Physics 2 – Classical Mechanics
Activity 3: **Conservation of Linear Momentum**

Objective:
- To study the principle of conservation of momentum in one and two dimensions.

Equipment needed:
→ projectile ramp
→ two marbles
→ sheets of carbon paper and white paper
→ meter stick
→ plumb line

Theory:
The linear momentum of a body is defined as the product of its mass and its velocity

$p = mv$

When two masses collide, the total momentum of the system (in this case, two marbles), is conserved. In symbols

$$m_{1i}v_{1i} + m_{2i}v_{2i} = m_1v_{1f} + m_2v_{2f} \qquad \text{(eq 1)}$$

where the subscript [*i*] refers to the values before collision and the subscript [*f*] refer to the values after collision.

If m_2 is initially at rest such that $v_2 = 0$, then

$$m_{1i}v_{1i} = m_1v_{1f} + m_2v_{2f} \qquad \text{(eq 2)}$$

If we neglect air resistance, the horizontal components of their velocities will remain unchanged. The horizontal distance may be expressed as

$x = v_xt$

where x = horizontal distance covered
t = time of fall
v_x = horizontal component of the velocity

Upon substitution, equation (2) becomes

$$m_1v_1 / t_{1i} = (m_1v_{1f} / t_{1f}) + (m_2v_{2f} / t_{2f}) \qquad \text{(eq 3)}$$

Objects projected from the same height with different horizontal velocities take the same time to fall to the floor, then $t_{1i} = t_{1f} = t_{2f}$. Furthermore, if $m_1 = m_2$, equation (3) becomes

$$x_1 = x_{1f} + x_{2f} \qquad \text{(eq 4)}$$

Using equation (4), one can verify experimentally the validity of the principle of conservation of momentum by simply determining displacement vectors. Their range is a representation of their momenta.

Procedure:
A. Collision in One Dimension

① Devise a procedure to determine the range of a marble launched from the projectile launcher. This displacement vector represents the initial momentum of the marble. Indicate the points from which measurements are to be made.

② Arrange the projectile launcher such that a collision in one dimension can be achieved. That is, after collision, the two marbles will be projected along the same axis.

③ Devise a procedure to determine the range of two marbles launched from the projectile launcher after a collision in one dimension, where one of the marbles is initially at rest. The displacement vectors represent the final momenta of the marbles.

④ Provide for several trials to be performed.

B. Collision in Two Dimensions

① Perform the same procedure as in part (A), but align the marbles so that the collision will be in two dimensions. That is, after collision, the two marbles will be projected along different axes.

② Provide for several trials to be performed.

Data Analysis:
Separately for parts A and B:

① Draw vectors representing the momentum of the balls in each case.

② Add the vectors graphically and determine their magnitude. Generate the appropriate tables. Provide for calculations of error.

③ Compare the total final momentum of the balls after collision with the initial momentum of the marble launched before (without) collision. Use the appropriate error calculation in your comparison.

④ Answer the following:

a. Explain why the horizontal components of the velocities of the balls used in the experiment may be considered constant.

b. Explain using mathematical equations why objects projected from the same height with different horizontal velocities take the same time to fall to the floor (as stated in the experiment).

c. If we define *surge* as the product of mass and speed (*not* velocity), will the principle of the "conservation of *surge*" be valid in this experiment?

d. How can the experiment be improved (to get less error) in the way the displacement vectors (x_1, x_{1f}, x_{2f}) are measured?

Lab Report:
Write a lab report for this activity. Include the sections shown below. Use the following format:
- 12 pt Helvetica/Arial, single-spaced
- 8.5" x 11" bond paper, 1–inch margins all around

Group members Date Performed

Year and Section

Activity 3: **Conservation of Linear Momentum**

Objective

Equipment needed

Setup (with descriptions and diagrams with labels; you may include photos, but you must still include diagrams)

Procedure

Data and Results (with tables and computations)

Analysis and Conclusion (discussion; do not just answer the questions above)