Conservation of Momentum

In the 17th century, Newton and others had measured the momentum of colliding objects before and after collision, and had discovered a strange phenomenon: the total momentum of the colliding objects was the same after the collision as it was before. Newton expressed this relationship in the **Law of Conservation of Momentum**:

The total momentum of a closed, isolated system does not change.

The group of objects involved in a collision is called a **system**. A system:

- may contain any number of objects.
- is considered **closed** provided that no object leaves or enters the system.
- is considered **isolated** if no net external force acts on it.

Note: To picture the difference between an external force and an internal force, consider the difference between sitting inside a car pushing on the dashboard (internal) and standing outside the car pushing against the bumper (external). Only the external force can produce a change in the momentum of the car.

Collisions

The Law of Conservation of Momentum is extremely useful for analyzing the collision of objects. Expressed in a more useful form, the Law states that:

total initial momentum = total final momentum

There are three types of collisions that we will consider at this time.

Elastic Collisions

- two objects collide and then move apart separately after the collision
- e.g. billiard balls

Example 1

Glider A of mass $0.355\ kg$ moves along a frictionless air track with a velocity of $0.095\ m/s$. It collides with glider B of mass $0.710\ kg$ moving in the same direction at a speed of $0.045\ m/s$. After the collision, glider A continues in the same direction with a constant velocity of $0.035\ m/s$. What is the velocity of glider B after the collision?

Inelastic Collisions

- two objects collide and stick together
- e.g. train cars coupling

Example 2

A 10000 kg railroad car traveling at a speed of 24.0 m/s strikes an identical car at rest. If the cars lock together as a result of the collision, what is their common speed afterward?

Explosions

- two objects that are initially stuck together separate in an "explosion"

Example 3

Calculate the recoil velocity of a $4.0\ kg$ rifle that shoots a $0.050\ kg$ bullet at a speed of $280\ m/s$.

Homework

Momentum Worksheet #3

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1. Two freight cars, each with a mass of $3.0\times10^5\ kg$ collide. One was initially moving at $2.2\ m/s$; the other was at rest. They stick together. What is their final speed? ($1.1\ m/s$)

2. A $0.105\ kg$ hockey puck moving at $24\ m/s$ is caught and held by a $75\ kg$ goalie at rest. With what speed does the goalie slide on the ice? ($0.034\ m/s$)

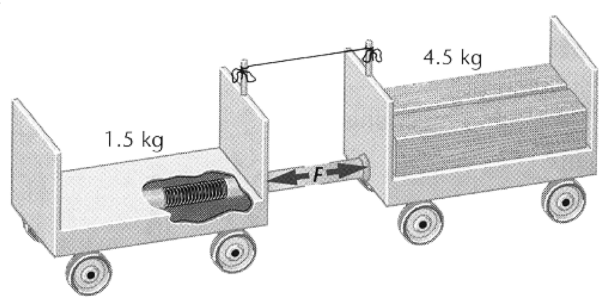
3. A $35.0\ g$ bullet strikes a $5.0\ kg$ stationary wooden block and embeds itself in the block. The block and bullet fly off together at $8.6\ m/s$. What was the original speed of the bullet? ($1.2\times10^3\ m/s$)

4. A $35.0\ g$ bullet moving at $475\ m/s$ strikes a $2.5\ kg$ wooden block that is at rest. The bullet passes through the block, leaving at $275\ m/s$. How fast is the block moving when the bullet leaves? ($2.8\ m/s$)

5. A $0.50\ kg$ ball traveling at $6.0\ m/s$ collides head-on with a $1.00\ kg$ ball moving in the opposite direction at a speed of $12.0\ m/s$. The $0.50\ kg$ ball bounces backward at $14\ m/s$ after the collision. Find the speed of the second ball after the collision. ($-2.0\ m/s$)

6. A $4.0\ kg$ model rocket is launched, shooting $50.0\ g$ of burned fuel from its exhaust at a speed of $625\ m/s$. What is the velocity of the rocket after the fuel has burned? **Hint**: Ignore the external forces of gravity and air resistance. ($7.91\ m/s$)

7. A thread holds two carts together, as shown below. After the thread is cut, a compressed spring pushes the carts apart, giving the $1.5\ kg$ cart a speed of $27\ cm/s$ to the left. What is the velocity of the $4.5\ kg$ cart? ($9.0\ cm/s\ [right]$)



8. Two campers dock a canoe. One camper has a mass of $80.0\ kg$ and moves forward at $4.0\ m/s$ as she leaves the boat to step onto the dock. With what speed and direction do the canoe and the other camper move if their combined mass is $115\ kg$? ($-2.8\ m/s$)

9. A colonial gunner sets up his $225\ kg$ cannon at the edge of the flat top of a high tower. It shoots a $4.5\ kg$ cannonball horizontally. The ball hits the ground $215\ m$ from the base of the tower. The cannon also moves on frictionless wheels, falls off the back of the tower, and lands on the ground.
   a. What is the horizontal distance of the cannon's landing measured from the base of the back of the tower? ($-4.3\ m$)
   b. Why don't you need to know the width of the tower?