PHYSICS 1A HOMEWORK SOLUTIONS - CHAPTER 7

7.5

The change in momentum for the ball is $\Delta p = m\Delta v = (0.425\,\text{kg})(26\,\text{m/s}) = 11\,\text{kg}\cdot\text{m/s}$. According to Eq. (7.4), this is equal to the impulse imparted to the ball.

7.6

The impulse delivered on the pea by an average force F_{av} over a time interval Δt is $F_{av}\Delta t$, which results in a change in momentum for the pea: $\Delta p = mv_f - mv_i = mv_f$, where m is the mass of the pea, v_i $(= 0)$ is its initial speed, and v_f is the final speed it acquires upon leaving the straw. Using Eq. (7.4), $F_{av}\Delta t = \Delta p = mv_f$, we obtain

$$v_f = \frac{F_{av}\Delta t}{m} = \frac{(0.070 \times 4.448\,\text{N})(0.10\,\text{s})}{0.50 \times 10^{-3}\,\text{kg}} = 62\,\text{m/s}.$$

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 $(400\,\text{N})(0.10\,\text{s}) = 40\,\text{N}\cdot\text{s}$; while that by the second one is $(2000\,\text{N})(0.02\,\text{s}) = 40\,\text{N}\cdot\text{s}$, 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

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

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 Δp: $mv - mv_i = 2.0 \times 10^{-3}\,\text{N}\cdot\text{s}$, and solve for v:

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

due east.

7.20

The initial momentum of the golf ball of mass m is zero, while its final momentum is $p_f = mv_f$, where v_f is its final speed. The change in momentum for the golf ball is then

$$\Delta p = p_f - p_i = mv_f = (47.0 \times 10^{-3}\,\mathrm{kg})(70.0\,\mathrm{m/s}) = 3.29\,\mathrm{kg{\cdot}m/s}\,.$$

7.21

Taking the initial direction of motion of the hammer as positive, then before the impact its initial velocity is $v_i = +5\,\mathrm{m/s}$, and afterwards $v_f = -1\,\mathrm{m/s}$. 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 $\Delta t = 1\,\mathrm{ms} = 1 \times 10^{-3}\,\mathrm{s}$, then from Eq. (7.2) the average force exerted by the nail on the hammer is

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

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 $-F_{av} = +6\,\mathrm{kN}$, in the initial direction of motion of the hammer.

7.24

The area under the force-time curve is $F_{av}\Delta t$, which is equal to $\Delta p = m\Delta v$ [see Eq. (7.4)]. In our case $m = 50\,\mathrm{kg}$ and $\Delta v = -40 \times 0.4770\,\mathrm{m/s} = -17.88\,\mathrm{m/s}$ (since the person's speed has been reduced to zero as a result of the crash), so the area is

$$F_{av}\Delta t = m\Delta v = (50\,\mathrm{kg})(-17.88\,\mathrm{m/s}) = -8.9 \times 10^2\,\mathrm{kg{\cdot}m/s}\,.$$

Now plug in $\Delta t = 100\,\mathrm{m/s} = 0.100\,\mathrm{s}$ and solve fro F_{av}:

$$F_{av} = \frac{F_{av}\Delta t}{\Delta t} = \frac{-8.9 \times 10^2\,\mathrm{kg{\cdot}m/s}}{0.100\,\mathrm{s}} = -8.9 \times 10^3\,\mathrm{N} = -8.9\,\mathrm{kN}\,,$$

where the force is negative since it is against the car's initial direction of motion, which is chosen as positive.

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:

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

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

7.49

Since friction is negligible, the horizontal momentum of the skater-snowball system is conserved. The initial momentum of the system is $\vec{p}_i = 0$, since neither the skater (S) nor the snowball (B) was moving. As the snowball is thrown out at a velocity $\vec{v}_B$, whose magnitude is $v_B = (20.0\,\text{km/h})(10^3\,\text{m/km})(1\,\text{h}/3600\,\text{s}) = 5.556\,\text{m/s}$, it picks up a momentum $m_B\vec{v}_B$. Meanwhile, the skater is moving backward at a velocity $\vec{v}_S$, resulting in a momentum of $m_S\vec{v}_S$. The total momentum of the system is now $\vec{p}_f = m_B\vec{v}_B + m_S\vec{v}_S$. From conservation of momentum $\vec{p}_i = \vec{p}_f$, which becomes $p_i = 0 = p_f = m_B v_B + m_S v_S$ in scalar form. Take the direction of $\vec{v}_B$ as positive and solve for v_S, the velocity of the skater:

$$v_S = -\frac{m_B v_B}{m_S} = -\frac{(200 \times 10^{-3}\,\text{kg})(5.556\,\text{m/s})}{55.0\,\text{kg}} = -0.0202\,\text{m/s},$$

where the minus sign indicates that $\vec{v}_S$ is opposite in direction to $\vec{v}_B$.

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.

7.68

The initial momentum of the two-block system just before the collision is $p_i = mv_{1i}$, where m_1 is the mass of the sliding block and v_{1i} is its velocity along the incline just before the impact, which satisfies $v_{1i}^2 = 2aL = 2gL\sin\theta$. Here L is the length of the incline, θ is the angle of its inclination, and $a = g\sin\theta$ is the acceleration of the sliding block. Thus $p_i = m_1\sqrt{2gL\sin\theta}$. After the collision, the two blocks sail off horizontally, so only the horizontal component of the initial momentum, $p_{ix} = p_i\cos\theta$, is left intact; while the vertical component is reduced to zero due to the impulse from the ground. Thus $p_f = (m_1 + m_2)v_f = p_{ix} = p_i\cos\theta = m_1\sqrt{2gL\sin\theta}\cos\theta$, which gives the common final horizontal speed v_f of the two blocks after the collision:

$$\begin{aligned} v_f &= \frac{m_1 \cos\theta\sqrt{2gL\sin\theta}}{m_1 + m_2} \\ &= \frac{(10.0\,\text{kg})(\cos 20.0°)\sqrt{2(9.81\,\text{m/s}^2)(10.0\,\text{m})(\sin 20.0°)}}{10.0\,\text{kg} + 10.0\,\text{kg}} \\ &= 3.85\,\text{m/s}. \end{aligned}$$

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.