

Instructor Solutions Manual

to accompany

University Physics

Second Edition

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UNIVERSITY PHYSICS, Second Edition**

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Chapter 1: Overview

Concept Checks

1.1. a 1.2. a) 4 b) 3 c) 5 d) 6 e) 2 1.3. a, c and e 1.4. b 1.5. e 1.6. a) 4th b) 2nd c) 3rd d) 1st

Multiple-Choice Questions

1.1. c 1.2. c 1.3. d 1.4. b 1.5. a 1.6. b 1.7. b 1.8. c 1.9. c 1.10. b 1.11. d 1.12. b 1.13. c 1.14. a 1.15. e 1.16. a

Conceptual Questions

1.17. (a) In Europe, gas consumption is in L/100 km. In the US, fuel efficiency is in miles/gallon. Let's relate these two: 1 mile = 1.609 km, 1 gal = 3.785 L.

$$\frac{1 \text{ mile}}{\text{gal}} = \frac{1.609 \text{ km}}{3.785 \text{ L}} = \frac{1.609}{3.785} \left(\frac{1}{100} \right) (100) \frac{\text{km}}{\text{L}} = (0.00425) \left(\frac{1}{\text{L}/100 \text{ km}} \right) = \frac{1}{235.24 \text{ L}/100 \text{ km}}$$

Therefore, 1 mile/gal is the reciprocal of 235.2 L/100 km.

(b) Gas consumption is $\frac{12.2 \text{ L}}{100 \text{ km}}$. Using $\frac{1 \text{ L}}{100 \text{ km}} = \frac{1}{235.24 \text{ miles/gal}}$ from part (a),

$$\frac{12.2 \text{ L}}{100 \text{ km}} = 12.2 \left(\frac{1 \text{ L}}{100 \text{ km}} \right) = 12.2 \left(\frac{1}{235.24 \text{ miles/gal}} \right) = \frac{1}{19.282 \text{ miles/gal}}.$$

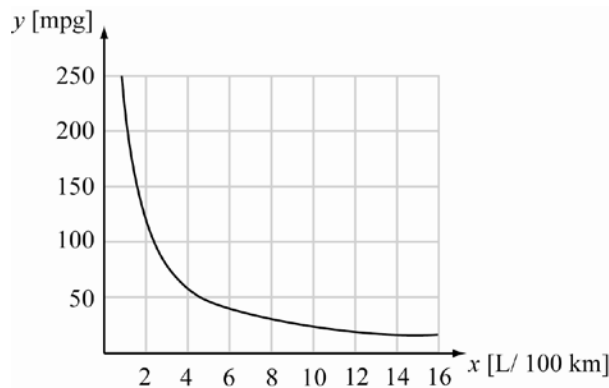
Therefore, a car that consumes 12.2 L/100 km of gasoline has a fuel efficiency of 19.3 miles/gal.

(c) If the fuel efficiency of the car is 27.4 miles per gallon, then

$$\frac{27.4 \text{ miles}}{\text{gal}} = \frac{27.4}{235.24 \text{ L}/100 \text{ km}} = \frac{1}{8.59 \text{ L}/100 \text{ km}}.$$

Therefore, 27.4 miles/gal is equivalent to 8.59 L/100 km.

(d)

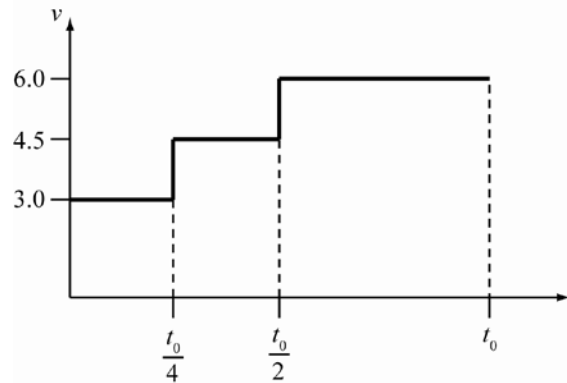


1.18. A vector is described by a set of components in a given coordinate system, where the components are the projections of the vector onto each coordinate axis. Therefore, on a two-dimensional sheet of paper there are two coordinates and thus, the vector is described by two components. In the real three-dimensional world, there are three coordinates and a vector is described by three components. A four-dimensional world would be described by four coordinates, and a vector would be described by four components.

1.19. A vector contains information about the distance between two points (the magnitude of the vector). In contrast to a scalar, it also contains information direction. In many cases knowing a direction can be as important as knowing a magnitude.

- 2.95. **THINK:** The distance to the destination is 199 miles or 320 km. To solve the problem it is easiest to draw a velocity versus time graph. The distance is then given by the area under the curve.

SKETCH:



RESEARCH: For a constant speed, the distance is given by $x = vt$.

SIMPLIFY: To simplify, divide the distance into three parts.

Part 1: from $t = 0$ to $t = t_0 / 4$.

Part 2: from $t = t_0 / 4$ to $t = t_0 / 2$.

Part 3: from $t = t_0 / 2$ to $t = t_0$.

CALCULATE:

(a) The distances are $x_1 = 3.0t_0 / 4$, $x_2 = 4.5t_0 / 4$ and $x_3 = 6.0t_0 / 2$. The total distance is given by

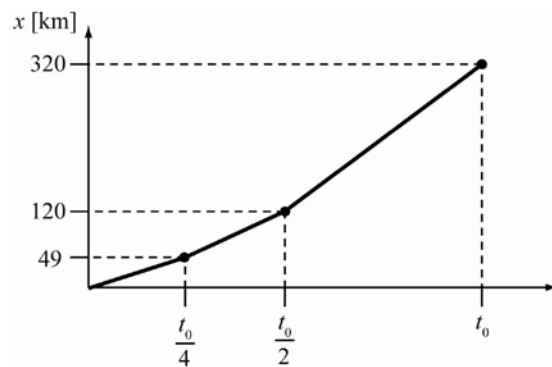
$$x = x_1 + x_2 + x_3 = \frac{(3.0 + 4.5 + 12)t_0}{4} \text{ m} = \frac{19.5t_0}{4} \text{ m} \Rightarrow t_0 = \frac{4x}{19.5} \text{ s.}$$

$$t_0 = \frac{4(320 \cdot 10^3)}{19.5} \text{ s} = 65.6410 \cdot 10^3 \text{ s} = 65641 \text{ s} \Rightarrow t_0 = 18.2336 \text{ h}$$

(b) The distances are:

$$x_1 = 3.0 \left(\frac{65641}{4} \right) \text{ m} = 49.23 \text{ km}, \quad x_2 = 4.5 \left(\frac{65641}{4} \right) \text{ m} = 73.85 \text{ km}, \quad x_3 = 6.0 \left(\frac{65641}{2} \right) \text{ m} = 196.92 \text{ km}.$$

ROUND: Since the speeds are given to two significant figures, the results should be rounded to $x_1 = 49 \text{ km}$, $x_2 = 74 \text{ km}$ and $x_3 = 2.0 \cdot 10^2 \text{ km}$. $x_1 + x_2 = 123 \text{ km} \approx 120 \text{ km}$, and then $x = x_1 + x_2 + x_3 = 323 \text{ km} \approx 320 \text{ km}$.



DOUBLE-CHECK: The sum of the distances x_1 , x_2 and x_3 must be equal to the total distance of 320 km:

$x_1 + x_2 + x_3 = 49.23 + 73.85 + 196.92 = 320 \text{ km}$ as expected. Also, note that $x_1 < x_2 < x_3$ since $v_1 < v_2 < v_3$.

RESEARCH: The energy is given by the change in the height from the top of the swing, mgh . It can be seen from the geometry that $h = l - d = l - l\cos\theta = l(1 - \cos\theta)$. At the bottom of the swinging motion, there is only kinetic energy, $K = (1/2)mv^2$.

SIMPLIFY: Equate the energy at the release point to the energy at the bottom of the swinging motion and solve for θ :

$$mgh = \frac{1}{2}mv^2 \Rightarrow gl(1 - \cos\theta) = \frac{1}{2}v^2 \Rightarrow \theta = \cos^{-1}\left(1 - \frac{v^2}{2gl}\right)$$

CALCULATE: $\theta = \cos^{-1}\left(1 - \frac{(3.00 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)(2.50 \text{ m})}\right) = 35.263^\circ$

ROUND: Rounding to three significant figures, $\theta = 35.3^\circ$.

DOUBLE-CHECK: This is a reasonable angle to attain such a speed on a swing.

5.72

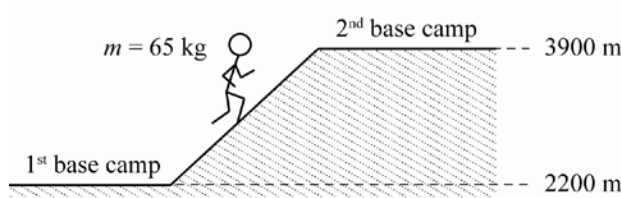
THINK:

(a) Determine the work done against gravity by a 65 kg hiker in climbing from height $h_1 = 2200 \text{ m}$ to a height $h_2 = 3900 \text{ m}$.

(b) The trip takes $t = 5.0 \text{ h}(3600 \text{ s/h}) = 18,000 \text{ s}$. Determine the average power output.

(c) Determine the energy input rate assuming the body is 15% efficient.

SKETCH:



RESEARCH:

(a) The work done against gravity is $W = mg(h_2 - h_1)$.

(b) $P = \frac{E_f - E_i}{t} = \frac{\Delta E}{t}$

(c) The energy output is given by $E_{\text{in}} \times \% \text{ conversion} = E_{\text{out}}$.

SIMPLIFY:

(a) Not necessary.

(b) Not necessary.

(c) $E_{\text{in}} = \frac{E_{\text{out}}}{\% \text{ conversion}}$

CALCULATE:

(a) $W = 65 \text{ kg}(9.81 \text{ m/s}^2)(3900 \text{ m} - 2200 \text{ m}) = 1,084,005 \text{ J}$

(b) $P = \frac{1,084,005 \text{ J}}{18,000 \text{ s}} = 60.22 \text{ W}$

(c) $E_{\text{in}} = \frac{1,084,005 \text{ J}}{0.15} = 7,226,700 \text{ J}$

ROUND:

(a) Rounding to two significant figures, $W = 1.1 \cdot 10^6 \text{ J}$.

(b) Rounding to two significant figures, $P = 60. \text{ W}$.

(c) Rounding to two significant figures, $E_{\text{in}} = 7.2 \cdot 10^6 \text{ J}$.

DOUBLE-CHECK:

(a) This is a reasonable value for such a long distance traveled.

(b) This value is reasonable for such a long period of time.

(c) The daily caloric requirements for a 65 kg man is 2432 calories, which is about $1.0 \cdot 10^7$ J. This is on the same order of magnitude as the result.

- 5.73. For work done by a force that varies with location, $W = \int_{x_1}^{x_2} F_x dx$. In order to oppose the force, equal work must be done opposite the direction of F_x .

$$W = \int_{x_1}^{x_2} F_x dx = \int_{x_1}^{x_2} (-cx^3) dx = -\frac{c}{4} [x^4]_{x_1}^{x_2} = \frac{c}{4} [x_1^4 - x_2^4]$$

This evaluates to:

$$W = \frac{19.1 \text{ N/m}^3}{4} [(0.810 \text{ m})^4 - (1.39 \text{ m})^4] = -15.77 \text{ J}$$

Therefore the work required to oppose F_x is the opposite: $W = 15.77 \text{ J}$ or 15.8 J when rounded to three significant figures.

- 5.74. Apply Hooke's law to find the spring constant k :

$$F = -kx_0 \rightarrow |k| = \frac{F}{x_0}$$

The work done to compress the spring further is equal to the change in spring energy.

$$W = \Delta E = \frac{1}{2} k [x_f^2 - x_0^2] = \frac{1}{2} \frac{F}{x_0} [x_f^2 - x_0^2]$$

$$W = \frac{1}{2} \left(\frac{63.5 \text{ N}}{0.0435 \text{ m}} \right) [(0.0815 \text{ m})^2 - (0.0435 \text{ m})^2] = 3.47 \text{ J}$$

- 5.75. The amount of power required to overcome the force of air resistance is given by $P = F \cdot v$. And the force of air resistance is given by the Ch. 4 formula

$$F_d = \left(\frac{1}{2} c_d A \rho \right) v^2$$

$$\Rightarrow P = \left(\frac{1}{2} c_d A \rho v^2 \right) \cdot v = \frac{1}{2} c_d A \rho v^3$$

This evaluates as:

$$P = \frac{1}{2} (0.333) (3.25 \text{ m}^2) (1.15 \text{ kg/m}^3) (26.8 \text{ m/s})^3 = 11,978.4 \text{ W} = (11,978.4 \text{ W}) \left(\frac{1 \text{ hp}}{745.7 \text{ W}} \right) = 16.06 \text{ hp}$$

To three significant figures, the power is 16.1 hp.

Multi-Version Exercises

- 5.76. **THINK:** This problem involves a variable force. Since we want to find the change in kinetic energy, we can find the work done as the object moves and then use the work-energy theorem to find the total work done.

SKETCH:



RESEARCH: Since the object started at rest, it had zero kinetic energy to start. Use the work-energy theorem $W = \Delta K$ to find the change in kinetic energy. Since the object started with zero kinetic energy, the total kinetic energy will equal the change in kinetic energy: $\Delta K = K$. The work done by a variable force in the x -direction is given by $W = \int_{x_0}^x F_x(x') dx'$ and the equation for our force is $F_x(x') = A(x')^6$. Since the object starts at rest at 1.093 m and moves to 4.429 m, we start at $x_0 = 1.093$ m and end at $x = 4.429$ m.

SIMPLIFY: First, find the expression for work by substituting the correct expression for the force:

$$W = \int_{x_0}^x A(x')^6 dx'. \text{ Taking the definite integral gives } W = \frac{A}{7}(x')^7 \bigg|_{x_0}^x = \frac{A}{7}(x^7 - x_0^7). \text{ Combining this with}$$

the work-energy theorem gives $\frac{A}{7}(x^7 - x_0^7) = W = K$.

CALCULATE: The problem states that $A = 11.45 \text{ N/m}^6$, that the object starts at $x_0 = 1.093$ m and that it ends at $x = 4.429$ m. Plugging these into the equation and calculating gives:

$$\begin{aligned} K &= \frac{A}{7}(x^7 - x_0^7) \\ &= \frac{11.45 \text{ N/m}^6}{7}((4.429 \text{ m})^7 - (1.093 \text{ m})^7) \\ &= 5.467930659 \cdot 10^4 \text{ J} \end{aligned}$$

ROUND: The measured values in this problem are the constant A in the equation for the force and the two distances on the x -axis. All three of these are given to four significant figures, so the final answer should have four significant figures: $5.468 \cdot 10^4 \text{ J}$ or 54.68 kJ .

DOUBLE-CHECK: Working backwards, if a variable force in the $+x$ -direction changes the kinetic energy from zero to $5.468 \cdot 10^4 \text{ J}$, then the object will have moved

$$\begin{aligned} x &= \sqrt[7]{\frac{7(5.468 \cdot 10^4 \text{ J})}{11.45 \text{ N/m}^6}} + 1.093^7 \\ &= 4.429008023 \text{ m}. \end{aligned}$$

This is, within rounding error, the 4.429 m given in the problem, so it seems that the calculations were correct.

5.77. $K = \frac{A}{7}(x^7 - x_0^7)$

$$\frac{7K}{A} = x^7 - x_0^7$$

$$x = \sqrt[7]{\frac{7K}{A} + x_0^7} = \sqrt[7]{\frac{7(5.662 \cdot 10^3 \text{ J})}{13.75 \text{ N/m}^6} + (1.105 \text{ m})^7} = 3.121 \text{ m}$$

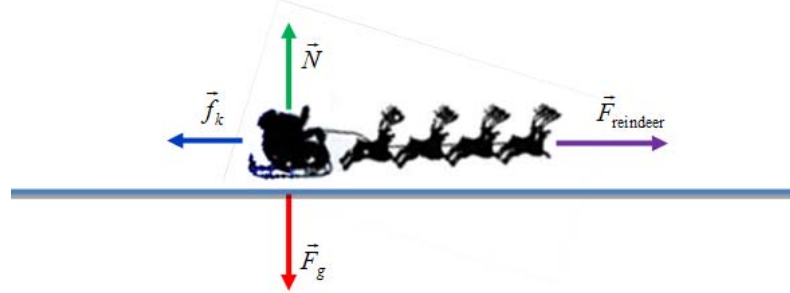
5.78. $K = \frac{A}{7}(x^7 - x_0^7)$

$$\frac{7K}{A} = x^7 - x_0^7$$

$$x_0 = \sqrt[7]{x^7 - \frac{7K}{A}} = \sqrt[7]{(3.313)^7 - \frac{7(1.00396 \cdot 10^4 \text{ J})}{16.05 \text{ N/m}^6}} = 1.114 \text{ m}$$

5.79. **THINK:** In this problem, the reindeer must pull the sleigh to overcome the friction between the runners of the sleigh and the snow. Express the friction force in terms of the speed and weight of the sleigh, and the coefficient of friction between the sleigh and the ground. It is then possible to find the power from the force and velocity.

SKETCH: Draw a free-body diagram for the sleigh:



RESEARCH: Since the sleigh is moving with a constant velocity, the net forces on the sleigh are zero. This means that the normal force and the gravitational force are equal and opposite ($\vec{N} = -\vec{F}_g$), as are the friction force and the force from the reindeer ($\vec{F}_{\text{reindeer}} = -\vec{f}_k$). From the data given in the problem, it is possible to calculate the friction force $f_k = \mu_k mg$. The power required to keep the sleigh moving at a constant speed is given by $P = F_{\text{reindeer}} v$. Eventually, it will be necessary to convert from SI units (Watts) to non-standard units (horsepower or hp). This can be done using the conversion factor $1 \text{ hp} = 746 \text{ W}$.

SIMPLIFY: To find the power required for the sleigh to move, it is necessary to express the force from the reindeer in terms of known quantities. Since the force of the reindeer is equal in magnitude with the friction force, use the equation for frictional force to find:

$$\begin{aligned} |\vec{F}_{\text{reindeer}}| &= |-\vec{f}_k| \\ &= f_k \\ &= \mu_k mg \end{aligned}$$

Use this and the speed of the sleigh to find that $P = F_{\text{reindeer}} v = \mu_k mgv$.

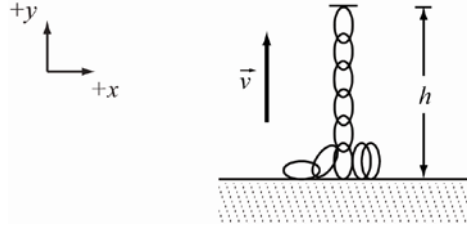
CALCULATE: With the exception of the gravitational acceleration, all of the needed values are given in the question. The coefficient of kinetic friction between the sleigh and the snow is 0.1337, the mass of the system (sleigh, Santa, and presents) is 537.3 kg, and the speed of the sleigh is 3.333 m/s. Using a gravitational acceleration of 9.81 m/s gives:

$$\begin{aligned} P &= \mu_k mgv \\ &= 0.1337 \cdot 537.3 \text{ kg} \cdot 9.81 \text{ m/s}^2 \cdot 3.333 \text{ m/s} \\ &= 2348.83532 \text{ W} \end{aligned}$$

This can be converted to horsepower: $2348.83532 \text{ W} \cdot \frac{1 \text{ hp}}{746 \text{ W}} = 3.148572815 \text{ hp}$.

ROUND: The measured quantities in this problem are all given to four significant figures. Though the conversion from watts to horsepower and the gravitational acceleration have three significant figures, they do not count for the final answer. The power required to keep the sleigh moving is 3.149 hp.

DOUBLE-CHECK: Generally, it is thought that Santa has 8 or 9 reindeer (depending on how foggy it is on a given Christmas Eve). This gives an average of between 0.3499 and 0.3936 horsepower per reindeer, which seems reasonable. Work backwards to find that, if the reindeer are pulling the sled with 3.149 hp, then the speed they are moving must be (rounding to four significant figures):

SKETCH:**RESEARCH:**

(a) Since the chain is raised at a constant rate, v , the net force is the thrust force, $F_{\text{thrust}} = v_c dm/dt$. Since the chain's mass in the air is increasing, $F_{\text{net}} = v dm/dt$.

(b) The applied force can be determined by considering the forces acting on the chain and the net force determined in part (a): $F_{\text{net}} = \sum F_i$.

SIMPLIFY:

$$(a) F_{\text{net}} = v \frac{dm}{dt} = v\lambda \frac{dh}{dt} = v\lambda v = v^2 \lambda$$

$$(b) F_{\text{net}} = F_{\text{applied}} - mg \Rightarrow F_{\text{applied}} = F_{\text{net}} + mg = v^2 \lambda + mg = v^2 \lambda + \lambda hg$$

CALCULATE:

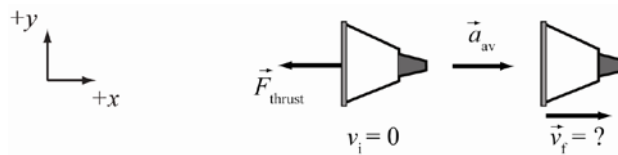
$$(a) F_{\text{net}} = (0.470 \text{ m/s})^2 (1.32 \text{ kg/m}) = 0.2916 \text{ N}$$

$$(b) F_{\text{applied}} = 0.2916 \text{ N} + (1.32 \text{ kg/m})(0.150 \text{ m})(9.81 \text{ m/s}^2) = 0.2916 \text{ N} + 1.942 \text{ N} = 2.234 \text{ N}$$

ROUND: v and h each have three significant figures, so the results should be rounded to $F_{\text{net}} = 0.292 \text{ N}$ and $F_{\text{applied}} = 2.23 \text{ N}$.

DOUBLE-CHECK: These forces are reasonable to determine for this system. Also, $F_{\text{net}} < F_{\text{applied}}$.

- 8.45. THINK:** The thrust force is $\vec{F}_{\text{thrust}} = 53.2 \cdot 10^6 \text{ N}$ and the propellant velocity is $v = 4.78 \cdot 10^3 \text{ m/s}$. Determine (a) dm/dt , (b) the final speed of the spacecraft, v_f , given $v_i = 0$, $m_i = 2.12 \cdot 10^6 \text{ kg}$ and $m_f = 7.04 \cdot 10^4 \text{ kg}$ and (c) the average acceleration, a_{av} until burnout.

SKETCH:**RESEARCH:**

(a) To determine dm/dt , use $\vec{F}_{\text{thrust}} = -v_c dm/dt$.

(b) To determine v_f , use $v_f - v_i = v_c \ln(m_i / m_f)$.

(c) Δv is known from part (b). Δt can be determined from the equivalent ratios,

$$\frac{dm}{dt} = \frac{\Delta m}{\Delta t}, \text{ where } \Delta m = m_i - m_f.$$

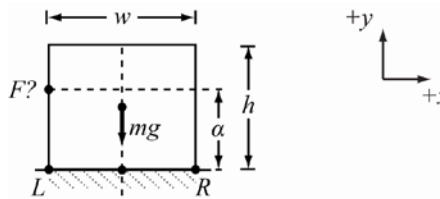
SIMPLIFY:

(a) Since \vec{F}_{thrust} and \vec{v}_c are in the same direction, the equation can be rewritten as:

$$F_{\text{thrust}} = v_c \frac{dm}{dt} \Rightarrow \frac{dm}{dt} = \frac{F_{\text{thrust}}}{v_c}.$$

contribute to the torque, because it is parallel to the moment arm.) Let's call the horizontal force component F_x and the vertical component F_y .

SKETCH:



RESEARCH: The equations for equilibrium are for the

- x -component of the forces: $-F_x + f = 0$, where f is the friction force between box and ground
- y -component of the forces: $F_y + N - mg = 0$
- torques: $\tau_{\text{net}} = F_x \alpha - mg \frac{1}{2} w = 0$

Here we assume that the force is directed to the right and upward. We do not know if the force has a positive or negative y -component. We assumed a positive value, but if it turns out to be negative, then our assumption was incorrect, and the y -component is negative.

For the case of the maximum friction force without slipping, we have $f = \mu_s N$.

SIMPLIFY: From the equation for zero net torque we obtain

$$\tau_{\text{net}} = F_x \alpha - mg \frac{1}{2} w = 0 \Rightarrow F_x = \frac{mgw}{2\alpha}.$$

From $F_y + N - mg = 0$ we can solve for the y -component of the force:

$$F_y = mg - N = mg - f / \mu = mg - F_x / \mu.$$

Then the magnitude of the force is $F = \sqrt{F_x^2 + F_y^2}$.

With F_x and F_y known, the direction of F is given by $\theta = \tan^{-1}(F_y / F_x)$.

CALCULATE:

$$(a) F_x = \frac{(20.0 \text{ kg})(9.81 \text{ m/s}^2)(0.300 \text{ m})}{2(0.500 \text{ m})} = 58.86 \text{ N},$$

$$\text{and } F_y = (20.0 \text{ kg})(9.81 \text{ m/s}^2) - \frac{58.86 \text{ N}}{0.280} = -14.01 \text{ N}.$$

Thus the y -component of the force is in the negative y -direction.

$$\text{Then, } F = \sqrt{(58.86 \text{ N})^2 + (14.01 \text{ N})^2} = 60.50 \text{ N}.$$

$$(b) \theta = \tan^{-1}\left(\frac{-14.01 \text{ N}}{58.86 \text{ N}}\right) = -13.39^\circ, \text{ so below the horizontal.}$$

ROUND: The least precise value given in the question has two significant figures. The answers should be rounded so they also have two significant figures. Therefore, the minimum force is 60.5 N and is directed at an angle of 13.4° below the horizontal.

DOUBLE-CHECK: Since the y -component of the force turned out to have a negative value, this indeed implies that we had to apply some downward force to prevent the box from slipping. Just to make sure that our solution is consistent, we can calculate the product of the box's weight and the coefficient of friction and make sure that this product is really smaller than our result for the horizontal component of the force, $\mu_s mg = (0.280)(20.0 \text{ kg})(9.81 \text{ m/s}^2) = 54.94 \text{ N}$. This is indeed smaller than our result for F_x , which shows that some downward force component was indeed needed.

- 11.80. THINK:** The torque exerted by a torsional spring is proportional to the angle over which it is displaced. The initial angular displacement gives the spring constant. The additional torque added by the hanging mass will create further angular displacement. The arm's mass is $m = 0.0450 \text{ kg}$ and is $l = 0.120 \text{ m}$ long. The

The change in volume of the is given by:

$$\Delta V = \beta_{\text{Al}} V \Delta T = (66.0 \cdot 10^{-6} / ^\circ\text{C})(5.00 \text{ gal})(12.0 ^\circ\text{C}) \left(\frac{3.785 \text{ L}}{1 \text{ gal}} \right) = 0.01499 \text{ L}.$$

Thus, 0.189 L of turpentine spills out of the container.

- 17.60.** The building has initial height of $L = 600. \text{ m}$. The change in temperature is $\Delta T = 45.0 ^\circ\text{C}$. The linear expansion coefficient of steel is $\alpha_s = 1.30 \cdot 10^{-5} / ^\circ\text{C}$.

$$\Delta L = \alpha_s L \Delta T = (1.30 \cdot 10^{-5} / ^\circ\text{C})(600. \text{ m})(45.0 ^\circ\text{C}) = 0.351 \text{ m}$$

Thus, the building grows by 0.351 m.

- 17.61.** The initial diameter of the rod at $20. ^\circ\text{C}$ is D_1 , and after being cooled by a change in temperature of $\Delta T = [77.0 \text{ K} - (20. ^\circ\text{C} + 273.15 \text{ K})] = -216.15 \text{ K}$, it will have a diameter of $D_2 = 10.000 \text{ mm}$. The linear expansion coefficient of aluminum is $\alpha_{\text{Al}} = 22 \cdot 10^{-6} \text{ K}^{-1}$.

$$\Delta D = \alpha_{\text{Al}} D_1 \Delta T, D_2 = D_1 + \Delta D = D_1(1 + \alpha_{\text{Al}} \Delta T)$$

$$D_2 = (1 + \alpha_{\text{Al}} \Delta T) D_1 \Rightarrow D_1 = \frac{D_2}{1 + \alpha_{\text{Al}} \Delta T} \Rightarrow D_1 = \frac{10.000 \text{ mm}}{1 + (22 \cdot 10^{-6} \text{ K}^{-1})(-216.15 \text{ K})} = 10.0478 \text{ mm}$$

Thus, the maximum diameter the aluminum rod can have at $20. ^\circ\text{C}$ is $D_1 = 10. \text{ mm}$.

- 17.62.** After the gas is heated up, its final volume is $V_f = 213 \text{ L}$. The change in temperature is $\Delta T = 63 ^\circ\text{F}$. The volume expansion coefficient of gas is $950 \cdot 10^{-6} \text{ K}^{-1}$. Convert the change in temperature to Kelvin:

$$\Delta T_c = \frac{5}{9} \Delta T_f \text{ and } \Delta T_c = \Delta T_k \Rightarrow \Delta T = \frac{5}{9} (63 ^\circ\text{F}) = 35 \text{ K}.$$

$$\Delta V = \beta_{\text{gas}} V_i \Delta T, V_f = V_i + \Delta V = V_i(1 + \beta_{\text{gas}} \Delta T) \Rightarrow V_i = \frac{V_f}{1 + \beta_{\text{gas}} \Delta T} = \frac{213 \text{ L}}{1 + (950 \cdot 10^{-6} \text{ K}^{-1})(35 \text{ K})} = 206.15 \text{ L}$$

Thus, the maximum amount of gasoline that should be put into the tank at $57 ^\circ\text{F}$ is 206.15 L. Rounding this value is dangerous, since the tank would overflow or possibly explode if 210 L is added.

- 17.63.** The initial volume of the mercury is $V = 8.00 \text{ mL}$, the cross-sectional area of the tube is $A = 1.00 \text{ mm}^2$ and the volume expansion coefficient of mercury is $\beta_{\text{Hg}} = 181 \cdot 10^{-6} / ^\circ\text{C}$. Consider a change in temperature of $\Delta T = 1.00 ^\circ\text{C}$. Since the cross-sectional area remains closely the same, $\Delta V = A \Delta L$.

$$\Delta V = \beta_{\text{Hg}} V \Delta T = A \Delta L \Rightarrow \Delta L = \frac{\beta_{\text{Hg}} V \Delta T}{A} = \frac{(181 \cdot 10^{-6} / ^\circ\text{C})(8.00 \text{ mL})(1.00 ^\circ\text{C})}{1.00 \text{ mm}^2} \left(\frac{1000. \text{ mm}^3}{\text{mL}} \right) = 1.448 \text{ mm}$$

Thus, the $1.00 ^\circ\text{C}$ tick marks should be spaced about 1.45 mm apart.

- 17.64.** The initial volume of gasoline is 14 gallons and the change in temperature is $\Delta T = 27 ^\circ\text{F}$. The volume expansion coefficient of gas is $9.6 \cdot 10^{-4} / ^\circ\text{C}$. Convert the temperature change from Fahrenheit to Celsius:

$$\Delta T_c = \frac{5}{9} \Delta T_f. \text{ Thus } \Delta T = \frac{5}{9} (27 ^\circ\text{F}) = 15 ^\circ\text{C}.$$

Thus, $\Delta V = \beta_{\text{gas}} V \Delta T = (9.6 \cdot 10^{-4} / ^\circ\text{C})(14 \text{ gal})(15 ^\circ\text{C}) = 0.2016 \text{ gal}$. So, 0.20 gallons of gasoline are lost.

- 17.65.** The change in temperature is $\Delta T = 37.8 ^\circ\text{C}$. The initial length of the slabs is $L = 12.0 \text{ m}$. The linear expansion coefficient of concrete is $\alpha_{\text{con}} = 15 \cdot 10^{-6} / ^\circ\text{C}$.

$$\Delta L = \alpha_{\text{con}} L \Delta T = (15 \cdot 10^{-6} / ^\circ\text{C})(12.0 \text{ m})(37.8 ^\circ\text{C}) = 0.006804 \text{ m}$$

Since the slabs expand uniformly, each side will grow by $\Delta L / 2$. However, the slabs expand towards each other, so each can grow by $\Delta L / 2$. Thus, the gap must be $2(\Delta L / 2) = \Delta L = 6.8 \text{ mm}$.

Chapter 21: Electrostatics

Concept Checks

21.1. d 21.2. a 21.3. e 21.4. e 21.5. c 21.6. b 21.7. a 21.8. a 21.9. c 21.10. b 21.11. a

Multiple-Choice Questions

21.1. b 21.2. b 21.3. b 21.4. d 21.5. b 21.6. b 21.7. a 21.8. a 21.9. c 21.10. b 21.11. a 21.12. b 21.13. a 21.14. e

Conceptual Questions

21.15. The given quantities are the charge of the two particles, $Q_1 = Q$ and $Q_2 = Q$. They are separated by a distance d . The Coulomb force between the charged particles is $F = k \frac{Q_1 Q_2}{d^2} = k \frac{Q^2}{d^2}$. If the charge on each particle is doubled so that $Q_1' = 2Q = Q_2'$ and the separation distance is $d' = 2d$ then the Coulomb Force is given by: $F' = k \frac{4Q^2}{4d^2} = k \frac{Q^2}{d^2}$ so the force is the same as it was in the initial situation.

21.16. The gravitational force between the Sun and the Earth is $F_g = G \frac{M_s M_E}{r^2}$ where G is the gravitational constant and is equal to $6.67 \cdot 10^{-11} \text{ N m}^2 / \text{kg}^2$, M_s is the mass of the Sun ($1.989 \cdot 10^{30} \text{ kg}$) and M_E is the mass of the Earth ($5.974 \cdot 10^{24} \text{ kg}$). The Coulomb force is given by the equation $F_c = k \frac{Q_1 Q_2}{r^2}$ where k is Coulomb's constant ($k = 8.99 \cdot 10^9 \text{ N m}^2 / \text{C}^2$). In this question $Q_1 = Q_2 = Q$ and is the charge given to the Earth and Sun to cancel out the gravitational force.

$$F_c = F_g \Rightarrow \frac{kQ^2}{r^2} = \frac{GM_s M_E}{r^2} \Rightarrow Q = \sqrt{\frac{GM_s M_E}{k}}$$

Therefore,

$$Q = \sqrt{\frac{(6.67 \cdot 10^{-11} \text{ N m}^2 / \text{kg}^2)(1.989 \cdot 10^{30} \text{ kg})(5.974 \cdot 10^{24} \text{ kg})}{8.99 \cdot 10^9 \text{ N m}^2 / \text{C}^2}} = 2.97 \cdot 10^{17} \text{ C}.$$

I can get the number of elementary charges, n , by dividing Q by $1.602 \cdot 10^{-19} \text{ C}$ (the charge of one electron):

$$n = \frac{2.97 \cdot 10^{17} \text{ C}}{1.602 \cdot 10^{-19} \text{ C}} = 1.85 \cdot 10^{36}.$$

To estimate the number of elementary change of either sign for the Earth I can assume the mass of the Earth is due to the mass of the protons, neutrons and electrons of which it is primarily composed. If I assume that the Earth's mass is due to the proton and neutron masses primarily (became an electrons mass is much smaller than a protons) and I assume that there are an equal number of protons and neutrons than I can get the number of protons by dividing the Earth's mass by two times the mass of a proton. The mass of a proton is $m_p \approx 1.6726 \cdot 10^{-27} \text{ kg}$, so you can estimate the number of elementary charges on the

Earth, n_e by: $n_e = \frac{m_E}{m_p} = \frac{5.97 \cdot 10^{24} \text{ kg}}{1.67 \cdot 10^{-27} \text{ kg}} = 3.57 \cdot 10^{51}$. So the percentage of the Earth's changes that would be

required to cancel out the gravitational force is $(n / n_e) \cdot 100\% = 5.18 \cdot 10^{-14}\%$, a very small percentage.

CALCULATE: The image distance for the lens is $d_{i,1} = \frac{(30. \text{ cm})(50. \text{ cm})}{(30. \text{ cm}) - (50. \text{ cm})} = -75 \text{ cm}$. The object distance for the plane mirror is $d_{o,2} = 40. \text{ cm} + |-75 \text{ cm}| = 115 \text{ cm}$. Therefore, the position of the final image is $x_{i,2} = 70. \text{ cm} + 115 \text{ cm} = 185 \text{ cm}$. The size of the final image is $h_{i,2} = -\frac{(-75 \text{ cm})(2.0 \text{ cm})}{(30. \text{ cm})} = 5.0 \text{ cm}$.

ROUND: To two significant figures, the final image is $x_{i,2} = 190 \text{ cm}$ to the right of the object and the size of the final image is $h_{i,2} = 5.0 \text{ cm}$.

DOUBLE-CHECK: Since $d_o < f$ for the converging lens, the image of the lens must be virtual, enlarged and upright. The plane mirror cannot change these attributes, so the calculated results agree with these expectations ($h_{i,2} > h_{o,1} > 0$).

- 33.92.** The distance from the lens to the retina at the back of the eye is 2.0 cm . The focal length can be found with the thin lens equation: $f = \left(\frac{1}{d_o} + \frac{1}{d_i} \right)^{-1}$. (a) The focal length of the lens when viewing a distant object

($d_o = \infty$) is $f = \left(\frac{1}{\infty} + \frac{1}{2.0 \text{ cm}} \right)^{-1} = 2.0 \text{ cm}$. (b) The focal length of the lens when viewing an object

$d_o = 25 \text{ cm}$ from the front of the eye is $f = \left(\frac{1}{25 \text{ cm}} + \frac{1}{2.0 \text{ cm}} \right)^{-1} = 1.9 \text{ cm}$.

- 33.93.** You require lenses of power $P = -8.4$ diopter. A negative power infers that the focal length is negative, so diverging lenses are being used. In a nearsighted eye, light comes to a focus before it reaches the retina and diverging lenses are required to correct this. Therefore, you are nearsighted. For nearsighted eyes, corrective lenses focus distant objects ($d_o = \infty$) at the near point, so $d_i = -d_{\text{near}}$. Solving the thin lens equation for d_{near} gives:

$$D = 1/f = 1/d_o + 1/d_i = 1/\infty - 1/d_{\text{near}} \Rightarrow -d_{\text{near}} = 1/D = -(1/-8.4 \text{ m}^{-1}) = 0.12 \text{ m}.$$

$$P = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{\infty} - \frac{1}{d_{\text{near}}} \Rightarrow -d_{\text{near}} = \frac{1}{P} = -\left(\frac{1}{-8.4 \text{ m}^{-1}} \right) = 0.12 \text{ m}.$$

Without glasses the book must be held 12 cm from your eye in order to read clearly.

- 33.94.** Jack has a near point of $d_{\text{near}} = 32 \text{ cm} = 0.32 \text{ m}$ and the power of the magnifier is $P = 25$ diopter. (a) The focal length is given by $f = 1/P$ and the angular magnification of a magnifier for an image formed at infinity is $m = \frac{d_{\text{near}}}{f}$. Therefore, $m = d_{\text{near}}P = (0.32 \text{ m})(25 \text{ m}^{-1}) = 8.0$.

(b) If the final image is at the near point then $m = \frac{-d_i}{d_o} = -\left(\frac{-d_{\text{near}}}{d_o} \right) = \frac{d_{\text{near}}}{d_o}$. Using the thin lens equation:

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow d_o = \left(\frac{1}{f} - \frac{1}{d_i} \right)^{-1} = \left(\frac{1}{f} + \frac{1}{d_{\text{near}}} \right)^{-1} = \frac{fd_{\text{near}}}{f + d_{\text{near}}}. \text{ Therefore the magnification is:}$$

$$m = \frac{d_{\text{near}}}{\frac{fd_{\text{near}}}{f + d_{\text{near}}}} = \frac{1}{f}(f + d_{\text{near}}) = 1 + \frac{d_{\text{near}}}{f} = 1 + Pd_{\text{near}} = 1 + (25 \text{ m})(0.32 \text{ m}) = 9.0.$$