1. A volleyball is spiked so that its incoming velocity of 4.0 m/s is changed to an outgoing velocity of 21 m/s. The mass of the volleyball is 0.35 kg. What impulse does the player apply to the ball?

\[ \boxed{F_{\text{Impulse}} = m(v_f - v_i)} \]

where
\[ m = 0.35 \text{ kg} \]
\[ v_i = -4.0 \text{ m/s} \]
\[ v_f = 21 \text{ m/s} \]

\[ F_{\text{Impulse}} = (0.35 \text{ kg})[-21 \text{ m/s} - (+4.0 \text{ m/s})] = -8.7 \text{ kg} \cdot \text{m/s} \]

The minus sign indicates that the direction of the impulse is the same as that of the final velocity of the ball.

2. A baseball (0.149 g) approaches a bat horizontally at a speed of 40.2 m/s (90 mi/h) and is hit straight back at a speed of 45.6 m/s (102 mi/h). If the ball is in contact with the bat for a time of 1.10 ms, what is the average force exerted on the ball by the bat? Neglect the weight of the ball, since it is so much less than the force of the bat. Choose the direction of the incoming ball as the positive direction.

\[ F = \frac{\Delta p}{t} \]

where
\[ m = 0.149 \text{ kg} \]
\[ v_i = 40.2 \text{ m/s} \]
\[ v_f = -45.6 \text{ m/s} \]
\[ t = 1.10 \times 10^{-3} \text{ s} \]

\[ F = \frac{(0.149 \text{ kg})(-45.6 \text{ m/s}) - (0.149 \text{ kg})(+40.2 \text{ m/s})}{1.10 \times 10^{-3} \text{ s}} = -11600 \text{ N} \]

where the positive direction for the velocity has been chosen as the direction of the incoming ball.

3. In a football game, a receiver is standing still, having just caught a pass. Before he can move, a tackler, running at a velocity of 4.5 m/s, grabs him. The tackler holds onto the receiver, and the two move off together with a velocity of 2.6 m/s. The mass of the tackler is 115 kg. Assuming that momentum is conserved, find the mass of the receiver.

The collision is an inelastic one, with the total linear momentum being conserved:

\[ P_{\text{before}} = P_{\text{after}} \]

\[ m_1 v_1 + m_2 v_2 = (m_1 + m_2) V \]

Before the collision, \( v_2 = 0 \). The mass \( m_2 \) of the receiver is

\[ m_2 = \frac{m_1 v_1}{V} - m_1 = \frac{(115 \text{ kg})(4.5 \text{ m/s})}{2.6 \text{ m/s}} - 115 \text{ kg} = 84 \text{ kg} \]
4. After sliding down a snow-covered hill on an inner tube, Ashley is coasting across a level snowfield at a constant velocity of +2.7 m/s. Miranda runs after her at a velocity of +4.5 m/s and hops on the inner tube. How fast do the two of them slide across the snow together on the inner tube? Ashley’s mass is 71 kg and Miranda’s is 58 kg. Ignore the mass of the inner tube and any friction between the inner tube and the snow.

The total momentum of the system is, therefore, conserved when Miranda hops onto the tube. We are ignoring the mass and momentum of the inner tube.

\[ P_{after} = P_{before} \]

\[ \frac{m_1 v_{f1} + m_2 v_{f2}}{Total \ momentum \ after \ Miranda \ hops \ on} = \frac{m_1 v_{01} + m_2 v_{02}}{Total \ momentum \ before \ Miranda \ hops \ on} \] or \[ v_{f1} = \frac{m_1 v_{01} + m_2 v_{02}}{m_1 + m_2} \]

Their common velocity after Miranda hops on is, therefore,

\[ v_{f1} = \frac{m_1 v_{01} + m_2 v_{02}}{m_1 + m_2} = \frac{(71 \ kg)(+2.7 \ m/s) + (58 \ kg)(+4.5 \ m/s)}{71 \ kg + 58 \ kg} = +3.5 \ m/s \]

The common speed is the magnitude of this value or \[ +3.5 \ m/s. \]

5. Batman (91 kg) jumps straight down from a bridge into a boat (510 kg) in which a criminal is fleeing. The velocity of the boat is initially 11 m/s. What is the velocity of the boat after Batman lands in it?

When Batman collides with the boat, the horizontal component of his velocity is zero, so the statement of conservation of linear momentum in the horizontal direction can be written as

\[ P_{after} = P_{before} \]

\[ \frac{(m_1 + m_2)v_f}{Total \ horizontal \ momentum \ after \ collision} = \frac{m_1 v_{01} + 0}{Total \ horizontal \ momentum \ before \ collision} \]

Here, \( m_1 \) is the mass of the boat, and \( m_2 \) is the mass of Batman. This expression can be solved for \( v_f \), the velocity of the boat after Batman lands in it. Solving for \( v_f \) gives

\[ v_f = \frac{m_1 v_{01}}{m_1 + m_2} = \frac{(510 \ kg)(+11 \ m/s)}{510 \ kg + 91 \ kg} = +9.3 \ m/s \]

The plus sign indicates that the boat continues to move in its initial direction of motion.
6. A car (1100 kg) is traveling at 32 m/s when it collides head-on with a sport utility vehicle (2500 kg) traveling in the opposite direction. In the collision, the two vehicles come to a halt. At what speed was the sport utility vehicle traveling?

Assuming that friction and other resistive forces can be ignored, we will treat the two-vehicle system as an isolated system and apply the principle of conservation of linear momentum. Using \( v_{0, \text{car}} \) and \( v_{0, \text{SUV}} \) to denote the velocities of the vehicles before the collision and applying the principle of conservation of linear momentum, we have

\[
P_{\text{after}} = P_{\text{before}}
\]

\[
\begin{align*}
0 &= m_{\text{car}} v_{0, \text{car}} + m_{\text{SUV}} v_{0, \text{SUV}} \\
&= \text{Total momentum after collision} + \text{Total momentum before collision}
\end{align*}
\]

Note that the total momentum of both vehicles after the collision is zero, because the collision brings each vehicle to a halt. Solving this result for \( v_{0, \text{SUV}} \) and taking the direction in which the car moves as the positive direction gives

\[
v_{0, \text{SUV}} = \frac{-m_{\text{car}} v_{0, \text{car}}}{m_{\text{SUV}}} = \frac{-1100 \text{ kg})(32 \text{ m/s})}{2500 \text{ kg}} = -14 \text{ m/s}
\]

This result is negative, since the velocity of the sport utility vehicle is opposite to that of the car, which has been chosen to be positive. The speed of the sport utility vehicle is the magnitude of \( v_{0, \text{SUV}} \) or \( 14 \text{ m/s} \).