Experiment 5: Projectile Motion Part 2

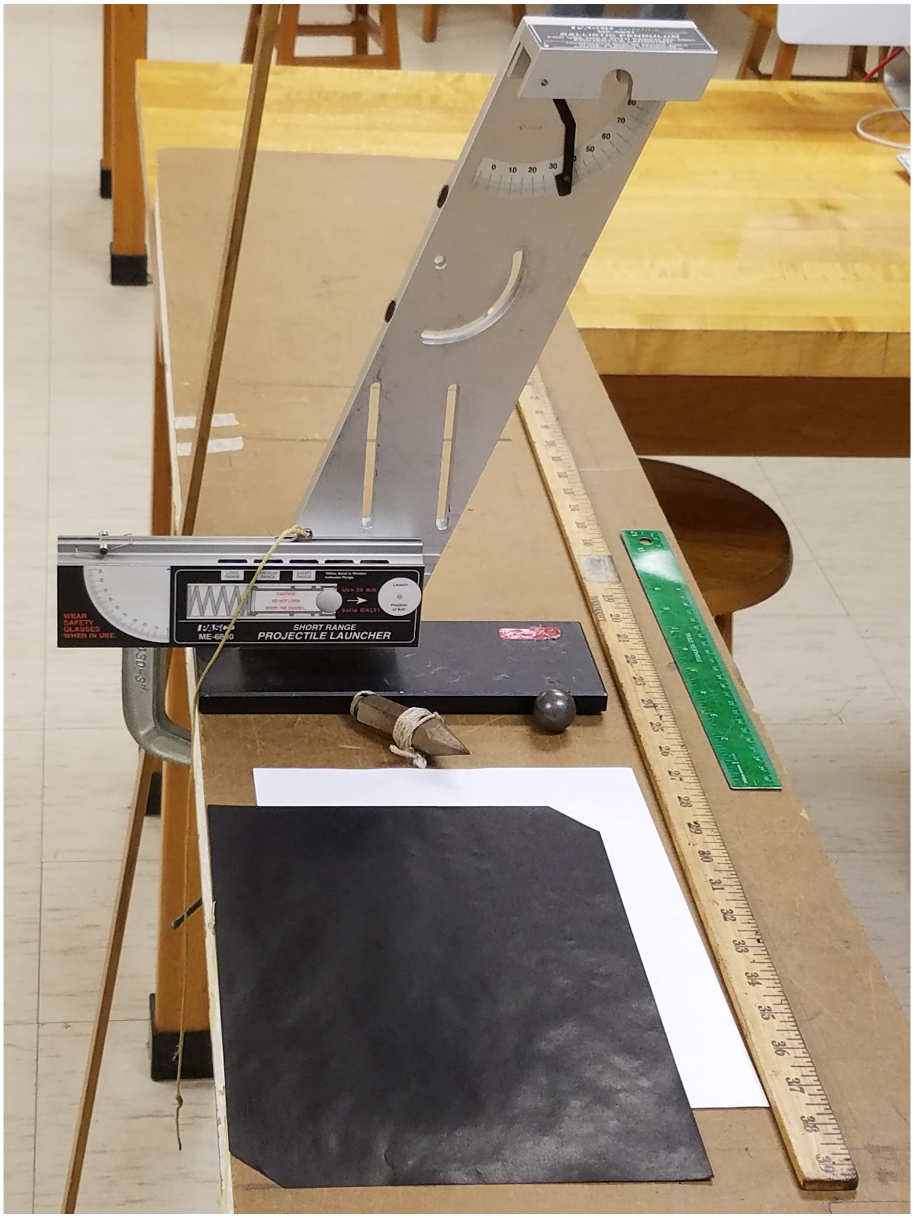


Figure 5.1: Ballistic Pendulum (Spring Gun)

EQUIPMENT

Pasco Ballistic Pendulum (Spring Gun)
2-Meter Stick
Meter Stick
Ruler
Plumb Bob
Carbon Paper
Target Paper
Launch Platform & C-clamps
Wall Guards

Advance Reading

Text: 2-D Projectile Motion (Serway and Vuille 3.1-3.2)

Objective

The objective of this lab is to measure the initial velocity of a projectile when fired from a spring gun horizontally (part 1) and to predict the landing point when the projectile is fired at a non-zero angle of elevation (part 2).

Theory

Projectile motion is an example of motion with a constant acceleration, with an initial velocity in any direction (horizontal, vertical, or at an angle). An object is considered to be a projectile when the only force acting on the object is gravity - so we are ignoring air resistance and starting our calculations the moment after the object has been launched and ending our calculations the moment before the object lands.

Gravity is a force between two objects with mass. The force of gravity on the projectile will be directed toward the center of the Earth - downward. The acceleration of the projectile will be due only to gravity and therefore the x-component of the acceleration will be zero and the y-component of the acceleration will be directed downward and have a magnitude of $g = 9.80 m/s^2$.

To predict where a projectile will land, one must know the object's starting position, $\vec{\mathbf{r}}_\mathbf{0}$, initial velocity, $\vec{\mathbf{v}}_\mathbf{0}$, and the acceleration it experiences, $\vec{\mathbf{a}}$. Position as a function of time is then described as:

$a_x = 0$

$a_y = -9.80 m/s^2$

Because the x-component of the acceleration is zero, the motion in the x-direction will be constant-velocity motion. Because the y-component of the acceleration is equal to a constant value of $g = -9.80 m/s^2$., the motion in the y-direction will be constant-acceleration motion. Both of these motions are happening simultaneously - the projectile is moving forward in the x-direction with constant velocity while it is accelerated downward due to gravity.

We will analyze the motion of the projectile using the kinematic equations, separated into x- and y-components. The only connection between the motion in the x-direction and the motion in the y-direction is that they both take place during the same time interval t.

$$v_x = v_{0x} + a_x t$$
$$x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2$$
$$v_x^2 = v_{0x}^2 + 2 a_x \Delta x$$

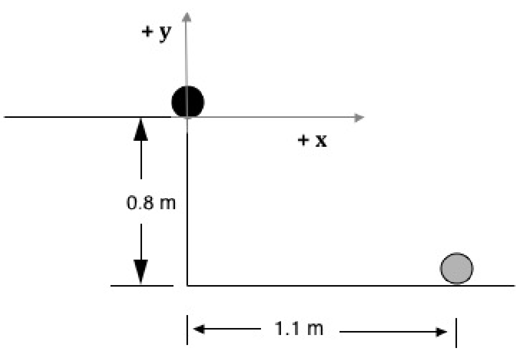
and

$$v_y = v_{0y} + a_y t$$
$$y = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$$
$$v_y^2 = v_{0y}^2 + 2 a_y \Delta y$$

Name: ____

1. What is projectile motion?

2. Find the initial velocity, v_0, of a ball rolling off the table in the figure below. The launch position is the origin of the coordinate system, positive directions as specified.



3. Predict the final landing distance in the x direction if the launcher is adjusted to an angle of 40°.

PROCEDURE

PART 1: Horizontal Launch ($\theta_0 = 0°$)

1. Ensure that the back edge of the spring gun is aligned with the back edge of the table.
2. Measure the initial height of the projectile above the ground.
3. As a group, choose the origin of your coordinate system. You will need to decide whether the origin is at the launch position or at the ground, and which direction is positive and which is negative. Record your decision below:
4. Read this step and the next step before proceeding. When the spring gun is fired for the first time, you will need to note where the ball lands. This is the location for your target. The target is a sheet of white paper taped to the floor with a sheet of carbon paper placed on top. Do not tape the carbon paper.
5. When the flight path is secure, cock the spring gun to the first (short range) detent, then fire to determine the target location. Place the target.
6. Fire the spring gun four times and measure the distance the ball travels before landing for each trial and record in the table below.
7. Calculate the initial firing velocity for each measurement and record in the table below. **Each group member perform one calculation for initial firing velocity.** You will need to determine time of flight.
8. Find the mean (average value) and standard deviation of your range measurements. Show your work. (Refer to the appendix for average and standard deviation calculations if necessary)
9. Find the mean (average value) and standard deviation of your initial velocity measurements. Show your work.

Part 2: Non-Horizontal Launch ($\theta_0 > 0°$)

10. Ask your TA to come adjust the launcher to a nonzero angle. Record the new firing angle below.
11. Knowing the firing velocity and launch angle, predict the landing position of the projectile, show work on separate page.
12. Repeat steps 4 through 6.
13. Compare the predicted landing position to the measured landing position

QUESTIONS

1. If we increased the angle of the projectile's initial velocity by a small amount from the angle you used in this lab:

   a) Would the range of the projectile increase or decrease? Explain.

   b) Would the time interval between launch and landing increase or decrease? Explain.

2. Does the range continue changing how you described in question 1(a) if we increase the angle of the projectile's initial velocity by a lot? Explain your answer by drawing trajectories for a projectile launched at 0°, 10°, 45°, 80°, and 90° above horizontal.

3. A projectile is launched from a nonzero height H above the ground with an initial velocity of v_0 at an angle of above the horizontal. (Write your answers in terms of H, v_0, θ, and g.)

   a) At what point in the trajectory is the projectile's speed minimum? What will be the projectile's speed at that point?

   b) At what point in the trajectory is the projectile's speed maximum? What will be the projectile's speed at that point?