LAB 4: Projectile Motion*

Equipment List:
ramp and support stand
ball (the projectile)
meter stick
carbon paper
masking tape
plumb bob
bubble level
photogate
vernier calipers

Purpose: To study projectile motion. You will calculate the initial horizontal velocity of a projectile by using the kinematic equations of motion and graphical methods. You will then compare the value of the initial horizontal velocity to the expected value by measuring its speed directly with a device called a photogate.

Theory Exercise: Use the kinematic equations derive an expression for the range R of the projectile (that is, the horizontal distance it travels from the launch point to where it strikes the lab bench) in terms of v_0 (initial horizontal velocity), g (acceleration of gravity), and h (height of launch of ball). Check the equation with your teacher before continuing.

Theory: The equation you find should show that R is directly proportional to $\sqrt{h}$. The constant of proportionality (call it k) should involve v_0 and h. If you plot $R = k\sqrt{h}$ with R on the vertical axis and h on the horizontal axis you will obtain a linear curve where the slope of the line is k.

You will collect a set of data by varying h and measuring R, then graph it using Microsoft Excel and then find the equation of the best-fit line. From the slope of this line you will then solve for the initial horizontal velocity v_0. You will compare this to a measurement of v_0 by measuring the diameter d of the ball and dividing by the time t that it takes for the ball to move across the photogate, $v_o = \frac{d}{t}$.

Procedure:

Part 1: Measuring the initial horizontal velocity v_0 by using graphical methods

1. Set the apparatus, securing the ramp the the vertical support on the lab bench. Make

*Based on the lab by Prof. Luna.

sure that the bottom end of the ramp is horizontal using the bubble level to ensure that ball only has a horizontal component of velocity.

2. Hang the plum bob down from the center of the end of the ramp and put some masking tape down on the lab bench. Mark the exact point on the tape where the plum bob hangs. This is the point vertically below the end of the ramp.

3. Measure the height h from this point to the bottom edge of the ramp.

4. Perform a sample run to locate the position of the carbon paper to measure the range R. Release the ball from rest at the top of the ramp and see where the ball strikes the table. Place the carbon paper starting just a bit closer to the ramp than where the ball struck the table, extending away from the ramp end and secure paper with tape.

5. Perform 3 trials (for 3 values of the range R) for each value of h for a total of 5 different heights $h = 30, 45, 60, 75,$ and 90 cm. You may wish to take an extra reading at any height where you see a large variation in R. Each time, make sure you release the ball from the very top of the ramp. Calculate the average value of the range R_{avg} for each height.

6. Using Excel (or other spreadsheet software) make a graph of R_{avg} vs. $\sqrt{h}$ and obtain the equation of the best-fit line.

7. Print the graph and tape it into your lab book.

8. Calculate v_0 from the slope.

Part 2: Measuring the initial horizontal velocity v_0 by using a photogate timer

1. Measure the diameter d of the ball with the vernier calipers.

2. Place the photogate at the end of the ramp so that the infrared beam passes through center of ball as it leaves the edge of the ramp. The timer portion of the gate will sit on the lab bench.

3. Set the photogate on GATE mode and the 0.1 ms setting, then hit the RESET button to zero the time. GATE mode measures the time for which the infrared photogate beam is blocked, allowing you to measure the time it takes the ball's diameter to go through the photogate.

4. Release the ball from rest at the top of the ramp then record the time t on the photogate.

5. Calculate the velocity of the ball by using $v = d/t$.

6. Repeat steps 4 and 5 three times to get three measurements of the initial velocity.

7. Calculate the average velocity and take this to be the "expected value" v_{exp}.

8. Calculate the percentage error between v_0 and v_{exp}.