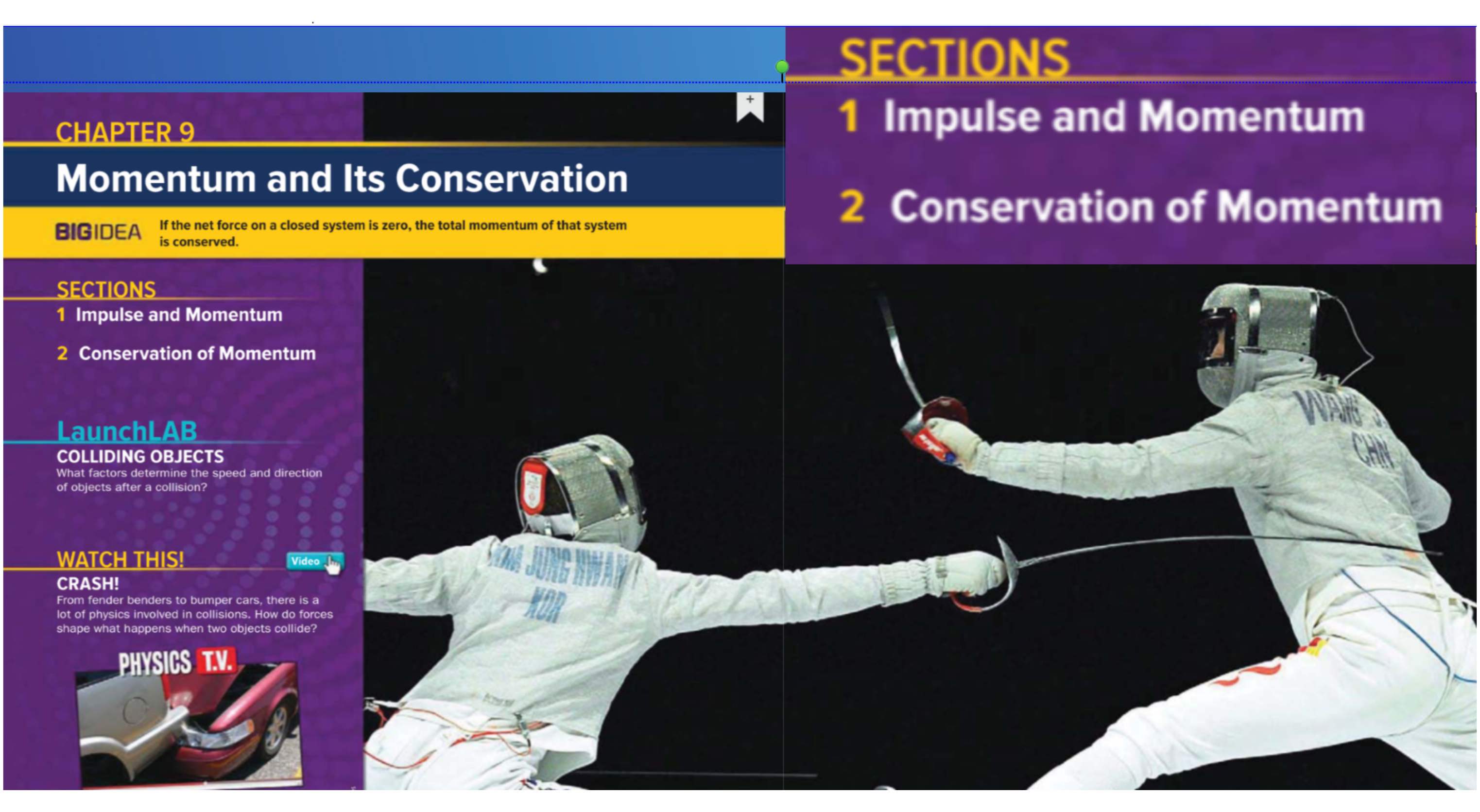
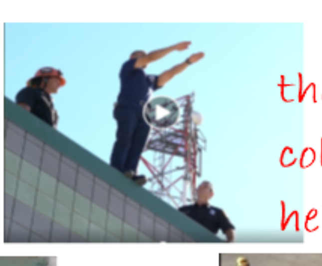
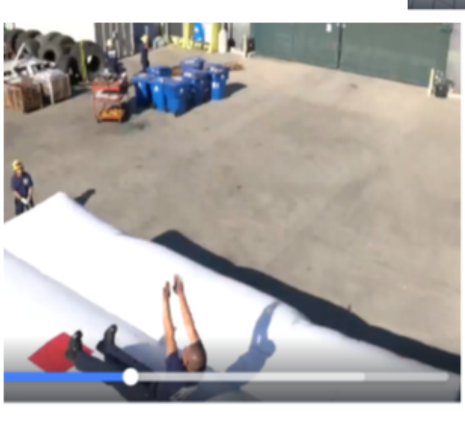
Impulse and Momentum

12/05/23 8:29 am





the speed before the collision depends on the height, it is constant



$$F \cdot \Delta t = m \cdot (\overset{zero}{\cancel{v}} - v_0) = -m \cdot v_0$$

$$F \cdot \Delta t = constant$$

If the collision's time increases the impact force decreases

Kinematics

$$v_x = v_{x0} + a_x t$$
$$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$$
$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

Newton

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$$
$$|\vec{F}_f| \leq \mu |\vec{F}_n| \qquad |\vec{F}_s| = k|\vec{x}| \qquad \vec{g} = \frac{\vec{F}_g}{m}$$

Work and Energy

$$\Delta E = W = F_{\parallel} d = Fd\cos\theta$$
$$P = \frac{\Delta E}{\Delta t}$$
$$K = \frac{1}{2} m v^2$$
$$\Delta U_g = mg\Delta y$$
$$U_s = \frac{1}{2} k x^2$$

Impulse and Linear Momentum

$$\vec{p} = m\vec{v}$$
$$\Delta \vec{p} = \vec{F}\,\Delta t$$

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m} \text{ (external force)}$$

$$F_{ext} = m \cdot a = m \cdot \frac{\Delta v}{\Delta t}$$

$$v_x = v_{x0} + a_x t$$

$$F_{ext} \cdot \Delta t = m(v - v_0)$$

$$\frac{v - v_0}{t} = a$$

$$F \cdot \Delta t = mv - mv_0$$

$$\boxed{P = mv}$$

$$F \cdot \Delta t = P - P_0$$

$$F \cdot \Delta t = \Delta P$$

Impulse (J) = change of Linear

J: Impulse (not Joules)

$$\boxed{J = \Delta P}$$

$$[J] = [F][\Delta t] = N \cdot s$$

(units

same units

$$[P] = [m] \cdot [v] = Kg \cdot \frac{m}{s}$$

IMPULSE-MOMENTUM THEOREM

An impulse acting on an object is equal to the object's final momentum minus the object's initial momentum.

$$F\Delta t = p_f - p_i$$

PRACTICE PROBLEMS Do additional problems. Online Practice

1. A compact car, with mass 725 kg, is moving at 115 km/h toward the east. Sketch the moving car.
   a. Find the magnitude and direction of its momentum. Draw an arrow on your sketch showing the momentum.
   b. A second car, with a mass of 2175 kg, has the same momentum. What is its velocity?
2. The driver of the compact car in the previous problem suddenly applies the brakes hard for 2.0 s. As a result, an average force of 5.0×10^3 N is exerted on the car to slow it down.
   a. What is the change in momentum, or equivalently, what is the magnitude and direction of the impulse on the car?
   b. Complete the "before" and "after" sketches, and determine the momentum and the velocity of the car now.
3. A 7.0-kg object, moving at 2.0 m/s, receives two impulses (one after the other) along the direction of its motion. Both of these impulses are illustrated in **Figure 2.** Find the resulting speed and direction of motion of the object after each impulse.
4. The driver accelerates a 240.0-kg snowmobile, which results in a force being exerted that speeds up the snowmobile from 6.00 m/s to 28.0 m/s over a time interval of 60.0 s.
   a. Sketch the event, showing the initial and final situations.
   b. What is the snowmobile's change in momentum? What is the impulse on the snowmobile?
   c. What is the magnitude of the average force that is exerted on the snowmobile?
5. **CHALLENGE** Suppose a 60.0-kg person was in the vehicle that hit the concrete wall in Example Problem 1. The velocity of the person equals that of the car both before and after the crash, and the velocity changes in 0.20 s. Sketch the problem.
   a. What is the average force exerted on the person?
   b. Some people think they can stop their bodies from lurching forward in a vehicle that is suddenly braking by putting their hands on the dashboard. Find the mass of an object that has a weight equal to the force you just calculated. Could you lift such a mass? Are you strong enough to stop your body with your arms?

Figure 2

PRACTICE PROBLEMS

1. A compact car, with mass 725 kg, is moving at 115 km/h toward the east. Sketch the moving car.
   a. Find the magnitude and direction of its momentum. Draw an arrow on your sketch showing the momentum.
   b. A second car, with a mass of 2175 kg, has the same momentum. What is its velocity?

$\vec{P}_0$ (East)

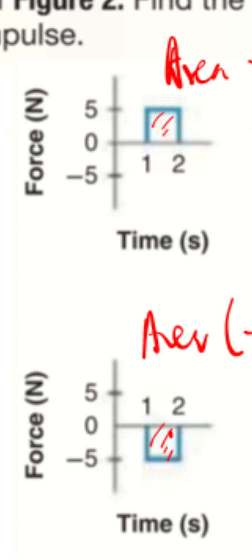
a) $P = m \cdot v = 725 Kg \cdot 31.9 \frac{m}{s}$

$P = 23200 \; Kg \cdot \frac{m}{s}$

$$v = 115 \frac{Km}{h} \times \frac{1000 m}{1 Km} \times \frac{1 h}{3600 s} = 31.9 \frac{m}{s}$$

$$b) \; v = \frac{P}{m} = \frac{23200 \cancel{Kg} \, m/s}{2175 \cancel{Kg}} = 10.65 \frac{m}{s}$$

3. A 7.0-kg object, moving at 2.0 m/s, receives two impulses (one after the other) along the direction of its motion. Both of these impulses are illustrated in **Figure 2.** Find the resulting speed and direction of motion of the object after each impulse.



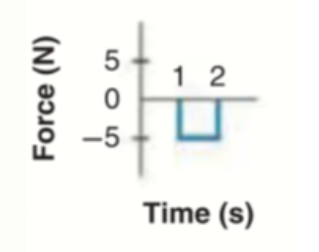


Figure 2

$$F \cdot \Delta t = \Delta P = P - P_0$$
$$5 - 5 = m \cdot v - m v_0$$
$$0 = 7 \cdot v - 7 \times 2$$
$$14 = 7 \cdot v$$
$$\frac{14}{7} = v = 2 \frac{m}{s}$$

13. **Impulse and Momentum** A 0.174-kg softball is pitched horizontally at 26.0 m/s. The ball moves in the opposite direction at 38.0 m/s after it is hit by the bat.
   a. Draw arrows showing the ball's momentum before and after the bat hits it.
   b. What is the change in momentum of the ball?
   c. What is the impulse delivered by the bat?
   d. If the bat and ball are in contact for 0.80 ms, what is the average force the bat exerts on the ball?

$$t = 0.8 ms \times \frac{10^{-3} s}{1 ms}$$
$$t = 8 \times 10^{-4} s$$

$$P_0 = m \cdot v_0 = 0.174 \times 26$$
$$P_0 = 4.5 \; Kg \frac{m}{s}$$

$$P = m \cdot v$$
$$P = 0.174 \times 38$$
$$P = -6.6 \; Kg \frac{m}{s}$$

$$b) \; \Delta P = P - P_0 = -6.6 - 4.5 = -11.1 \; Kg \frac{m}{s}$$

$$c) \; \vec{F} \cdot \Delta t = \Delta \vec{P}$$
$$\vec{J} = \Delta \vec{P} = -11.1 \; Kg \frac{m}{s}$$

impulse

$$d) \; F \cdot \Delta t = \Delta P$$
$$F = \frac{-11.1}{8 \times 10^{-4}} = 13{,}875 \; N$$