PROJECTILE MOTION

Objective

To 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.

Equipment

1. sliding ramp, ball, and stand
2. meter stick
3. detecting paper (carbon paper)
4. tape
5. plumb bob
6. photogate

Diagram 1 (setup of apparatus)

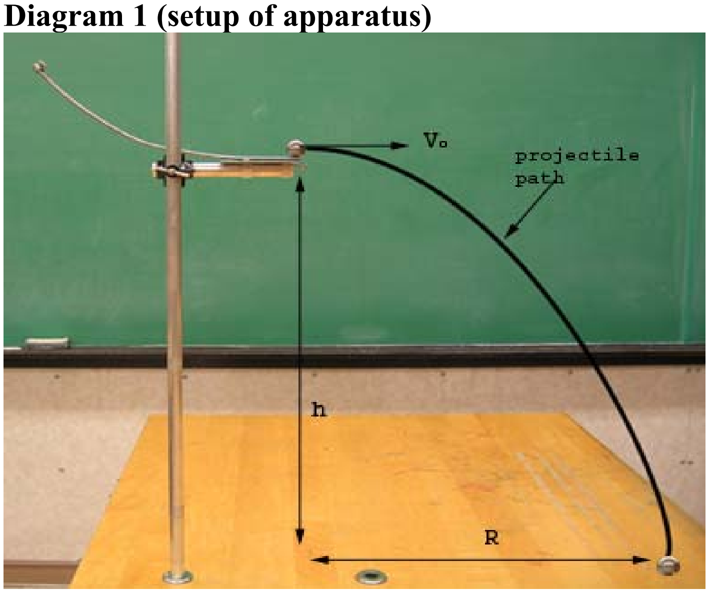
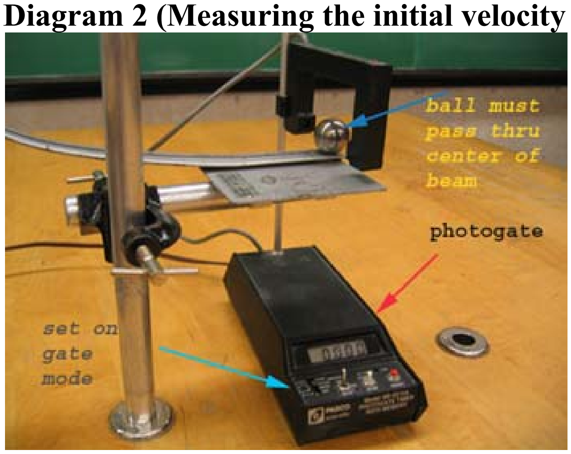
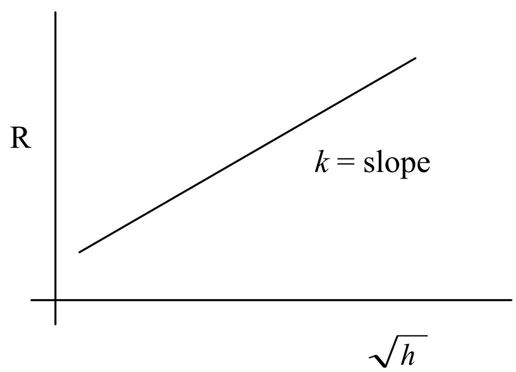


Diagram 2 (Measuring the initial velocity V_o with the photogate)



Theory

1. Using the kinematic equations derive an expression for the range R of the projectile in terms of V_o (initial horizontal velocity), g (acceleration of gravity), and h (height of launch of ball). Have instructor check equation before continuing.
2. The derived equation for the range R should be directly proportional to the square root of the height $\sqrt{h}$. That is $R = k\sqrt{h}$ where k is the proportionality constant which you can deduce from the derived equation for R. The constant k involves the initial velocity V_o and g.
3. If you graph the equation $R = k\sqrt{h}$ with R on the **vertical axis** and $\sqrt{h}$ on the **horizontal axis** you will obtain a linear curve where the slope of the curve equals k.



4. Using Microsoft EXCEL you will graph a set of data (R, $\sqrt{h}$) and then obtain the equation of the best curve-fit. From the slope of this equation you will then solve for the initial horizontal velocity V_o.

5. The initial horizontal velocity can also be determined 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. That is $V_o = d/t$.

Procedure

Part I (Measuring the initial horizontal velocity V_o by using graphical methods)

1. Set the apparatus as shown on Figure 1 above.
2. Make sure that the ramp is secure and that the bottom end of the ramp is horizontal to ensure that ball only has a horizontal component of velocity.
3. Mark the point right below the bottom edge of the ramp by using a plumb bob.
4. Measure the height h from this point to the bottom edge of the ramp.
5. You will now 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. Center the carbon paper where the ball struck the table and secure paper with tape.

6. You will now perform 3 trials (for 3 values of the range *R*) for each value of *h* for a total of 5 different heights *h*. Make a data table like the following:

h (cm)	R_1	R_2	R_3	R_{ave}	$\sqrt{h}$
30					
45					
60					
75					
90					

Note: make sure that you release the ball from the same initial point every time

7. Using MS EXCEL make a graph of R_{ave} vs. $\sqrt{h}$ and obtain the equation of the best curve fit.
8. Calculate V_o from the slope.

Part II (Measuring the initial horizontal velocity V_o by using a photogate timer)

1. Setup the apparatus as shown on Figure 2.
2. Measure the diameter *d* of the ball with the vernier calipers.
3. Adjust the photogate so that the infrared beam passes through center of ball as it leaves the edge of the ramp.
4. Set the photogate on GATE mode and reset to zero. GATE mode allows you to measure the time it takes the ball's diameter to go through the photogate.
5. Release the ball from rest at the top of the ramp then record the time *t* on the photogate.
6. Calculate the velocity of the ball by using V = d/t.
7. Repeat for a total of 3 runs for 3 velocities.
8. Calculate the average velocity and take this to be the expected value $V_{exp.}$
9. Compare the V_o to the expected value $V_{exp.}$