20. (a) We choose $+x$ along the initial direction of motion and apply momentum conservation:

$$\begin{aligned} m_{\text{bullet}}\vec{v}_i &= m_{\text{bullet}}\vec{v}_1 + m_{\text{block}}\vec{v}_2 \\ (5.2\,\text{g})(672\,\text{m/s}) &= (5.2\,\text{g})(428\,\text{m/s}) + (700\,\text{g})\vec{v}_2 \end{aligned}$$

which yields $v_2 = 1.81$ m/s.

(b) It is a consequence of momentum conservation that the velocity of the center of mass is unchanged by the collision. We choose to evaluate it before the collision:

$$\vec{v}_{\text{com}} = \frac{m_{\text{bullet}}\vec{v}_i}{m_{\text{bullet}} + m_{\text{block}}} = \frac{(5.2\,\text{g})(672\,\text{m/s})}{5.2\,\text{g} + 700\,\text{g}}$$

which gives the result $\vec{v}_{\text{com}} = 4.96$ m/s.

34. We think of this as having two parts: the first is the collision itself – where the blocks "join" so quickly that the 1.0-kg block has not had time to move through any distance yet – and then the subsequent motion of the 3.0 kg system as it compresses the spring to the maximum amount x_m. The first part involves momentum conservation (with $+x$ rightward):

$$(2.0\,\text{kg})(4.0\,\text{m/s}) = (3.0\,\text{kg})\vec{v}$$

which yields $\vec{v} = 2.7$ m/s. The second part involves mechanical energy conservation:

$$\frac{1}{2}(3.0\,\text{kg})(2.7\,\text{m/s})^2 = \frac{1}{2}(200\,\text{N/m})x_m^2$$

which gives the result $x_m = 0.33$ m.

56. (a) Choosing upward as the positive direction, the momentum change of the foot is

$$\Delta\vec{p} = 0 - m_{\text{foot}}\,\vec{v}_i = -(0.003\,\text{kg})(-1.5\text{m/s})$$

which yields an impulse of 4.50×10^{-3} N·s.

(b) Using Eq. 10-8 and now treating *downward* as the positive direction, we have

$$\vec{J} = \vec{F}_{\text{avg}}\Delta t = m_{\text{lizard}}\,g\,\Delta t = (0.090)(9.8)(0.6)$$

which yields $\vec{J} = 0.529$ N·s.

(c) Considering the large difference between the answers for part (a) and part (b), we see that the slap cannot account for the support; we infer, then, that the push does the job.

62. In the momentum relationships, we could as easily work with weights as with masses, but because part (b) of this problem asks for kinetic energy – we will find the masses at the outset: $m_1 = 280 \times 10^3/9.8 = 2.86 \times 10^4$ kg and $m_2 = 210 \times 10^3/9.8 = 2.14 \times 10^4$ kg. Both cars are moving in the $+x$ direction: $v_{1i} = 1.52$ m/s and $v_{2i} = 0.914$ m/s.

(a) If the collision is completely elastic, momentum conservation leads to a final speed of

$$V = \frac{m_1 v_{1i} + m_2 v_{2i}}{m_1 + m_2} = 1.26 \text{ m/s} .$$

(b) We compute the total initial kinetic energy and subtract from it the final kinetic energy.

$$K_i - K_f = \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 - \frac{1}{2} (m_1 + m_2) V^2 = 2.25 \times 10^3 \text{ J} .$$

(c) and (d) Using Eq. 10-38 and Eq. 10-39, we find

$$\begin{aligned} v_{2\,f} &= \frac{2m_1}{m_1 + m_2} v_{1\,i} + \frac{m_2 - m_1}{m_1 + m_2} v_{2\,i} = 1.61 \text{ m/s} \quad \text{and} \\ v_{1\,f} &= \frac{m_1 - m_2}{m_1 + m_2} v_{1\,i} + \frac{2m_2}{m_1 + m_2} v_{2\,i} = 1.00 \text{ m/s} . \end{aligned}$$