Chap 6 Conservation of Linear Momentum

Linear Momentum:

The momentum of an object is the product of that object's mass and velocity.

$$p = m \times v$$

Momentum is a vector quantity.
When adding or subtracting momenta, follow rules for vector addition.

4. A 20-metric-ton train moves south at 50 m/s.

a. At what speed must it travel to have twice its original momentum?

b. At what speed must it travel to have a momentum of 500,000 kg-m/s?

c. If there were a speed limit for this train as it traveled through a city, but not a weight limit, what mass in kilograms must be added to the train to slow it down to 20 m/s, while at the same time keeping the momentum the same as in part b?

Momentum and Newton's Laws

Newton's 2nd Law:

$$F = m \times a$$

Plug in definition for acceleration:

$$F = m\frac{\Delta v}{\Delta t}$$

Δ : "change in"

$$m\,\Delta v = \Delta(mv)$$

$$F = \frac{\Delta(mv)}{\Delta t}$$

Total force equals the rate of change in linear momentum!

We are used to constant mass for any object. However, mass may change!

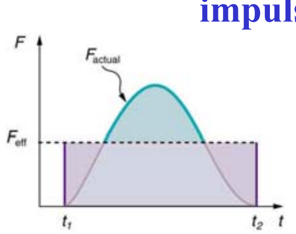
Impulse

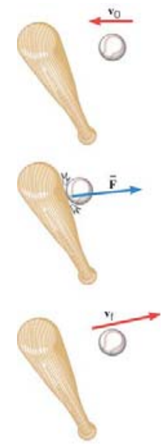
$$F = \frac{\Delta(mv)}{\Delta t}$$

$$\Delta(mv) = F \times \Delta t$$

impulse

The change in momentum is equal to the product of the net external force and the time during which it acts.





Impulse = change in momentum

$$\Delta(mv) = F \times \Delta t$$

Impulse = change in momentum

This may be thought of as an alternative statement of Newton's Second Law

5. A. Calculate the impulse imparted to the object in the following collisions.

a. A 0.5-kg hockey puck moving at 35 m/s hits a straw bale, stopping in 1 second.

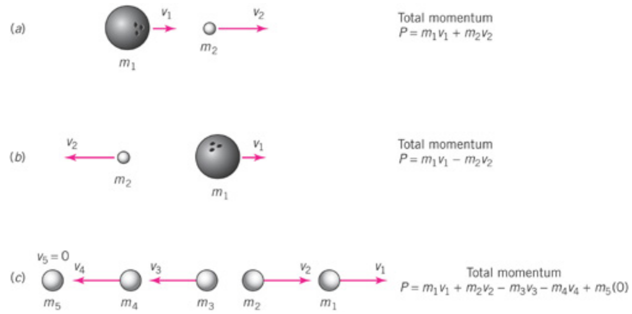
b. A T-ball with a mass of 0.2 kg travels in the air at 15 m/s until it is stopped in the glove of a shortstop over a period of 0.1 seconds.

c. A 12,000-kg tank moving at 4 m/s is brought to a halt in 2 seconds by a reinforced-steel tank barrier.

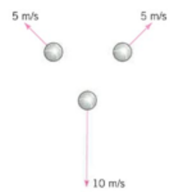
B. What is the average net force exerted by these object on the objects they collide with?

C. Which is more important in determining the amount o damage an object sustains in a collision: the total mo mentum change (impulse) or the momentum chang per unit time? Is the total area over which this force i applied important in determining how much damag is done?

Adding Momenta



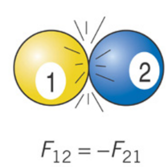
7. What is the direction of the total momentum of the system of identical tennis balls shown in the figure? Explain your answer.



Internal Forces

$$F_{12} = -F_{21}$$

F_{12} : internal force the first ball exerts on the second, and vice versa.



$$\Delta(mv_1) = F_{21}\Delta t$$

$$\Delta(mv_2) = F_{12}\Delta t$$

$$\Delta(mv_1 + mv_2) = (F_{21} + F_{12}) \cdot \Delta t = 0$$

Results always hold, no matter how many balls, or internal forces, are in the system.

Law of Conservation of Momentum

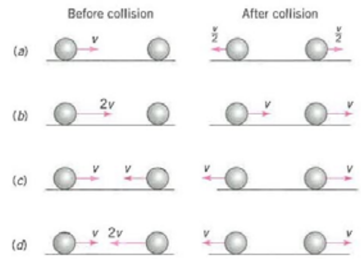
In the absence of external forces the change in the total momentum of a system is zero. (The momentum of an isolated system cannot change.)

$$\Delta P = 0$$

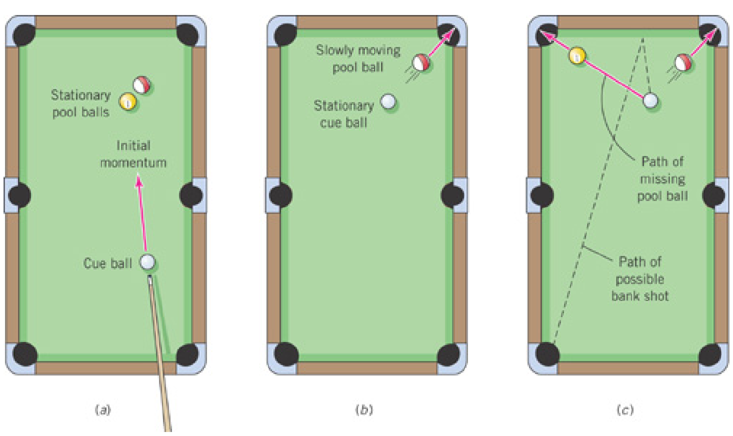
Initial momentum =Final momentum

$$P_i = P_f$$

9. Which of the collisions in the figure are possible and which are impossible? The objects have identical masses. (*Hint:* Which collisions violate conservation of momentum?)

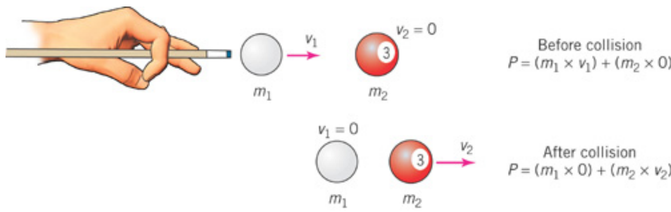


Conservation of Momentum



Which pocket is the missing ball in?

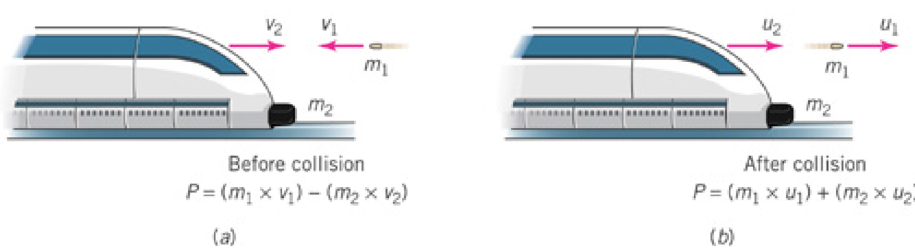
Collison of Two Objects



$$(m_1 \times v_1) + (m_2 \times 0) = (m_1 \times 0) + (m_2 \times v_2)$$

$$v_2 = \left(\frac{m_1}{m_2}\right) v_1$$

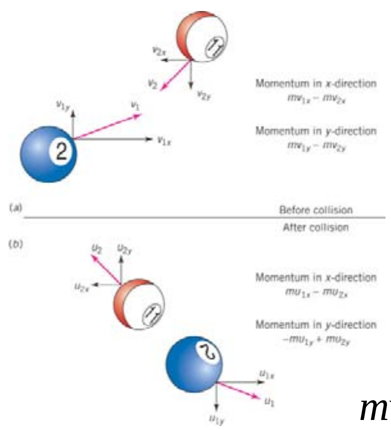
Momentum Transfer



$$P = (m_1 \times v_1) - (m_2 \times v_2)$$ **before collision**

$$P = (m_1 \times u_1) + (m_2 \times u_2)$$ **after collision**

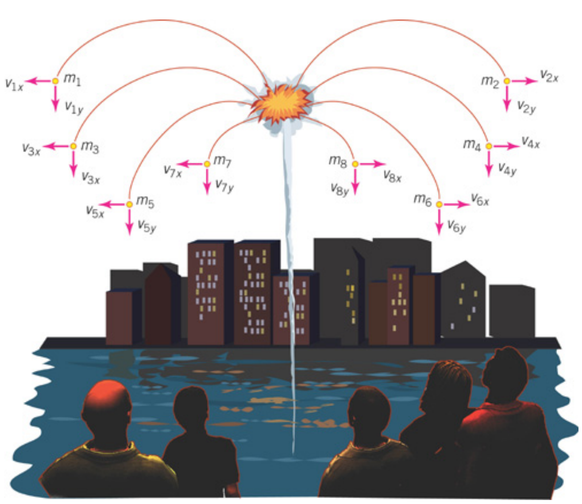
Two Dimensional Collisions



$$mv_{1x} - mv_{2x} = mu_{1x} - mu_{2x}$$

$$mv_{1y} - mv_{2y} = mu_{1y} - mu_{2y}$$

Collisions : External Force



Example Problems

7. In Problem 6 in Chapter 4, you were asked to solve the following problem using the knowledge of Newton's laws that you had accumulated up to that point.

Margie (45 kg) and Bill (65 kg), both with brand new roller blades, are at rest facing each other in the parking lot. They push off each other and move in opposite directions, Margie moving at a constant speed of 14 ft/s. At what speed is Bill moving?

a. Use what you have now learned about momentum to answer this problem in a different way.

b. Which method was easier for you to use to solve this problem, the Chapter 4 method or this one? How do the approaches compare? Are they really that different? Explain.

6. A racing car with a mass of 1400 kg hits a slick spot and crashes head-on into a concrete wall at 90 km/hour, coming to a halt in 0.8 s. An ambulance weighing 3000 kg comes racing to the rescue, hits the same slick spot, and then collides with a padded part of the wall at 80 km/hr, coming to a halt in 2 seconds.

a. What is the impulse exerted on each vehicle?

b. What was the force exerted by each vehicle on the wall? What was the force exerted by the wall on each of the vehicles?

c. What was the deceleration of each vehicle, from the time it contacted the wall to the time it completely stopped?