SOLUTION MANUAL FOR

FOURTH EDITION

PHYSICS

for

SCIENTISTS & ENGINEERS

with Modern Physics

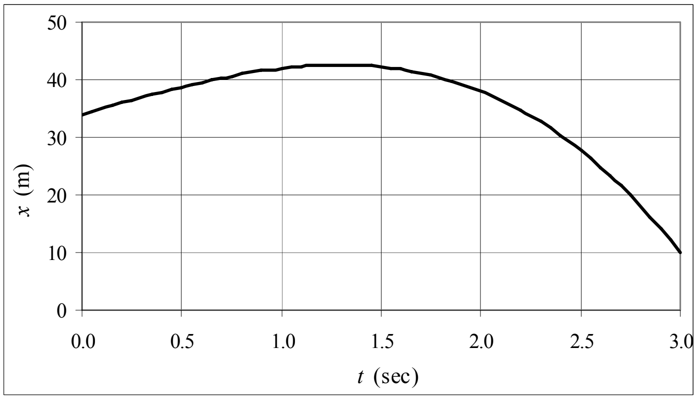
GIANCOLI

7. The distance traveled is $116\text{ km} + \frac{1}{2}(116\text{ km}) = 174\text{ km}$, and the displacement is $116\text{ km} - \frac{1}{2}(116\text{ km}) = 58\text{ km}$. The total time is 14.0 s + 4.8 s = 18.8 s.

(*a*) Average speed $= \dfrac{\text{distance}}{\text{time elapsed}} = \dfrac{174\text{ m}}{18.8\text{ s}} = \boxed{9.26\,\text{m/s}}$

(*b*) Average velocity $= v_{\text{avg}} = \dfrac{\text{displacement}}{\text{time elapsed}} = \dfrac{58\text{ m}}{18.8\text{ s}} = \boxed{3.1\,\text{m/s}}$

8. (*a*)



The spreadsheet used for this problem can be found on the Media Manager, with filename "PSE4_ISM_CH02.XLS", on tab "Problem 2.8a".

(*b*) The average velocity is the displacement divided by the elapsed time.

$$\bar{v} = \frac{x(3.0) - x(0.0)}{3.0\,\text{s} - 0.0\,\text{s}} = \frac{\left[34 + 10(3.0) - 2(3.0)^3\right]\text{m} - (34\,\text{m})}{3.0\,\text{s}} = \boxed{-8.0\,\text{m/s}}$$

(*c*) The instantaneous velocity is given by the derivative of the position function.

$$v = \frac{dx}{dt} = \left(10 - 6t^2\right)\text{m/s} \qquad 10 - 6t^2 = 0 \;\rightarrow\; t = \sqrt{\frac{5}{3}}\text{s} = \boxed{1.3\,\text{s}}$$

This can be seen from the graph as the "highest" point on the graph.

9. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The instantaneous velocity is given by the slope of the tangent line to the curve. At $t = 10.0\,\text{s}$, the slope is approximately $v(10) \approx \dfrac{3\,\text{m} - 0}{10.0\text{ s} - 0} = \boxed{0.3\,\text{m/s}}$.

(*b*) At $t = 30.0\,\text{s}$, the slope of the tangent line to the curve, and thus the instantaneous velocity, is approximately $v(30) \approx \dfrac{22\,\text{m} - 10\,\text{m}}{35\,\text{s} - 25\,\text{s}} = \boxed{1.2\,\text{m/s}}$.

(*c*) The average velocity is given by $\bar{v} = \dfrac{x(5) - x(0)}{5.0\,\text{s} - 0\,\text{s}} = \dfrac{1.5\,\text{m} - 0}{5.0\,\text{s}} = \boxed{0.30\,\text{m/s}}$.

(*d*) The average velocity is given by $\bar{v} = \dfrac{x(30) - x(25)}{30.0\,\text{s} - 25.0\,\text{s}} = \dfrac{16\,\text{m} - 9\,\text{m}}{5.0\,\text{s}} = \boxed{1.4\,\text{m/s}}$.

(*e*) The average velocity is given by $\bar{v} = \dfrac{x(50) - x(40)}{50.0\,\text{s} - 40.0\,\text{s}} = \dfrac{10\,\text{m} - 19.5\,\text{m}}{10.0\,\text{s}} = \boxed{-0.95\,\text{m/s}}$.

equation for x-direction projectile motion to find the speed in the x-direction, which is the speed the slingshot imparts. The meter stick is used to measure the initial height and the horizontal distance the rock travels.

13. No. The arrow will fall toward the ground as it travels toward the target, so it should be aimed above the target. Generally, the farther you are from the target, the higher above the target the arrow should be aimed, up to a maximum launch angle of 45º. (The maximum range of a projectile that starts and stops at the same height occurs when the launch angle is 45º.)

14. As long as air resistance is negligible, the horizontal component of the projectile's velocity remains constant until it hits the ground. It is in the air longer than 2.0 s, so the value of the horizontal component of its velocity at 1.0 s and 2.0 s is the same.

15. A projectile has the least speed at the top of its path. At that point the vertical speed is zero. The horizontal speed remains constant throughout the flight, if we neglect the effects of air resistance.

16. If the bullet was fired from the ground, then the y-component of its velocity slowed considerably by the time it reached an altitude of 2.0 km, because of both acceleration due to gravity (downward) and air resistance. The x-component of its velocity would have slowed due to air resistance as well. Therefore, the bullet could have been traveling slowly enough to be caught!

17. (*a*) Cannonball A, because it has a larger initial vertical velocity component.
    (*b*) Cannonball A, same reason.
    (*c*) It depends. If $\theta_A < 45^\circ$, cannonball A will travel farther. If $\theta_B > 45^\circ$, cannonball B will travel farther. If $\theta_A > 45^\circ$ and $\theta_B < 45^\circ$, the cannonball whose angle is closest to 45º will travel farther.

18. (*a*) The ball lands back in her hand.
    (*b*) The ball lands behind her hand.
    (*c*) The ball lands in front of her hand.
    (*d*) The ball lands beside her hand, to the outside of the curve.
    (*e*) The ball lands behind her hand, if air resistance is not negligible.

19. This is a question of relative velocity. From the point of view of an observer on the ground, both trains are moving in the same direction (forward), but at different speeds. From your point of view on the faster train, the slower train (and the ground) will appear to be moving backward. (The ground will be moving backward faster than the slower train!)

20. The time it takes to cross the river depends on the component of velocity in the direction straight across the river. Imagine a river running to the east and rowers beginning on the south bank. Let the still water speed of both rowers be v. Then the rower who heads due north (straight across the river) has a northward velocity component v. The rower who heads upstream, though, has a northward velocity component of less than v. Therefore, the rower heading straight across reaches the opposite shore first. (However, she won't end up straight across from where she started!)

21. As you run forward, the umbrella also moves forward and stops raindrops that are at its height above the ground. Raindrops that have already passed the height of the umbrella continue to move toward the ground unimpeded. As you run, you move into the space where the raindrops are continuing to fall (below the umbrella). Some of them will hit your legs and you will get wet.

Using this initial velocity and an angle of 45° in the range formula (from Example 3-10) will give the maximum range for the gun.

$$R = \frac{v_0^2 \sin 2\theta_0}{g} = \frac{(19.6\,\text{m/s})^2 \sin(90°)}{9.80\,\text{m/s}^2} = \boxed{39\,\text{m}}$$

38. Choose the origin to be the point on the ground directly below the point where the baseball was hit. Choose upward to be the positive y direction. Then $y_0 = 1.0\,\text{m}$, $y = 13.0\,\text{m}$ at the end of the motion, $v_{y0} = (27.0 \sin 45.0°)\,\text{m/s} = 19.09\,\text{m/s}$, and $a_y = -9.80\,\text{m/s}^2$. Use Eq. 2-12b to find the time of flight.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 \quad \rightarrow \quad \tfrac{1}{2}a_y t^2 + v_{y0}t + (y_0 - y) = 0 \quad \rightarrow$$

$$t = \frac{-v_{y0} \pm \sqrt{v_{y0}^2 - 4\left(\tfrac{1}{2}a_y\right)(y_0 - y)}}{2\tfrac{1}{2}a_y} = \frac{-19.09 \pm \sqrt{(19.09)^2 - 2(-9.80)(-12.0)}}{-9.80}$$

$$= 0.788\,\text{s},\ 3.108\,\text{s}$$

The smaller time is the time the baseball reached the building's height on the way up, and the larger time is the time the baseball reached the building's height on the way down. We must choose the larger result, because the baseball cannot land on the roof on the way up. Now calculate the horizontal distance traveled using the horizontal motion at constant velocity.

$$\Delta x = v_x t = \left[(27.0 \cos 45.0°)\,\text{m/s}\right](3.108\,\text{s}) = \boxed{59.3\,\text{m}}$$

39. We choose the origin at the same place. With the new definition of the coordinate axes, we have the following data: $y_0 = 0$, $y = +1.00\,\text{m}$, $v_{y0} = -12.0\,\text{m/s}$, $v_{x0} = -16.0\,\text{m/s}$, $a = 9.80\,\text{m/s}^2$.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}gt^2 \quad \rightarrow \quad 1.00\,\text{m} = 0 - (12.0\,\text{m/s})t + \left(4.90\,\text{m/s}^2\right)t^2 \quad \rightarrow$$

$$\left(4.90\,\text{m/s}^2\right)t^2 - (12.0\,\text{m/s})t - (1.00\,\text{m}) = 0$$

This is the same equation as in Example 3-11, and so we know the appropriate solution is $t = 2.53\,\text{s}$. We use that time to calculate the horizontal distance the ball travels.

$$x = v_{x0}t = (-16.0\,\text{m/s})(2.53\,\text{s}) = -40.5\,\text{m}$$

Since the x-direction is now positive to the left, the negative value means that the ball lands $\boxed{40.5\,\text{m}}$ to the right of where it departed the punter's foot.

40. The horizontal range formula from Example 3-10 can be used to find the launching velocity of the grasshopper.

$$R = \frac{v_0^2 \sin 2\theta_0}{g} \quad \rightarrow \quad v_0 = \sqrt{\frac{Rg}{\sin 2\theta_0}} = \sqrt{\frac{(1.0\text{m})\left(9.80\,\text{m/s}^2\right)}{\sin 90°}} = 3.13\,\text{m/s}$$

Since there is no time between jumps, the horizontal velocity of the grasshopper is the horizontal component of the launching velocity.

$$v_x = v_0 \cos\theta_0 = (3.13\,\text{m/s})\cos 45° = \boxed{2.2\,\text{m/s}}$$

41. (*a*) Take the ground to be the $y = 0$ level, with upward as the positive direction. Use Eq. 2-12b to solve for the time, with an initial vertical velocity of 0.

$$y = y_0 + v_{0y}t + \tfrac{1}{2}a_y t^2 \quad \rightarrow \quad 150\,\text{m} = 910\,\text{m} + \tfrac{1}{2}\left(-9.80\,\text{m/s}^2\right)t^2 \quad \rightarrow$$

The path of the child (shown by the dashed line) is projectile motion. With the same origin and coordinate system, the horizontal motion of the child is given by $x = v_0 \cos 15^\circ (t)$, and the vertical motion of the child will be given by Eq. 2-12b, $y = v_0 \sin 15^\circ t - \frac{1}{2} g t^2$. The landing point of the child is given by $x_{\text{landing}} = 1.4 \cos 12^\circ$ and $y_{\text{landing}} = -1.4 \sin 12^\circ$. Use the horizontal motion and landing point to find an expression for the time the child is in the air, and then use that time to find the initial speed.

$$x = v_0 \cos 15^\circ (t) \quad \rightarrow \quad t = \frac{x}{v_0 \cos 15^\circ}, \; t_{\text{landing}} = \frac{1.4 \cos 12^\circ}{v_0 \cos 15^\circ}$$

Equate the *y* expressions, and use the landing time. We also use the trigonometric identity that $\sin 12^\circ \cos 15^\circ + \sin 15^\circ \cos 12^\circ = \sin(12^\circ + 15^\circ)$.

$$y_{\text{landing}} = y_{\text{projectile}} \quad \rightarrow \quad -1.4 \sin 12^\circ = v_0 \sin 15^\circ t_{\text{landing}} - \tfrac{1}{2} g t_{\text{landing}}^2 \quad \rightarrow$$

$$-1.4 \sin 12^\circ = v_0 \sin 15^\circ \frac{1.4 \cos 12^\circ}{v_0 \cos 15^\circ} - \tfrac{1}{2} g \left(\frac{1.4 \cos 12^\circ}{v_0 \cos 15^\circ} \right)^2 \quad \rightarrow$$

$$v_0^2 = \tfrac{1}{2} g \frac{\cos^2 12^\circ}{\sin 27^\circ} \left(\frac{1.4}{\cos 15^\circ} \right) \quad \rightarrow \quad v_0 = 3.8687 \text{ m/s} \approx \boxed{3.9 \text{ m/s}}$$

93. Find the time of flight from the vertical data, using Eq. 2-12b. Call the floor the $y = 0$ location, and choose upwards as positive.

$$y = y_0 + v_{0y} t + \tfrac{1}{2} a_y t^2 \quad \rightarrow \quad 3.05 \text{ m} = 2.4 \text{ m} + (12 \text{ m/s}) \sin 35^\circ t + \tfrac{1}{2}(-9.80 \text{ m/s}^2) t^2$$

$$4.90 t^2 - 6.883 t + 0.65 \text{ m} = 0 \quad \rightarrow$$

$$t = \frac{6.883 \pm \sqrt{6.883^2 - 4(4.90)(0.65)}}{2(4.90)} = 1.303 \text{ s}, 0.102 \text{ s}$$

(*a*) Use the larger time for the time of flight. The shorter time is the time for the ball to rise to the basket height on the way up, while the longer time is the time for the ball to be at the basket height on the way down.

$$x = v_x t = v_0 (\cos 35^\circ) t = (12 \text{ m/s})(\cos 35^\circ)(1.303 \text{ s}) = 12.81 \text{ m} \approx \boxed{13 \text{ m}}$$

(*b*) The angle to the horizontal is determined by the components of the velocity.

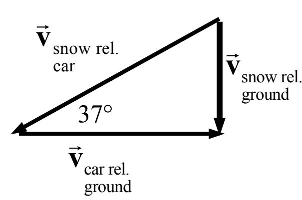
$$v_x = v_0 \cos \theta_0 = 12 \cos 35^\circ = 9.830 \text{ m/s}$$

$$v_y = v_{y0} + at = v_0 \sin \theta_0 - gt = 12 \sin 35^\circ - 9.80(1.303) = -5.886 \text{ m/s}$$

$$\theta = \tan^{-1} \frac{v_y}{v_x} = \tan^{-1} \frac{-5.886}{9.830} = -30.9^\circ \approx \boxed{-31^\circ}$$

The negative angle means it is below the horizontal.

94. We have $v_{\substack{\text{car rel.}\\ \text{ground}}} = 25 \text{ m/s}$. Use the diagram, illustrating $\vec{\mathbf{v}}_{\substack{\text{snow rel.}\\ \text{ground}}} = \vec{\mathbf{v}}_{\substack{\text{snow rel.}\\ \text{car}}} + \vec{\mathbf{v}}_{\substack{\text{car rel.}\\ \text{ground}}}$, to calculate the other speeds.



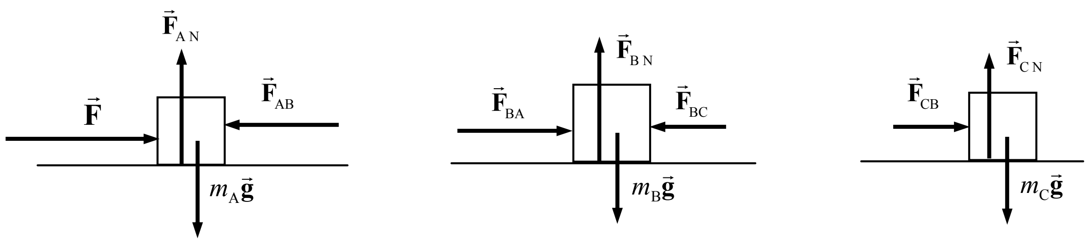
$$\cos 37^\circ = \frac{v_{\substack{\text{car rel.}\\ \text{ground}}}}{v_{\substack{\text{snow rel.}\\ \text{car}}}} \quad \rightarrow \quad v_{\substack{\text{snow rel.}\\ \text{car}}} = \frac{25 \text{ m/s}}{\cos 37^\circ} = \boxed{31 \text{ m/s}}$$

$$F_{\text{net}\atop y} = F_{\mathrm{T}}\cos\theta - mg = 0 \;\rightarrow\; F_{\mathrm{T}} = \frac{mg}{\cos\theta} \;\rightarrow$$

$$F_{\mathrm{H}} = \frac{mg}{\cos\theta}\sin\theta = mg\tan\theta = (27\,\mathrm{kg})(9.80\,\mathrm{m/s^2})\tan 2.15^\circ = \boxed{9.9\,\mathrm{N}}$$

(*b*) $$F_{\mathrm{T}} = \frac{mg}{\cos\theta} = \frac{(27\,\mathrm{kg})(9.80\,\mathrm{m/s^2})}{\cos 2.15^\circ} = \boxed{260\,\mathrm{N}}$$

46. (*a*) In the free-body diagrams below, $\vec{\mathbf{F}}_{\mathrm{AB}}$ = force on block A exerted by block B, $\vec{\mathbf{F}}_{\mathrm{BA}}$ = force on block B exerted by block A, $\vec{\mathbf{F}}_{\mathrm{BC}}$ = force on block B exerted by block C, and $\vec{\mathbf{F}}_{\mathrm{CB}}$ = force on block C exerted by block B. The magnitudes of $\vec{\mathbf{F}}_{\mathrm{BA}}$ and $\vec{\mathbf{F}}_{\mathrm{AB}}$ are equal, and the magnitudes of $\vec{\mathbf{F}}_{\mathrm{BC}}$ and $\vec{\mathbf{F}}_{\mathrm{CB}}$ are equal, by Newton's third law.



(*b*) All of the vertical forces on each block add up to zero, since there is no acceleration in the vertical direction. Thus for each block, $F_N = mg$. For the horizontal direction, we have the following.

$$\sum F = F - F_{\mathrm{AB}} + F_{\mathrm{BA}} - F_{\mathrm{BC}} + F_{\mathrm{CB}} = F = (m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}})a \;\rightarrow\; \boxed{a = \frac{F}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}}$$

(*c*) For each block, the net force must be *ma* by Newton's second law. Each block has the same acceleration since they are in contact with each other.

$$\boxed{F_{\mathrm{A\,net}} = F\frac{m_{\mathrm{A}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}} \quad \boxed{F_{\mathrm{B\,net}} = F\frac{m_{\mathrm{B}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}} \quad \boxed{F_{3\,net} = F\frac{m_{\mathrm{C}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}}$$

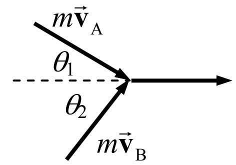
(*d*) From the free-body diagram, we see that for m_{C}, $F_{\mathrm{CB}} = F_{\mathrm{C\,net}} = \boxed{F\frac{m_{\mathrm{C}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}}$. And by Newton's third law, $F_{\mathrm{BC}} = F_{\mathrm{CB}} = \boxed{F\frac{m_{\mathrm{C}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}}$. Of course, $\vec{\mathbf{F}}_{23}$ and $\vec{\mathbf{F}}_{32}$ are in opposite directions. Also from the free-body diagram, we use the net force on m_{A}.

$$F - F_{\mathrm{AB}} = F_{\mathrm{A\,net}} = F\frac{m_{\mathrm{A}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}} \;\rightarrow\; F_{\mathrm{AB}} = F - F\frac{m_{\mathrm{A}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}} \;\rightarrow$$

$$\boxed{F_{\mathrm{AB}} = F\frac{m_{\mathrm{B}} + m_{\mathrm{C}}}{m_{\mathrm{A}} + m_{\mathrm{B}} + m_{\mathrm{C}}}}$$

By Newton's third law, $F_{\mathrm{BC}} = F_{\mathrm{AB}} = \boxed{F\frac{m_2 + m_3}{m_1 + m_2 + m_3}}$.

102. Call the final direction of the joined objects the positive x axis. A diagram of the collision is shown. Momentum will be conserved in both the x and y directions. Note that $v_A = v_B = v$ and $v' = v/3$.



$$p_y: \quad -mv\sin\theta_1 + mv\sin\theta_2 = 0 \quad \rightarrow \quad \sin\theta_1 = \sin\theta_2 \quad \rightarrow \quad \theta_1 = \theta_2$$

$$p_x: \quad mv\cos\theta_1 + mv\cos\theta_2 = (2m)(v/3) \quad \rightarrow \quad \cos\theta_1 + \cos\theta_2 = \tfrac{2}{3}$$

$$\cos\theta_1 + \cos\theta_2 = 2\cos\theta_1 = \tfrac{2}{3} \quad \rightarrow \quad \theta_1 = \cos^{-1}\tfrac{1}{3} = 70.5^\circ = \theta_2$$

$$\theta_1 + \theta_2 = \boxed{141^\circ}$$

$\boxed{103.}$ The original horizontal distance can be found from the range formula from Example 3-10.

$$R = v_0^2 \sin 2\theta_0 / g = (25\,\text{m/s})^2 (\sin 56^\circ)/(9.8\,\text{m/s}^2) = 52.87\,\text{m}$$

The height at which the objects collide can be found from Eq. 2-12c for the vertical motion, with $v_y = 0$ at the top of the path. Take up to be positive.

$$v_y^2 = v_{y0}^2 + 2a(y - y_0) \quad \rightarrow \quad (y - y_0) = \frac{v_y^2 - v_{y0}^2}{2a} = \frac{0 - [(25\,\text{m/s})\sin 28^\circ]^2}{2(-9.80\,\text{m/s}^2)} = 7.028\,\text{m}$$

Let m represent the bullet and M the skeet. When the objects collide, the skeet is moving horizontally at $v_0\cos\theta = (25\,\text{m/s})\cos 28^\circ = 22.07\,\text{m/s} = v_x$, and the bullet is moving vertically at $v_y = 230\,\text{m/s}$. Write momentum conservation in both directions to find the velocities after the totally inelastic collision.

$$p_x: \quad Mv_x = (M+m)v_x' \quad \rightarrow \quad v_x' = \frac{Mv_x}{M+m} = \frac{(0.25\,\text{kg})(22.07\,\text{m/s})}{(0.25+0.015)\,\text{kg}} = 20.82\,\text{m/s}$$

$$p_y: \quad mv_y = (M+m)v_y' \quad \rightarrow \quad v_y' = \frac{mv_y}{M+m} = \frac{(0.015\,\text{kg})(230\,\text{m/s})}{(0.25+0.015)\,\text{kg}} = 13.02\,\text{m/s}$$

(*a*) The speed v_y' can be used as the starting vertical speed in Eq. 2-12c to find the height that the skeet–bullet combination rises above the point of collision.

$$v_y^2 = v_{y0}^2 + 2a(y - y_0)_{\text{extra}} \quad \rightarrow$$

$$(y - y_0)_{\text{extra}} = \frac{v_y^2 - v_{y0}^2}{2a} = \frac{0 - (13.02\,\text{m/s})^2}{2(-9.80\,\text{m/s}^2)} = 8.649\,\text{m} \approx \boxed{8.6\,\text{m}}$$

(*b*) From Eq. 2-12b applied to the vertical motion after the collision, we can find the time for the skeet–bullet combination to reach the ground.

$$y = y_0 + v_y't + \tfrac{1}{2}at^2 \quad \rightarrow \quad 0 = 8.649\,\text{m} + (13.02\,\text{m/s})t + \tfrac{1}{2}(-9.80\,\text{m/s}^2)t^2 \quad \rightarrow$$

$$4.9t^2 - 13.02t - 8.649 = 0 \quad \rightarrow \quad t = 3.207\,\text{s}\,,\ -0.550\,\text{s}$$

The positive time root is used to find the horizontal distance traveled by the combination after the collision.

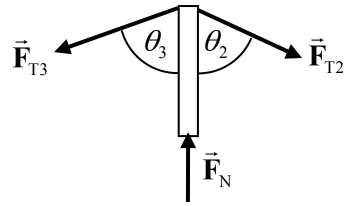
$$x_{\text{after}} = v_x't = (20.82\,\text{m/s})(3.207\,\text{s}) = 66.77\,\text{m}$$

If the collision would not have happened, the skeet would have gone $\tfrac{1}{2}R$ horizontally from this point.

$$\Delta x = x_{\text{after}} - \tfrac{1}{2}R = 66.77\,\text{m} - \tfrac{1}{2}(52.87\,\text{m}) = 40.33\,\text{m} \approx \boxed{40\,\text{m}}$$

Note that the answer is correct to 2 significant figures.

65. We consider the right half of the bridge in the diagram in the book. We divide it into two segments of length d_1 and $\frac{1}{2}d_2$, and let the mass of those two segments be *M*. Since the roadway is uniform, the mass of each segment will be in proportion to the length of the section, as follows.



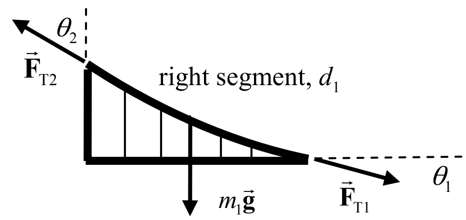
$$\frac{m_2}{m_1} = \frac{\frac{1}{2}d_2}{d_1} \rightarrow \frac{d_2}{d_1} = 2\frac{m_2}{m_1}$$

The net horizontal force on the right tower is to be 0. From the force diagram for the tower, we write this.

$$F_{T3}\sin\theta_3 = F_{T2}\sin\theta_2$$

From the force diagram for each segment of the cable, write Newton's second law for both the vertical and horizontal directions.

Right segment:



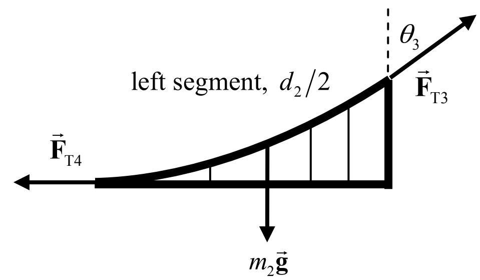
$$\sum F_x = F_{T1}\cos\theta_1 - F_{T2}\sin\theta_2 = 0 \rightarrow$$

$$F_{T1}\cos\theta_1 = F_{T2}\sin\theta_2$$

$$\sum F_y = F_{T2}\cos\theta_2 - F_{T1}\sin\theta_1 - m_1 g = 0 \rightarrow$$

$$m_1 g = F_{T2}\cos\theta_2 - F_{T1}\sin\theta_1$$

Left segment:



$$\sum F_x = F_{T3}\sin\theta_3 - F_{T4} = 0 \rightarrow F_{T3}\sin\theta_3 = F_{T4}$$

$$\sum F_y = F_{T3}\cos\theta_3 - m_2 g = 0 \rightarrow$$

$$m_2 g = F_{T3}\cos\theta_3$$

We manipulate the relationships to solve for the ratio of the masses, which will give the ratio of the lengths.

$$F_{T1}\cos\theta_1 = F_{T2}\sin\theta_2 \rightarrow F_{T1} = F_{T2}\frac{\sin\theta_2}{\cos\theta_1}$$

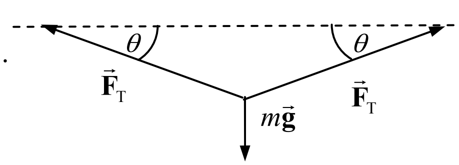
$$m_1 g = F_{T2}\cos\theta_2 - F_{T1}\sin\theta_1 = F_{T2}\cos\theta_2 - F_{T2}\frac{\sin\theta_2}{\cos\theta_1}\sin\theta_1 = F_{T2}\left(\cos\theta_2 - \frac{\sin\theta_2}{\cos\theta_1}\sin\theta_1\right)$$

$$F_{T3}\sin\theta_3 = F_{T2}\sin\theta_2 \rightarrow F_{T3} = F_{T2}\frac{\sin\theta_2}{\sin\theta_3} \rightarrow m_2 g = F_{T3}\cos\theta_3 = F_{T2}\frac{\sin\theta_2}{\sin\theta_3}\cos\theta_3$$

$$\frac{d_2}{d_1} = 2\frac{m_2}{m_1} = 2\frac{m_2 g}{m_1 g} = \frac{2F_{T2}\dfrac{\sin\theta_2}{\sin\theta_3}\cos\theta_3}{F_{T2}\left(\cos\theta_2 - \dfrac{\sin\theta_2}{\cos\theta_1}\sin\theta_1\right)} = \frac{2\sin\theta_2\cos\theta_3\cos\theta_1}{\left(\cos\theta_2\cos\theta_1 - \sin\theta_2\sin\theta_1\right)\sin\theta_3}$$

$$= \frac{2\sin\theta_2\cos\theta_1}{\cos\left(\theta_1+\theta_2\right)\tan\theta_3} = \frac{2\sin 60^\circ\cos 19^\circ}{\cos 79^\circ\tan 66^\circ} = 3.821 \approx \boxed{3.8}$$

66. The radius of the wire can be determined from the relationship between stress and strain, expressed by Eq. 12-5.



$$\frac{F}{A} = E\frac{\Delta\ell}{\ell_0} \rightarrow A = \frac{F\ell_0}{E\Delta\ell} = \pi r^2 \rightarrow r = \sqrt{\frac{1}{\pi}\frac{F}{E}\frac{\ell_0}{\Delta\ell}}$$

$$\frac{f_B}{f_A} = \frac{v_B/\lambda}{v_A/\lambda} = \frac{v_B}{v_A} = \frac{\sqrt{\dfrac{F_{TB}}{m/L}}}{\sqrt{\dfrac{F_{TA}}{m/L}}} = \sqrt{\frac{F_{TB}}{F_{TA}}} \rightarrow \frac{F_{TB}}{F_{TA}} = \left(\frac{f_B}{f_A}\right)^2 = \left(\frac{392}{494}\right)^2 = \boxed{0.630}$$

82. Relative to the fixed needle position, the ripples are moving with a linear velocity given by

$$v = \left(33\frac{\text{rev}}{\text{min}}\right)\left(\frac{1\,\text{min}}{60\ \text{s}}\right)\left(\frac{2\pi(0.108\ \text{m})}{1\ \text{rev}}\right) = 0.3732\,\text{m/s}$$

This speed is the speed of the ripple waves moving past the needle. The frequency of the waves is

$$f = \frac{v}{\lambda} = \frac{0.3732\,\text{m/s}}{1.55\times10^{-3}\text{m}} = 240.77\,\text{Hz} \approx \boxed{240\,\text{Hz}}$$

83. The speed of the pulses is found from the tension and mass per unit length of the wire.

$$v = \sqrt{\frac{F_T}{\mu}} = \sqrt{\frac{255\,\text{N}}{0.152\,\text{kg}/10.0\,\text{m}}} = 129.52\,\text{m/s}$$

The total distance traveled by the two pulses will be the length of the wire. The second pulse has a shorter time of travel than the first pulse, by 20.0 ms.

$$\ell = d_1 + d_2 = vt_1 + vt_2 = vt_1 + v\left(t_1 - 2.00\times10^{-2}\right)$$

$$t_1 = \frac{\ell + 2.00\times10^{-2}v}{2v} = \frac{(10.0\,\text{m}) + 2.00\times10^{-2}(129.52\,\text{m/s})}{2(129.52\,\text{m/s})} = 4.8604\times10^{-2}\,\text{s}$$

$$d_1 = vt_1 = (129.52\,\text{m/s})\left(4.8604\times10^{-2}\,\text{s}\right) = 6.30\,\text{m}$$

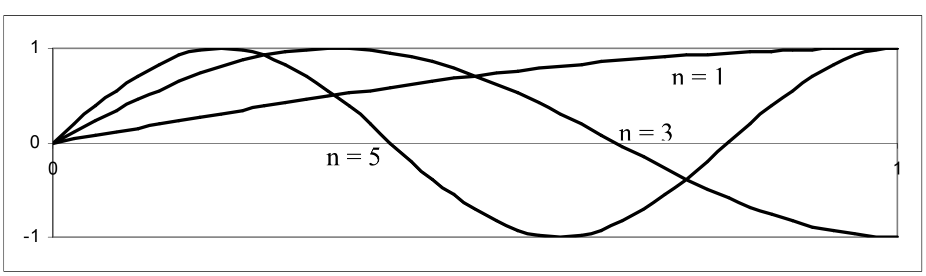
The two pulses meet $\boxed{6.30\,\text{m}}$ from the end where the first pulse originated.

84. We take the wave function to be $D(x,t) = A\sin(kx - \omega t)$. The wave speed is given by $v = \frac{\omega}{k} = \frac{\lambda}{f}$, while the speed of particles on the cord is given by $\frac{\partial D}{\partial t}$.

$$\frac{\partial D}{\partial t} = -\omega A\cos(kx - \omega t) \rightarrow \left(\frac{\partial D}{\partial t}\right)_{\max} = \omega A$$

$$\omega A = v = \frac{\omega}{k} \rightarrow A = \frac{1}{k} = \frac{\lambda}{2\pi} = \frac{10.0\,\text{cm}}{2\pi} = \boxed{1.59\,\text{cm}}$$

$\boxed{85.}$ For a resonant condition, the free end of the string will be an antinode, and the fixed end of the string will be a node. The minimum distance



from a node to an antinode is $\lambda/4$. Other wave patterns that fit the boundary conditions of a node at

6. (*a*) For the resistors in series, use Eq. 26-3, which says the resistances add linearly.

$$R_{eq}=3(45\Omega)+3(65\Omega)=\boxed{330\Omega}$$

(*b*) For the resistors in parallel, use Eq. 26-4, which says the resistances add reciprocally.

$$\frac{1}{R_{eq}}=\frac{1}{45\Omega}+\frac{1}{45\Omega}+\frac{1}{45\Omega}+\frac{1}{65\Omega}+\frac{1}{65\Omega}+\frac{1}{65\Omega}=\frac{3}{45\Omega}+\frac{3}{65\Omega}=\frac{3(65\Omega)+3(45\Omega)}{(65\Omega)(45\Omega)}\rightarrow$$

$$R_{eq}=\frac{(65\Omega)(45\Omega)}{3(65\Omega)+3(45\Omega)}=\boxed{8.9\Omega}$$

7. (*a*) The maximum resistance is made by combining the resistors in series.

$$R_{eq}=R_1+R_2+R_3=680\,\Omega+720\,\Omega+1200\,\Omega=\boxed{2.60\,\text{k}\Omega}$$

(*b*) The minimum resistance is made by combining the resistors in parallel.

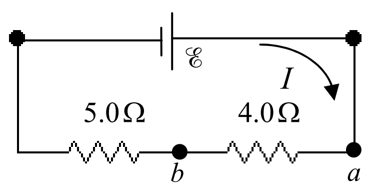
$$\frac{1}{R_{eq}}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\rightarrow$$

$$R_{eq}=\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)^{-1}=\left(\frac{1}{680\,\Omega}+\frac{1}{720\,\Omega}+\frac{1}{1200\,\Omega}\right)^{-1}=\boxed{270\,\Omega}$$

8. The equivalent resistance of five 100-Ω resistors in parallel is found, and then that resistance is divided by 10Ω to find the number of 10-Ω resistors needed.

$$R_{eq}=\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right)^{-1}=\left(\frac{5}{100\Omega}\right)^{-1}=20\Omega=n(10\Omega)\rightarrow n=\frac{20\Omega}{10\Omega}=\boxed{2}$$

9. Connecting nine of the resistors in series will enable you to make a voltage divider with a 4.0 V output. To get the desired output, measure the voltage across four consecutive series resistors.



$$R_{eq}=9(1.0\Omega)\qquad I=\frac{\mathscr{E}}{R_{eq}}=\frac{\mathscr{E}}{9.0\Omega}$$

$$V_{ab}=(4.0\Omega)I=(4.0\Omega)\frac{\mathscr{E}}{9.0\Omega}=(4.0\Omega)\frac{9.0\,\text{V}}{9.0\Omega}=\boxed{4.0\,\text{V}}$$

10. The resistors can all be connected in series.

$$R_{eq}=R+R+R=3(1.70\,\text{k}\Omega)=\boxed{5.10\,\text{k}\Omega}$$

The resistors can all be connected in parallel.

$$\frac{1}{R_{eq}}=\frac{1}{R}+\frac{1}{R}+\frac{1}{R}\rightarrow R_{eq}=\left(\frac{3}{R}\right)^{-1}=\frac{R}{3}=\frac{1.70\,\text{k}\Omega}{3}=\boxed{567\,\Omega}$$

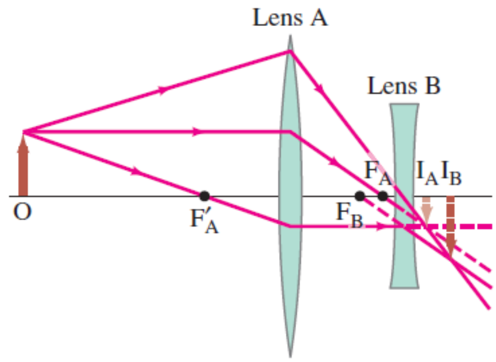
Two resistors in series can be placed in parallel with the third.

$$\frac{1}{R_{eq}}=\frac{1}{R}+\frac{1}{R+R}=\frac{1}{R}+\frac{1}{2R}=\frac{3}{2R}\rightarrow R_{eq}=\frac{2R}{3}=\frac{2(1.70\,\text{k}\Omega)}{3}=\boxed{1.13\,\text{k}\Omega}$$

Two resistors in parallel can be placed in series with the third.

$$R_{eq}=R+\left(\frac{1}{R}+\frac{1}{R}\right)^{-1}=R+\frac{R}{2}=\frac{3}{2}(1.70\,\text{k}\Omega)=\boxed{2.55\,\text{k}\Omega}$$

(*c*) See the diagram here.



26. We find the focal length of the combination by finding the image distance for an object very far away. For the converging lens, we have the following from Eq. 33-2.

$$\frac{1}{d_{o1}}+\frac{1}{d_{i1}}=\frac{1}{f_C}=\frac{1}{\infty}+\frac{1}{d_{i1}} \quad \rightarrow \quad d_{i1}=f_C$$

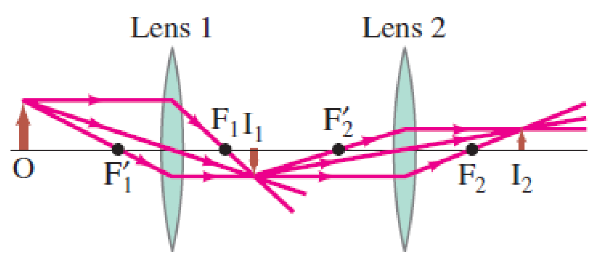
The first image is the object for the second lens. Since the first image is real, the second object distance is negative. We also assume that the lenses are thin, and so $d_{o2}=-d_{i1}=-f_C$. For the second diverging lens, we have the following from Eq. 33-2.

$$\frac{1}{d_{o2}}+\frac{1}{d_{i2}}=\frac{1}{f_D}=-\frac{1}{f_C}+\frac{1}{d_{i2}}$$

Since the original object was at infinity, the second image must be at the focal point of the combination, and so $d_{i2}=f_T$.

$$\frac{1}{f_D}=-\frac{1}{f_C}+\frac{1}{d_{i2}}=-\frac{1}{f_C}+\frac{1}{f_T}$$

27. (*a*) We see that the image is real and upright. We estimate that it is 30 cm beyond the second lens, and that the final image height is half the original object height.



(*b*) Find the image formed by the first lens, using Eq. 33-2.

$$\frac{1}{d_{o1}}+\frac{1}{d_{i1}}=\frac{1}{f_1} \quad \rightarrow$$

$$d_{i1}=\frac{d_{o1}f_1}{d_{o1}-f_1}=\frac{(36\,\text{cm})(13\,\text{cm})}{(36\,\text{cm})-(13\,\text{cm})}=20.35\,\text{cm}$$

This image is the object for the second lens. Because it is between the lenses, it has a positive object distance.

$$d_{o2}=56\,\text{cm}-20.35\,\text{cm}=35.65\,\text{cm}$$

Find the image formed by the second lens, again using Eq. 33-2.

$$\frac{1}{d_{o2}}+\frac{1}{d_{i2}}=\frac{1}{f_2} \quad \rightarrow \quad d_{i2}=\frac{d_{o2}f_2}{d_{o2}-f_2}=\frac{(35.65\,\text{cm})(16\,\text{cm})}{(35.65\,\text{cm})-(16\,\text{cm})}=29.25\,\text{cm}$$

Thus the final image is real, $\boxed{\text{29 cm beyond the second lens.}}$

The total magnification is the product of the magnifications for the two lenses:

$$m=m_1m_2=\left(-\frac{d_{i1}}{d_{o1}}\right)\left(-\frac{d_{i2}}{d_{o2}}\right)=\frac{(20.35\,\text{cm})(29.25\,\text{cm})}{(36\,\text{cm})(35.65\,\text{cm})}=\boxed{0.46\times}$$

$$e^x(5-x)=5\ ;\ x=\frac{hc}{\lambda_{\rm p}kT}$$

This transcendental equation will have some solution x = constant, and so $\frac{hc}{\lambda_{\rm p}kT}$ = constant, and so $\boxed{\lambda_{\rm p}T=\text{constant}}$. The constant could be evaluated from solving the transcendental equation,

(*b*) To find the value of the constant, we solve $e^x(5-x)=5$, or $5-x=5e^{-x}$. This can be done graphically, by graphing both $y=5-x$ and $y=5e^{-x}$ on the same set of axes and finding the intersection point. Or, the quantity $5-x-5e^{-x}$ could be calculated, and find for what value of x that expression is 0. The answer is $x=4.966$. We use this value to solve for h. The spreadsheet used for this problem can be found on the Media Manager, with filename "PSE4_ISM_CH37.XLS," on tab "Problem 37.5."

$$\frac{hc}{\lambda_{\rm p}kT}=4.966\ \rightarrow$$

$$h=4.966\frac{\lambda_{\rm P}Tk}{c}=4.966\frac{\left(2.90\times10^{-3}\,\text{m}\bullet\text{K}\right)\left(1.38\times10^{-23}\,\text{J/K}\right)}{3.00\times10^{8}\,\text{m/s}}=\boxed{6.62\times10^{-34}\,\text{J}\bullet\text{s}}$$

(*c*) We integrate Planck's radiation formula over all wavelengths.

$$\int_0^\infty I(\lambda,T)\,d\lambda=\int_0^\infty\left(\frac{2\pi hc^2\lambda^{-5}}{e^{hc/\lambda kT}-1}\right)d\lambda\ ;\ \text{let}\ \frac{hc}{\lambda kT}=x\ ;\ \lambda=\frac{hc}{xkT}\ ;\ d\lambda=-\frac{hc}{x^2kT}dx$$

$$\int_0^\infty I(\lambda,T)\,d\lambda=\int_0^\infty\left(\frac{2\pi hc^2\lambda^{-5}}{e^{hc/\lambda kT}-1}\right)d\lambda=\int_\infty^0\left(\frac{2\pi hc^2\left(\frac{hc}{xkT}\right)^{-5}}{e^x-1}\right)\left(-\frac{hc}{x^2kT}dx\right)=\frac{2\pi k^4T^4}{h^3c^2}\int_0^\infty\left(\frac{x^3}{e^x-1}\right)dx$$

$$=\frac{2\pi k^4}{h^3c^2}\left[\int_0^\infty\left(\frac{x^3}{e^x-1}\right)dx\right]T^4\propto T^4$$

Thus the total radiated power per unit area is proportional to T^4. Everything else in the expression is constant with respect to temperature.

6. We use Eq. 37-3.

$$E=hf=\left(6.626\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(104.1\times10^6\,\text{Hz}\right)=\boxed{6.898\times10^{-26}\,\text{J}}$$

$\boxed{7.}$ We use Eq. 37-3 along with the fact that $f=c/\lambda$ for light. The longest wavelength will have the lowest energy.

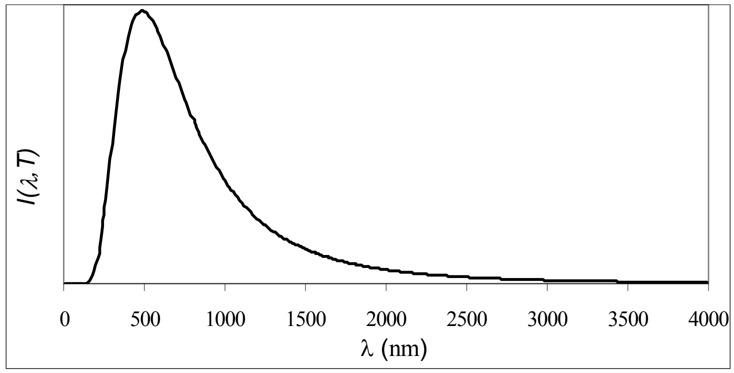
$$E_1=hf_1=\frac{hc}{\lambda_1}=\frac{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(3.00\times10^8\,\text{m/s}\right)}{\left(410\times10^{-9}\,\text{m}\right)}=4.85\times10^{-19}\,\text{J}\left(\frac{1\,\text{eV}}{1.60\times10^{-19}\,\text{J}}\right)=3.03\,\text{eV}$$

$$E_2=hf_2=\frac{hc}{\lambda_2}=\frac{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(3.00\times10^8\,\text{m/s}\right)}{\left(750\times10^{-9}\,\text{m}\right)}=2.65\times10^{-19}\,\text{J}\left(\frac{1\,\text{eV}}{1.60\times10^{-19}\,\text{J}}\right)=1.66\,\text{eV}$$

Thus the range of energies is $\boxed{2.7\times10^{-19}\,\text{J}<E<4.9\times10^{-19}\,\text{J}}$ or $\boxed{1.7\,\text{eV}<E<3.0\,\text{eV}}$.

photon produces only one electron-hole pair, even though many of them would have enough energy to create more than one.

The spreadsheet used for this problem can be found on the Media Manager, with filename "PSE4_ISM_CH40.XLS," on tab "Problem 40.89."



$$\frac{I}{A}=\left(\frac{\text{Solar energy}}{\text{s}\bullet\text{m}^2}\right)\left(\frac{1\text{ "average" photon}}{\text{Energy for 500 nm photon}}\right)\left(\frac{1\text{ electron produced}}{1\text{ solar photon}}\right)\left(\frac{\text{Charge}}{\text{electron}}\right)$$

$$=\left(790\,\text{W/m}^2\right)\left(\frac{\lambda}{hc}\right)\left(1.60\times10^{-19}\,\text{C}\right)=\left(790\,\text{W/m}^2\right)\frac{\left(500\times10^{-9}\,\text{m}\right)\left(1.60\times10^{-19}\,\text{C}\right)}{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(3.00\times10^{8}\,\text{m/s}\right)}$$

$$=318\,\text{C/s}\bullet\text{m}^2=\boxed{32\,\text{mA/cm}^2}$$