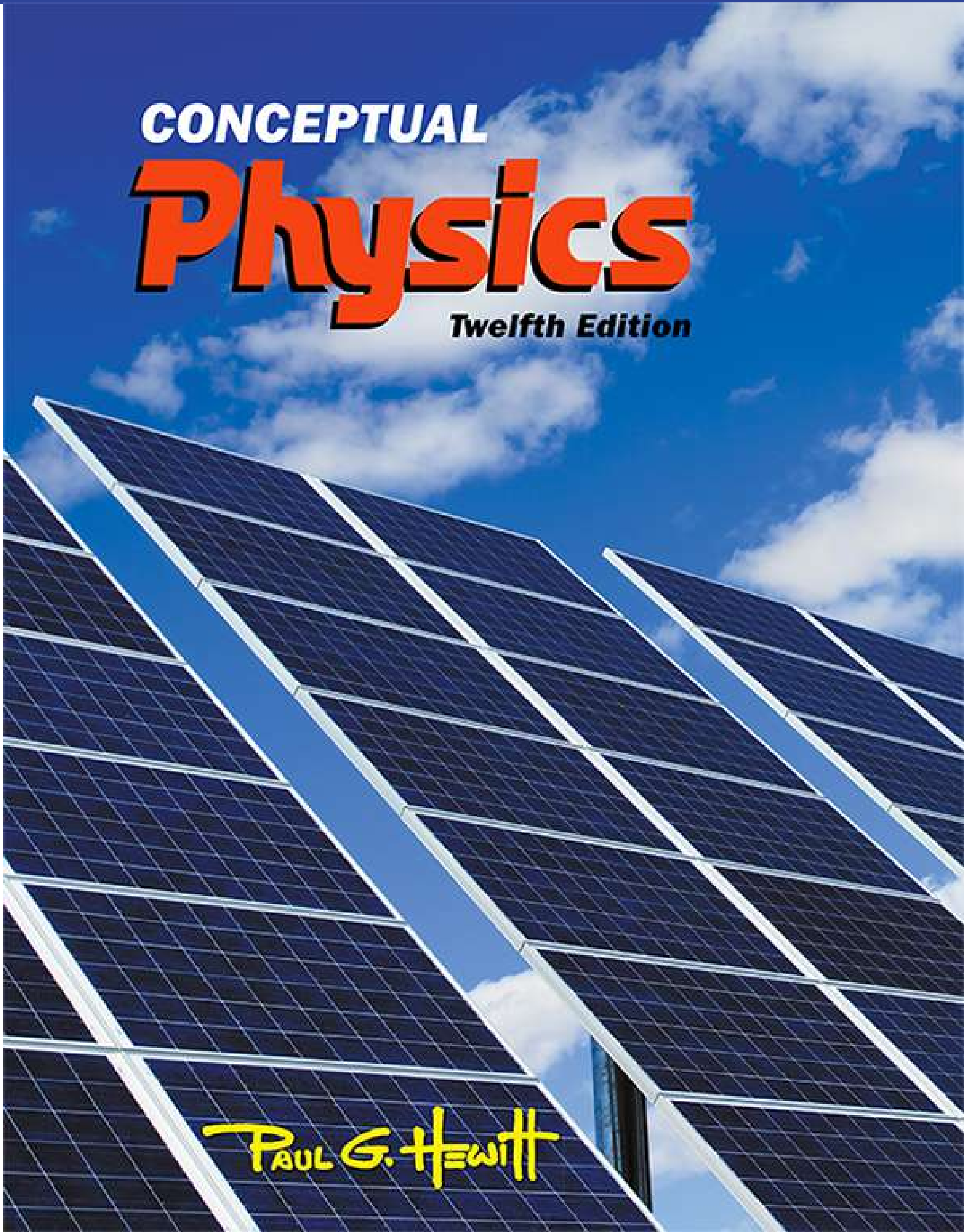
Chapter 6: Momentum



This lecture will help you understand:

- Momentum
- Impulse
- Impulse Changes Momentum
- Bouncing
- Conservation of Momentum
- Collisions
- More Complicated Collisions

Momentum

- a property of moving things
- means inertia in motion
- more specifically, mass of an object multiplied by its velocity
- in equation form:

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

Momentum, Continued

- Example:
  - A moving boulder has more momentum than a stone rolling at the same speed.
  - A fast boulder has more momentum than a slow boulder.
  - A boulder at rest has no momentum.

Momentum
CHECK YOUR NEIGHBOR

A moving object has

A. momentum.
B. energy.
C. speed.
D. All of the above.

Momentum
CHECK YOUR ANSWER

A moving object has

D. **All of the above.**

Comment:

We will see in the next chapter that energy in motion is called kinetic energy.

Momentum
CHECK YOUR NEIGHBOR, Continued

When the speed of an object is doubled, its momentum

A. remains unchanged in accord with the conservation of momentum.
B. doubles.
C. quadruples.
D. decreases.

Momentum
CHECK YOUR ANSWER, Continued

When the speed of an object is doubled, its momentum

B. doubles.

Impulse

- Product of force and time (force x time)
- In equation form: Impulse = Ft
- Example:
  – A brief force applied over a short time interval produces a smaller change in momentum than the same force applied over a longer time interval.
- or
  – If you push with the same force for twice the time, you impart twice the impulse and produce twice the change in momentum.

Impulse Changes Momentum

- The greater the impulse exerted on something, the greater the change in momentum.
  - In equation form: $Ft = \Delta(mv)$

Impulse Changes Momentum
CHECK YOUR NEIGHBOR

When the force that produces an impulse acts for twice as much time, the impulse is

A. not changed.
B. doubled.
C. quadrupled.
D. halved.

Impulse Changes Momentum
CHECK YOUR ANSWER

When the force that produces an impulse acts for twice as much time, the impulse is

B. doubled.

Impulse Changes Momentum, Continued

- Case 1: increasing momentum
  - Apply the greatest force for as long as possible and you extend the time of contact.
  - Force can vary throughout the duration of contact.
  - Examples:
    - Golfer swings a club and
    - follows through.
    - Baseball player hits a ball and
    - follows through.

Impulse Changes Momentum
CHECK YOUR NEIGHBOR, Continued

A cannonball shot from a cannon with a long barrel will emerge with greater speed because the cannonball receives a greater

A. average force.
B. impulse.
C. Both of the above.
D. None of the above.

Impulse Changes Momentum CHECK YOUR ANSWER, Continued

A cannonball shot from a cannon with a long barrel will emerge with greater speed because the cannonball receives a greater

B. **impulse.**

Explanation:

The average force on the cannonball will be the same for a short- or long-barreled cannon. The longer barrel provides for a longer time for the force to act, and therefore, a greater impulse. (The long barrel also provides a longer distance for the force to act, providing greater work and greater kinetic energy to the cannonball.)

Impulse Changes Momentum, Continued-1

- Case 2: decreasing momentum over a long time
  - extend the time during which momentum is reduced

Impulse Changes Momentum
CHECK YOUR NEIGHBOR, Continued-1

A fast-moving car hitting a haystack or hitting a cement wall produces vastly different results.

1. Do both experience the same change in momentum?
2. Do both experience the same impulse?
3. Do both experience the same force?

A. Yes for all three

B. Yes for 1 and 2

C. No for all three

D. No for 1 and 2

Impulse Changes Momentum
CHECK YOUR ANSWER, Continued-1

A fast-moving car hitting a haystack or hitting a cement wall produces vastly different results.

1. Do both experience the same change in momentum?
2. Do both experience the same impulse?
3. Do both experience the same force?

B. **Yes for 1 and 2**

Explanation:

Although stopping the momentum is the same whether done slowly or quickly, the force is vastly different. Be sure to distinguish among momentum, impulse, and force.

Impulse Changes Momentum
CHECK YOUR NEIGHBOR, Continued-2

When a dish falls, will the change in momentum be less if it lands on a carpet than if it lands on a hard floor? (Careful!)

A. No, both are the same.
B. Yes, less if it lands on the carpet.
C. No, less if it lands on a hard floor.
D. No, more if it lands on a hard floor.

Impulse Changes Momentum
CHECK YOUR ANSWER, Continued-2

When a dish falls, will the change in momentum be less if it lands on a carpet than if it lands on a hard floor? (Careful!)

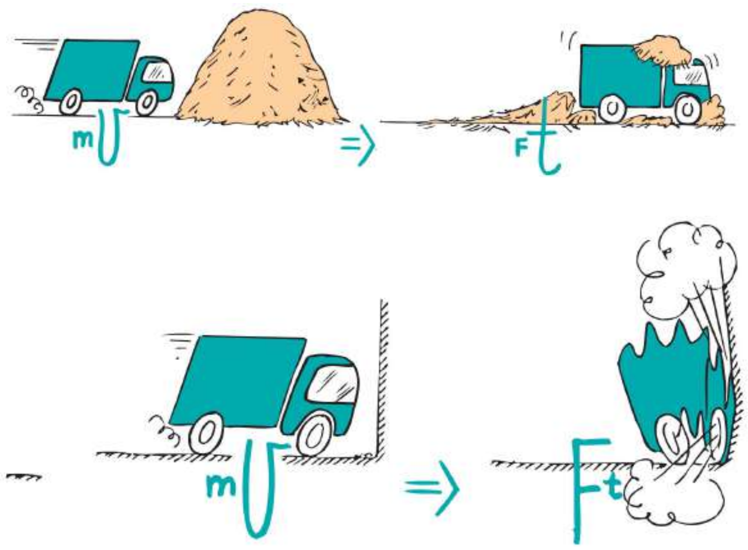
A. **No, both are the same.**

Explanation:

The momentum becomes zero in both cases, so both change by the same amount. Although the momentum change and impulse are the same, the force is less when the time of momentum change is extended. Be careful to distinguish among force, impulse, and momentum.

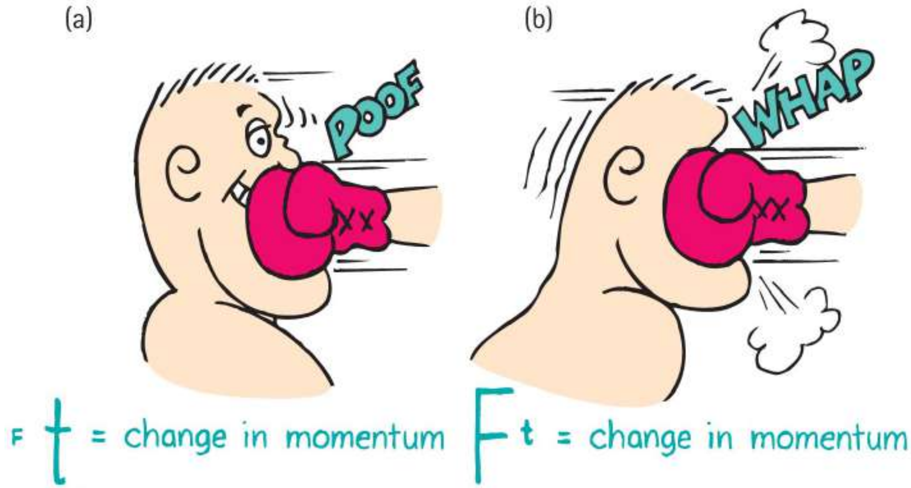
Impulse Changes Momentum, Continued-2

- Examples:
  - When a car is out of control, it is better to hit a haystack than a concrete wall.
- Physics reason: Same impulse either way, but extension of hitting time reduces the force.



Impulse Changes Momentum, Continued-3

- Example (continued):
  - In jumping, bend your knees when your feet make contact with the ground because the extension of time during your momentum decrease reduces the force on you.
  - In boxing, ride with the punch.



Impulse Changes Momentum, Continued-4

- Case 3: decreasing momentum over a short time
  - short time interval produces large force.

- Example: Karate expert splits a stack of bricks by bringing her arm and hand swiftly against the bricks with considerable momentum. Time of contact is brief and force of impact is huge.

Bouncing

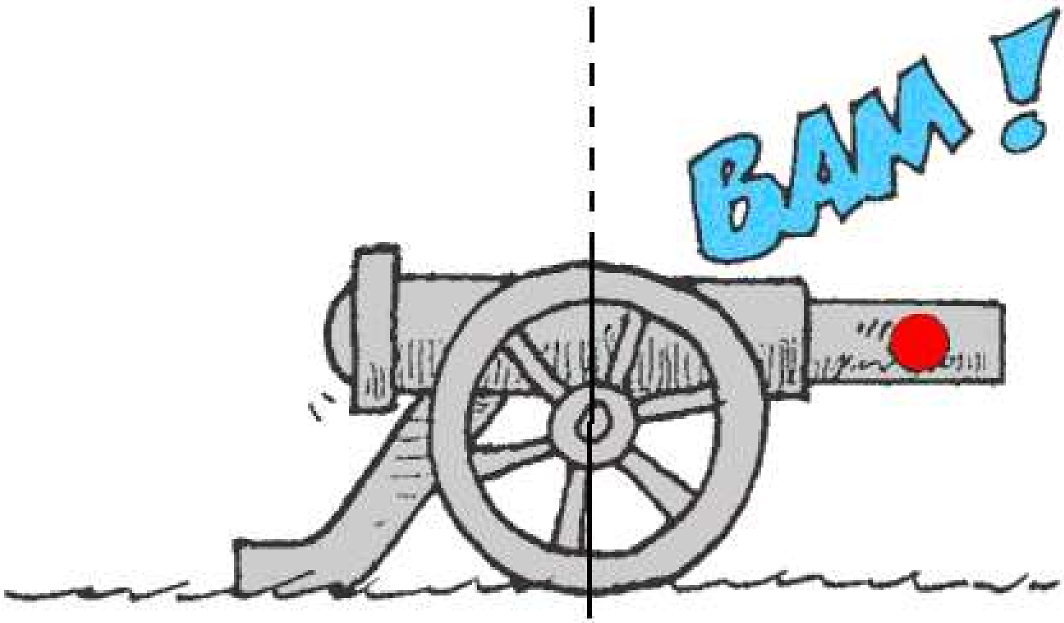
- Impulses are generally greater when objects bounce.
  - Example:
    - Catching a falling flower pot from a shelf with your hands. You provide the impulse to reduce its momentum to zero. If you throw the flower pot up again, you provide an additional impulse. This "double impulse" occurs when something bounces.

Bouncing, Continued

- Pelton wheel designed to "bounce" water when it makes a U-turn on impact with the curved paddle

Conservation of Momentum

- Law of conservation of momentum:
  - In the absence of an external force, the momentum of a system remains unchanged.



Conservation of Momentum, Continued

- Examples:
  - When a cannon is fired, the force on the cannonball inside the cannon barrel is equal and opposite to the force of the cannonball on the cannon.
  - The cannonball gains momentum, while the cannon gains an equal amount of momentum in the opposite direction—the cannon recoils.
- When no external force is present, no external impulse is present, and no change in momentum is possible.

Conservation of Momentum, Continued-1

- Examples (continued):
  - Internal molecular forces within a baseball come in pairs, cancel one another out, and have no effect on the momentum of the ball.
  - Molecular forces within a baseball have no effect on its momentum.
  - Pushing against a car's dashboard has no effect on its momentum.

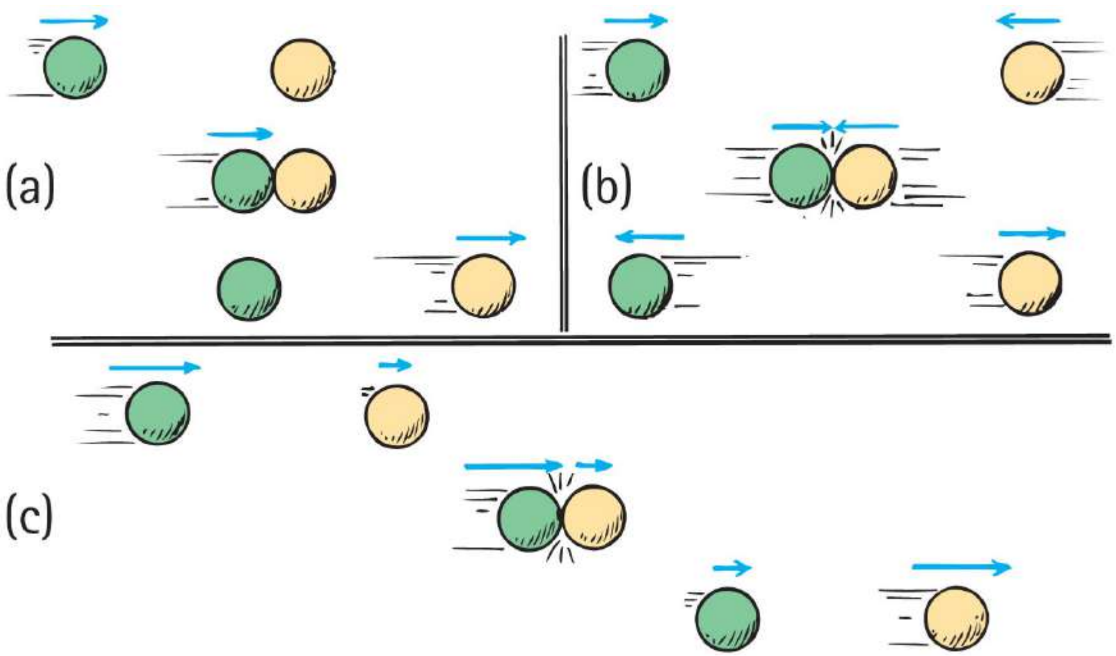
Collisions

- For all collisions in the absence of external forces,
  - net momentum before collision equals net momentum after collision.
  - in equation form:

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

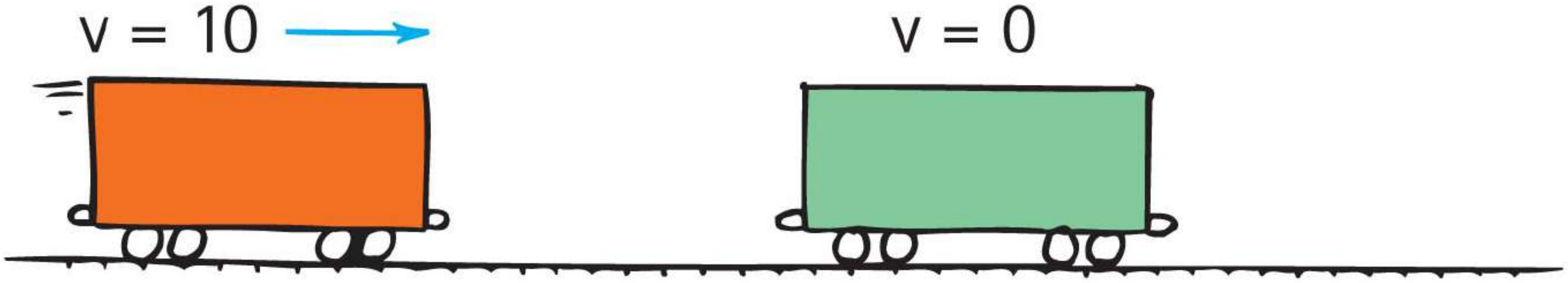
Collisions, Continued

- Elastic collision
  - occurs when colliding objects rebound without lasting deformation or any generation of heat.



Collisions, Continued-1

- Inelastic collision
  – occurs when colliding objects result in deformation and/or the generation of heat.



Collisions, Continued-2

- Example of elastic collision:
- single car moving at 10 m/s collides with another car of the same mass, *m*, at rest

- From the conservation of momentum,

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

$$(m \times 10)_{\text{before}} = (2\text{m} \times V)_{\text{after}}$$

$$V = 5 \text{ m/s}$$

Collisions
CHECK YOUR NEIGHBOR

Freight car A is moving toward identical freight car B that is at rest. When they collide, both freight cars couple together. Compared with the initial speed of freight car A, the speed of the coupled freight cars is

A. the same.
B. half.
C. twice.
D. None of the above.

Collisions
CHECK YOUR ANSWER

Freight car A is moving toward identical freight car B that is at rest. When they collide, both freight cars couple together. Compared with the initial speed of freight car A, the speed of the coupled freight cars is

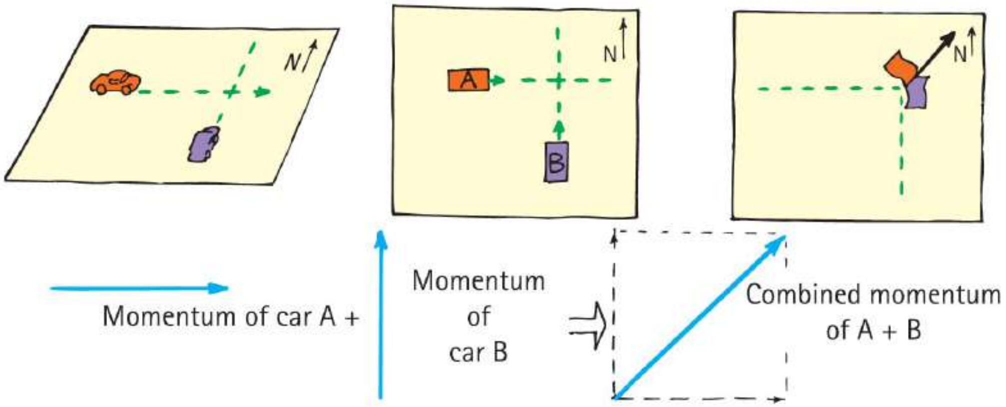
B. **half.**

Explanation:

After the collision, the mass of the moving freight cars has doubled. Can you see that their speed is half the initial velocity of freight car A?

More Complicated Collisions

- Sometimes the colliding objects are not moving in the same straight line.
- In this case you create a parallelogram of the vectors describing each initial momentum to find the combined momentum.
  - Example: collision of two cars at a corner



More Complicated Collisions, Continued

- Another example:
  - A firecracker exploding; the total momentum of the pieces after the explosion can be added vectorially to get the initial momentum of the firecracker before it exploded.