PHYSICS LAB EXPERIMENT- 5: PROJECTILE MOTION

OBJECTIVE: To determine the horizontal launch velocity of a projectile by measuring its horizontal range and the vertical distance it falls, and practice a graphical analysis of physical results.

APPARATUS: Wooden blocks, marble tracks, ball bearing, plumb line, meter stick.

THEORY:

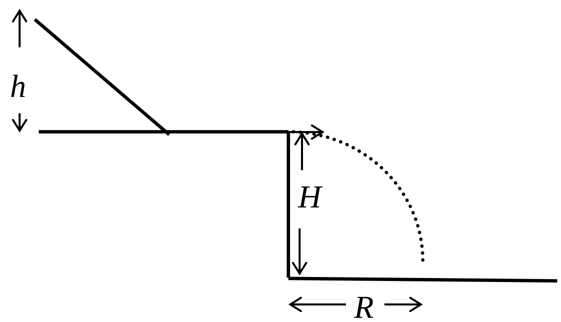

Figure 1: diagram of the experimental setup of the projectile, with some of the relevant variables labeled. *R* is the horizontal distance the projectile travels before hitting the ground, *H* is the height at which the projectile is launched, and *h* is the height of the projectile above the point where it is launched.

For an object starting from an initial displacement of $\vec{d}_0$ with an initial velocity $\vec{v}_0$ and undergoing a constant acceleration $\vec{a}$, the object's displacement $\vec{d}$ is given as a function of time *t* by the equation: $\vec{d}(t) = \vec{d}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$. If the object is a projectile, then the only source of acceleration for the object is from gravity, which is acts solely in the vertical direction, and with a magnitude *g*. Thus, the horizontal (*x*) and vertical (*y*) components of the objects displacement can be written as:

$$d_x(t) = d_{0,x} + v_{0,x}t \qquad \text{and} \qquad d_y(t) = d_{0,y} + v_{0,y}t + \frac{1}{2}gt^2$$

For a projectile launched with an initial velocity $\vec{v}_0$ at an angle of θ measured counterclockwise from the horizontal (*x*) axis, the horizontal component of the velocity is given by $v_{0,x} = v_0\cos(\theta)$ (where v_0 represents the magnitude of the velocity vector $\vec{v}_0$) and the vertical (*y*) component of the velocity is given by $v_{0,y} = v_0\sin(\theta)$. Therefore, if a projectile is launched horizontally so that $\theta = 0$, the displacement equations reduce to:

$$d_x(t) = d_{0,x} + v_0 t \qquad \text{and} \qquad d_y(t) = d_{0,y} + \frac{1}{2}gt^2$$

Please take a moment to make sure you understand each term for the equations above, work through their derivation to verify that they are correct.

For a horizontal projectile that travels a distance R in a time t while falling from a height H, the equations above can be written:

$$R = v_0 t \qquad \text{and} \qquad 0 = H + \frac{1}{2} g t^2$$

For this lab, we will take measurements of H and R and use these two equations to calculate the initial velocity v_0 of a projectile by first solving the vertical displacement equation for t, and substituting that t in the horizontal equation to solve for v_0.

PROCEDURE:

1. Place the marble track flat on the tabletop with its end at the edge of the tabletop. Lift the back end of the track by inserting a wooden block between the track and the base of the track so that the back end of the track is inclined. Since the end of the track where the marble will be launched remains nearly horizontal, it is a reasonable assumption that the launch angle θ is zero.
2. Practice launching the ball bearing down the track from a few different heights (h) to find a position that gives consistent results for the range of the marble, and then mark a position on the ramp corresponding to that height. You will be releasing the ball bearing from that same point for every trial for a given height h.
3. Where the projectile was hitting the floor for your height, place carbon paper on top of a sheet of plain paper and stick it to the floor.
5. Use the plumb line (or similar method) to find a point on the floor directly below the end of the track where the ball becomes a projectile.
6. Measure the vertical height H the ball falls below the horizontal end of the track.
7. Launch the projectile, and measure its range R four times. Record your data for each launch into the first table below, or directly into a spreadsheet program such as Excel.
8. Repeat this procedure two more times to collect data for two additional values of h.
9. Use the formula presented in the theory section to calculate a value of the average launch velocity v_0 for each height h.

OBSERVATIONS AND ADDITIONAL ANALYSIS:

h_1 (m)	H (m)	R (m)	t (s)	v_0 (m/s)
			Avg. $v_{0,1}$ (m/s)	

h_2 (m)	H (m)	R (m)	t (s)	v_0 (m/s)
			Avg. $v_{0,2}$ (m/s)	

h_3 (m)	H (m)	R (m)	t (s)	v_0 (m/s)
			Avg. $v_{0,3}$ (m/s)	

A conservation of energy principle that you will learn later in this course states that the gravitational potential energy lost by a projectile as it falls is equal to the kinetic energy gained by the projectile as its speed increases. Mathematically, for a projectile initially at rest, the square of the magnitude of its velocity after falling a height h is given by $v^2 = 2gh$. Make a computer-generated plot (i.e. in Excel) of the average values of v_0^2 vs. h for your three different values for h, and calculate a linear fit to the slope of that plot. The slope of this line would be equal to $2g$ if all of the gravitational potential energy lost by the ball bearing as it rolled downhill was converted to translational kinetic energy associated with the speed of the projectile.

Calculate a value of *g* from the slope of your graph, and find the percentage error of this value from the standard value of 9.81 m/s^2. Please also include this graph with the linear fit and all of your data in your lab report.

Value of g calculated from the slope:________________

Percent Error from Standard Value:_________________

POST LAB QUESTIONS:

1. For the equations $R = v_0 t$ and $0 = H + \frac{1}{2}gt^2$, presented in the theory section, where is the location in space where the projectile has zero displacement? Sketch a diagram similar to Figure 1 and clearly mark the position of $\vec{d}_0$.

2. If the projectile is launched horizontally off the table with a higher initial velocity, what will be the effect on the projectile's time of flight?

3. With a projectile such as an Olympic ski jumper where the time of flight, range, and initial velocity are much larger than in this lab, what factors might cause the projectile to deviate from our theory?

4. How does the *acceleration* of the projectile change as the projectile falls from height *H* to the ground?

5. The value of *g* calculated from the slope of your v_0^2 vs. *h* graph assumes all of the gravitational potential energy is converted into the kinetic energy associated with the speed of the projectile. Where else might some of the energy be going?

6. A punter on a football team tries to kick a football so that it has maximum range. If the ball is kicked with a velocity of 30 m/s, what is its time of flight?