

## 2-D Collision 4-62412

### Warning:

- **Not a toy; use only in a laboratory or educational setting.**
- **Choking Hazard- small parts**
- **California Proposition 65 Warning: This product can expose you to chemicals including lead and nickel, which are known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov).**



### Introduction

Sir Isaac Newton was an English physicist and mathematician who made a massive contribution to the 17th century Scientific Revolution. He developed the principles of modern physics, including the laws of motion. Newton's first law states, an object at rest remains at rest, and an object in motion remains in motion at a constant speed and in a straight line unless acted upon by an unbalanced force. His second law states, the acceleration of an object depends on the mass of the object and the amount of force applied. The third law of motion states, for every action, there is an equal and opposite reaction.

Sir Isaac Newton's laws of motion explain the relationship between an object and the forces acting upon it. Understanding this information provides us with the basics of modern physics.

The 2-D Collision apparatus is designed for students to investigate the momentum and kinetic energy in elastic and inelastic collisions. Isaac Newton's laws of motion are critical in experiments such as these; they are fundamentally based off of them.

### Principles

When a ball is projected horizontally with a velocity  $v_o$ , its position can be determined by:

1.  $x = v_o t$
2.  $y = \frac{1}{2} g t^2$

When  $x$  is the horizontal displacement or "range", and  $y$  is the height (air resistance neglected).

From equations 1 & 2 we have:

$$3. v_o = \frac{x \sqrt{g}}{\sqrt{2y}}$$

Therefore, we can calculate the horizontal velocity given the range,  $x$ , and the height,  $y$ .

In the following experiments, a ball will fall on the track and collide with a second ball on the pin. Both balls will start trajectory motions with different horizontal velocities. We can determine their values with equation 3. Since momentum  $p = mv$ , we can determine the momentum for each ball right after the collision:

$$4. p_1 = m_1v_1$$

$$5. p_2 = m_2v_1$$

Where  $v_1$  and  $v_2$  can be determined with equation 3. The total momentum before collision is:

$$6. p_f = p_1 + p_2 = m_1v_1 + m_2v_2$$

If we neglect the friction between the ball and the track, the potential energy the ball has when it is at the top of the track will turn into kinetic energy before it collides with the second ball:

$$7. mgh = \frac{1}{2}mv^2$$

Therefore, we have:

$$8. v = \sqrt{2gh}$$

Since the second ball was at rest before the collision, the total momentum before collision is equal to the momentum of the first ball:

$$9. p_i = m_1v$$

Where  $v$  can be determined with equation 8.

In a "head on" collision as the above case, momentum conserves. In other words, the final momentum equals the initial momentum ( $p_f = p_i$ ).

The kinetic energy of each ball can be determined with:

$$10. E_k = \frac{1}{2}mv^2$$

Therefore, the total kinetic energy of the balls before the collision is:

$$11. E_i = \frac{1}{2}m_1v^2$$

Where  $v$  can be determined with equation 8. The total kinetic energy of the balls after the collision is:

$$12. E_f = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

If the total kinetic energy conserves in a collision ( $E_f = E_i$ ), the collision is said to be an elastic collision. Otherwise, it's an inelastic collision.

### What's Included:

- Aluminum track with table clamp
- 2 steel balls
- 1 glass ball
- 1 hollow wooden ball
- 1 plumb bob

### What's Needed:

- Meter stick
- Carbon paper
- White paper
- Masking tape



## Experiment

1. Clamp the unit onto the edge of a solid and level table.
2. Adjust the height of the pin so that the center of the ball that rolls down the track is aligned with the center of the ball placed on the pin. (The pin needs to be readjusted when a ball with a different diameter is used).
3. Tape a piece of white paper under the pin. Run the string on the plumb bob through the pin. Lower the string until it just touches the paper. Mark down the position of the bob tip on the paper. This is called the reference point.
4. Place a steel ball on the pin. Place the other steel ball on the track against the stopper and release it.
5. Repeat step 4 a few times to locate the two positions where the balls will most likely strike the floor. Tape a piece of white paper on the floor at each position. Lay a piece of carbon paper on the top of the white paper.
6. Repeat step 4. Measure the distance between the reference point and the landing point for each ball. Those distances are the horizontal ranges mentioned in section 4.
7. Place a steel ball on the pin. Measure the vertical distance from the center of the ball to the floor ( $Y$ ) and the vertical distance from the center of the ball to the stop ( $H$ ).
8. Determine the total momenta before and after the collision with equations 9 & 6. Compare them and is the momentum conserved?
9. Determine the total kinetic energies before and after the collision with equations 11 & 12. Compare them and is the kinetic energy conserved? Is the collision elastic or inelastic?
10. Repeat the above experiment with different balls and compare the initial and final momenta for each combination.