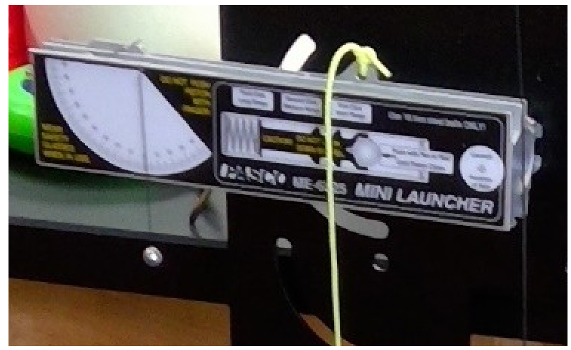
Survey of Physics
Lab 5: Projectile Motion

Name:______________________

partner name(s):______________________

Theory:



In this lab we will predict and measure the range of a projectile fired from a ballistic gun. In Part 1, you will use experimental data to calculate the initial velocity of the ball when the ballistic gun is horizontal ($\theta = 0°$). You will then change the angle of the gun and, in Part 2, use the initial velocity to determine the theoretical range of the ball when it is fired at a nonzero angle, θ. In Part 3 we perform the experiment and measure the range.

Purpose:

Use motion equations to determine the initial velocity of a projectile, and predict the range of the projectile for a launch angle above horizontal.

Equipment: Ballistic gun, plumb bob, c-clamps, support rods, right angle clamps, carbon paper, level, safety glasses.

Procedure:

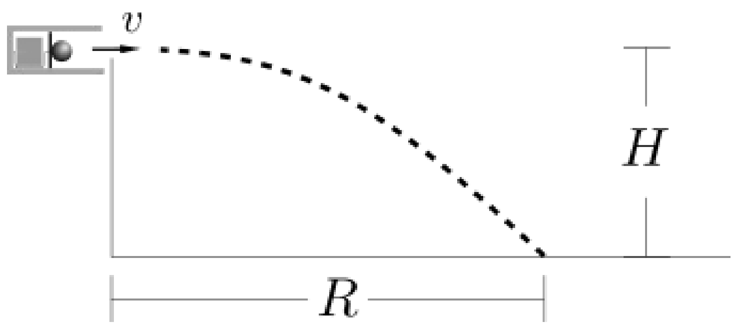
<u>Part 1 – Find the muzzle velocity</u>

1. Make sure the ballistic gun is level and the protractor reads 0°.

2. Hang a plumb line so that the string of the plumb line is just in contact with the end of the shaft of the gun. The plumb bob should be very close to the floor but not touching the floor. Put masking tape onto the floor directly underneath the plumb. Mark the location of the plumb bob. This is the initial x position of the ball, $x_i = 0$.

3. Choose how many "clicks" you push the ball into the gun (1, 2, or 3 clicks). For the entire lab, you must always push the ball into the gun with the same amount of clicks. Test fire the ballistic gun to determine approximately where the ball hits the floor. At this location, tape a sheet of paper on the floor, place carbon paper on top, and another sheet of paper on top of the carbon paper.

4. Shoot the gun four times. Record the horizontal displacement (the measurement from the mark below the gun to the mark on the carbon paper) in the table below. Calculate the average range.



	Range, R
Trial 1	
Trial 2	
Trial 3	
Trial 4	
Average	

5. Measure the height at which the ball exits the gun. This will be the distance from the plumb bob mark on the floor to the bottom of the ball when it exits the gun. This variable will be called H.

H = ______________________m

6. With this information, we will find v, the "muzzle velocity" of the projectile. This is the speed at which the ball leaves the gun.

   First consider the vertical motion of the projectile: $\Delta y = \frac{1}{2}at^2$

   where
   - Δy is the vertical distance it drops (should be negative)
   - a is the acceleration due to gravity (–9.8 m/s²)
   - t is the time-of-flight

   Use this information to find the time-of-flight for the ball.

   t = ______________________________

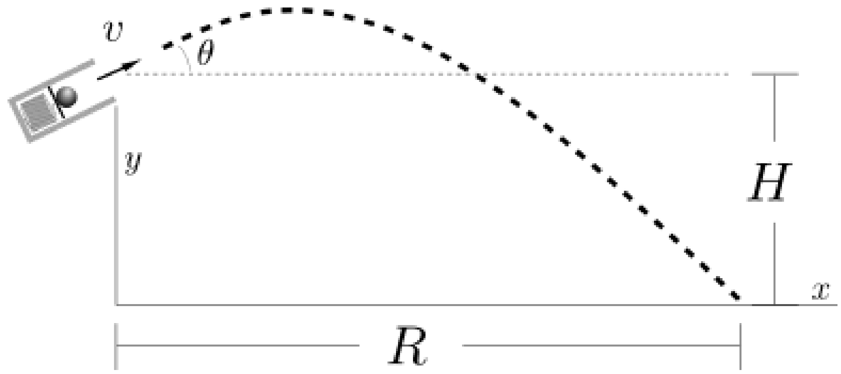
7. Next consider the horizontal motion of the projectile: $x = vt$, where x is the horizontal distance it moves, v is the muzzle velocity, and t is the same time-of-flight as above.

   Use this information to find the muzzle velocity, v.

   $v =$ ______________________________

Part 2 – Predict the range

Knowing the muzzle velocity, we will predict where the ball will land when fired at some angle.



1. Choose some angle for launch, and record it.

   θ = ____________________

2. Adjust the gun to the new angle, then measure the new height from the floor to the exit point of the ball.

   H = ________________________________

3. The muzzle velocity is the same as in Part 1, but now the ball leaves the gun at the new height. We will use this information to find the new range of the projectile – where the ball will hit the floor.

   First find the initial horizontal velocity and the initial vertical velocity of the ball.

   $v_x = v \cos\theta =$ ________________________________

   $v_y = v \sin\theta =$ ________________________________

4. Next we need to find the time it takes for the ball to reach the top of its trajectory (where $v_y = 0$). This time will be called t_1.

   Compute this time using the vertical velocity equation $\Delta v_y = at_1$, where
   - Δv_y is "final minus initial vertical velocity". That is $\Delta v_y = 0 - v_y$ with the initial vertical velocity you found above
   - a is the acceleration due to gravity (–9.8 m/s²)
   - t_1 is the time-to-peak

   $t_1 =$ ________________________________

5. Next, find the greatest vertical distance above the launch point that the ball reaches. This is done with the vertical motion of the projectile:

   $$Y = v_y t_1 + \frac{1}{2} a t_1^2$$

   where
   - Y is the vertical distance above the launch point (should be positive)
   - v_y is the initial vertical velocity (from above)
   - a is the acceleration due to gravity (–9.8 m/s²)
   - t_1 is the time-to-peak

   $Y =$ ________________________________

6. Next we find peak-to-land time for the projectile, t_2. This is the time it takes to move from its greatest height (where $v_y = 0$) to the ground. This is just like the case when we fired the projectile horizontally but with initial height of $H + Y$ (with the new value of H). That is:

   $$-(H + Y) = \frac{1}{2} a t_2^2$$

   $t_2 =$ ________________________________

7. Finally, use the total flight time ($t = t_1 + t_2$) to find the range. Use the x-motion equation:

   $$x = v_x t$$

   Predicted Range: $R =$ ____________________________

Part 3 – Measure the range

1. Shoot the gun at the new angle. Record the horizontal displacement (the measurement from the mark below the gun to the mark on the carbon paper).

   Measured Range: $R =$ ______________________________

2. Find the percent difference between the measured and predicted range.

   $\frac{R_{meas} - R_{pred}}{R_{pred}} \times 100\%$ = __________________________________