25. We choose $+y$ upward, which means $\vec{v}_i = -25\,\text{m/s}$ and $\vec{v}_f = +10\,\text{m/s}$. During the collision, we make the reasonable approximation that the net force on the ball is equal to F_{avg}, the average force exerted by the floor up on the ball.

(a) Using the impulse momentum theorem (Eq. 9-31) we find

$$\vec{J} = m\vec{v}_f - m\vec{v}_i = (1.2)(10) - (1.2)(-25) = 42\ \text{kg}\cdot\text{m/s}.$$

(b) From Eq. 9-35, we obtain

$$\vec{F}_{\text{avg}} = \frac{\vec{J}}{\Delta t} = \frac{42}{0.020} = 2.1\times10^3\,\text{N}.$$

31. (a) By energy conservation, the speed of the passenger when the elevator hits the floor is

$$\frac{1}{2}mv^2 = mgh \quad \Rightarrow \quad v = \sqrt{2gh} = \sqrt{2(9.8\ \text{m/s}^2)(36\ \text{m})} = 26.6\ \text{m/s}.$$

Thus, the magnitude of the impulse is

$$J = |\Delta p| = m\,|\Delta v| = mv = (90\ \text{kg})(26.6\ \text{m/s}) \approx 2.39\times10^3\ \text{N}\cdot\text{s}.$$

(b) With duration of $\Delta t = 5.0\times10^{-3}\ \text{s}$ for the collision, the average force is

$$F_{\text{avg}} = \frac{J}{\Delta t} = \frac{2.39\times10^3\ \text{N}\cdot\text{s}}{5.0\times10^{-3}\ \text{s}} \approx 4.78\times10^5\ \text{N}.$$

(c) If the passenger were to jump upward with a speed of $v' = 7.0\ \text{m/s}$, then the resulting downward velocity would be

$$v'' = v - v' = 26.6\ \text{m/s} - 7.0\ \text{m/s} = 19.6\ \text{m/s},$$

and the magnitude of the impulse becomes

$$J'' = |\Delta p''| = m\,|\Delta v''| = mv'' = (90\ \text{kg})(19.6\ \text{m/s}) \approx 1.76\times10^3\ \text{N}\cdot\text{s}.$$

(d) The corresponding average force would be

$$F''_{\text{avg}} = \frac{J''}{\Delta t} = \frac{1.76\times10^3\ \text{N}\cdot\text{s}}{5.0\times10^{-3}\ \text{s}} \approx 3.52\times10^5\ \text{N}.$$

45. **THINK** The moving body is an isolated system with no external force acting on it. When it breaks up into three pieces, momentum remains conserved, both in the *x*- and the *y*-directions.

EXPRESS Our notation is as follows: the mass of the original body is M = 20.0 kg; its initial velocity is $\vec{v}_0 = (200\text{ m/s})\hat{\text{i}}$; the mass of one fragment is m_1 = 10.0 kg; its velocity is $\vec{v}_1 = (100\text{ m/s})\hat{\text{j}}$; the mass of the second fragment is m_2 = 4.0 kg; its velocity is $\vec{v}_2 = (-500\text{ m/s})\hat{\text{i}}$; and, the mass of the third fragment is m_3 = 6.00 kg. Conservation of linear momentum requires

$$M\vec{v}_0 = m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 .$$

The energy released in the explosion is equal to $\Delta K,$ the change in kinetic energy.

ANALYZE (a) The above momentum-conservation equation leads to

$$\begin{aligned}\vec{v}_3 &= \frac{M\vec{v}_0 - m_1\vec{v}_1 - m_2\vec{v}_2}{m_3} \\ &= \frac{(20.0\text{ kg})(200\text{ m/s})\hat{\text{i}} - (10.0\text{ kg})(100\text{ m/s})\hat{\text{j}} - (4.0\text{ kg})(-500\text{ m/s})\hat{\text{i}}}{6.00\text{ kg}} . \\ &= (1.00\times10^3\text{ m/s})\,\hat{\text{i}} - (0.167\times10^3\text{ m/s})\,\hat{\text{j}}\end{aligned}$$

The magnitude of $\vec{v}_3$ is $v_3 = \sqrt{(1000\text{ m/s})^2 + (-167\text{ m/s})^2} = 1.01\times10^3\text{ m/s}$. It points at $\theta = \tan^{-1}$ (–167/1000) = –9.48° (that is, at 9.5° measured clockwise from the +*x* axis).

(b) The energy released is ΔK:

$$\Delta K = K_f - K_i = \left(\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 + \frac{1}{2}m_3v_3^2\right) - \frac{1}{2}Mv_0^2 = 3.23\times10^6\text{ J}.$$

LEARN The energy released in the explosion, of chemical nature, is converted into the kinetic energy of the fragments.

52. We think of this as having two parts: the first is the collision itself – where the bullet passes through the block so quickly that the block has not had time to move through any distance yet – and then the subsequent "leap" of the block into the air (up to height *h* measured from its initial position). The first part involves momentum conservation (with +*y* upward):

$$(0.01\text{ kg})(1000\text{ m/s}) = (5.0\text{ kg})\vec{v} + (0.01\text{ kg})(400\text{ m/s})$$

which yields $\vec{v} = 1.2\ \text{m/s}$. The second part involves either the free-fall equations from Ch. 2 (since we are ignoring air friction) or simple energy conservation from Ch. 8. Choosing the latter approach, we have

$$\frac{1}{2}(5.0\ \text{kg})(1.2\ \text{m/s})^2 = (5.0\ \text{kg})\left(9.8\ \text{m/s}^2\right)h$$

which gives the result h = 0.073 m.

55. We choose $+x$ in the direction of (initial) motion of the blocks, which have masses m_1 = 5 kg and m_2 = 10 kg. Where units are not shown in the following, SI units are to be understood.

(a) Momentum conservation leads to

$$\begin{gathered} m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f} \\ (5\ \text{kg})(3.0\ \text{m/s}) + (10\ \text{kg})(2.0\ \text{m/s}) = (5\ \text{kg})\vec{v}_{1f} + (10\ \text{kg})(2.5\ \text{m/s}) \end{gathered}$$

which yields $\vec{v}_{1f} = 2.0\ \text{m/s}$. Thus, the speed of the 5.0 kg block immediately after the collision is $2.0\ \text{m/s}$.

(b) We find the reduction in total kinetic energy:

$$\begin{aligned} K_i - K_f &= \frac{1}{2}(5\ \text{kg})(3\ \text{m/s})^2 + \frac{1}{2}(10\ \text{kg})(2\ \text{m/s})^2 - \frac{1}{2}(5\ \text{kg})(2\ \text{m/s})^2 - \frac{1}{2}(10\ \text{kg})(2.5\ \text{m/s})^2 \\ &= -1.25\ \text{J} \approx -1.3\ \text{J}. \end{aligned}$$

(c) In this new scenario where $\vec{v}_{2f} = 4.0\ \text{m/s}$, momentum conservation leads to $\vec{v}_{1f} = -1.0\ \text{m/s}$ and we obtain $\Delta K = +40\ \text{J}$.

(d) The creation of additional kinetic energy is possible if, say, some gunpowder were on the surface where the impact occurred (initially stored chemical energy would then be contributing to the result).