Projectile Motion: Calibrating a Cannon

1 INTRODUCTION

The key parameter required to estimate the range of a cannon is the muzzle velocity. The muzzle velocity is the initial velocity v_o with which a projectile leaves the launcher. In this lab, you will use your knowledge of kinematics to measure the muzzle velocity of a projectile launcher.

2 LEARNING GOALS

- Experiment with the physics of projectile motion.
- Measure the muzzle velocity of a projectile launcher.

3 BACKGROUND

3.1 PROJECTILE MOTION

A special case of two-dimensional motion is called *projectile motion*. In projectile motion, an object is projected (or launched) with some initial velocity $\vec{v}_o$. The object moves in a vertical plane with some constant horizontal velocity, v_{ox}, with a constant free-fall acceleration of $-g$ vertically; the horizontal and vertical motion are independent. Essentially projectile motion boils down to two independent one-dimensional kinematics problems.

The general kinematic equation of motion is given by the familiar expression;

$$\vec{x}(t) = \vec{x}_o + \vec{v}_o t + \frac{1}{2}\vec{a}t^2. \tag{3.1}$$

In projectile motion, the horizontal acceleration is zero (neglecting the effect of air resistance). Thus the horizontal equation of motion simplifies to;

$$x(t) = x_o + v_{ox} t. \tag{3.2}$$

In the vertical direction, the gravitational acceleration is constant (represented by $-g$). The vertical equation of motion is;

$$y(t) = y_o + v_{oy} t - \frac{1}{2} g t^2 \tag{3.3}$$

4 PROCEDURE

You will be using a Pasco ME-6800, short range projectile launcher to study projectile motion. The launcher is powered by a steel spring that can be set to one of three settings; “short”, “medium”, and “long range”. For this lab, use the “medium range” setting exclusively.

Design an experiment to measure the muzzle velocity, $\vec{v}_o$, of the medium range setting, for your projectile launcher. Specifically, the goal is to measure the muzzle velocity with a precision better than 1%.

Before you begin your experiment, be sure to record the number of your projectile launcher. You will use the projectile launcher in future experiments.

In designing and conducting your experiment, you may want to consider the following points:

- How many trials are sufficient to measure $\delta_{vo}/v_o < 1\%$?
- There will be some spread in the impact position for various shots from the projectile launcher. How will you deal with these random fluctuations?
- What factors are most important to accurately calculate the muzzle velocity?

5 CONCLUSION

Write a lab report to record and communicate your work. Your report should addresses the following ideas:

- Experiment Purpose and Design
  - In your own words, state the purpose of this experiment.
  - In a couple of sentences, describe how you will use the available equipment to make your measurements. Include pictures or diagrams as appropriate.
- Data Collection and Calculations
  - List the quantities you measured directly in this experiment.
  - For each quantity above, state the range of values over which you decided to make measurements. Describe how your measurements were distributed within that range. Justify your choice of measuring this way.
  - Demonstrate calculations where measured quantities are used to compute other quantities of interest.
  - Explain why you need to calculate each quantity listed above to arrive at your final result.
- Presentation and Analysis
  - Present the data you collected.
  - Analyze your data using insightful and well-formatted plot(s).
  - Using your plot(s), identify trends that your data exhibit or other apparent relationships between your independent and dependent variables.

  - If your data were fit with a trendline, interpret the results of the fit. What do you conclude from the results of the fit?

- Results
  - Identify and clearly state the final result(s) of your experiment.

- Uncertainty and Error Propagation
  - Demonstrate error propagation calculations used to quantify the uncertainty of your measurement.
  - Identify at least one source on random error in your experiment. Explain why each source of uncertainty can be considered random. If you are unable to identify a resonable source of random error, explain and justify this conclusion.
  - Identify at least one source of systematic error in your experiment. Explain why each source of uncertainty can be considered systematic. If you are unable to identify a reasonable source of systematic error, explain and justify this conclusion.
  - Describe actions you took or special procedures used while collecting data to minimize the impact of these sources of error on your final results.

- Discussion
  - Do your results agree with what you expected to see before you started the experiment?
  - Interpret your results. What are you able to conclude from your data? Describe how your conclusions relate to the physical principles being studied.
  - List at least one improvement you would make if you were to repeat the experiment. What effect do you think your improvement would have on your final results?

- Answers to Inline Questions
  - Include answers to specific inline questions as appropriate to the laboratory activity.