**7.3**

Taking the initial direction of motion of the wad of clay (of mass $m$) as positive, then before its impact with the wall $v_i = +10\,\mathrm{m/s}$, and afterwards $v_f = 0$. The change in momentum for the clay is then

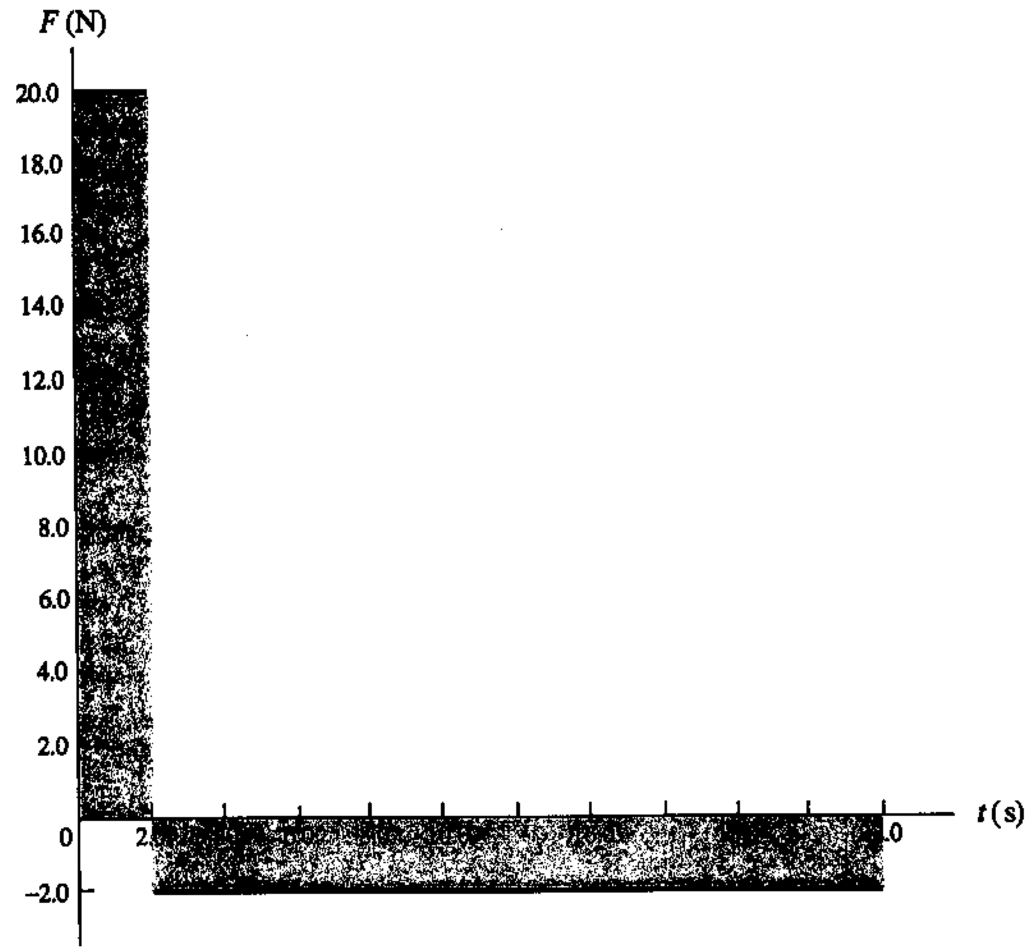
$$\Delta p = mv_f - mv_i = -(1.0\,\mathrm{kg})(10\,\mathrm{m/s}) = -10\,\mathrm{N{\cdot}s}\,,$$

which, according to Eq. (7.4), is equal to the impulse delivered on the clay by the wall.

**7.7**

The first force $F_1$ is along the positive $x$-direction and delivers an impulse $F_1\Delta t_1 = (+20\,\mathrm{N}) \times (2.0\,\mathrm{s}) = +40\,\mathrm{N{\cdot}s}$; while the second force $F_2$ is along the negative $x$-direction, delivering an impulse $F_2\Delta t_2 = (-2.0\,\mathrm{N})(20\,\mathrm{s}) = -40\,\mathrm{N{\cdot}s}$. Both impulses are represented by the corresponding shaded areas in the force vs time plot shown below, with the area below the $t$-axis counted as negative. The net impulse experienced by the body is then $F_1\Delta t_1 + F_2\Delta t_2 = +40\,\mathrm{N{\cdot}s} - 40\,\mathrm{N{\cdot}s} = 0$; so there is no net change in the momentum of the body, whose final momentum $p_f$ must then be the same as its initial value:

$$p_f = p_i = mv_i = (1.0\,\mathrm{kg})(10\,\mathrm{m/s}) = 10\,\mathrm{kg{\cdot}m/s}\,.$$



7.10

Compared with a karate chop, a boxer's punch is softer (i.e. with a smaller value of $F_{av}$) but lasts a longer time interval. Thus the first graph, with $F_{av} \approx 400\,\text{N}$ and $\Delta t \approx 0.12\,\text{s} - 0.02\,\text{s} = 0.1\,\text{s}$, is likely a boxer's punch; while the second one, with $F_{av} \approx 2000\,\text{N}$ and $\Delta t \approx 0.06\,\text{s} - 0.04\,\text{s} = 0.02\,\text{s}$, is likely a karate's chop.

The impulse represented by the first curve is approximately $(400\,\text{N})(0.10\,\text{s}) = 40\,\text{N·s}$; while that by the second one is $(2000\,\text{N})(0.02\,\text{s}) = 40\,\text{N·s}$, roughly the same as the first one.

The karate's chop involves a peak force of about 2000 N, which is 5 times as much as that of the boxer's punch. So the karate's chop is more likely to break bones.

7.14

Taking east as positive, the force of the wind is expressed as $F(t) = +(0.025\,\text{N/s})\,t$. The impulse it delivered on the balloon between 0 and 0.40 s is then

$$\int_0^{0.40\,\text{s}} F(t)\,dt = \int_0^{0.40\,\text{s}} (0.025\,\text{N/s})t\,dt = (0.025\,\text{N/s})\left[\frac{1}{2}t^2\right]_0^{0.40\,\text{s}} = +2.0 \times 10^{-3}\,\text{N·s}.$$

The resulting change in momentum of the balloon, with mass $m = 20.0\,\text{g} = 0.020\,\text{kg}$ and initial speed $v_i = 0.10\,\text{m/s}$, is $\Delta p = mv - mv_i$, with $v$ its speed at $t = 0.40\,\text{s}$. Equate the impulse with $\Delta p$: $mv - mv_i = 2.0 \times 10^{-3}\,\text{N·s}$, and solve for $v$:

$$v = v_i + \frac{2.0 \times 10^{-3}\,\text{N·s}}{m} = 0.10\,\text{m/s} + \frac{2.0 \times 10^{-3}\,\text{N·s}}{0.020\,\text{kg}} = +0.20\,\text{m/s},$$

due east.

7.21

Taking the initial direction of motion of the hammer as positive, then before the impact its initial velocity is $v_i = +5\,\text{m/s}$, and afterwards $v_f = -1\,\text{m/s}$. The change in momentum for the hammer of mass $m$ is then $\Delta p = mv_f - mv_i = m(v_f - v_i)$. If this is accomplished in $\Delta t = 1\,\text{ms} = 1 \times 10^{-3}\,\text{s}$, then from Eq. (7.2) the average force exerted by the nail on the hammer is

$$F_{av} = \frac{\Delta p}{\Delta t} = \frac{m(v_f - v_i)}{\Delta t} = \frac{(1\,\text{kg})\,[(-1\,\text{m/s}) - (+5\,\text{m/s})]}{1 \times 10^{-3}\,\text{s}} = -6 \times 10^3\,\text{N} = -6\,\text{kN},$$

where the negative sign indicates that $\vec{\mathbf{F}}_{av}$ is against the initial direction of motion of the hammer. According to Newton's Third Law, the force exerted by the nail on the hammer is $-F_{av} = +6\,\text{kN}$, in the initial direction of motion of the hammer.



7.39

The initial momentum of the system consisting the person (P) and the boat (B) is $\vec{\mathbf{p}}_i = 0$, since neither was moving. As the person picks up a velocity $\vec{\mathbf{v}}_P$ with respect to the stationary water, due north (which is taken to be positive), her momentum is $m_P\vec{\mathbf{v}}_P$. Meanwhile, the boat is moving at a velocity $\vec{\mathbf{v}}_B$, resulting in a momentum of $m_B\vec{\mathbf{v}}_B$. The total momentum of the system is now $\vec{\mathbf{p}}_f = m_P\vec{\mathbf{v}}_P + m_B\vec{\mathbf{v}}_B$. Conservation of momentum requires that $\vec{\mathbf{p}}_i = \vec{\mathbf{p}}_f$, which becomes $0 = m_P v_P + m_B v_B$ in scalar form. Solve for $v_B$, the velocity of the boat:

$$v_B = -\frac{m_P v_P}{m_B} = -\frac{(50\,\text{kg})(10\,\text{m/s})}{150\,\text{kg}} = -3.3\,\text{m/s},$$

where the minus sign indicates that $\vec{\mathbf{v}}_B$ due south, opposite in direction to $\vec{\mathbf{v}}_P$.

**7.50**

Use conservation of momentum. The initial momentum of the system consisting of the astronaut (A), the TV camera (C), and the backpack (B) is $\vec{\mathbf{p}}_i = 0$. As the astronaut throws the TV camera out at a velocity $\vec{\mathbf{v}}_C$, the momentum of the camera is $m_C\vec{\mathbf{v}}_C$. Meanwhile, the rest of the system (with mass $m_A + m_B$) recoils backward at a velocity $\vec{\mathbf{v}}$, resulting in a momentum of $(m_A + m_B)\vec{\mathbf{v}}$. The total momentum of the system is now $\vec{\mathbf{p}}_f = m_C\vec{\mathbf{v}}_C + (m_A + m_B)\vec{\mathbf{v}}$. Conservation of momentum requires that $\vec{\mathbf{p}}_i = \vec{\mathbf{p}}_f$, which in scalar form is $p_i = 0 = p_f = m_C v_C + (m_A + m_B)v$. Take the direction of $\vec{\mathbf{v}}_C$ as positive and solve for $v$, the recoiling velocity of the astronaut (plus the backpack):

$$v = -\frac{m_C v_C}{m_A + m_B} = -\frac{(1.0\,\text{kg})(15\,\text{m/s})}{90\,\text{kg} + 10\,\text{kg}} = -0.15\,\text{m/s},$$

where the minus sign indicates that the recoiling velocity $\vec{\mathbf{v}}$ of the astronaut is opposite in direction to $\vec{\mathbf{v}}_C$. So after the first throw the astronaut gains a speed of 0.15 m/s towards the spaceship.

Similarly, suppose that the astronaut further gains a speed of $v'_A$ towards the spaceship after throwing the backpack out with a speed of $v_B$, then $0 = m_B v_B + m_A v'_A$, which gives

$$v'_A = -\frac{m_B v_B}{m_A} = -\frac{(10\,\text{kg})(10\,\text{m/s})}{90\,\text{kg}} = -1.1\,\text{m/s},$$

meaning that he gains another 1.1 m/s in speed toward the spaceship after tossing out the backpack.

**7.57**

Apply conservation of momentum each time an astronaut throws or catches the asteroid (A).

For the first step, in which Neil (N) throws the asteroid at sally (S), $p_{Ni} + p_{Ai} = 0 = p_{Nf} + p_{Af}$, or

$$m_N v_{Nf} + m_A v_{Af} = 0,$$

where $m_N = 100\,\text{kg}$, $m_A = 0.500\,\text{kg}$ and, taking the direction of motion of the asteroid as positive, $v_{Af} = +20.0\,\text{m/s}$. This gives $v_{Nf} = -0.100\,\text{m/s}$, opposite to the direction of motion of the asteroid.

Now the second step, in which Sally catches the asteroid. We have $p_{Af} = p'_{Ai} = p'_{Af} + p'_{Sf}$, or

$$m_A v_{Af} = (m_A + m_S)v'_{Sf},$$

where $m_S = 50.0\,\text{kg}$, $m_A = 0.500\,\text{kg}$, and $v_{Af} = +20.0\,\text{m/s}$. This gives $v'_{Sf} = +0.198\,\text{m/s}$, in the same direction of motion as that of the asteroid.

Finally, as Sally throws the asteroid back to Neil, $p''_{Af} + p''_{Sf} = p''_{Ai} + p''_{Si} = p'_{Af} + p'_{Sf}$, or

$$m_A v''_{Af} + m_S v''_{Sf} = (m_A + m_S)v'_{Sf}.$$

Plugging in the values of $m_A$, $m_S$, and noting that $v''_{Af} = -20.0\,\text{m/s}$ and $v'_{Sf} = +0.198\,\text{m/s}$, we solve for $v''_{Sf}$, the final velocity of Sally, to obtain $v''_{Sf} = +0.400\,\text{m/s}$.

**7.58**

Since the two cars are of equal mass and travel at the same speed in opposite directions, their initial momenta cancel, yielding $p_i = 0$ for the two-car system before the collision. After the collision, the final momentum of the wreckage is $p_f = mv_f$, where $m$ is its total mass. Conservation of momentum then gives $p_f = mv_f = p_i = 0$, or $v_f = 0$. So the wreckage won't move after the collision.

**7.71**

Apply conservation of momentum to the system consisting of the two billiard balls, each with mass $m$:

$$p_i = mv_{1i} + mv_{2i} = p_f = mv_{1f} + mv_{2f}\,.$$

Also, for elastic collisions

$$v_{2i} - v_{1i} = v_{1f} - v_{2f}\,.$$

Taking north as positive, then $v_{1i} = +15.0\,\text{m/s}$ and $v_{2i} = -10\,\text{m/s}$. Solve for $v_{1f}$ and $v_{2f}$ to obtain $v_{1f} = v_{2i} = 15\,\text{m/s}$ and $v_{2f} = v_{1i} = -10\,\text{m/s}$. So the two balls just exchanged their velocities as a result of their elastic collision.



**7.73**

Since there is no external force in the horizontal direction, the momentum of the bullet-block system is conserved in the collision. The initial momentum of the system is entirely borne by the bullet: $p_i = m_B v_B$. After the collision the bullet and the clay block (C) has reached a common speed $v_C$, so $p_f = (m_B + m_C)v_C$. Equate $p_i$ with $p_f$ to obtain

$$m_B v_B = (m_B + m_C)v_C\,.$$

After the collision, the bullet-block system rises to a new height $h$, trading its kinetic energy $\frac{1}{2}(m_B + m_C)v_C^2$ for the gravitational potential energy, $(m_B + m_C)gh$:

$$\frac{1}{2}(m_B + m_C)v_C^2 = (m_B + m_C)gh\,.$$

Solve the second equation for $v_C$: $v_C = \sqrt{2gh}$. Plug this result into the first one and solve for $v_B$, the initial speed of the bullet:

$$v_B = \left(\frac{m_B + m_C}{m_B}\right)\sqrt{2gh}\,.$$