1. The magnitude of the impulse is
\[ I = \Delta p = p_f - p_i = m(v_f - v_i) \]
or
\[ I = (0.450 \text{ kg})(12.8 \text{ m/s} - 3.20 \text{ m/s}) = 4.32 \text{ kg} \cdot \text{m/s} \]
making (b) the correct choice.

2. The impulse given to the ball is
\[ F_{av} = \frac{m(v_f - v_i)}{(\Delta t)} = \frac{(57.0 \times 10^{-3} \text{ kg})[+25.0 \text{ m/s} - (-21.0 \text{ m/s})]}{0.060 \text{ s}} = 43.7 \text{ kg} \cdot \text{m/s}^2 = 43.7 \text{ N} \]
and the correct choice is (c).

3. Assuming that the collision was head-on so that, after impact, the wreckage moves in original direction of the car's motion, conservation of momentum during the impact gives
\[ (m_c + m_t) v_f = m_c v_{oc} + m_t v_{ot} = m_c v + m_t (0) \]
or
\[ v_f = \left( \frac{m_c}{m_c + m_t} \right) v = \left( \frac{m}{m + 2m} \right) v = \frac{v}{3} \]
showing that (c) is the correct choice.

4. The mass in motion after the rice ball is added to the bowl is twice the original moving mass. Therefore, to conserve momentum, the speed of the (rice ball + bowl) after the event must be one half of the initial speed of the bowl (i.e., \( v_f = v_i / 2 \)). The final kinetic energy is then
\[ KE_f = \frac{1}{2} (m_{ball} + m_{bowl}) v_f^2 = \frac{1}{2} (2m_{bowl}) \left( \frac{v_i}{2} \right)^2 = \frac{1}{2} \left( \frac{1}{2} m_{bowl} v_i^2 \right) = \frac{E}{2} \]
and the correct choice is (c).

6. We choose the original direction of motion of the cart as the positive direction. Then, \( v_i = 6 \text{ m/s} \) and \( v_f = -2 \text{ m/s} \). The change in the momentum of the cart is
\[ \Delta p = m v_f - m v_i = m(v_f - v_i) = (5 \text{ kg})(-2 \text{ m/s} - 6 \text{ m/s}) = -40 \text{ kg} \cdot \text{m/s} \]
and choice (c) is the correct answer.
7. As in question 5 above, the requirements of conserving both momentum and kinetic energy in this one-dimensional, elastic collision are summarized by the equations

\[ m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f} \]  \[1\]

and

\[ v_{1i} - v_{2i} = -(v_{1f} - v_{2f}) \]  \[2\]

Choosing eastward as the positive direction, we have \( m_1 = 0.10 \text{ kg}, \ v_{1i} = +0.20 \text{ m/s}, \)
\( m_2 = 0.15 \text{ kg}, \) and \( v_{2i} = 0. \) The general equations then become

\[ (0.10 \text{ kg})(+0.20 \text{ m/s}) + (0.15 \text{ kg})(0) = (0.10 \text{ kg})v_{1f} + (0.15 \text{ kg})v_{2f} \]

or, after simplifying,

\[ v_{1f} + 1.50v_{2f} = 0.20 \text{ m/s} \]  \[1\]

and

\[ 0.20 \text{ m/s} - 0 = -v_{1f} + v_{2f} \quad \text{or} \quad v_{2f} = v_{1f} + 0.20 \text{ m/s} \]  \[2\]

Substitute the final version of [2] into the final version of [1] to obtain 
\( 2.50v_{1f} = -0.10 \text{ m/s} \)

yielding

\[ v_{1f} = -0.040 \text{ m/s} \quad \text{or} \quad v_{1f} = 0.040 \text{ m/s} \text{ westward} \]

This means that (d) the correct choice for this question.

9. With the kinetic energy written as \( KE = p^2/2m, \) we solve for the magnitude of the momentum as \( p = \sqrt{2m(KE)}. \) The ratio of the final momentum of the rocket to its initial momentum is then given by

\[ \frac{p_f}{p_i} = \sqrt{\frac{2m_f(KE)_f}{2m_i(KE)_i}} = \sqrt{\frac{m_f}{m_i}} \frac{(KE)_f}{(KE)_i} = \sqrt{\left(\frac{1}{2}\right)^8} = 2 \quad \text{or} \quad p_f = 2p_i \]

and the correct choice is (a).
12. Consider the sketches at the right. The leftmost sketch shows the rocket immediately after the engine is fired (while the rocket's velocity is still essentially zero). It has two forces acting on it, an upward thrust $F$ exerted by the burnt fuel being ejected from the engine, and a downward force of gravity. These forces produce the upward acceleration $a$ of the rocket according to Newton's second law:

$$\Sigma F_y = F - F_g = Ma$$

Since $F_g = Mg$, the thrust exerted on the rocket by the ejected fuel is

$$F = F_g + Ma = M(a + g)$$

The rightmost part of the sketch shows a quantity of burnt fuel that was initially at rest within the rocket, but a very short time $\Delta t$ later is moving downward at speed $v$. As this material is ejected, it exerts the upward thrust $F$ on the rocket. By Newton's third law, the rocket exerts a downward force of equal magnitude on this burnt fuel. This force imparts an impulse $I = F(\Delta t) = \Delta p = \Delta m(v - 0)$ to the ejected material. Thus, the rate the rocket is burning and ejecting fuel must be

$$\frac{\Delta m}{\Delta t} = \frac{F}{v - 0} = \frac{M(a + g)}{v} = \frac{(3.00 \times 10^5 \text{ kg})[(36.0 + 9.80) \text{ m/s}^2]}{4.50 \times 10^3 \text{ m/s}} = 3.05 \times 10^3 \text{ kg/s}$$

and we see that choice (a) is the correct response.

*Note: Failure to include the gravitational force in this analysis will lead some students to incorrectly select choice (b) as their answer.*

4. No. Only in a precise head-on collision with equal and opposite momentum can both objects end up at rest. Yes. In the second case, assuming equal masses for the two objects, if object 2, originally at rest, is struck head-on by object 1, object 2 will depart with the original velocity of object 1. Then object 1 is left at rest.

10. The resulting collision is intermediate between an elastic and a completely inelastic collision. Some energy of motion is transformed as the pieces buckle, crumple, and heat up during the collision. Also, a small amount is lost as sound. The most kinetic energy is lost in a head-on collision, so the expectation of damage to the passengers is greatest.

14. Its speed decreases as its mass increases. There are no external horizontal forces acting on the box, so its momentum cannot change as it moves along the horizontal surface. As the box slowly fills with water, its mass increases with time. Because the product $mv$ must be constant, and because $m$ is increasing, the speed of the box must decrease.
6.4  (a) Since the ball was thrown straight upward, it is at rest momentarily \((v = 0)\) at its maximum height. Therefore, \(p = 0\).

(b) The maximum height is found from \(v_y^2 = v_{0y}^2 + 2a_y(Δy)\) with \(v_y = 0\).

\[0 = v_{0y}^2 + 2(−g)(Δy)_{max}\]

Thus,

\[Δy_{max} = \frac{v_{0y}^2}{2g}\]

We need the velocity at \(Δy = (Δy)_{max}/2 = v_{0y}^2 / 4g\); thus \(v_y^2 = v_{0y}^2 + 2a_y(Δy)\) gives

\[v_y^2 = v_{0y}^2 + 2(−g)\left(\frac{v_{0y}^2}{4g}\right) = \frac{v_{0y}^2}{2}, \quad \text{or} \quad v_y = \frac{v_{0y}}{\sqrt{2}} = \frac{15 \text{ m/s}}{\sqrt{2}}\]

Therefore,

\[p = mv_y = \frac{(0.10 \text{ kg})(15 \text{ m/s})}{\sqrt{2}} = \frac{1.1 \text{ kg} \cdot \text{m/s}}{\text{upward}}\]

6.7  From problem 6.6, \(KE = p^2/2m\), and hence, \(p = \sqrt{2m(KE)}\). Thus,

\[m = \frac{p^2}{2 \cdot KE} = \frac{(25.0 \text{ kg} \cdot \text{m/s})^2}{2(275 \text{ J})} = 1.14 \text{ kg}\]

and

\[v = \frac{p}{m} = \frac{\sqrt{2m(KE)}}{m} = \frac{\sqrt{2(KE)}}{m} = \frac{\sqrt{2(275 \text{ J})}}{1.14 \text{ kg}} = 22.0 \text{ m/s}\]

6.11  The velocity of the ball just before impact is found from \(v_y^2 = v_{0y}^2 + 2a_yΔy\) as

\[v_1 = -\sqrt{v_{0y}^2 + 2a_yΔy} = -\sqrt{0 + 2(−9.80 \text{ m/s}^2)(−1.25 \text{ m})} = -4.95 \text{ m/s}\]

and the rebound velocity with which it leaves the floor is

\[v_2 = +\sqrt{v_y^2 - 2a_yΔy} = +\sqrt{0 - 2(−9.80 \text{ m/s}^2)(+0.960 \text{ m})} = +4.34 \text{ m/s}\]

The impulse given the ball by the floor is then

\[\bar{I} = \bar{F}Δt = Δ(m\bar{v}) = m(\bar{v}_2 - \bar{v}_1)\]

\[= (0.150 \text{ kg})[+4.34 \text{ m/s} - (-4.95 \text{ m/s})] = +1.39 \text{ N}⋅\text{s} = \boxed{1.39 \text{ N}⋅\text{s upward}}\]
6.14 \hspace{1cm} Choose toward the east as the positive direction.

(a) The impulse delivered to the ball as it is caught is

\[
\vec{I} = \Delta \vec{p} = m \vec{v}_f - m \vec{v}_i = 0 - (0.500 \text{ kg})(+15.0 \text{ m/s}) = -7.50 \text{ kg \cdot m/s}
\]

or

\[
\vec{I} = \boxed{7.50 \text{ kg \cdot m/s westward}}
\]

(b) The average force exerted by the ball on the receiver is the negative of the average force exerted by the receiver on the ball, or

\[
\left( \vec{F}_{av} \right)_{\text{receiver}} = -\left( \vec{F}_{av} \right)_{\text{ball}} = -\frac{\vec{I}}{\Delta t} = -\left( \frac{7.50 \text{ kg \cdot m/s}}{0.0200 \text{ s}} \right) = +375 \text{ N}
\]

\[
\left( \vec{F}_{av} \right)_{\text{receiver}} = \boxed{375 \text{ N eastward}}
\]

6.15 \hspace{1cm} (a) The impulse equals the area under the $F$ versus $t$ graph. This area is the sum of the area of the rectangle plus the area of the triangle. Thus,

\[
I = (2.0 \text{ N})(3.0 \text{ s}) + \frac{1}{2} (2.0 \text{ N})(2.0 \text{ s}) = \boxed{8.0 \text{ N \cdot s}}
\]

(b) \[
I = F_{av} (\Delta t) = \Delta p = m (v_f - v_i)
\]

\[
8.0 \text{ N \cdot s} = (1.5 \text{ kg}) v_f - 0, \quad \text{giving} \quad v_f = \boxed{5.3 \text{ m/s}}
\]

(c) \[
I = F_{av} (\Delta t) = \Delta p = m (v_f - v_i), \quad \text{so} \quad v_f = v_i + \frac{I}{m}
\]

\[
v_f = -2.0 \text{ m/s} + \frac{8.0 \text{ N \cdot s}}{1.5 \text{ kg}} = \boxed{3.3 \text{ m/s}}
\]
6.22  (a)  The mass of the rifle is

\[ m = \frac{w}{g} = \frac{30 \text{ N}}{9.80 \text{ m/s}^2} = \left( \frac{30}{9.8} \right) \text{ kg} \]

We choose the direction of the bullet’s motion to be negative. Then, conservation of momentum gives

\[ (m_{\text{rifle}}v_{\text{rifle}} + m_{\text{bullet}}v_{\text{bullet}})_i = (m_{\text{rifle}}v_{\text{rifle}} + m_{\text{bullet}}v_{\text{bullet}})_f \]

or

\[ \left[ (30/9.8) \text{ kg} \right] v_{\text{rifle}} + (5.0 \times 10^{-3} \text{ kg})(-300 \text{ m/s}) = 0 + 0 \]

and

\[ v_{\text{rifle}} = \frac{9.8(5.0 \times 10^{-3} \text{ kg})(300 \text{ m/s})}{30 \text{ kg}} = 0.49 \text{ m/s} \]

(b)  The mass of the man plus rifle is

\[ m = \frac{730 \text{ N}}{9.80 \text{ m/s}^2} = 74.5 \text{ kg} \]

We use the same approach as in (a), to find

\[ v = \left( \frac{5.0 \times 10^{-3} \text{ kg}}{74.5 \text{ kg}} \right)(300 \text{ m/s}) = 2.0 \times 10^{-2} \text{ m/s} \]

6.27  Consider the thrower first, with velocity after the throw of \( v_{\text{thrower}} \). Applying conservation of momentum yields

\[ (65.0 \text{ kg})v_{\text{thrower}} + (0.0450 \text{ kg})(30.0 \text{ m/s}) = (65.0 \text{ kg} + 0.0450 \text{ kg})(2.50 \text{ m/s}) \]

or \( v_{\text{thrower}} = 2.48 \text{ m/s} \).

Now, consider the (catcher + ball), with velocity of \( v_{\text{catcher}} \) after the catch. From momentum conservation,

\[ (60.0 \text{ kg} + 0.0450 \text{ kg})v_{\text{catcher}} = (0.0450 \text{ kg})(30.0 \text{ m/s}) + (60.0 \text{ kg})(0) \]

or

\[ v_{\text{catcher}} = 2.25 \times 10^{-2} \text{ m/s} \]