LAB 2. PROJECTILE RANGE

Supplies: Projectile launcher, projectile, ramrod, clamp, plumb line, measuring tape, meter stick, carbon paper, white paper, tape, sturdy table

Safety considerations

- The projectile launcher fires a 1″ steel or hard plastic ball at speeds that can be considerable. To avoid eye injury, **everyone in the room must wear safety glasses or goggles at all times**.
- **Never look down the muzzle** of barrel. You can see into the barrel through the slots cut in the sides.
- Once the barrel is loaded, be careful not to place any part of your body in front of the launcher.
- Use the ramrod for loading and cocking the launcher. **Never** poke your fingers into the launcher—you could very easily break them! That would be bad.
- Load the projectile launcher with 1″ balls only. Other loads may cause dangerous conditions.

Guidelines for using the projectile launcher

Description

The projectile launcher propels its load using a cocked spring. The spring can be set at three positions, with increasing force and travel distance. The barrel pivots up and down to adjust the firing angle. An angle gauge with a small built-in plumb line measures the firing angle. The muzzle is the end of the barrel close to the pivot.

In this activity you will clamp the launcher to a table and fire a projectile onto the floor from different initial angles. You will then compare the observed trajectories to predictions from a simple ballistic model.

Care of the launcher

Do not fire the launcher without a load. Such a "dry fire" may damage the launcher. If you wish to release a cocked spring without firing, insert the ramrod into the barrel against the cradle and, while holding the ramrod firmly, release the trigger. Slowly pull the ramrod out of the barrel.

Do not over tighten the wing nuts; they can easily strip and break.

Setup

Place the launcher at the edge of the table, with the muzzle of the barrel pointing away from the table. Clear the line of fire so that the trajectory is not obstructed.

Clamp the launcher firmly to the table. Use two clamps, one on either side of the base, if available. If only one clamp is available, put it on the side under the barrel of the launcher.

Firing

Place the projectile into the muzzle of the launcher. Push it into the barrel using the ramrod. As you push it in, the trigger on the top of the barrel will rise and fall with a click up to three times. After each click, the launcher is cocked in that position.

If the barrel is horizontal, check that the projectile is against the cradle by looking through the slots in the side of the barrel. If the projectile has rolled forward, gently push it back against the cradle with the ramrod.

Check that no one is in the line of fire.

Fire the launcher by pulling up on the trigger.

Watch the projectile as it travels and bounces so that you can retrieve it.

Lab activities

Data sheet

Read the activities. Note the measurements and observations to be taken in each activity. Make a data sheet to record the data. Get it approved by your instructor before taking data.

Activity1. Finding projectile speed

Vertical launch

1. Adjust to barrel to fire vertically.
2. Measure and record the height of the muzzle above the table.
3. Hold the meter stick vertically behind the launcher.
4. Load, cock, and fire the launcher. Catch the projectile on the way down.
5. Observe how high the projectile rises against the meter stick. Record the value if you think you got a good reading.
6. Repeat for a total of five readings.

Horizontal launch

1. Adjust the barrel to fire horizontally.
2. Measure the height of the muzzle above the floor.
3. Using the plumb line, find the position on the floor directly beneath the muzzle. Mark this position with tape.
4. Load, cock, and fire the launcher. Note where the projectile lands.
5. Tape a piece of white paper onto the floor where you saw the projectile land. Place a piece of carbon paper, carbon side down, atop it. Place another piece of white paper atop the carbon paper to protect it from tearing.
6. Check that the launch angle is still horizontal. Adjust if not.
7. Load, cock, and fire the launcher.
8. The projectile should have landed on the paper and made a mark on the white paper on the bottom. Leaving this paper taped to the floor, find the mark and label it.
9. Replace the carbon paper.
10. Repeat for a total of five shots onto the paper.
11. Measure the distances from the point on the floor beneath the muzzle to the shots on the paper. Record these distances.

Activity 2. Range

Carry out each set of measurements for launch angles of 10°, 20°, 30°, 40°, 50°, and 60° above horizontal. (You already have values for 0°.)

1. Set the launch angle to the desired value.
2. Load, cock, and fire the launcher. Note where the projectile lands.
3. Tape a piece of white paper onto the floor where you saw the projectile land. Place a piece of carbon paper, carbon side down, atop it. Place another piece of white paper atop the carbon paper to protect it from tearing.
4. Check that the barrel is still at the desired angle. Adjust if not.
5. Load, cock, and fire the launcher.
6. The projectile should have landed on the paper and made a mark on the white paper on the bottom. Leaving this paper taped to the floor, find the mark and label it.
7. Replace the carbon paper.
8. Repeat for a total of five shots onto the paper.
9. Measure the distances from the point on the floor beneath the muzzle to the shots on the paper. Record these distances.

Record measurements at two more launch angles of your own choosing to find the angle giving the greatest horizontal distance from the launcher.

Processing, Analysis, and Interpretation

Activity 1. Finding projectile speed

Vertical launch

1. Find the kinematic equation for maximum height h of a free-fall trajectory.
2. Solve the equation for initial projectile speed (muzzle speed) $\underline{v_0}$.
3. Calculate the mean value $\bar{h}$ of the height measurements you made above.
4. Calculate the standard deviation σ of the height measurements. Use the formula

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i-1}^{N}\left(h_i - \bar{h}\right)}$$

5. Calculate your estimate of v_0 from the mean value of h.

7. Calculate the uncertainty range of your estimate of v_0 from $\bar{h} \pm 2\sigma$.

Horizontal launch

1. Find the kinematic equation for the height decrease with time of an object in free-fall from rest.
2. Solve the equation for time of fall. Calculate the time for your projectiles.

3. Find the kinematic equation for the horizontal distance x traveled at speed v in time t. Solve the equation for v.
4. Calculate the mean and standard deviation of the horizontal distances.
5. Calculate your estimate of v from the mean value of x.
6. Calculate the uncertainty range of your estimate from $\bar{x} \pm 2\sigma$.

Best estimate

Decide on your best estimate for v_0. Is it the value calculated from the vertical shots? From the horizontal shots? Some other value?

Activity 2: Range

1. For each launch angle, calculate the mean and standard deviation of your horizontal distance measurements.
2. Find the kinematic equation for horizontal distance x traveled by a projectile launched at an angle α and speed v_0 from a height h above the floor.
3. Calculate the expected distance x for enough angles to plot a smooth curve between $\alpha = 0°$ and $\alpha = 65°$. Use your best estimate of v_0.
4. Estimate the launch angle giving the greatest horizontal travel distance, and estimate the distance it would produce.

Lab Report

The report for this first lab should not be lengthy. It should not take long for me to read it! It will contain the following sections.

Methods: Briefly describe the apparatus and activity, including measurements taken and

Data: Include your raw data sheet with your report.

Calculations: Report the means and standard deviations that you calculated. Report your best estimate of v_0.

Show a graph of horizontal distances vs. launch angles. For each experimental launch angle, plot the average horizontal distance x and "error bars" at $\pm 2\sigma$. Make a smooth curve of the calculated distances.

Discussion:

- Explain your best estimate for v_0.
- Identify and discuss sources of uncertainty in your measurements.
- Discuss how well the calculated values of the horizontal travel distances match your observations.
- Identify and explain your best estimate of the optimal launch angle α and its resulting horizontal travel distance x.
- Discuss how and why the optimal angle matches, or does not match, the theoretical optimal angle for a projectile landing at the same height as its launch.