *_Physics with Vernier\08A Projectile Motion.cml*. A data table and two graphs are displayed; one graph shows "Gate 1 to Gate 2 Time" for each trial and the other graph is the velocity of the marble calculated from the time and the spacing between the photogates.

The spacing between the photogates is set in the program to 0.100 m or 10.0 cm. This may or may not be the actual spacing. Carefully measure the distance between the two gates and record it under data Table 1. It may be easier to measure from the leading edge of Photogate 1 to the leading edge of Photogate 2. If the actual spacing is different from 10.0 cm, you need to enter it into Logger Pro by double-clicking "gate_spacing".

Click  to clear any trial data and prepare for data collection.

Release the marble from the nail on the ramp and allow it to roll through both photogates. Catch the ball immediately after it leaves the table – don't let it hit the floor. Check that Photogate 1 triggers only once and then Photogate 2 triggers only once, and that the resulting speed is reasonable. Repeat nine times. After the last trial, click  to end the data collection.

Inspect your velocity data on the screen. Did you get similar values every time? If you didn't, you may have connected your gates backwards. If you are satisfied with your results, record the velocity data in your report in a table similar to Table 1 on next page.

To predict the horizontal displacement as the marble drops from the table, you also need the drop height and the vertical acceleration. Measure and record the distance from the desk's top to the floor and record it in a table similar to Table 2.

Now we will let the ball hit the floor and directly measure the horizontal distance it travels. Place a sheet of your loose paper on the floor, holding its corners down with masses from your mass box, where the marble will land on it. Use a plumb bob to locate the point on the floor just beneath the point where the marble will leave the table (see Figure 2). Mark this point on the paper: it is the origin on the floor.

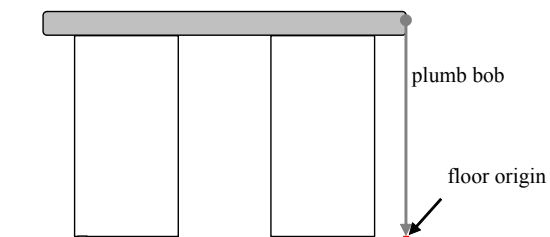


Figure 2

Place a sheet of carbon paper over the loose paper, near to where you expect the marble to land. Release the marble from the nail on the ramp, and let the ball roll off the table and onto the floor. Repeat 4 or 5 times to get an estimate of the uncertainty in the horizontal displacement.

On the paper, draw a line that best represents the horizontal displacement of the ball while it travels through the air, x_m . Measure the horizontal displacement x_m directly on the paper. Record the value and its uncertainty on the paper and in your report in a table like Table 3.

Each partner will do his/her own run on a separate sheet of paper, and will submit the sheet with his/her lab report. Compare your result with that of your partner(s). If there is a huge difference between your results, you may want to do another run.

Table 1: The initial velocity v (m/s)

Trial	Reading
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Average	
Uncertainty	

Note 1: the distance between the two photogates is _____ \pm _____ cm.

Note 2: the uncertainty of the velocity is calculated by $(\max v - \min v)/2$.

Table 2: Finding the drop time

	Reading	Uncertainty
Drop height y ()		
Gravity acceleration g (m/s^2)	9.81	0.01

Table 3: The measured horizontal displacement

	Reading	Uncertainty
Horizontal displacement x_m ()		

Calculations

Calculate the predicted horizontal displacement based on your answers to the pre-lab and the measurements in the lab. We call this result the reference value of the horizontal displacement x_{ref} . Keep at least 5 non-zero digits in calculations to avoid rounding errors.

Uncertainty Analysis

Calculate δx_{ref} using the uncertainty equation you derived in pre-lab.

Conclusions

In sentences, state your measured horizontal displacement, x_m , briefly mentioning how you got it. For example:

“The horizontal impact distance measured from the landing site was found to be ...”

You must report the numerical result in the correct format, namely, the absolute uncertainty has one or two non-zero digits, and the value ends in the same decimal place as the uncertainty. Centimeters are a good unit to report this result. Although not necessary, it is good practice to include the percentage uncertainty too (no need to show its calculation).

Similarly, state your predicted horizontal displacement, x_{ref} . To make comparison easy, it should have the same format and unit as x_m .

Discussion

You want to compare the two results: one calculated from the initial velocity, x_{ref} , one measured from the landing site, x_m . Each result has a value and an uncertainty, together defining a “window” of valid values. If the two windows overlap, we say the two results agree within uncertainty. Check if your results overlap and state whether they agree.

Similarly, compare your measured result x_m with that of your partner's. Do they agree?

Next discuss physical factors that may have affected your result but have been ignored. For example, you may have noticed that x_{ref} tends to be bigger than x_m , and the reason could be that we neglected air resistance in calculating x_{ref} . Can you think of other such physical factors in this lab? You are expected to discuss such physical factors at the end of all your lab reports.