2. For a constant force, Eq. 9-2 can be written as $\Delta\vec{\mathbf{p}} = \vec{\mathbf{F}}\Delta t$. For a constant mass object, $\Delta\vec{\mathbf{p}} = m\Delta\vec{\mathbf{v}}$. Equate the two expressions for $\Delta\vec{\mathbf{p}}$.

$$\vec{\mathbf{F}}\Delta t = m\Delta\vec{\mathbf{v}} \quad \rightarrow \quad \Delta\vec{\mathbf{v}} = \frac{\vec{\mathbf{F}}\Delta t}{m}$$

If the skier moves to the right, then the speed will decrease, because the friction force is to the left.

$$\Delta v = -\frac{F\Delta t}{m} = -\frac{(25\,\mathrm{N})(15\,\mathrm{s})}{65\,\mathrm{kg}} = \boxed{-5.8\,\mathrm{m/s}}$$

The skier loses $5.8\,\mathrm{m/s}$ of speed.

13. The throwing of the package is a momentum-conserving action, if the water resistance is ignored. Let A represent the boat and child together, and let B represent the package. Choose the direction that the package is thrown as the positive direction. Apply conservation of momentum, with the initial velocity of both objects being 0.

$$p_{\text{initial}} = p_{\text{final}} \quad \rightarrow \quad (m_A + m_B)v = m_A v'_A + m_B v'_B \quad \rightarrow$$

$$v'_A = -\frac{m_B v'_B}{m_A} = -\frac{(5.70\,\mathrm{kg})(10.0\,\mathrm{m/s})}{(24.0\,\mathrm{kg} + 35.0\,\mathrm{kg})} = \boxed{-0.966\,\mathrm{m/s}}$$

The boat and child move in the opposite direction as the thrown package, as indicated by the negative velocity.

25. The impulse given the ball is the change in the ball's momentum. From the symmetry of the problem, the vertical momentum of the ball does not change, and so there is no vertical impulse. Call the direction AWAY from the wall the positive direction for momentum perpendicular to the wall.

$$\Delta p_{\perp} = mv_{\perp_{\text{final}}} - mv_{\perp_{\text{initial}}} = m\left(v\sin 45^{\circ} - -v\sin 45^{\circ}\right) = 2mv\sin 45^{\circ}$$

$$= 2\left(6.0\times10^{-2}\,\text{km}\right)\left(25\,\text{m/s}\right)\sin 45^{\circ} = \boxed{2.1\,\text{kg}\cdot\text{m/s, to the left}}$$

26. (*a*) The momentum of the astronaut–space capsule combination will be conserved since the only forces are "internal" to that system. Let A represent the astronaut and B represent the space capsule, and let the direction the astronaut moves be the positive direction. Due to the choice of reference frame, $v_A = v_B = 0$. We also have $v'_A = 2.50\,\text{m/s}$.

$$p_{\text{initial}} = p_{\text{final}} \rightarrow m_A v_A + m_B v_B = 0 = m_A v'_A + m_B v'_B \rightarrow$$

$$v'_B = -v'_A \frac{m_A}{m_B} = -\left(2.50\,\text{m/s}\right)\frac{130\text{ kg}}{1700\text{ kg}} = -0.1912\,\text{m/s} \approx \boxed{-0.19\,\text{m/s}}$$

The negative sign indicates that the space capsule is moving in the opposite direction to the astronaut.

(*b*) The average force on the astronaut is the astronaut's change in momentum, divided by the time of interaction.

$$F_{\text{avg}} = \frac{\Delta p}{\Delta t} = \frac{m\left(v'_A - v_A\right)}{\Delta t} = \frac{\left(130\text{ kg}\right)\left(2.50\,\text{m/s} - 0\right)}{0.500\text{ s}} = \boxed{6.5\times10^{2}\,\text{N}}$$

(*c*) $K_{\text{astronaut}} = \frac{1}{2}\left(130\,\text{kg}\right)\left(2.50\,\text{m/s}\right)^2 = \boxed{4.0\times10^{2}\,\text{J}}$

$K_{\text{capsule}} = \frac{1}{2}\left(1700\,\text{kg}\right)\left(-0.1912\,\text{m/s}\right)^2 = \boxed{31\,\text{J}}$

41. (*a*) At the maximum compression of the spring, the blocks will not be moving relative to each other, and so they both have the same forward speed. All of the interaction between the blocks is internal to the mass-spring system, and so momentum conservation can be used to find that common speed. Mechanical energy is also conserved, and so with that common speed, we can find the energy stored in the spring and then the compression of the spring. Let A represent the 3.0 kg block, let B represent the 4.5 kg block, and let x represent the amount of compression of the spring.

$$p_{\text{initial}} = p_{\text{final}} \rightarrow m_A v_A = (m_A + m_B) v' \rightarrow v' = \frac{m_A}{m_A + m_B} v_A$$

$$E_{\text{initial}} = E_{\text{final}} \rightarrow \tfrac{1}{2} m_A v_A^2 = \tfrac{1}{2}(m_A + m_B) v'^2 + \tfrac{1}{2} k x^2 \rightarrow$$

$$x = \sqrt{\frac{1}{k}\left[m_A v_A^2 - (m_A + m_B) v'^2\right]} = \sqrt{\frac{1}{k}\frac{m_A m_B}{m_A + m_B} v_A^2}$$

$$= \sqrt{\left(\frac{1}{850\,\text{N/m}}\right)\frac{(3.0\,\text{kg})(4.5\,\text{kg})}{(7.5\,\text{kg})}(8.0\,\text{m/s})^2} = \boxed{0.37\,\text{m}}$$

(*b*) This is a stationary target elastic collision in one dimension, and so the results of Example 9-8 may be used.

$$v_A' = v_A\left(\frac{m_A - m_B}{m_A + m_B}\right) = (8.0\,\text{m/s})\left(\frac{-1.5\,\text{kg}}{7.5\,\text{kg}}\right) = \boxed{-1.6\,\text{m/s}}$$

$$v_B' = v_A\left(\frac{2m_A}{m_A + m_B}\right) = (8.0\,\text{m/s})\left(\frac{6.0\,\text{kg}}{7.5\,\text{kg}}\right) = \boxed{6.4\,\text{m/s}}$$

(*c*) **Yes**, the collision is elastic. All forces involved in the collision are conservative forces.

50. The swinging motion will conserve mechanical energy. Take the zero level for gravitational potential energy to be at the bottom of the arc. For the pendulum to swing exactly to the top of the arc, the potential energy at the top of the arc must be equal to the kinetic energy at the bottom.

$$K_{\text{bottom}} = U_{\text{top}} \rightarrow \tfrac{1}{2}(m + M) V_{\text{bottom}}^2 = (m + M) g (2L) \rightarrow V_{\text{bottom}} = 2\sqrt{gL}$$

Momentum will be conserved in the totally inelastic collision at the bottom of the arc. We assume that the pendulum does not move during the collision process.

$$p_{\text{initial}} = p_{\text{final}} \rightarrow mv = (m + M) V_{\text{bottom}} \rightarrow v = \frac{m + M}{m} = \boxed{2\frac{m + M}{m}\sqrt{gL}}$$

100. (*a*) Use conservation of energy to find the speed of mass *m* before the collision. The potential energy at the starting point is all transformed into kinetic energy just before the collision.

$$mgh_A = \tfrac{1}{2}mv_A^2 \quad \rightarrow \quad v_A = \sqrt{2gh_A} = \sqrt{2\left(9.80\,\text{m/s}^2\right)(3.60\text{ m})} = 8.40\,\text{m/s}$$

Use Eq. 9-8 to obtain a relationship between the velocities, noting that $v_B = 0$.

$$v_A - v_B = v_B' - v_A' \quad \rightarrow \quad v_B' = v_A' + v_A$$

Apply momentum conservation for the collision, and substitute the result from Eq. 9-8.

$$mv_A = mv_A' + Mv_B' = mv_A' + M\left(v_A + v_A'\right) \quad \rightarrow$$

$$v_A' = \frac{m-M}{m+M}v_A = \left(\frac{2.20\text{ kg} - 7.00\text{ kg}}{9.20\text{ kg}}\right)(8.4\,\text{m/s}) = -4.38\,\text{m/s} \approx \boxed{-4.4\,\text{m/s}}$$

$$v_B' = v_A' + v_A = -4.4\,\text{m/s} + 8.4\,\text{m/s} = \boxed{4.0\,\text{m/s}}$$

(*b*) Again use energy conservation to find the height to which mass *m* rises after the collision. The kinetic energy of *m* immediately after the collision is all transformed into potential energy. Use the angle of the plane to change the final height into a distance along the incline.

$$\tfrac{1}{2}mv_A'^2 = mgh_A' \quad \rightarrow \quad h_A' = \frac{v_A'^2}{2g}$$

$$d_A' = \frac{h_A'}{\sin 30^\circ} = \frac{v_A'^2}{2g\sin 30^\circ} = \frac{(-4.38\,\text{m/s})^2}{2\left(9.8\,\text{m/s}^2\right)g\sin 30^\circ} = 1.96\text{ m} \approx \boxed{2.0\text{ m}}$$