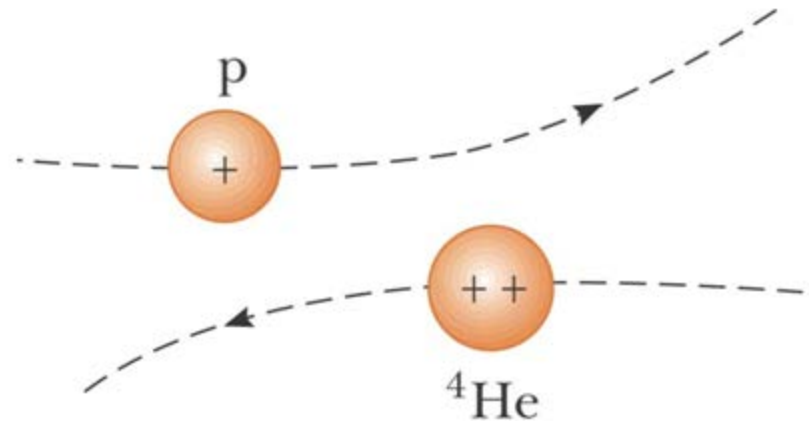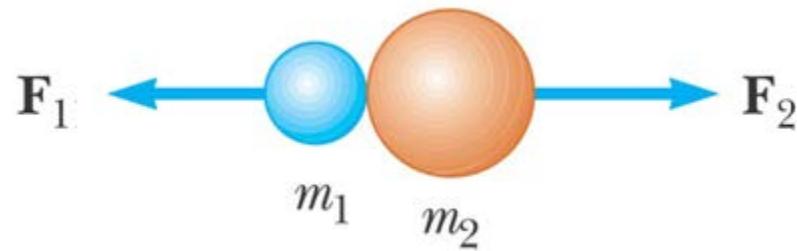# *Collisions: Action-Reaction*

World's Biggest Bomb
The Hydrogen Bomb

Newton's 2nd and 3rd Laws

$$p = mv$$

Momentum

$$F_1 = -F_2 \Rightarrow m_1 \frac{\Delta v_1}{\Delta t} = -m_2 \frac{\Delta v_2}{\Delta t}$$

$$\frac{\Delta}{\Delta t}\left(m_1 v_1 + m_2 v_2\right) = 0$$
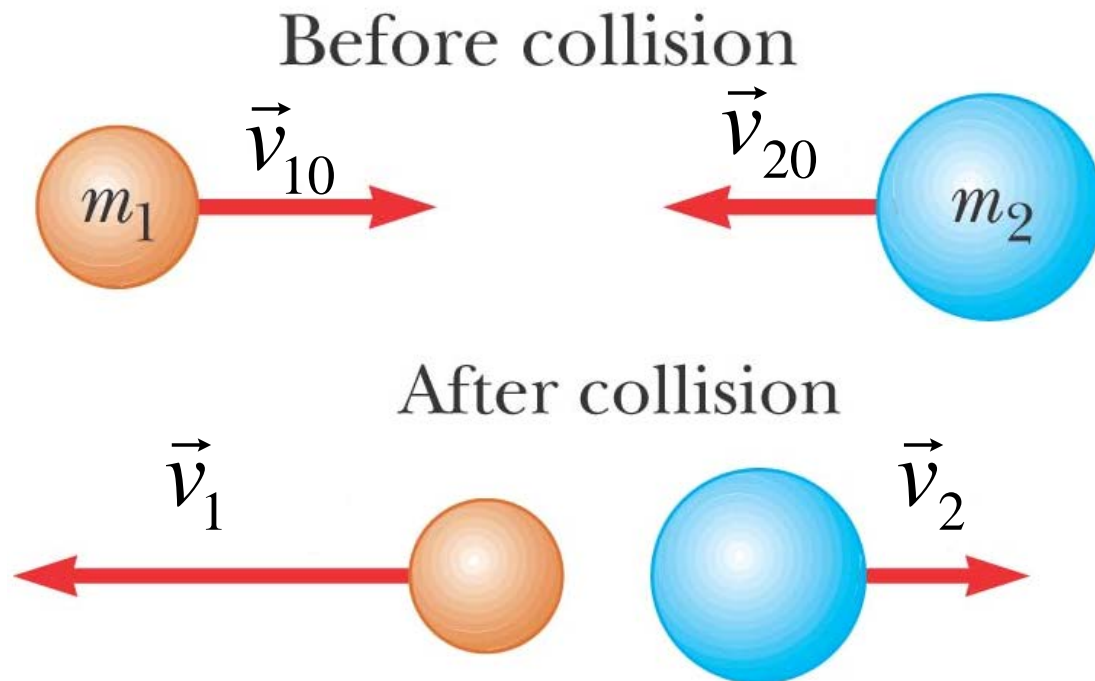
$$\Rightarrow m_1 v_1 + m_2 v_2 = \text{constant}$$

or $\quad m_1 v_{1o} + m_2 v_{2o} = m_1 v_1 + m_2 v_2$

Conservation of TOTAL Momentum

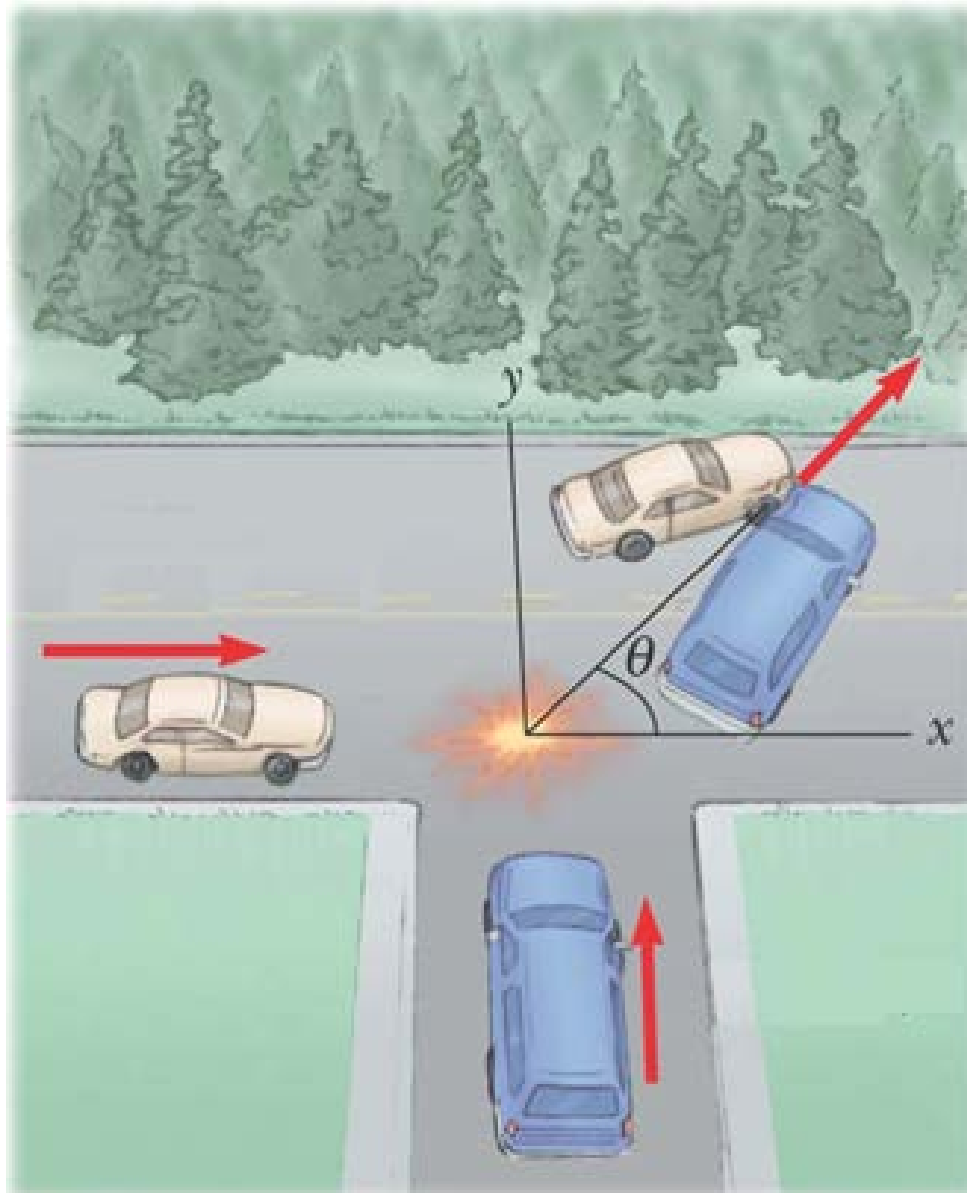$$m_1\vec{v}_{10} + m_2\vec{v}_{20} = m_1\vec{v}_1 + m_2\vec{v}_2$$

Conservation of TOTAL Momentum

$$m_1 \vec{v}_{10} + m_2 \vec{v}_{20} = m_1 \vec{v}_1 + m_2 \vec{v}_2$$

Before collision

$\vec{v}_{10}$

m_1

$\vec{v}_{20}$

m_2

After collision

$\vec{v}_1$
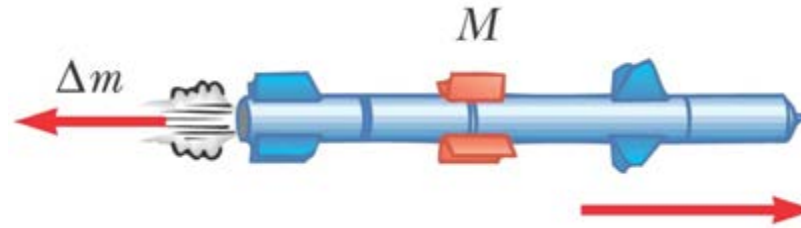
$\vec{v}_2$

Traffic Accident

Crash between a 1959 Chevy Bel Air and a 2009 Chevy Malibu

In celebration of the
Insurance Institute for Highway Safety's
50th anniversary, a 1959 Chevrolet
Bel Air was crashed into a 2009
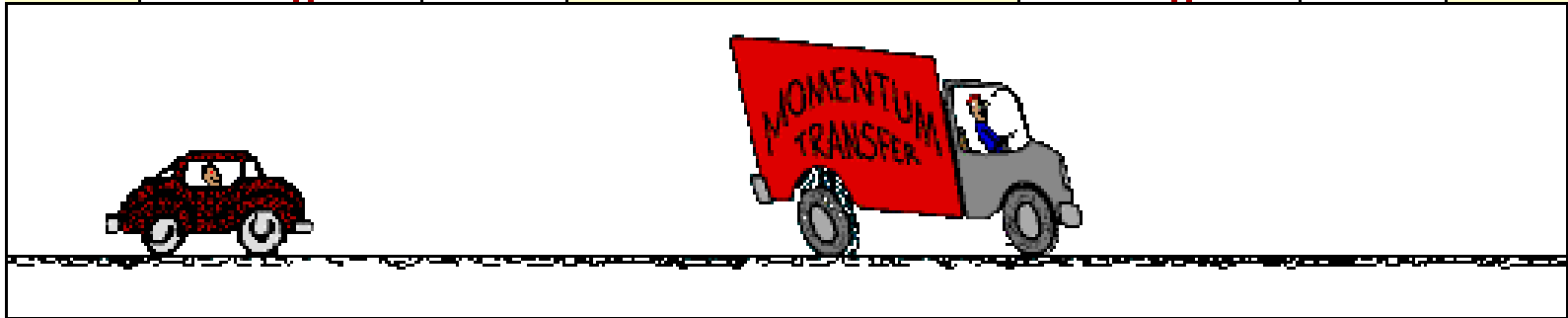Chevrolet Malibu.

Rocket Propulsion

Total Momentum is **ALWAYS** conserved

Car				Truck	
mass (kg)	1000			mass (kg)	3000
vel. (m/s)	20.0			vel. (m/s)	0.0
mom. (kg m/s)	20 000			mom. (kg m/s)	0

Truck				Car	
mass (kg)	3000			mass (kg)	1000
vel. (m/s)	20.0			vel. (m/s)	0.0
mom. (kg m/s)	60 000			mom. (kg m/s)	0

Momentum is also conserved in inelastic collisions!

Car		
mass (kg)	1000	
vel. (m/s)	20.0	
mom. (kg m/s)	20 000	

Truck		
mass (kg)	3000	
vel. (m/s)	0.0	
mom. (kg m/s)	0	

Truck		
mass (kg)	3000	
vel. (m/s)	20.0	
mom. (kg m/s)	60 000	
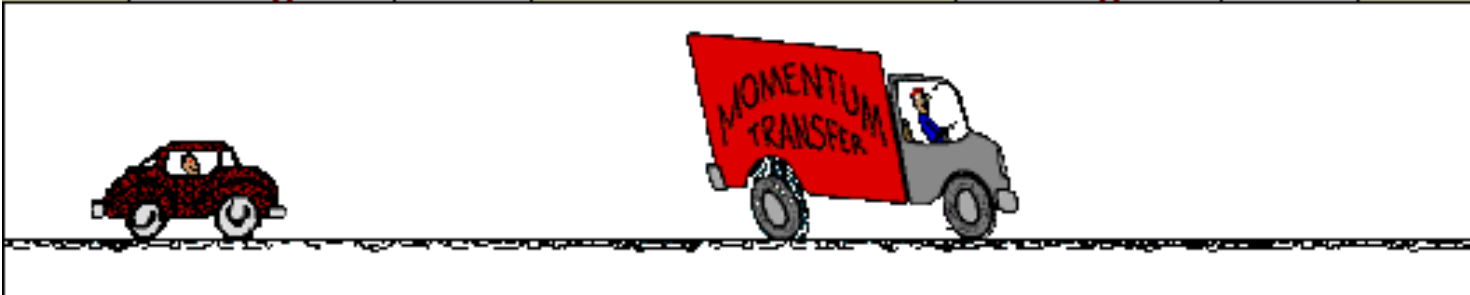
Car		
mass (kg)	1000	
vel. (m/s)	0.0	
mom. (kg m/s)	0	

Elastic Collisions

Before collision

$\mathbf{v}_{1i}$ m_1 $\mathbf{v}_{2i}$ m_2

(a)

After collision

$\mathbf{v}_{1f}$ $\mathbf{v}_{2f}$

(b)

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$$

$$\frac{1}{2}m_1\mathbf{v}_{1i}^2 + \frac{1}{2}m_2\mathbf{v}_{2i}^2 = \frac{1}{2}m_1\mathbf{v}_{1f}^2 + \frac{1}{2}m_2\mathbf{v}_{2f}^2$$

$$\mathbf{v}_{1i} - \mathbf{v}_{2i} = -(\mathbf{v}_{1f} - \mathbf{v}_{2f})$$

Elastic Collisions

- **Total momentum is conserved**
- **Total kinetic energy is conserved**

$$m_1 \mathbf{v}_{1i} + m_2 \mathbf{v}_{2i} = m_1 \mathbf{v}_{1f} + m_2 \mathbf{v}_{2f}$$

$$\frac{1}{2} m_1 \mathbf{v}_{1i}^2 + \frac{1}{2} m_2 \mathbf{v}_{2i}^2 = \frac{1}{2} m_1 \mathbf{v}_{1f}^2 + \frac{1}{2} m_2 \mathbf{v}_{2f}^2$$
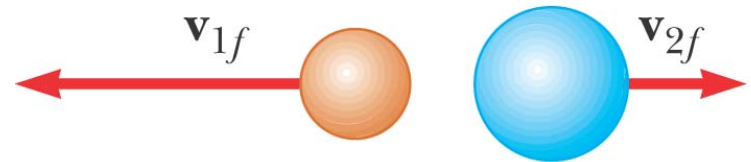
Elastic Collisions (Page 224)

Before collision

$\mathbf{v}_{1i}$ m_1 →   ← $\mathbf{v}_{2i}$ m_2

(a)

After collision

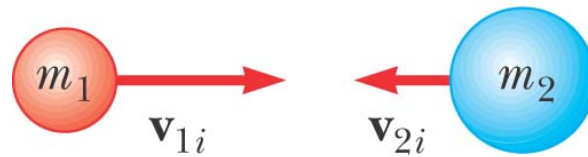← $\mathbf{v}_{1f}$ $\mathbf{v}_{2f}$ →

(b)

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$$\mathbf{v}_{1f} = \mathbf{v}_{1i}\left(\frac{m_1 - m_2}{m_1 + m_2}\right) + \mathbf{v}_{2i}\left(\frac{2m_2}{m_1 + m_2}\right)$$

$$\mathbf{v}_{2f} = \mathbf{v}_{1i}\left(\frac{2m_1}{m_1 + m_2}\right) + \mathbf{v}_{2i}\left(\frac{m_2 - m_1}{m_1 + m_2}\right)$$
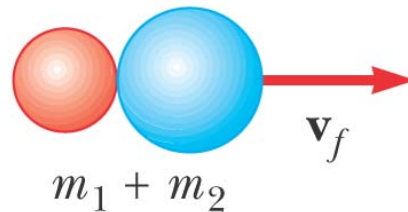
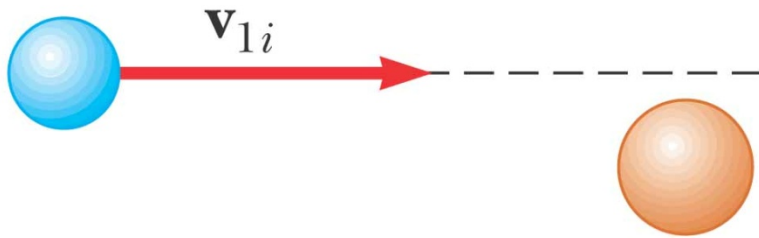# Inelastic Collisions
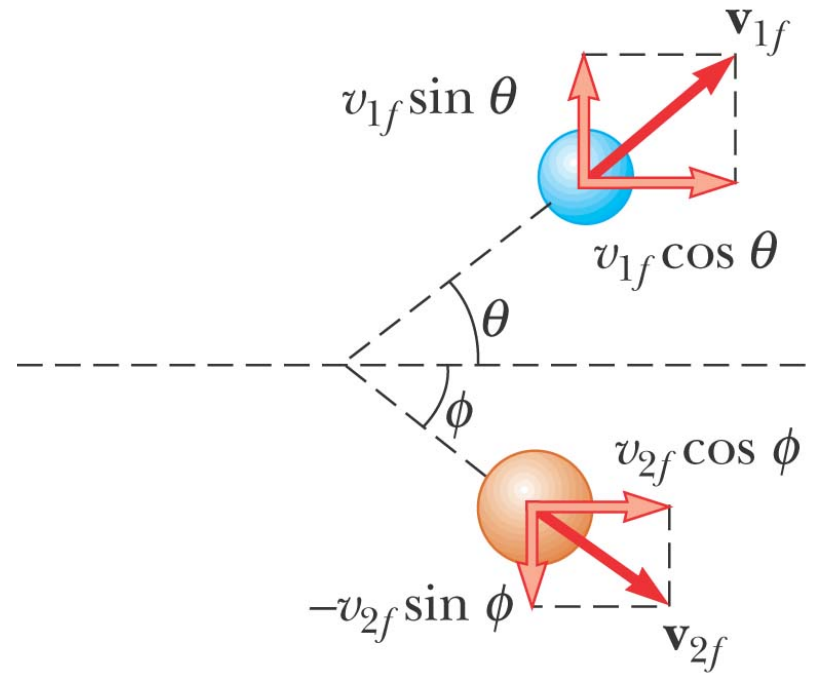
Before collision

(a)

After collision

(b)

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$$

Total momentum is conserved
Total kinetic energy is not conserved

Two-Dimensional Collision

$v_{1f} \sin \theta$

$\mathbf{v}_{1f}$

$v_{1f} \cos \theta$

θ

ϕ

$v_{2f} \cos \phi$

$-v_{2f} \sin \phi$

$\mathbf{v}_{2f}$

(b) After the collision

$\mathbf{v}_{1i}$

(a) Before the collision

World's Biggest Bomb
The Hydrogen Bomb

Golf Ball Hitting Steel

Smart Car Collision