Experiment 7
Conservation of Momentum / Projectile Motion

This experiment will apply the conservation of momentum principle to totally inelastic collisions. A collision is totally inelastic if the colliding objects stick together after the collisions.

Theory

Contrary to the opinion of most students, physics is always attempting to simplify our view of nature. Consider the following situation: two cars slide toward each other across a frozen lake. The ensuing collision would be an extremely involved one with a great deal of irreversible bending of the cars taking place. It would not seem likely that a simple mathematical statement could be made about such a complicated incident but, in fact, it can. The mass of one car times the velocity of the car before the collision plus the mass of the other car times its initial velocity is equal to the sum of the masses of the two cars times the final velocity of the crumpled remnants. Mathematically

\[
m_1 \dot{v}_1 + m_2 \dot{v}_2 = (m_1 + m_2)\dot{v}_f
\]

In the absence of external forces, the momentum of the system does not change no matter how complicated the collision. The initial momentum is always equal to the final momentum.

Apparatus:
The ballistic or Blackwood pendulum is a device, which can catch a projectile fired from a spring gun and then convert the kinetic energy into potential energy through the use of a pendulum. The pendulum is caught at the top of its swing by a pawl, which catches on a rack. The maximum height of the pendulum may be measured to determine the kinetic energy of the pendulum and projectile after the collision. During the collision, momentum, as was previously discussed, is conserved but kinetic energy is not. During the collision (conservation of momentum)

\[
mv = (m + M)V
\]

where
\[
m = \text{mass of the projectile} \\
v = \text{initial velocity of the projectile} \\
M = \text{mass of the pendulum} \\
V = \text{initial velocity of the pendulum and projectile}
\]
After the collision (conservation of energy)

**Total energy at the Bottom = Total energy at the Top**

\[ KE_B + PE_B = KE_T + PE_T \]

\[
\frac{1}{2}(m + M)v^2 + 0 = 0 + (m + M)gh
\]

or

\[
v = \sqrt{2gh}
\]

Where \( h \) is the vertical distance through which the center of mass was raised.

Combining the results of the two conservation equations yields

\[
v = \frac{(m + M)}{m} \sqrt{2gh}
\]

where \( h = R(1 - \cos \theta) \)

A second method may be used to determine the velocity of the projectile. The range and fall method involves firing the projectile **horizontally** from some height and measuring the vertical and horizontal distances traveled. These can be calculated using the equations for projectile motion.

**Vertical:** \( y = \frac{1}{2}gt^2 \)

**Horizontal:** \( x = vt \)

By eliminating \( t \):

\[
y = \frac{1}{2}g \left( \frac{x}{v} \right)^2
\]

Thus \( v \) can be solved as:

\[
v = x \sqrt{\frac{g}{2y}}
\]
Procedure

1. Use the ballistic pendulum to determine the velocity of the exiting projectile. Make sure to use either the medium or high settings on the pendulum, two or three clicks. Fire the projectile 3 to 5 times and take the average angle from the apparatus. Make sure your angle measurement is accurate. A small error in reading a small angle can have a large effect on cosine.

2. Use the average angle value from Part 1 to calculate the exit velocity of the projectile.

3. Remove the pendulum from the spring gun.

4. Use the range and fall method to calculate the exit velocity from the spring gun. If the two methods don’t match use the range and fall number.

5. To earn points for the lab, fire the projectile from the central instructor’s table at a target provided by the lab instructor. You will place the target wherever you wish so that the projectile hits the target area.

Points:

- 10 points - hitting the paper target on the first try
- *11 points - arcing shot at the paper or flat shot into can
- *12 points - arcing shot into can

*extra credit at lab instructor’s discretion

You will be deducted one point for each miss. Your final grade will be determined by how many shots it takes to hit the target.

Rules for Firing:

1. Do not look down the barrel of the spring gun for any reason.

2. Do not load the spring gun with your finger. Use the ramrod.

3. Be aware of your surroundings when practicing. Do not fire with someone else in the line of fire.
4. You may not practice from the central table or build a tower of books, folders, etc. that is the same height as the table.

5. Lab instructor must witness shot for points. If the lab instructor doesn’t see the shot, it doesn’t count.

6. No retroactive extra credit (if offered). You cannot shoot at the paper, hit it, and then want to shoot at the can.

7. **YOU MUST RETURN BALL TO LAB INSTRUCTOR AFTER COMPLETION OF THE LAB. FAILURE TO DO SO WILL RESULT IN A ZERO FOR THE LAB.**