Conservation of Momentum

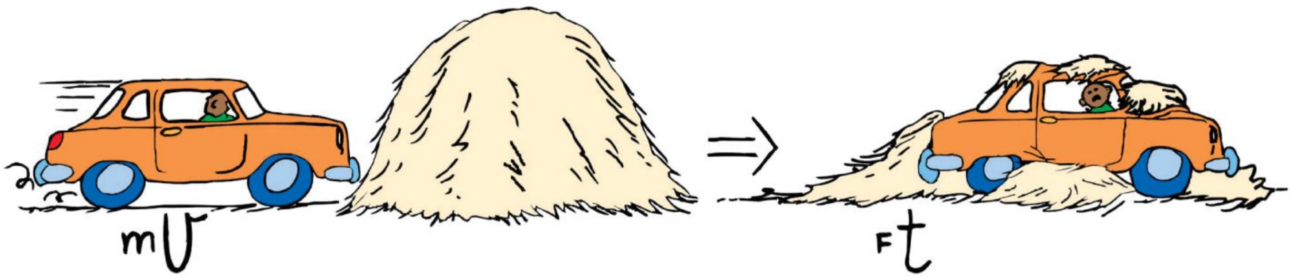
Learning Target:

- I can describe the Law of Conservation of Momentum, and how it relates to elastic and inelastic collisions.

Review of Impulse During Collisions

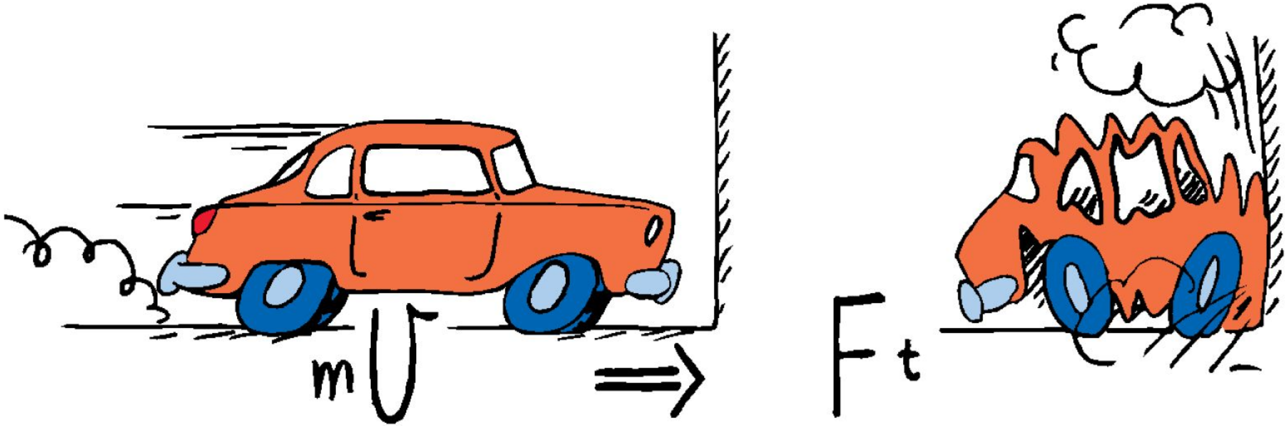
8.2 Impulse Changes Momentum

If the change in momentum occurs over a long time, the force of impact is small.



8.2 Impulse Changes Momentum

If the change in momentum occurs over a short time, the force of impact is large.



8.2 Impulse Changes Momentum

When hitting either the wall or the haystack and coming to a stop, the momentum is decreased by the same impulse.

- The same impulse does not mean the same amount of force or the same amount of time.
- It means the same *product* of force and time.
- To keep the force small, we extend the time.

8.2 Impulse Changes Momentum

When you extend the time, you reduce the force.

- A padded dashboard in a car is safer than a rigid metal one.
- Airbags save lives.
- To catch a fast-moving ball, extend your hand forward and move it backward after making contact with the ball.

8.4 Conservation of Momentum

The law of conservation of momentum states that, in the absence of an external force, the momentum of a system remains unchanged.

$p = mv$

$p_{bullet} + p_{gun} = 0$

$m_b v_b + m_g v_g = 0$

$m_b(0\,m/s) + m_g(0\,m/s) = 0$

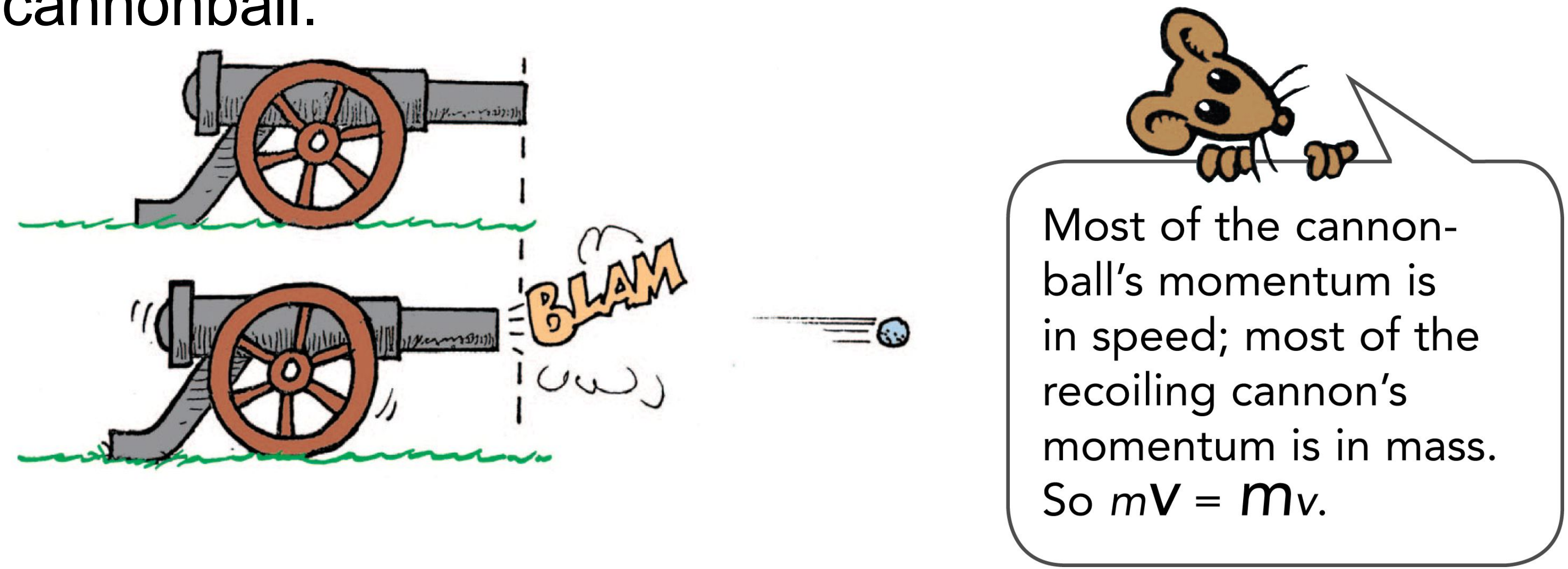
$m_g = 2.38\,kg$

$m_b = 0.00260\,kg$

$V_b = 378\,m/s$

8.4 Conservation of Momentum

The momentum before firing is zero. After firing, the net momentum is still zero because the momentum of the cannon is equal and opposite to the momentum of the cannonball.



8.4 Conservation of Momentum

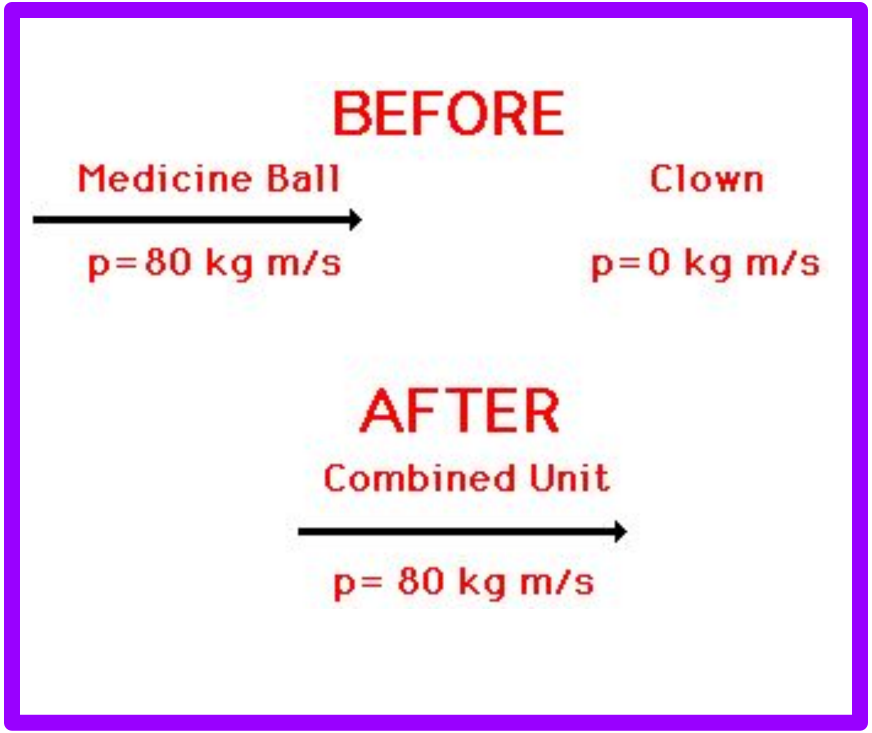
Momentum has both direction and magnitude. It is a *vector quantity.*

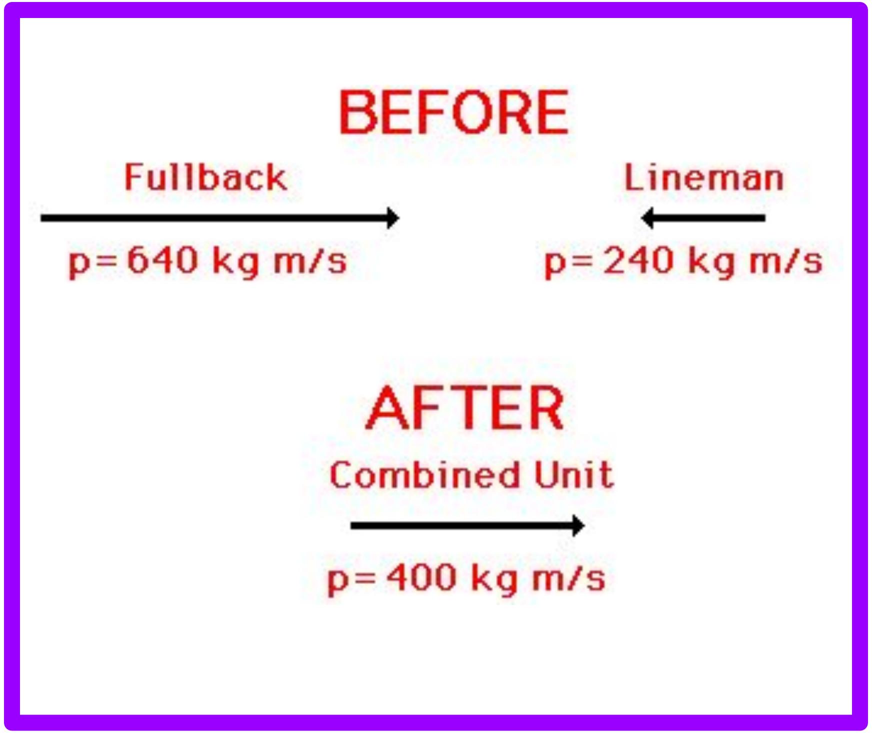
- The cannonball gains momentum and the recoiling cannon gains momentum in the opposite direction.
- The cannon-cannonball *system* gains none.
- The momenta of the cannonball and the cannon are equal in magnitude and opposite in direction.
- No net force acts on the system so there is no net impulse on the system and there is no net change in the momentum.

8.5 Collisions

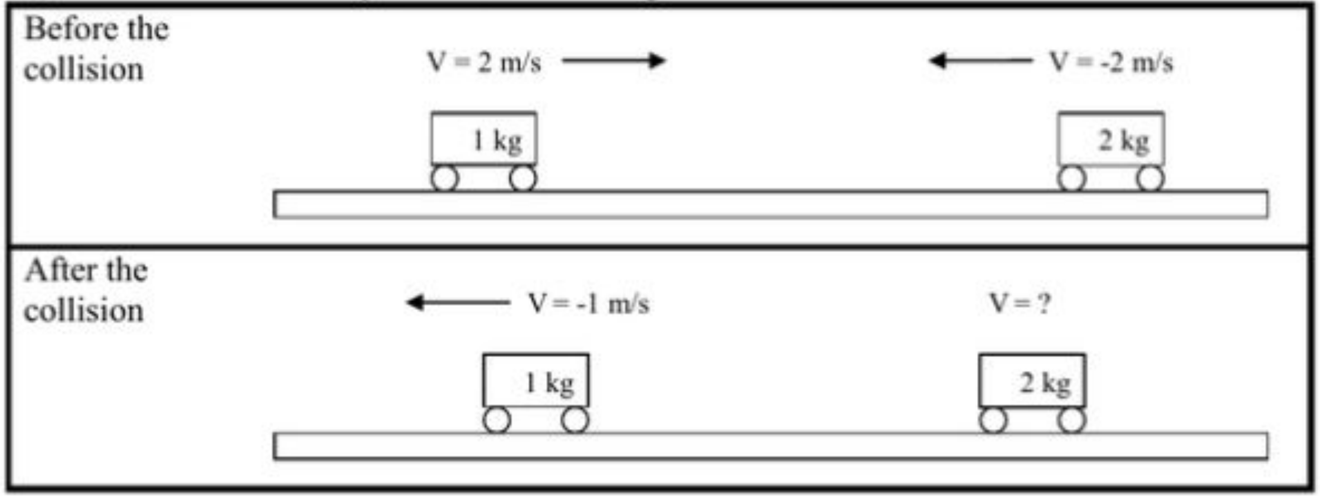
The collision of objects clearly shows the conservation of momentum.

$$\text{net momentum}_{\text{before collision}} = \text{net momentum}_{\text{after collision}}$$


BEFORE
Medicine Ball
p=80 kg m/s
Clown
p=0 kg m/s
AFTER
Combined Unit
p= 80 kg m/s

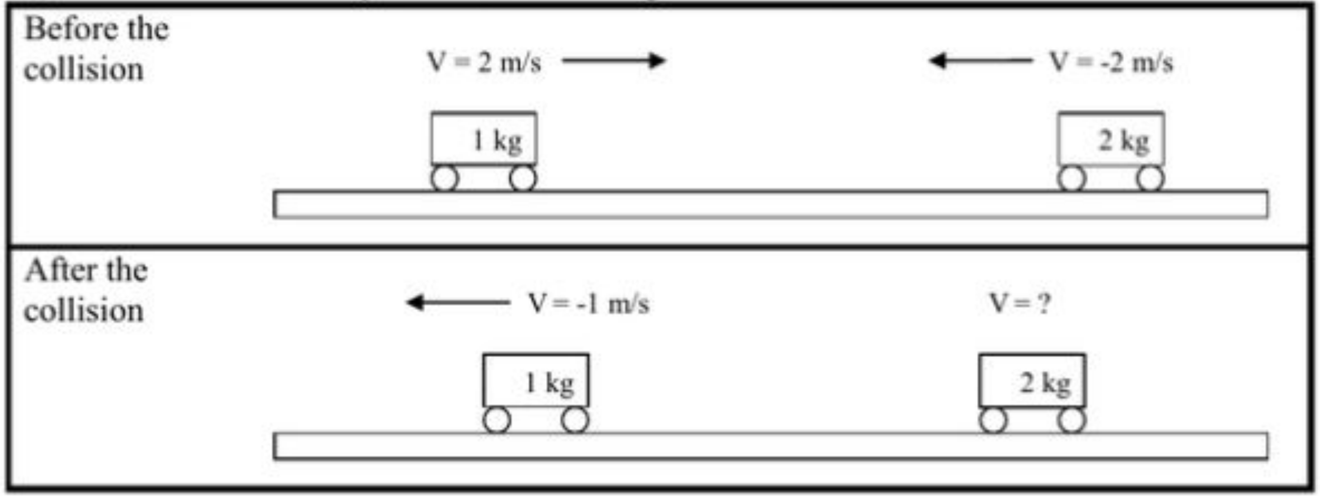

BEFORE
Fullback
p=640 kg m/s
Lineman
p=240 kg m/s
AFTER
Combined Unit
p=400 kg m/s

1) Find the final velocity of the car on the right hand side.



Elastic Collision

1) Find the final velocity of the car on the right hand side.

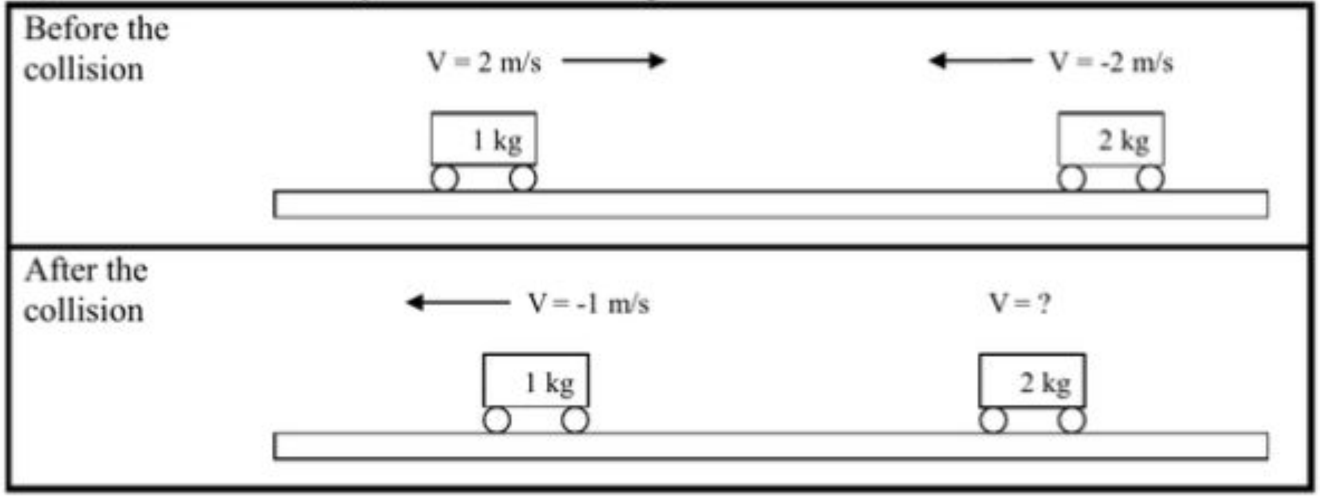


$$M_1v_1+M_2v_2 = \text{Total } p$$

$$(1kg)(2m/s)+(2kg)(-2m/s) =$$

$$(2kgm/s)+(-4kgm/s) = -2 \text{ kgm/s}$$

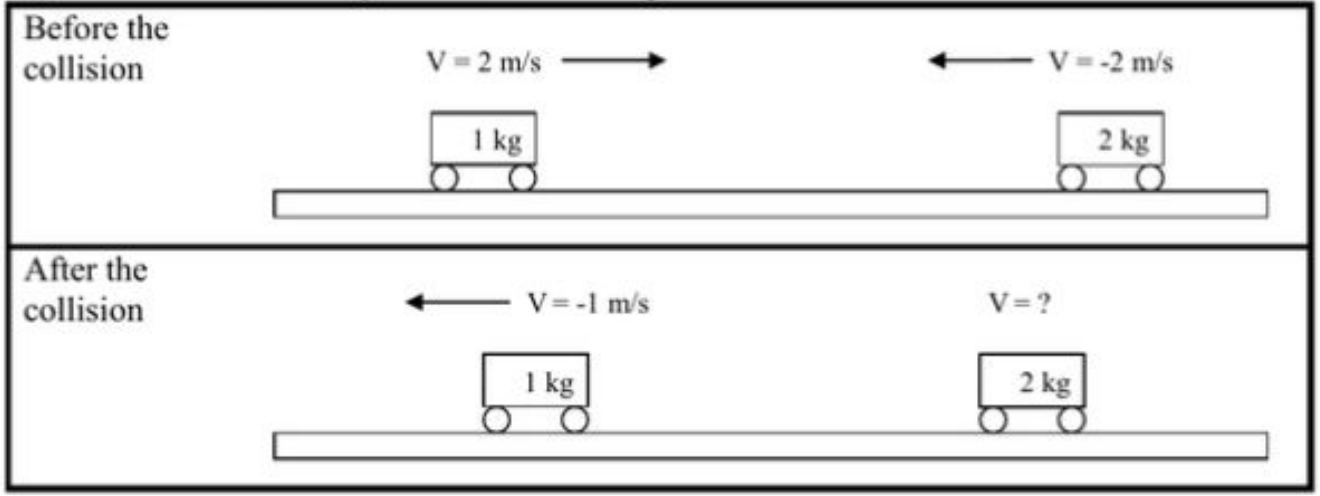
1) Find the final velocity of the car on the right hand side.



P before = p after

P after = -2kg m/s

1) Find the final velocity of the car on the right hand side.



$$V = \frac{\text{total } p - (m_1 v_1)}{m_2} \qquad V = \frac{(-2 - (1\text{kg} * -1\text{m/s}))}{2\text{kg}}$$

$$V = -0.5 \text{ m/s}$$

8.5 Collisions

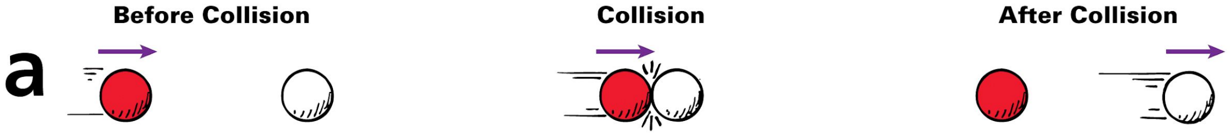
Elastic Collisions

When a moving billiard ball collides head-on with a ball at rest, the first ball comes to rest and the second ball moves away with a velocity equal to the initial velocity of the first ball.

Momentum is transferred from the first ball to the second ball.

8.5 Collisions

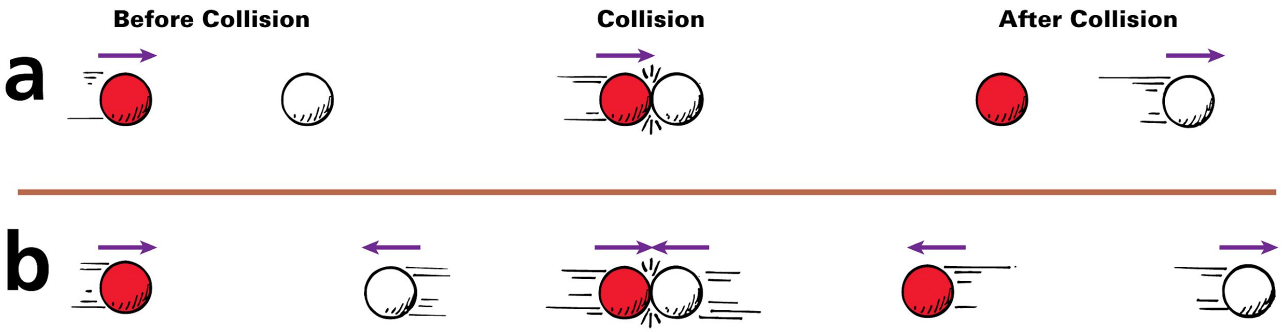
a. A moving ball strikes a ball at rest.



8.5 Collisions

a. A moving ball strikes a ball at rest.

b. Two moving balls collide head-on.



8.5 Collisions

Inelastic Collisions

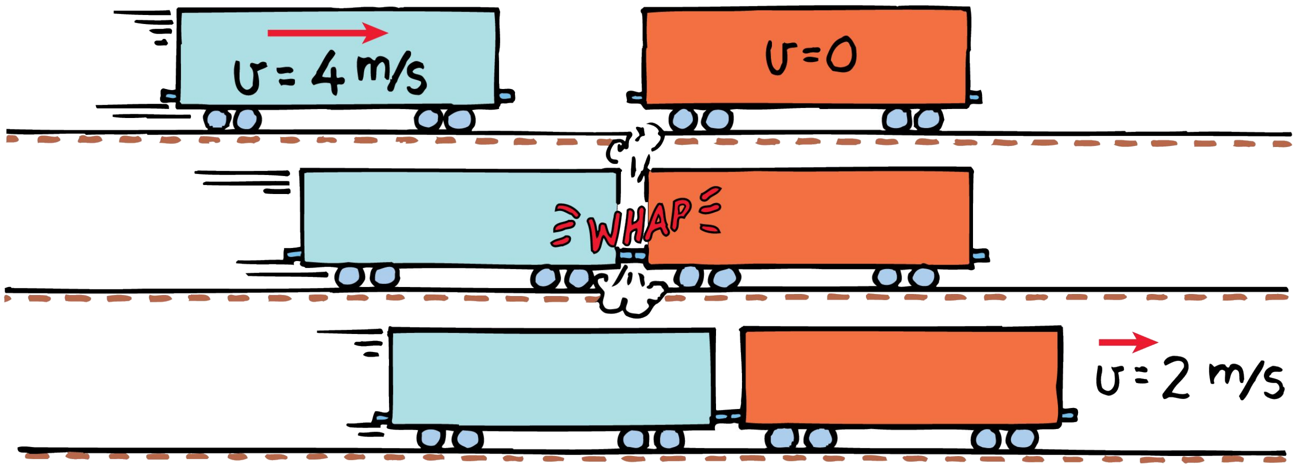
A collision in which the colliding objects become distorted and generate heat during the collision is an **inelastic collision.**

Momentum conservation holds true even in inelastic collisions.

Whenever colliding objects become tangled or couple together, a totally inelastic collision occurs.

8.5 Collisions

In an inelastic collision between two freight cars, the momentum of the freight car on the left is shared with the freight car on the right.



8.5 Collisions

The freight cars are of equal mass *m*, and one car moves at 4 m/s toward the other car that is at rest.

net momentum $_{\text{before collision}}$ = net momentum $_{\text{after collision}}$

$(\text{net } mv)_{\text{before}} = (\text{net } mv)_{\text{after}}$

$(m)(4 \text{ m/s}) + (m)(0 \text{ m/s}) = (2m)(v_{\text{after}})$

8.5 Collisions

Twice as much mass is moving after the collision, so the velocity, v_{after}, must be one half of 4 m/s.

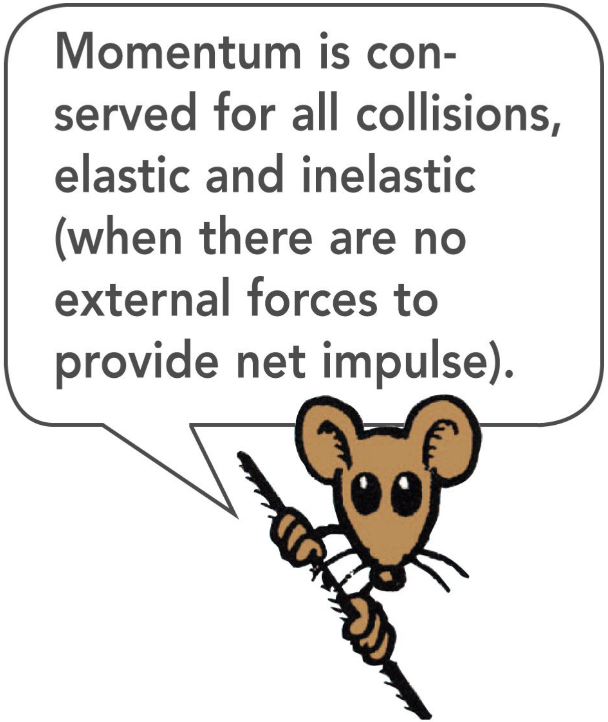
v_{after} = 2 m/s in the same direction as the velocity before the collision, v_{before}.

8.5 Collisions

The initial momentum is shared by both cars without loss or gain.

Momentum is conserved.

External forces are usually negligible during the collision, so the net momentum does not change during collision.



8.5 Collisions

External forces may have an effect after the collision:

- Billiard balls encounter friction with the table and the air.
- After a collision of two trucks, the combined wreck slides along the pavement and friction decreases its momentum.
- Two space vehicles docking in orbit have the same net momentum just before and just after contact. Since there is no air resistance in space, the combined momentum is then changed only by gravity.

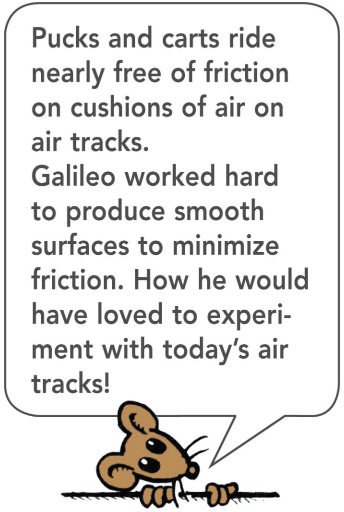
8.5 Collisions

Perfectly elastic collisions are not common in the everyday world. Drop a ball and after it bounces from the floor, both the ball and the floor are a bit warmer.

At the microscopic level, however, perfectly elastic collisions are commonplace. For example, electrically charged particles bounce off one another without generating heat; they don’t even touch in the classic sense of the word.

8.5 Collisions

An air track nicely demonstrates conservation of momentum. Many small air jets provide a nearly frictionless cushion of air for the gliders to slide on.



8.5 Collisions

think!

One glider is loaded so it has three times the mass of another glider. The loaded glider is initially at rest. The unloaded glider collides with the loaded glider and the two gliders stick together. Describe the motion of the gliders after the collision.

8.5 Collisions

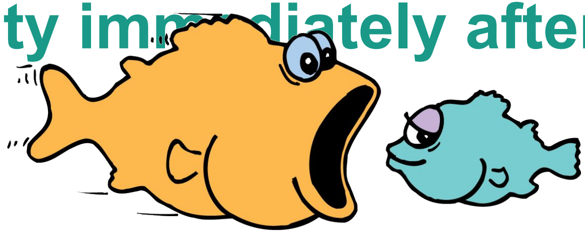
think!

One glider is loaded so it has three times the mass of another glider. The loaded glider is initially at rest. The unloaded glider collides with the loaded glider and the two gliders stick together. Describe the motion of the gliders after the collision.

Answer: The mass of the stuck-together gliders is four times that of the unloaded glider. The velocity of the stuck-together gliders is one fourth of the unloaded glider's velocity before collision. This velocity is in the same direction as before, since the direction as well as the amount of momentum is

8.5 Collisions
do the math!

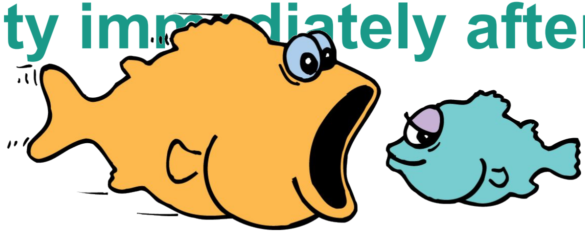
Consider a 6-kg fish that swims toward and swallows a 2-kg fish that is at rest. If the larger fish swims at 1 m/s, what is its velocity immediately after lunch?



8.5 Collisions

do the math!

Consider a 6-kg fish that swims toward and swallows a 2-kg fish that is at rest. If the larger fish swims at 1 m/s, what is its velocity immediately after lunch?



Momentum is conserved from the instant before lunch until the instant after (in so brief an interval, water resistance does not have time to change the momentum).

8.5 Collisions
do the math!

$$\text{net momentum}_{\text{before lunch}} = \text{net momentum}_{\text{after lunch}}$$

$$(\text{net } mv)_{\text{before}} = (\text{net } mv)_{\text{after}}$$

$$(6\text{ kg})(1\text{ m/s}) + (2\text{ kg})(0\text{ m/s}) = (6\text{ kg} + 2\text{ kg})(v_{\text{after}})$$

$$6\text{ kg·m/s} = (8\text{ kg})(v_{\text{after}})$$

$$v_{\text{after}} = \frac{6\text{ kg·m/s}}{8\text{ kg}} = \frac{3}{4}\text{ m/s}$$

8.5 Collisions
do the math!

Suppose the small fish is not at rest but is swimming toward the large fish at 2 m/s.

8.5 Collisions

do the math!

Suppose the small fish is not at rest but is swimming toward the large fish at 2 m/s.

If we consider the direction of the large fish as positive, then the velocity of the small fish is –2 m/s.

8.5 Collisions

do the math!

The negative momentum of the small fish slows the large fish.

$$(\text{net } mv)_{\text{before}} = (\text{net } mv)_{\text{after}}$$

$$(6 \text{ kg})(1 \text{ m/s}) + (2 \text{ kg})(-2 \text{ m/s}) = (6 \text{ kg} + 2 \text{ kg})(v_{\text{after}})$$

$$(6 \text{ kg·m/s}) + (-4 \text{ kg·m/s}) = (8 \text{ kg})(v_{\text{after}})$$

$$v_{\text{after}} = \frac{2 \text{ kg·m/s}}{8 \text{ kg}} = \frac{1}{4} \text{ m/s}$$