Video Analysis – Projectile Motion

1 LEARNING OBJECTIVES

At the conclusion of this activity you should be able to:

- Launch projectiles with a trebuchet.
- Use video analysis techniques to analyze the motion of an object in video data.
- Analyze a trebuchet projectile using the physics of projectile motion.

2 BACKGROUND

2.1 READING ASSIGNMENT

Please read:

- Error Propagation Reference (available on Blackboard: 🗀 `Reference Material > Error Propagation Reference`). Pay particular attention to the recipe for error propagation given in Section 3 of that document.

2.2 PROJECTILE MOTION

Recall that the general kinematic equation of motion is given by;

$$\vec{x}(t) = \vec{x_o} + \vec{v}_o t + \frac{1}{2}\vec{a}t^2. \tag{2.1}$$

Which, for a projectile near the surface of the earth[1] (where the acceleration due to gravity is constant), can be decomposed into independent equations of motion in the horizontal

$$x(t) = x_o + v_{ox} t, \tag{2.2}$$

and vertical

$$y(t) = y_o + v_{oy} t - \frac{1}{2} g t^2, \tag{2.3}$$

components.

The range, R, of a projectile is the horizontal distance traveled (see Figure 2.1). The range can be found by setting $x - x_o = R$ and $y - y_o = 0$ in the equations above. The range can then be found by eliminating time from the pair of equations.

The result is an expression for the range of a shot in terms of the shot angle θ_o and the magnitude of the initial velocity v_o:

$$R = \frac{v_o^2}{g} \sin(2\theta_o). \tag{2.4}$$

Note that the coordinate system used in this formula has its origin at the point where the projectile is launched. The formula also assumes that the initial and final y-positions are the same.

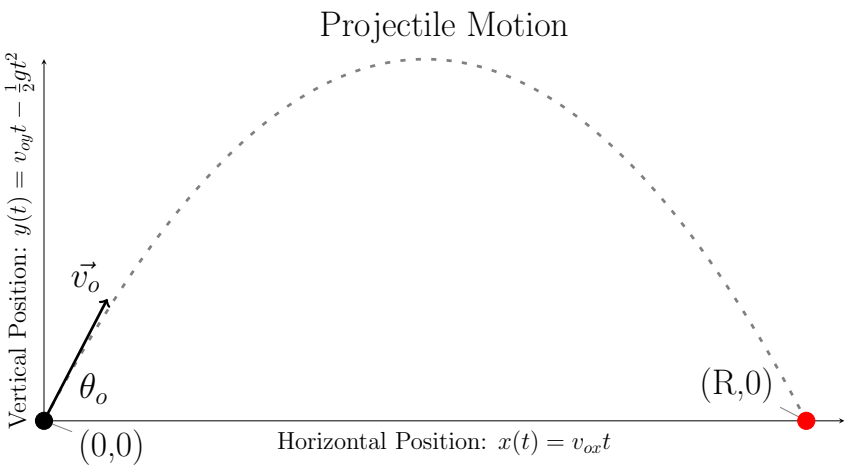

Figure 2.1: A projectile is fired with some velocity $\vec{v_o}$ and angle θ_o above the horizon. The projectile travels a horizontal distance R before hitting the ground.

2.3 Collecting Videos for Physics Analysis

The following link has some important tips for collecting videos for physics analysis:

https://www.vernier.com/til/1464

3 Procedure

A trebuchet[2] will be used to launch various projectiles. The goals of the experiment are to determine the:

- initial velocity
- release angle
- range

of a trebuchet shot. Each of these quantities will be measured using data collected from video analysis.

The trebuchet will be fired in the outfield of Babb Field on the Homewood campus. Babb Field is located at the North Gate off of University Parkway, across the circle from the O'Connor Recreation Center.

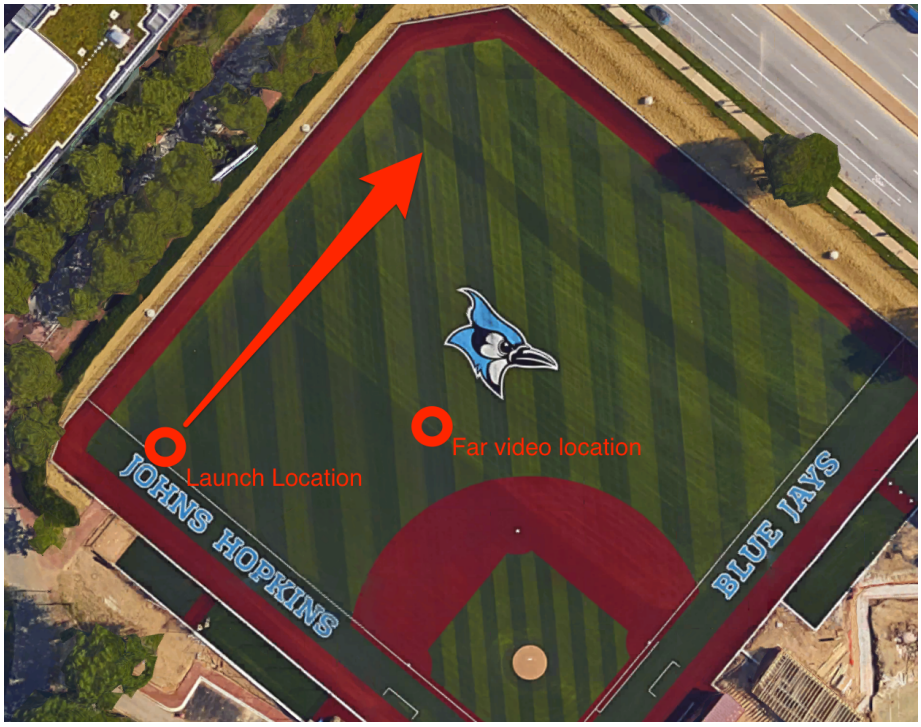

Figure 3.1: An aerial photograph of Babb Field on the Homewood campus. The trebuchet will be fired from the left field foul line towards center field.

4 Lab Notebook

Your submission will be evaluated using the following rubric:

Lab Notebook Practices

- Lab Notebook Mechanics (6 points)
  - Relevant information *e.g.*: your name, your lab partner's name, date, *etc.* is present.
  - The notebook is organized and easy to read. Markdown cells are used for narrative text. Code cells are clearly organized and commented.
  - The ZIP file of the notebook is healthy and runs correctly.
- Data Analysis & Plots (6 points)
  - The notebook tells a scientific story; it is an accurate record of the work that you did.
  - The notebook should show evidence of trial and error. Keep a good record of your work – recording mistakes is useful.
  - Record rough data and plots that you used to verify that the analysis was on the right track. Final versions of plots should be well formatted and meet the plotting guidelines for the course.
  - Use models to identify trends that your data exhibit or other apparent relationships between your independent and dependent variables.
- Results and Comparison (6 points)
  - Clearly state the final result(s) of your experiment. Remember to quote your result with units and appropriate significant digits.
  - Final result plots are well formatted and meet the standards described in the Figure Formatting reference.
  - A useful comparison is made to a known/expected value or another similar result.
  - Choose the best available tools for your comparison (*e.g.* plots, pictures, discrepancy, significance of discrepancy, etc).
- Uncertainty and Error Propagation (6 points)
  - Identify the dominant source(s) of error in your experiment.
  - Support your conclusions with appropriate error estimates and error propagation calculations.
- Physical Interpretation (6 points)
  - Throughout the notebook, interpret the data, rough plots, and final results in terms of the underlying physics.
  - What are you able to conclude from your data? Clearly explain how you arrived at your conclusions from your experimental observations.
  - Reflect on how your experiments connects with the physics concepts you are studying.

REFERENCES

[1] Resnick, R., Halliday, D., Krane, K. S. (2002) *Physics, Vol. 1, 5th Edition*. Danvers, MA: John Wiley & Sons, Inc.. See Chapter 4-3 (pp. 68-71)

[2] See this Wikipedia article on Trebuchets: https://en.wikipedia.org/wiki/Trebuchet.