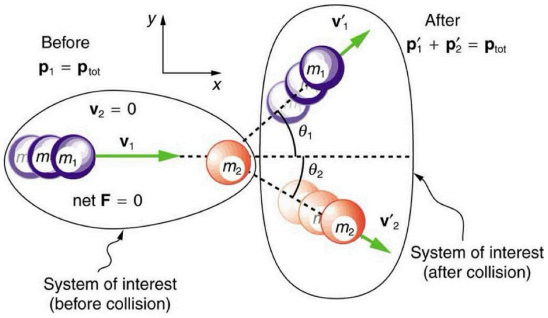
KEY Momentum Pt 2

Recap

Collision of 2 Point masses



Conservation of momentum

$p_{1x} + p_{2x} = p'_{1x} + p'_{2x}$ and $p_{1y} + p_{2y} = p'_{1y} + p'_{2y}$

Conceptual questions

An object that has a small mass and an object that has a large mass have the same momentum. Which object has the largest kinetic energy?

The small object

An object that has a small mass and an object that has a large mass have the same kinetic energy. Which mass has the largest momentum?

Larger object

How can a small force impart the same momentum to an object as a large force?

This can be done by acting over a longer period of time. This is because momentum is the product of mass and velocity, and velocity is the change in position over time.

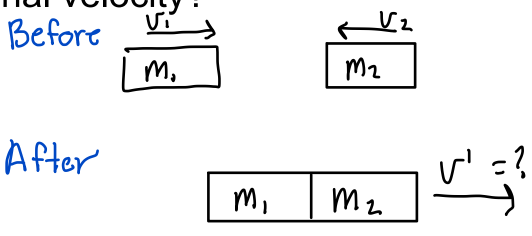
Under what circumstances is momentum conserved?

When there is no net external force

Practice Problems

Train cars are coupled together by being bumped into one another. Suppose two loaded train cars are moving toward one another, the first having a mass of 150,000 kg and a velocity of 0.300 m/s, and the second having a mass of 110,000 kg and a velocity of -0.120 m/s. (The minus indicates direction of motion.) What is their final velocity?

Video on how to solve



Totally inelastic

$m_1 = 150{,}000\,kg$
$m_2 = 110{,}000\,kg$
$v_1 = 0.300\,m/s$
$v_2 = -0.120\,m/s$
$p_1 + p_2 - p_{12}$

$$\frac{m_1 v_1 + m_2 v_2}{(m_1 + m_2)} = \frac{(m_1 + m_2) v'}{(m_1 + m_2)}$$

$+ .122\,m/s = v'$

A 70.0-kg ice hockey goalie, originally at rest, catches a 0.150-kg hockey puck slapped at him at a velocity of 35.0 m/s. Suppose the goalie and the ice puck have an elastic collision and the puck is reflected back in the direction from which it came. What would their final velocities be in this case? **Video on how to solve**

Goali: $m_1 = 70.0\,kg$ $\quad v_{i1} = 0\,m/s$
Puck: $m_2 = .150\,kg$ $\quad v_{i2} = {}^{-}35.0\,m/s$

$p_b = p_a$

$\overset{0}{\cancel{m_1 v_{1b}}} + m_2 v_{2b} = m_1 v_{1a} + m_2 v_{2a}$

$m_2 v_{2b} = m_1 v_{1a} + m_2 (v_{1a} - v_{2b})$

$m_2 v_{2b} = m_1 v_{1a} + m_2 v_{1a} - m_2 v_{2b}$

$2(m_2 v_{2b}) = v_{1a}(m_1 + m_2)$

$$v_{1a} = \frac{2 m_2 v_{2b}}{m_1 + m_2} = \frac{2 \cdot .150 \cdot {}^{-}35}{70 + .150} = -.150\,m/s$$

$v_{1b} - v_{2b} = v_{2a} - v_{1a}$
$v_{2a} = v_{1a} + \cancel{v_{1b}}^{0} - v_{2b}$
$v_{2a} = v_{1a} - v_{2b}$
$v_{2a} = -.150 - {}^{-}35$
$v_{2a} = 34.9\,m/s$

A 0.240-kg billiard ball that is moving at 3.00 m/s strikes the bumper of a pool table and bounces straight back at 2.40 m/s (80% of its original speed). The collision lasts 0.0150 s. **Video on how to solve**

$m = .240kg$ $v_0 = 3.00 \, m/s$ $v_f = -2.40 \, m/s$ $t = .0150s$

(a) Calculate the average force exerted on the ball by the bumper.

ⓐ $\Delta p = F_{net} \longrightarrow m(v_f - v_0) = F_{net} t \rightarrow$

$$F_{net} = \frac{(m(v_f - v_0))}{t} = \frac{.240 \cdot (-2.40 - 3)}{.015} = -86.4N$$

(b) How much kinetic energy in joules is lost during the collision?

ⓑ $\Delta KE = KE_i - KE_f = \frac{1}{2} \cdot m v_i^2 - \frac{1}{2} m v_f^2 = \frac{1}{2} \cdot .240 \cdot 3^2 - \frac{1}{2} \cdot .240 \cdot -2.40^2 = .389$

(c) What percent of the original energy is left?

ⓒ $\frac{KE_f}{KE_i} \times 100$

$\frac{.6912}{1.08} \times 100\%$

64% left

A 0.0250-kg bullet is accelerated from rest to a speed of 550 m/s in a 3.00-kg rifle. The pain of the rifle's kick is much worse if you hold the gun loosely a few centimeters from your shoulder rather than holding it tightly against your shoulder. **Video on how to solve**

$m_b = .0250\text{Kg}$ $v_{fb} = 550\,\text{m/s}$ $m_R = 3\text{Kg}$ $v_0 = 0\,\text{m/s}$

(a) Calculate the recoil velocity of the rifle if it is held loosely away from the shoulder.

$$\cancelto{0}{\vec{P}_T} = \vec{P}_R + \vec{P}_B$$

$$0 = m_R \boxed{v_R} + m_b v_b$$

$$-m_b v_b \qquad\qquad -m_b v_b$$

$$\frac{-m_b v_b = m_R v_R}{m_R}$$

$$v_R = \frac{-m_b v_b}{m_R} = \frac{.0250\,\text{kg} \cdot 550\,\text{m/s}}{3\,\text{kg}} \approx -4.58\,\text{m/s}$$

(b) How much kinetic energy does the rifle gain?

$$KE = \frac{1}{2} m v^2 \qquad KE_r = \frac{1}{2}\ 3\text{kg} \cdot (-4.58\,\text{m/s})^2$$

$$KE_r \approx 31.5\,\text{J}$$

(c) What is the recoil velocity if the rifle is held tightly against the shoulder, making the effective mass 28.0 kg? $m_{s+R} = 28\text{kg}$

$$v_{s+R} = \frac{m_b + v_b}{m_{s+R}} = \frac{.025\text{Kg} \cdot 550\,\text{m/s}}{28\,\text{kg}} = -.491\,\text{m/s}$$

(d) How much kinetic energy is transferred to the rifle-shoulder combination? The pain is related to the amount of kinetic energy, which is significantly less in this latter situation.

$$KE_{R+S} = \frac{1}{2} m v^2 = \frac{1}{2} \cdot 28\text{Kg} \cdot (-.491\,\text{m/s})^2 \approx 3.38\,\text{J}$$

What is the speed of a garbage truck that is 1.20 × 104 kg and is initially moving at 25.0 m/s just after it hits and adheres to a trash can that is 80.0 kg and is initially at rest? **Video on how to solve**

$v_f = ?$ $m_1 = 1.2\times10^4\,\text{kg}$ $v_{o1} = 25.0\,\text{m/s}$ $m_2 = 80.0\,\text{kg}$ $v_{o2} = 0$

$$P_1 + P_2 = P_T$$

$$m_1 \cdot v_{o1} + \cancelto{0}{m_2 \cdot v_{o2}} = (m_1 + m_2) v_f$$

$$v_f = \frac{m_1 \cdot v_{o1}}{m_1 + m_2} = \frac{12000 \cdot 25)}{(12000+80)} = 24.8\,\text{m/s}$$