Q8.3

A 3.00-kg rifle fires a 0.00500-kg bullet at a speed of 300 m/s. Which force is greater in magnitude:

(i) the force that the *rifle* exerts on the *bullet*; or

(ii) the force that the *bullet* exerts on the *rifle?*

A. the force that the rifle exerts on the bullet

B. the force that the bullet exerts on the rifle

C. both forces have the same magnitude

D. not enough information given to decide

Ch 8.1-2
Momentum & Impulse

PHYS 1210 - Prof. Jang-Condell

Goals for Chapter 8

- To learn the meaning of the momentum of a particle and how an impulse causes it to change
- To learn how to use the conservation of momentum
- To learn how to solve problems involving collisions
- To learn the definition of the center of mass of a system and what determines how it moves
- To analyze situations, such as rocket propulsion, in which the mass of a moving body changes

Momentum

$$\vec{\boldsymbol{p}} = m\vec{\mathbf{v}}$$

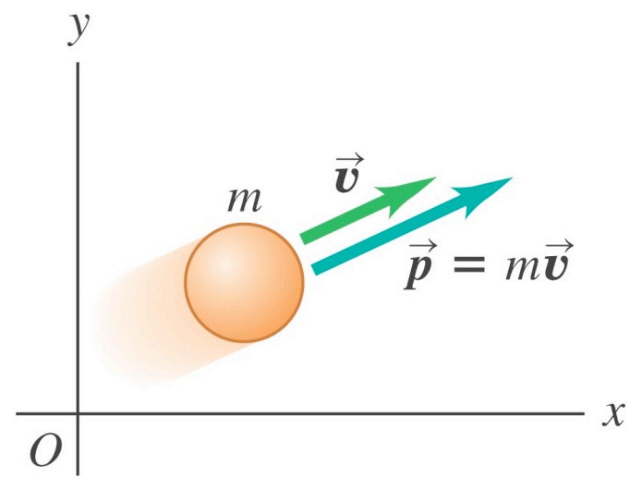
Newton's Second Law, revisited

$$\sum \vec{\boldsymbol{F}} = \frac{d\vec{\boldsymbol{p}}}{dt}$$

Momentum and Newton's second law

- The *momentum* of a particle is the product of its mass and its velocity: $\vec{p} = m\vec{v}$
- Newton's second law can be written in terms of momentum as

$$\sum \vec{F} = \frac{d\vec{p}}{dt}$$



Momentum $\vec{p}$ is a vector quantity; a particle's momentum has the same direction as its velocity $\vec{v}$.

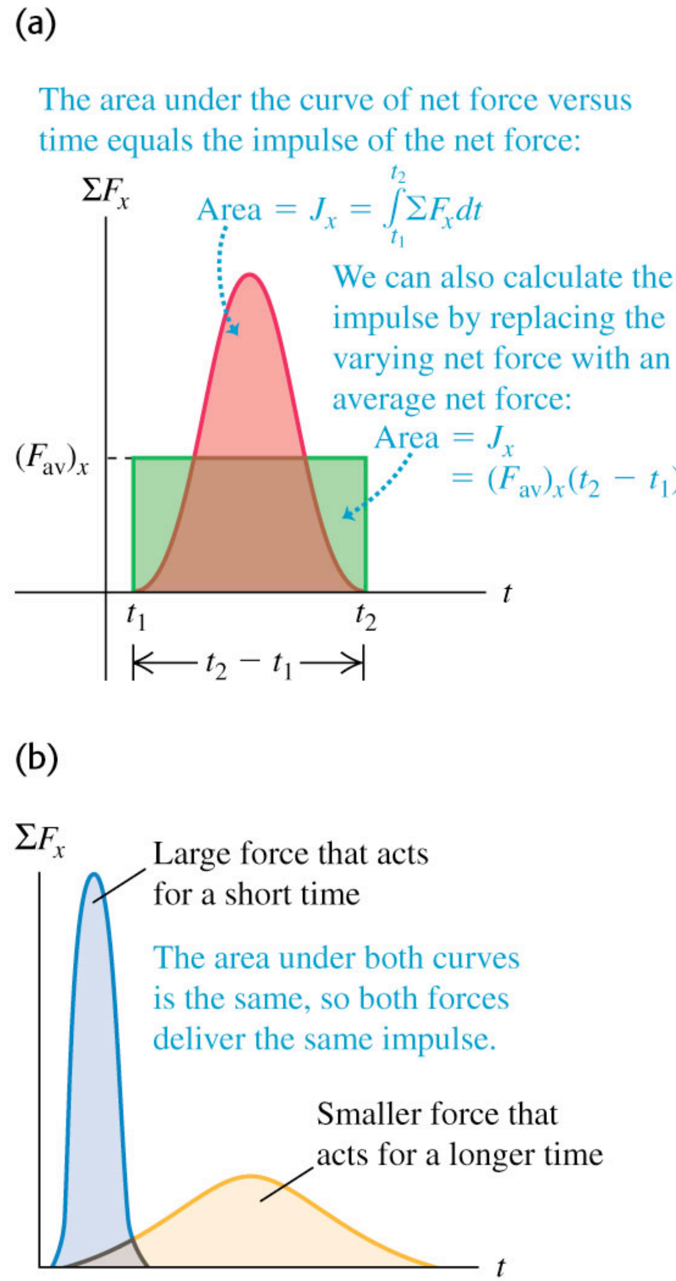
Impulse

Impulse = Force × time

$$\vec{\boldsymbol{J}} = \int \left(\sum \vec{\boldsymbol{F}}\right) dt$$

Impulse and momentum

- The *impulse* of a force is the product of the force and the time interval during which it acts.
- On a graph of ΣF_x versus time, the impulse is equal to the area under the curve, as shown in Figure 8.3 to the right.
- *Impulse-momentum theorem*: The change in momentum of a particle during a time interval is equal to the impulse of the net force acting on the particle during that interval.



Impulse-Momentum Theorem

The change in momentum of a particle during a time interval is equal to the impulse of the net force acting on the particle during that interval

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

Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the time intervals to stop them compare?

F. It takes less time to stop the ping-pong ball.

G. Both take the same time.

H. It takes more time to stop the ping-pong ball.

Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the distances needed to stop them compare?

K. It takes a shorter distance to stop the ping-pong ball.

L. Both take the same distance.

M. It takes a longer distance to stop the ping-pong ball

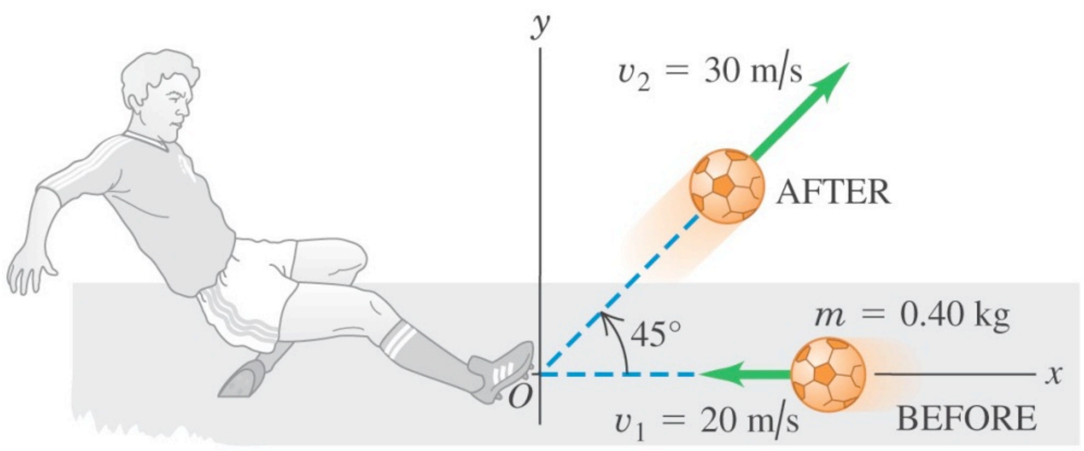
Example

- You go ice skating with your Aunt Dee and your little cousin Jay. They aren't very good at it.
- Aunt Dee (60 kg) comes at you at 2.5 m/s, and you catch her to bring her to a stop.
- Then Jay (30 kg) plows into you at 5 m/s, and you catch him, too.
- What are the momenta of your aunt and cousin?
- What are their kinetic energies?
- What is the impulse of the force you exert to stop them?
- How much work do you apply?
- You exert a constant force of 50 N to stop each of them. How long does it take to stop them? How far do you get pushed back?

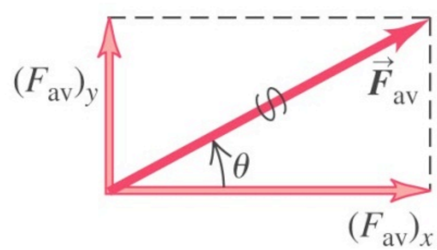
Kicking a soccer ball

- In Example 8.3, a kick changes the direction of a soccer ball.

(a) Before-and-after diagram

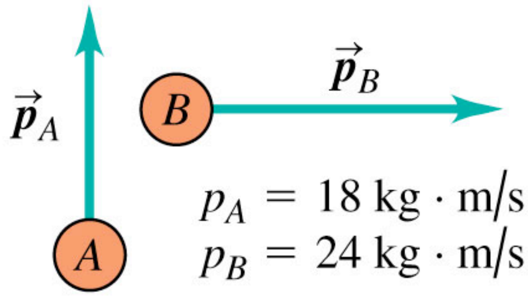


(b) Average force on the ball



Remember that momentum is a vector!

- When applying conservation of momentum, remember that momentum is a vector quantity!
- Use vector addition to add momenta, as shown in Figure 8.10 at the right.

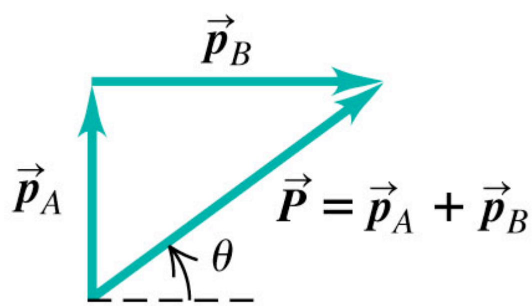


A system of two particles with momenta in different directions

You CANNOT find the magnitude of the total momentum by adding the magnitudes of the individual momenta!

$P = p_A + p_B = 42\ \mathrm{kg\cdot m/s}$ ◀ WRONG

Instead, use vector addition:

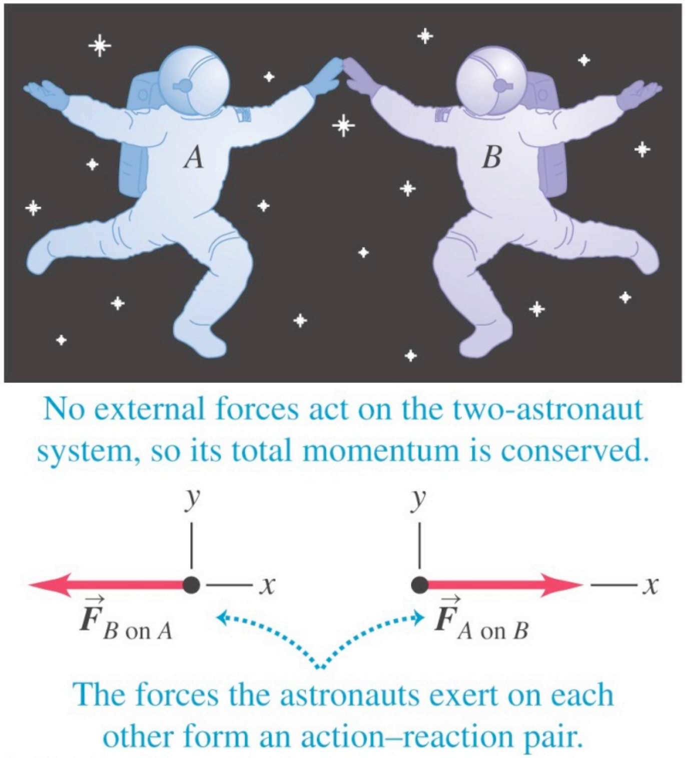


◀ RIGHT!

$$P = |\vec{p}_A + \vec{p}_B| = 30\ \mathrm{kg\cdot m/s}\ \text{at}\ \theta = 37°$$

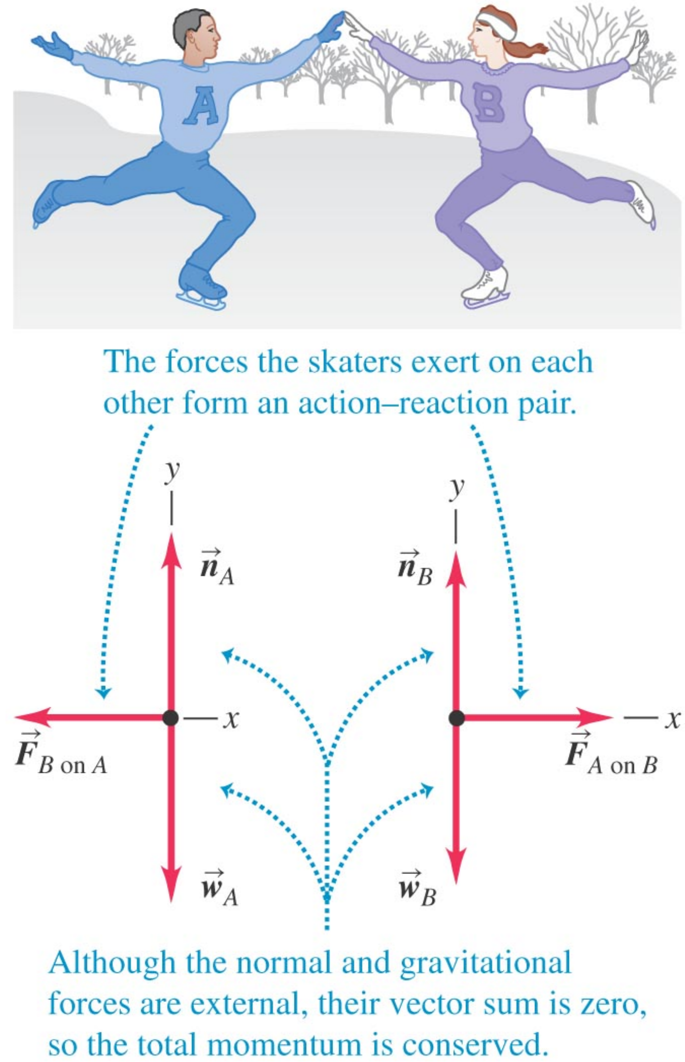
An isolated system

- The *total momentum* of a system of particles is the vector sum of the momenta of the individual particles.
- No *external forces* act on the *isolated system* consisting of the two astronauts shown below, so the total momentum of this system is conserved.



Conservation of momentum

- External forces (the normal force and gravity) act on the skaters shown in Figure 8.9 at the right, but their vector sum is zero. Therefore the total momentum of the skaters is conserved.
- *Conservation of momentum*: If the vector sum of the external forces on a system is zero, the total momentum of the system is constant.



Which of these systems are isolated?

A. While slipping on a patch of ice, a car collides totally inelastically with another car. **System: both cars**
B. Same situation as in A. **System: slipping car**
C. A single car slips on a patch of ice. **System: car**
D. A car makes an emergency stop on a road. **System: car**
E. A ball drops to Earth. **System: ball**
F. A billiard ball collides elastically with another billiard ball on a pool table. **System: both balls**

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Recoil of a rifle

- In Example 8.4, a rifle fires a bullet, causing the rifle to recoil.