NILE UNIVERSITY OF NIGERIA

Faculty of Natural and Applied Sciences

Department of Computer Science

Physics Unit

PHY 107: Experimental Physics I (Mechanics)

Experiment 3: PROJECTILE MOTION

Student Name:

Student ID:

Department:

Date of the Experiment:

Group:

Purpose:

1. To determine the range (horizontal displacement) as a function of the projectile angle.
2. To determine the maximum height of projection as a function of the angle of inclination.

Apparatus:

- Ballistic unit
- Recording paper
- A steel ball (diameter 19mm)
- A two-tier platform support
- A meter scale
- Speed measuring attachment
- Barrel base

Theoretical background:

Projectile is defined as, any object thrown with some initial velocity, which is then allowed to move under the action of gravity alone, without being propelled by any engine or fuel. The path followed by a projectile is called its trajectory. A projectile move at a constant speed in the horizontal direction while experiencing a constant acceleration of 9.8 m/s^2 downwards in the vertical direction. To be consistent, we define the up or upwards direction to be the positive direction. Therefore, the acceleration of gravity is, -9.8 m/s^2.

Horizontal motion of projectile

The speed in the horizontal direction is 'v_x' and this speed doesn't change. The equation which predicts the position at any time in the horizontal direction is simply,

$$x = v_x t$$

Vertical motion of projectile

Because gravity has a downward pull, the vertical velocity changes constantly. The equation that predicts the vertical velocity at any time 'v_y' is

$$v_y = v_0 + at$$

The 'V_{oy}' is simply the original velocity in the vertical or y-direction. To calculate the position in the y-direction, the full distance formula must be used. 'Y_o', represents the original position in the y-direction.

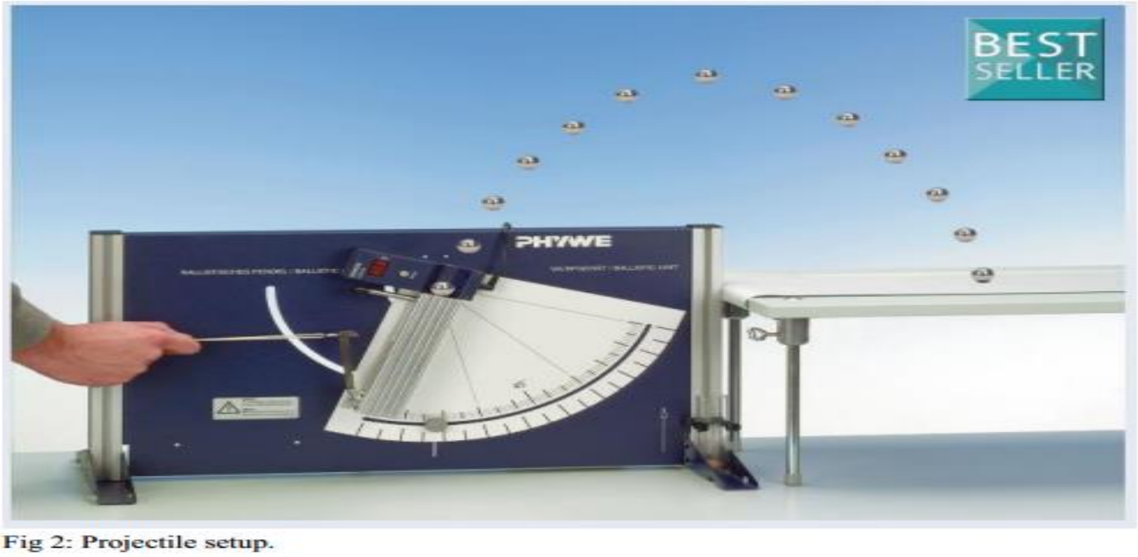

Fig 2: Projectile setup.

$$y_t = y_0 + v_{0y}t + \frac{1}{2}at^2$$

Acceleration for projectiles near the Earth's surface is -9.8 m/s^2. We don't re-write the equation with a negative sign. Rather, we use the negative acceleration value when solving problems. When a projectile is launched horizontally a ball rolls off a table, a car runs off the edge of a cliff, etc. Here the original y-velocity is zero. For example, if the projectile drops 10 meters, you can set the Y_o = 0 and Y_f = -10 m. Or, you can set Y_o = 10 m and Y_f = 0. Either works out the same.

Velocity

To determine the total velocity of a projectile, we combine the horizontal velocity ('v_x') and the vertical velocity ('v_y') using the Pythagorean Theorem,

At maximum height

At the top of its path, the projectile no longer is going up and hasn't started down, yet. Its vertical velocity is zero ($v_y = 0$). The only velocity it has is just its horizontal velocity, v_x. Remember, the horizontal speed stays constant throughout the projectile path. A common misconception occurs at the top of a projectile's arc. When asked what the acceleration of the projectile is at this point, many people answer "zero". If it were zero, the projectile would simply keep going in a straight line. However, gravity is still acting, pulling it down, and accelerating it towards the earth. Thus, the acceleration at the top is still -9.8 m/s2, just as it's been all along.

Range of projectile motion

For a projectile that is launched at an angle and returns to the same height, we can determine the range or distance it goes horizontally using a fairly simple equation. However, we will focus on the results of studying that equation rather than solving it here.

- When the projectile is launched at a steep angle, it spends more time in the air than it does when launched at a shallow angle.
- When the projectile is launched at a shallow angle, it goes faster in the horizontal direction than if it is launched at a steep angle. The ideal combination of time in the air and horizontal speed occurs at 45^o. Thus, the maximum range or distance occurs when the projectile is launched at this angle. This applies to long jumpers and soccer balls that are two good examples. However, if the projectile starts at a point higher than where it lands, the ideal distance doesn't occur at a 45^o angle. Ask your instructor for an explanation. If you calculate the range for a projectile launched at 30^o, you will find it's the same as a projectile launched at 60^o. The same goes for 40^o and 50^o. The graph of range vs angle is symmetrical around the 45^o maximum. The equations used to find out various parameters are shown below;

$$Time\ of\ Flight = \frac{2U\sin\theta}{g}$$

$$Maximum\ Height = \frac{U^2\sin^2\theta}{2g}$$

$$Horizontal\ Range = \frac{U^2\sin 2\theta}{g}$$

If the body is projecting from a height “h” above the ground level, the additional height ‘h’ is to be considered and the equations modified accordingly.

Setup and Procedure:

1. The ballistic unit is set up as shown in the Figure 2. The height of the ballistic unit platform is adjusted properly.
2. The projection angle is set at 30° by turning the adjusting screw.
3. The ball is set in ballistic units; the spring is pulled inside the unit using Setting 1and the ball is let fire upwards until it reaches the recording carbon paper (point of impact).
4. The point of impact is marked.
5. The range (maximum displacement) is measured from the starting point until the point of impact and record the readings.
6. The initial velocity of the ball is recorded as shown on the speed measuring attachment. The maximum height (vertical distance) of the ball projection and total time taken are also calculated using the formula for maximum height and total time of flight.
7. The step 5 is repeated for three times and the average value for each quantity is calculated and recorded.
8. The step 2 – 6 is repeated for angle 45°, 55° and 65°
9. The data obtain from the experiment is tabulated.
10. Plot a graph of
    a) Time of Flight against Angle of Inclination
    b) Range against Angle of Inclination

Data Sheet:

Angle (^{o})	Velocity (m/s) First Trial	Velocity (m/s) Second Trial	Velocity (m/s) Average	Range (m) First Trial	Range (m) Second Trial	Range (m) Average	Maximum Height (m)	Time of Flight (s)
30								
40								
50								
60								
70								

Instructor Signature and Date____

Title: **Scale:**

Title: **Scale:**

Precautions:

State the precautions taken to ensure accurate results**.**

Discussion of Result and Conclusion:

Calculations:

1. Suppose a large rock is ejected from a volcano with a speed of 25m/s and at an angle of 35° above the horizontal. If the rock strikes the side of the volcano at an altitude 20m lower than the starting point.

(a) Calculate the time it takes the rock to reach the starting point.

(b) What are the magnitude and direction of the rock's velocity at impact?

2. A projectile is fired with an initial speed of 113 m/s at an angle of 60.0 degrees above the horizontal from the top of a cliff 49.0 m high.

Determine the (a) time to reach maximum height, (b) maximum height above the base of the cliff reached by the projectile, (c) the total time it is in the air, and

(d) horizontal range of the projectile.