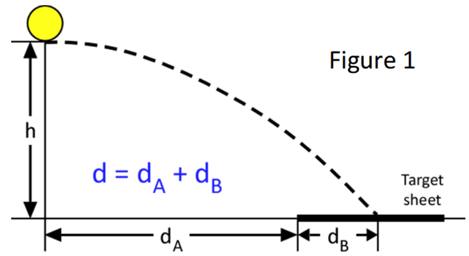
Projectile Motion

Fall 2023

Introduction

The purpose of this experiment is to measure the initial velocity of a projectile, then calculate the distance it will travel when fired at an angle. A trash can placed at this distance will demonstrate your understanding of the theory.

Experiment

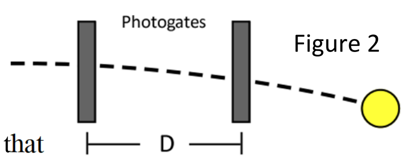


A. Parabolic Trajectory

1. Set up the spring launcher *horizontally* ($\theta = 0^o$), and firmly tighten both adjustment screws. *Figure 1* shows where you will be taking measurements.
2. Your instructor will show you how to load and shoot the projectile. Measure the height, ***h***, of the projectile above the floor (measure to the *bottom* of the picture of the projectile on the right side of the launcher). In your sketch, indicate the launcher you used (A, B, C, etc. – the label is on the vertical support)

   Note: Be sure to set the launcher for ***medium*** *range throughout the experiment; the long-range setting will hit the ceiling or opposite wall!*
3. Fire the launcher a few times, noting the place the projectile hits the ground. *Be sure to check that the launcher angle has not changed after each shot*. Place a wooden catch box at this location; fire a few more shots to check its position. Remove the catch box and replace it with a target sheet (ink-side-up carbon paper under a sheet of graph paper). Tape the graph paper to the floor and use another piece of tape on the floor to mark the front position of the target sheet; don't remove this tape until you are ready to leave!
4. Measure the distance along the floor from a position directly below the release point of the projectile (the side of the launcher is marked with a small cross) to the front edge of the target sheet. Call this distance d_A. *Make sure you know where the zero point is located on the tape measure!*
5. Fire the launcher *at least* 10 times; again, check that the angle has not changed after each shot. The projectile will leave a mark on the underside of the graph paper. After your 10 shots, pick up the target sheet and measure the distance from the front edge of the paper to the center of each spot, d_B. (Don't worry about which shot is the first, the second, etc.)
6. Calculate the horizontal distance, $d = d_A + d_B$ the projectile traveled for each shot. Also calculate the minimum distance, d_{min}; the average distance, $\langle d \rangle$; and the maximum distance, d_{max}.
7. In the pre-lab discussion the initial velocity of the projectile, v_{ox}, as a function of the distance traveled, the height of the projectile, and g (approximately 9.80 m/s^2) was derived. **Show the steps of this derivation in your journal** (if you have not done so already), and use this function to calculate the minimum, average, and maximum velocity of the projectile.

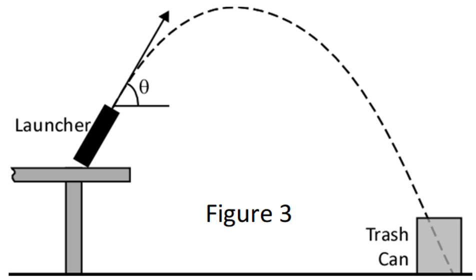
B. Time of Flight



8. Attach the double–photogate assembly to your launcher. Position it so that the first photogate is as close to the end of the launcher as possible.
9. Measure the distance between the photogates, D, the distance between the gate-beams on the bottom, where they are attached to the bracket (*Figure 2*). Set the timer mode to *pulse, memory on*.
10. Repeatedly fire the launcher, recording each time interval in a table in your journal until you are satisfied with the results. Calculate the average flight time, $\langle t_{flight} \rangle$ excluding any which seem clearly incorrect.

11. Use $\langle t_{flight} \rangle$ and *D* to calculate the average initial velocity of the projectile. Compare this value (calculate % difference) to the average velocity calculated using the trajectory data. *Note*: If the photogate velocity is much larger or smaller than the calculated maximum and minimum velocity, check your measurements and calculations. More than a 5% difference with the average velocity can be too much!

12. Remove the photogate assembly from the launcher and turn the timer off.



Sink the Ball

13. Set your launcher to any angle between 30° and 50° (*Note: if you're working in the hallway, the ceiling is lower, so you'll only be able to pick a 30° and 45° angle.*) Check that the height of the projectile is the same as before.

14. Open the Excel spreadsheet *Projectile Motion - 103* from the *PHYS103* folder on the *T:* drive and read the instructions at the top of the page. Enter all lab partner names in the appropriate box, select the launcher used from the pull-down menu, and then enter the projectile height (units: *meters*), the launcher angle, and your velocities from Part A (units: *m/s*). Click the **Graph** button to see the trajectory of the projectile. A scale trash can appears on the graph; move it to the desired position to catch the projectile.

15. Print a copy of the graph for each member of the group. You will use this graph to determine where to place the can to catch the projectile when fired at an angle. **Draw *Figure 3* in your journal**, being sure to state the launcher used, make your measurements, and take your shot. The rules are as follows:

    I. The placement of the can is accomplished by calculation and measurement, *not* trial and error. Once the can is in place for the shot, it *cannot* be moved closer to, or further from the launcher; only left-right adjustments will be allowed. No practice shots are allowed; your instructor must witness your trash can shot!

    II. If you miss the can on the first attempt, you will be given a second shot, *without* moving the launcher or the distance to the can; left-right adjustments of the can will be allowed to account for aiming errors. Further attempts will not count. Rim shots count only if the projectile bounces into the can (which rarely happens). *You will be given credit for a first shot if you sink the ball in the can on the second shot after making only left-right adjustments!*

    III. You will earn +1 extra point on your lab if you sink the projectile into the can on the first shot.

    IV. For the more daring amongst you, a smaller target will be made available (as time allows). You must choose a different launch angle if you want additional credit for this smaller target.

It is traditional to gather the whole lab section together to share in your success!

Discussion

- Restate your numerical results: the three initial velocities, the photogate velocity, and the percent difference.
- Compare the average velocities measured from the two parts of the experiment. How well do they agree with each other? What factors may have affected the results?
- Describe the results of your trash can shot. Be sure to indicate where you placed the can, and *why* you placed it there!
- Don't forget to attach your target sheet to the journal of one group member. *Never throw away data!*

BEFORE LEAVING THE LAB, PLEASE REMOVE ANY TAPE YOU APPLIED TO THE FLOOR OR THE LAB BENCH AND RETURN THE PROJECTILE TO THE BOX UP FRONT.