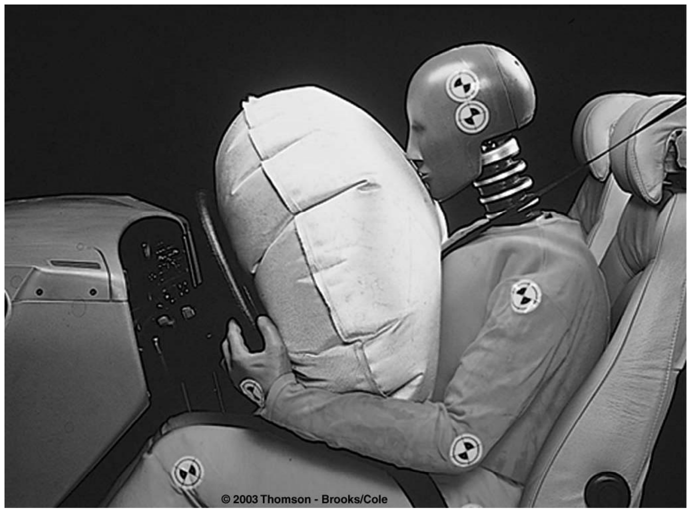
Chapter 6: Momentum and collisions

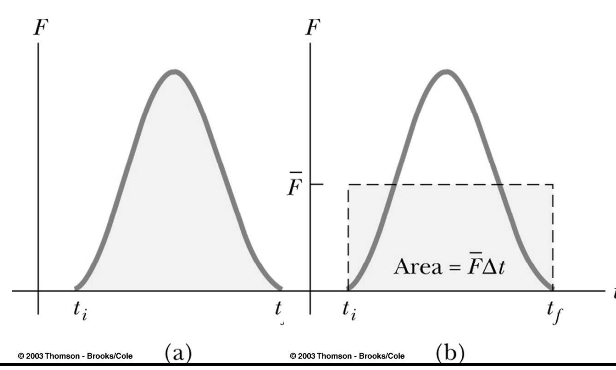


Impulse of force

The impulse done by a force during an interval of time is the area under the force-time graph

$$I = \overline{F}\ \Delta t$$

Units $1\,Ns$



Linear Momentum

The momentum of a particle is a vector with the same direction as its velocity, proportional to the mass of the particle and the speed.

$$\vec{p} = m\,\vec{v}$$

Units

$$1 Kgms^{-1} \equiv 1\,Ns$$

Two objects have equal KE. How do the magnitude of their momenta compare?

a) $p_1 > p_2$, b) $p_1 = p_2$, c) $p_1 < p_2$, d) not enough information

Momentum and force

The time rate of change of momentum of an object is equal to the net force acting on the object.

$$\vec{F} = \frac{\Delta \vec{p}}{\Delta t}$$

Derivation:

$$\frac{\Delta \vec{p}}{\Delta t} = \frac{(m\vec{v}_f - m\vec{v}_i)}{\Delta t} = m\frac{\Delta \vec{v}}{\Delta t} = m\vec{a} = \vec{F}$$

Impulse-momentum theorem

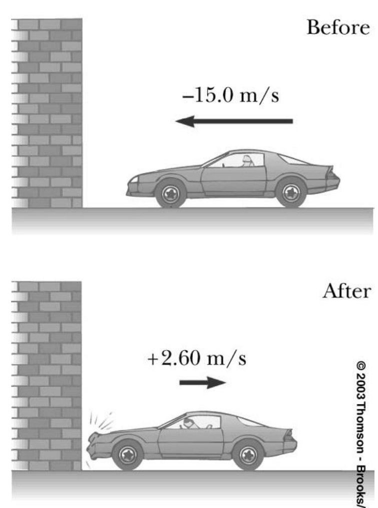
The impulse of the force acting on an object equals the change in momentum of the object.

$$\vec{F}\Delta t = \Delta\vec{p}$$

Linear momentum: example

A car of mass $1.00\text{x}10^3$ kg is heading straight into a brick wall.

a) Calculate its initial momentum
b) Calculate the variation in the momentum of the car.
c) If the impact lasted 1.50 s, what was the average force acting on the car?

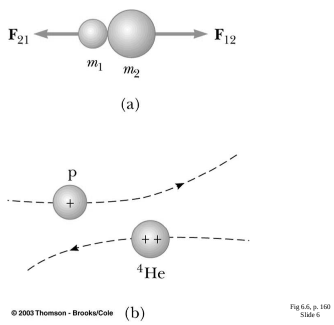


(a)

Conservation of momentum

If there are no external force acting on the system consisting of two objects that collide, the total momentum of the system is conserved.

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



From the 3rd Newton Law we know the force are the same, the collision time is the same, thus the impulse on 1 has to be the same as the impulse on 2.

Momentum conservation: questions

A boy stands at one end of a floating raft stationary relative to the shore. He then walks to the opposite end of the raft, away from the shore. What happens to the raft?

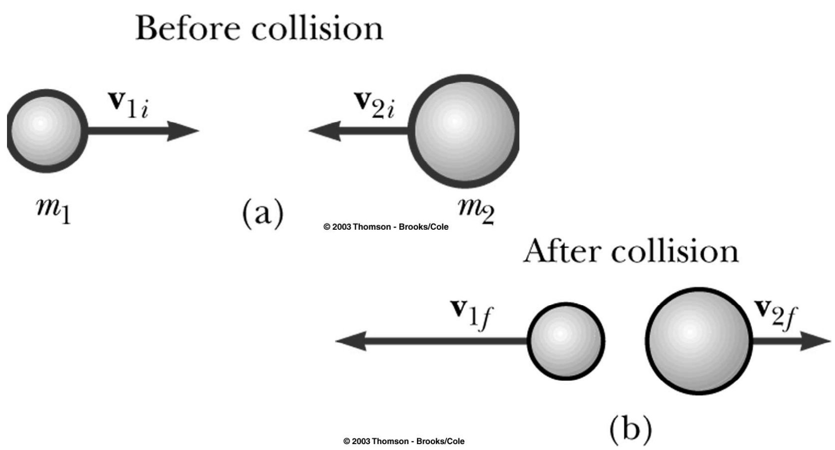
a) Remains stationary?
b) Moves away from the shore?
c) Moves toward the shore?

Two objects (m1>m2) rest on a frictionless surface. When a force is applied to 1 it accelerates through a distance d. the force is removed from 1 and applied to 2. At the moment when 2 has travelled the same distance, which statement is true?

a) $p_1<p_2$, b) $p_1=p_2$, c) $KE_1>KE_2$, d) $KE_1=KE_2$

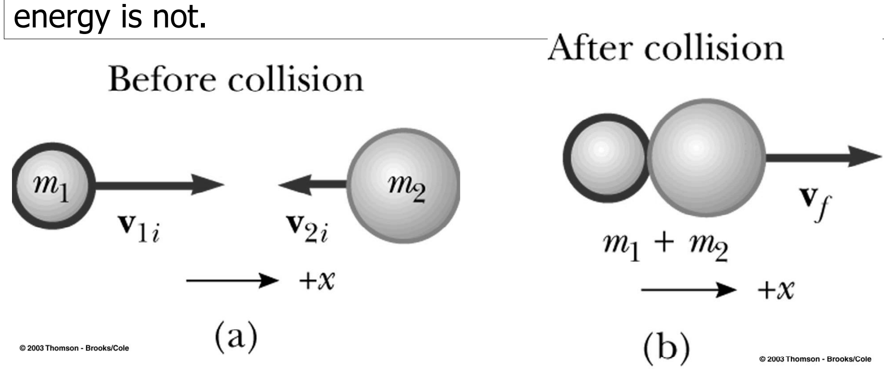
Elastic collisions in 1 dim

In **elastic collisions** both energy and momentum are conserved



Inelastic collisions

In **inelastic collisions** the momentum is conserved but the energy is not.

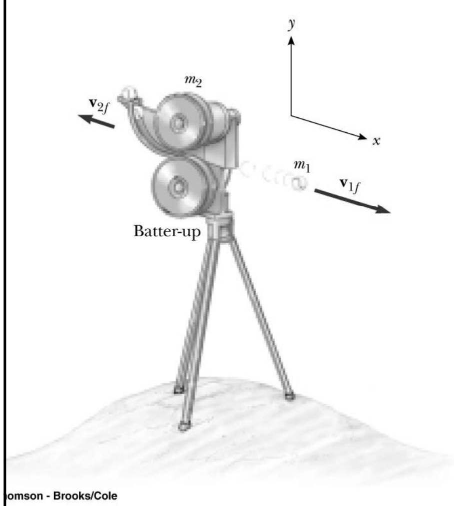


In **perfect inelastic collisions** the two objects stick together after the collision.

Strategy for collisions

- ❑ set up the coordinate system and define the velocities (align one of the axis with an initial velocity)
- ❑ sketch the collision: draw all velocities with labels
- ❑ determine momenta of each object before and after the collision
- ❑ write down the total momentum before and after the collision
- ❑ if the collision is inelastic solve the equation for conserving momentum and find the unknown quantities
- ❑ if the collision is elastic, the kinetic energy is also conserved. Write down both conservation equations and solve for the unknowns

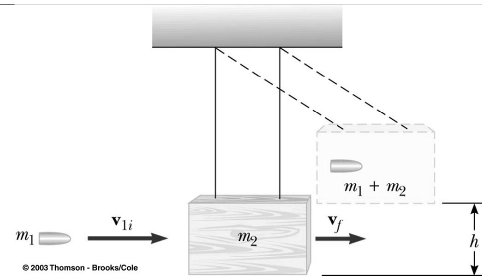
Inelastic collisions: example



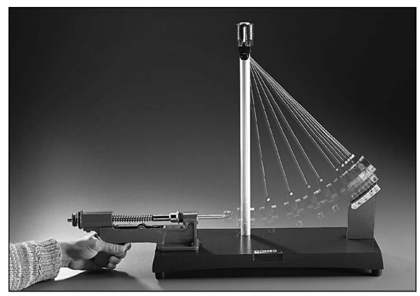
A baseball player uses a 50.0 kg machine to practice. Imagine there is no friction between the machine and the ground. The machine fires a 0.15 kg baseball horizontally with v=36m/s. What is the recoil speed of the machine?

Inelastic collisions: ballistic pendulum

Find the relation between the height and the initial speed of the bullet in a ballistic pendulum.



Assume the mass of the bullet is 5.00 g and that of the block is 1.00 kg. The height that the block reaches after it has been shot is 5.00 cm. Find the initial speed of the bullet.



 (b)

Inelastic collisions: questions

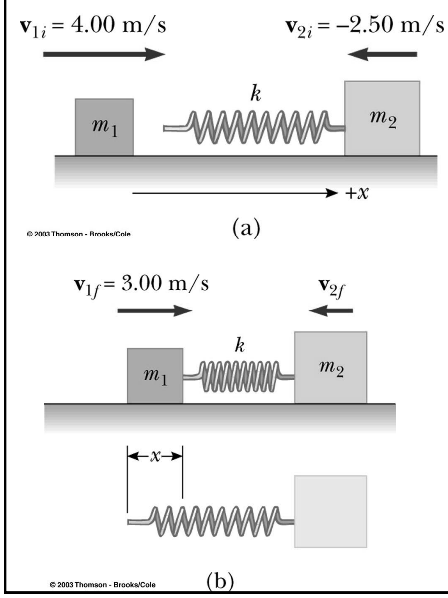
An object of mass m moves to the right with speed v. It collides head-on with an object with 3m moving at v/3 in the opposite direction. If the two objects stick together, what is the speed of the combined object after the collision?

a) 0; b) v/2; c) v; d) 2v

In a perfect inelastic collision, all of the system's kinetic energy is transformed into other forms of energy when:

a) The final momentum of the system is zero
b) When both objects have the same speed
c) When they are initially moving toward each other with different speeds.

Elastic collisions: example



A block of mass m1=1.60 kg Moves initially to the right with 4.00 m/s on a frictionless horizontal track. It collides with a massless spring attached to another block m2=2.10 kg moving to the left. The spring constant is 600 N/m.

a) When the speed of 1 is 3.00 m/s, what is the speed of 2?

b) Determine the distance the spring is compressed at that instant.

Elastic collisions: example

Two metal balls have the same mass and are on a frictionless 1dimensional track. **A** is moving to the right with speed v, and **B** is at rest. What happens after the collision?

a) **A** recoils back and **B** stays at rest

b) Both **A** and **B** move toward the right

c) **A** stays at rest and **B** moves to the right

d) **B** moves to the right but **A** moves to the left