Experiment 2: Projectile Motion

In this lab we will study two dimensional projectile motion of an object in *free fall* - that is, an object that is launched into the air and then moves under the influence of gravity alone. Examples of projectiles include rockets, baseballs, fireworks, and the steel balls that will be used in this lab. To describe projectile motion, such as the trajectory (path), we will use a coordinate system where the y-axis is vertically upward and the x-axis is horizontal and in the direction of the initial launch (or initial velocity). To simplify projectile motion, we assume that the gravitational acceleration (g=9.8 m/s^2) is constant, such that $a_x = 0$ and $a_y = -g$, and we will ignore any air resistance. The equations of motion in the x and y directions for a projectile launched with a velocity v_0 at an angle θ are given as

$$v_x = v_{x0} \tag{1}$$

$$x = x_0 + v_{x0}t \tag{2}$$

$$v_y = v_{y0} - gt \tag{3}$$

$$y = y_0 + v_{y0}t - \frac{1}{2}gt^2 \tag{4}$$

where t is the time, and g is taken to be positive. The components of the initial velocity v_0 are $v_{x0} = v_0 cos(\theta)$ and $v_{y0} = v_0 sin(\theta)$.

Experimental Objectives

In this lab you are given a mini-launcher, a time of flight sensor (TOF) pad, steel balls, carbon paper, a plumb-bob and rulers. The mini-launcher is equipped with a photogate sensor that is connected to the time of flight sensor: When a steel ball passes through the photogate sensor, it starts a timer in the computer software system that records the time it takes for the ball to hit the TOF sensor pad. The total time of flight can be displayed by double cliking the "Digits" option under the Displays tab in the Capstone software. The mini-launcher can be cocked to 3 different position settings and can therefore release the ball with three different initial velocities. The protractor on the side of the mini-launcher can give you any desired launch angle. The carbon paper will be used to mark where the projectile lands, giving you an accurate measurement of the total horizontal distance traveled. With this equipment, complete the following experiments (*please read the warning at the bottom before doing the experiment*):

- Using the set-up shown in Figure 1, determine the initial velocities of the ball released for the first two firing settings, that is, the first two "clicks". To accurately measure the distance from the launch platform to the TOF sensor, use the plumb-bob to avoid paralax measuring error. In order to minimize random errors, it is very important that all of your measurements be performed several times.

- Devise an experiment to measure the relationship between the range (horizontal distance of the projectile motion) and the launch angle. Experimentally show which angle gives you the longest range. What is the range and total time for the different velocity settings when $\theta = 0°$?

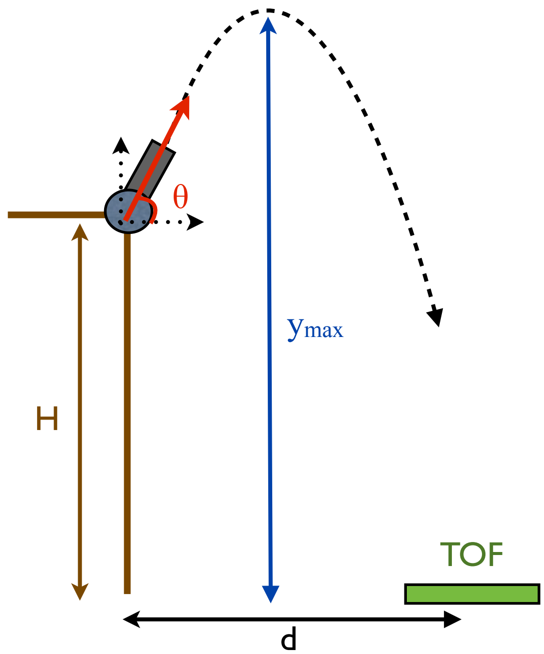

Figure 1: A projectile is launched at an angle θ off a platform with height H above the around. The projectile lands the on time of flight sensor (TOF), a distance d away from the base of the platform.

- Devise an experiment to measure the acceleration due to gravity using the TOF sensor, assuming you do not know the initial velocities of the launcher (*Hint*: try a free-fall experiment). Do enough trials to reasonably compare your results with the accepted value of g = 9.80 m/s^2. What are possible sources of error for this experiment?

WARNING: THE PROJECTILE LAUNCHER CAN SHOOT STEEL BALLS AT HIGH VELOCITIES. IF A PROJECTILE WERE TO HIT YOU IN THE FACE IT COULD CAUSE PERMANENT DAMAGE! ALWAYS WEAR SAFETY GOGGLES WHEN OPERATING THE LAUNCHER! NEVER FIRE THE LAUNCHER WHEN SOMEONE IS DIRECTLY IN FRONT OF THE LAUNCHER, NO MATTER HOW FAR AWAY THEY SEEM TO BE! NEVER EVER POINT THE LAUNCHER AT YOUR FACE! VIOLATING ANY OF THESE SAFETY RULES WILL RESULT IN LOST POINTS AND A POSSIBLE EXPULSION FROM THE LABORATORY. HORSEPLAY IS NOT TOLERATED AT ALL! REMEMBER, IT IS ONLY FUNNY UNTIL SOMEONE LOSES AN EYE! AND PLEASE DO NOT STEP ON THE TIME OF FLIGHT SENSOR PAD.

A full lab report is not necessary for this lab. Answer the questions on the following page and turn it in with your signed data sheet.

PHYS 123, Lab 2 Questions

Name: **CWID:**

Write your answers on a separate sheet and attach your signed data sheet when turning it in. You must show all of your work for full credit. Make it clear that you understand what you're doing. Any graphs or tables should be made via computer software and also attached.

1. Answer the following questions using the data you acquired in this experiment:

   (a) What are the two initial velocities for the first two firing settings (the first two "clicks")? Make a table consisting of the initial velocities, its components v_x and v_y, the launch angles, the time of flight, and the horizontal range.

   (b) Consider the angle that gave you the longest range. Using the angle and initial velocity calculate the maximum height (y_{max}) reached at this angle? What is the overall maximum height reached in your experimental data? Which angle gave you the maximum height?

   (c) Make a graph of launch angle vs. horizontal range for the second experiment. Label the axes appropriately with correct units.

   (d) For the third experiment, how do your measured values of the gravitational acceleration compare to the accepted value of $g = 9.8\ m/s^2$? What are possible sources of error for this experiment?

   (e) If the steel ball is shot vertically upward, how long would it take for it to hit the floor below? Calculate for both initial velocities.

2. Ideally, what kind of mathematical curve is the projectile motion trajectory? Describe two examples of projectile motion which you have observed or experienced outside of this physics lab that follow this mathematical curve.

3. Are there two different launch angles that would give you the same range? Are there two different launch angles that would give you the same height? Explain.

4. If the steel ball is shot *horizontally* off the table, how much time would it take the ball to hit the ground for each of the velocity settings of the launcher? Explain your answer using the equations of motion and your experimental data. How does this relate to the ball being dropped *vertically* from the table top to the floor below?