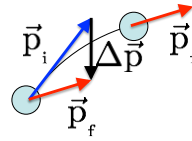


## CH02-4 Conservation of Momentum

## The Momentum Principle

The change in the momentum of a system is equal to the net external impulse on the system.



$$\Delta \vec{p} = \vec{F}_{\text{net}} \Delta t$$

$$\vec{p}_f = \vec{p}_i + \Delta \vec{p}$$

$$\vec{p}_f = \vec{p}_i + \vec{F}_{\text{net}} \Delta t$$

## Conservation of Momentum

If the net external force on a system is zero, then its momentum is constant.

$$\vec{p}_f = \vec{p}_i + \vec{F}_{\text{net}} \Delta t$$

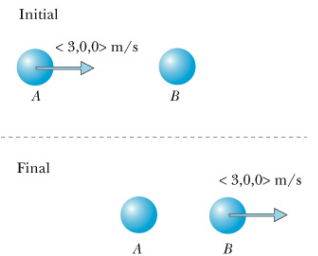
$$\vec{p}_f = \vec{p}_i + \vec{0} \Delta t$$

$$\vec{p}_f = \vec{p}_i$$

$$\Delta \vec{p} = 0$$

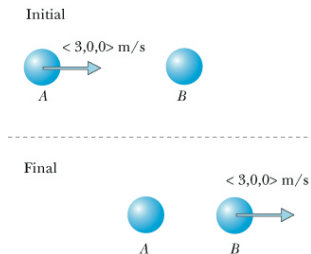
## System and Surroundings

If Ball A is the System, what is the change in momentum of the System?



## System and Surroundings

If Ball B is the System, what is the change in momentum of the System?



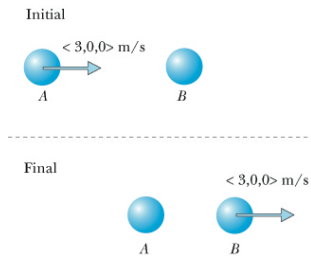
## Interactions

How does the **force on A by B** compare to the **force on B by A**?

**LAB:** Collide two carts with force sensors and measure the force on each cart.

## System and Surroundings

If Balls A and B together are the System, what is the change in momentum of the System?



## Conservation of Momentum for a Multiparticle System

The total momentum of a system is the sum of the momenta of the particles in the system.

$$\vec{p}_{\text{total}} = \vec{p}_1 + \vec{p}_2 + \dots$$

If the net external force on the system is zero, then the total momentum of the system is constant.

$$\vec{p}_{\text{total},f} = \vec{p}_{\text{total},i}$$

$$\vec{p}_{1,f} + \vec{p}_{2,f} + \dots = \vec{p}_{1,i} + \vec{p}_{2,i} + \dots$$

## Conservation of Momentum for a Multiparticle System

$$\Delta \vec{p}_{\text{sys}} = 0$$

$$\Delta \vec{p}_1 + \Delta \vec{p}_2 + \dots = 0$$

## Example: Collision

A 3 kg car is at rest on a track (Car A). A 1 kg car (Car B) moving in the +x direction with a speed of 3 m/s collides with the car at rest. After the collision, Car A moves to the right with a speed of 1.5 m/s. What is the momentum of Car B after the collision? What is the velocity of Car B after the collision?

## Example: Explosion

A fireworks shell has a mass of 2 kg and a velocity of  $\langle 10, 5, 0 \rangle$  m/s when it “explodes” into two pieces. One piece has a mass of 0.5 kg and a velocity  $\langle -4, 6, 0 \rangle$  m/s. What is the momentum of the other piece? What is the velocity of the other piece?

## Example: Binary Star Orbits

The total momentum of a binary star system is zero. Star A has a mass of  $8e30$  kg. Star B has a mass of  $4e30$  kg. At a certain instant Star B has a velocity  $\langle 0, 2.4e4, 0 \rangle$  m/s. What is the momentum and velocity of Star A?