1. **Question 9.11** (a) The initial momentum of the system (Megan and Jason combined) is \( p_i = 0 \) kg \( \cdot \) m/s. By conservation of momentum, the final momentum must also be \( p_f = 0 \) kg \( \cdot \) m/s = \( p_{\text{Jason}} + p_{\text{Megan}} \). This implies that \( p_{\text{Jason}} = -p_{\text{Megan}} \), and so each has the same (but opposite) momentum. Impulse is a measure of the change in momentum, so the impulse must be the same for each (but opposite in direction).

Note that this is also a consequence of Newton’s 3rd Law. Jason and Megan push on each other with equal (but opposite) forces, \( F_{12} = -F_{21} \), and they do so for the same amount of time \( \Delta t \). So, the impulse if Jason on Megan is \( \Delta p_1 = F_{12} \Delta t \), and the impulse of Megan on Jason is \( \Delta p_2 = F_{21} \Delta t = -F_{12} \Delta t \). These are obviously equal (but opposite in direction).

(b) The velocities of each skater will depend on their mass, since \( v = \frac{p}{m} \). Jason has more mass than Megan, so his velocity will be smaller than Megan’s. Mathematically, we would write this as \( v_{\text{Jason}} = \frac{p_{\text{Jason}}}{m_{\text{Jason}}} < \frac{p_{\text{Megan}}}{m_{\text{Megan}}} = v_{\text{Megan}} \).

2. **Question 9.14** (a) Momentum is not conserved, because the ball is gaining speed! Also, there is a net force acting on the object (\( F_g \)), so there must be an impulse on the object (which means momentum changes).

(b) In the case of the Earth and ball system, momentum *is* conserved. It’s an inelastic collision, where the Earth has an equal but opposite momentum from the ball (but since it’s so massive, we don’t notice the change in velocity).

3. **Question 9.19** [D]. In curling (eh!), the rocks experience elastic collisions as they collide with one another. A stone sliding at \( v_i = 1 \) m/s with mass \( m = 20 \) kg has an initial momentum \( p_{1i} = 20 \) kg \( \cdot \) m/s. If it comes to rest in \( t = 0.002 \) s after striking the second rock, we know that its final momentum is \( p_{1f} = 0 \) kg \( \cdot \) m/s. The change in momentum is \( \Delta p = -20 \) kg \( \cdot \) m/s, and so from the impulse-momentum theorem the average force must be \( F = \frac{\Delta p}{\Delta t} = \frac{-20}{0.002} = 10000 \) N.

4. **Problem 9.2** The initial momentum of the tennis ball is \( p_i = 0 \) kg \( \cdot \) m/s, and the final momentum is \( p_f = mv_f = (0.057)(45) = 25.7 \) kg \( \cdot \) m/s. The impulse is, by definition, the change in momentum: \( \Delta p = p_f - p_i = 25.7 \) kg \( \cdot \) m/s.

5. **Problem 9.6** The falling stone is acted on by the force of gravity, \( F_g = mg \). The change in momentum is \( \Delta p = mv_f - mv_i \). The impulse-momentum theorem in this case states \( \Delta p = F_g \Delta t \), so substituting in these expressions gives

\[ mv_f - mv_i = mg \Delta t \implies \Delta t = \frac{v_f - v_i}{g} = \frac{10.4 - 5.5}{9.8} = 0.5 \text{ s} \]
6. **Problem 9.12** (a) The ball’s initial momentum is \( p_i = mv_i = (0.145)(15.0) = 2.18 \text{ kg} \cdot \text{m/s} \). After the batter hits the ball, it’s momentum is \( p_f = mv_f = (0.145)(-20.0) = 2.90 \text{ kg} \cdot \text{m/s} \), so the change in momentum is \( \Delta p = p_f - p_i = -5.08 \text{ kg} \cdot \text{m/s} \). This is the impulse – it’s directed in the opposite direction that the ball was originally traveling. The magnitude of the impulse is just \[ |\Delta p| = 5.08 \text{ kg} \cdot \text{m/s}. \]

(b) The magnitude of the average force exerted by the bat is calculated from the impulse-momentum theorem: \[
F = \frac{\Delta p}{\Delta t} = \frac{5.08}{0.0015} = 3387 \text{ N}.
\]