1. Correct Response: E

Young's Modulus has dimensions of force per area, which has SI units N/m^2:

$$\frac{\text{N}}{\text{m}^2}=\frac{\text{kg}\cdot\text{m/s}^2}{\text{m}^2}=\frac{\text{kg}}{\text{s}^2\cdot\text{m}}$$

2. Correct Response: B

$$\left[\frac{P}{A}\right]=\left[\frac{E}{A\cdot t}\right]=\frac{\text{M}\cdot\text{L}^2/\text{T}^2}{\text{L}^2\cdot\text{T}}=\frac{\text{M}}{\text{T}^3}$$

3. Correct Response: B

Using a coordinate system with the +x-direction toward the east and the +y direction toward the north, the total of the first two displacements is

$$\left|d_1+d_2\right|=\left|(4.00\,\text{mi})\hat{\imath}+(3.00\,\text{mi})\hat{\jmath}\right|=\sqrt{(4.00\,\text{mi})^2+(3.00\,\text{mi})^2}=5.00\,\text{mi}$$

The average speed is the total path length divided by the total duration,

$$\bar{v}=\frac{|d_1|+|d_2|+|d_3|}{t_1+t_2+t_3}=\frac{4.00\,\text{mi}+3.00\,\text{mi}+5.00\,\text{mi}}{1.00\,\text{hr}+0.750\,\text{hr}+1.667\,\text{hr}}=3.51\,\text{mi/hr}$$

4. Correct Response: C

$$v_f^2=v_i^2+2a(x-x_0)\quad\Rightarrow\quad x-x_0=\frac{v_f^2-v_i^2}{2a}=\frac{(1.00\,\text{m/s})^2-(3.00\,\text{m/s})^2}{2\left(-0.200\,\text{m/s}^2\right)}=20.0\,\text{m}$$

5. Correct Response: E

$$x_f=x_i+v_it+\tfrac{1}{2}at^2$$

In this case,

$$x_f=x_i\quad\Rightarrow\quad 0=v_it+\tfrac{1}{2}at^2\quad\Rightarrow\quad t=0\quad or\quad t=-\frac{2v_i}{a}=-\frac{2(3.00\,\text{m/s})}{-0.200\,\text{m/s}^2}=30.0\,\text{s}$$

6. Correct Response: D

Using a coordinate system with the +x axis to the East and the +y axis to the North,

$$\vec{v}_{boat\,to\,bank}=\vec{v}_{boat\,to\,river}+\vec{v}_{river\,to\,bank}\quad\Rightarrow\quad\vec{v}_{boat\,to\,river}=\vec{v}_{boat\,to\,bank}-\vec{v}_{river\,to\,bank}$$

$$\Rightarrow\quad\vec{v}_{boat\,to\,river}=12.0\,\text{m/s}\,\hat{\mathbf{i}}-5.00\,\text{m/s}\,\hat{\mathbf{j}}\quad\Rightarrow\quad v_{boat\,to\,river}=\sqrt{(12.0\,\text{m/s})^2+(5.00\,\text{m/s})^2}=13.0\,\text{m/s}$$

7. Correct Response: E

Using a coordinate system with horizontal as the *x* direction and vertical upward as the *y* direction,

$$v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$$

$$\Rightarrow \quad v_{0y} = \sqrt{v_y^2 - 2a_y(y - y_0)} = \sqrt{0 - 2(-9.80\, m/s^2)(30.0\, m)} = 24.25\,\text{m/s}$$

$$0 = y - y_0 = v_{0y}t + \tfrac{1}{2}a_y t^2 \quad \Rightarrow \quad t = 0 \quad or \quad t = -\frac{2v_{0y}}{a_y} = -\frac{2(24.25\,\text{m/s})}{-9.80\,\text{m/s}^2} = 4.949\,\text{s}$$

$$\tan\theta_0 = \frac{v_{0y}}{v_{0x}} \quad \Rightarrow \quad v_{0x} = \frac{v_{0y}}{\tan\theta_0} = \frac{24.25\,\text{m/s}}{\tan 50.0°} = 20.35\,\text{m/s}$$

$$x - x_0 = v_{0x}t = (20.35\,\text{m/s})(4.949\,\text{s}) = 101\,\text{m}$$

8. Correct Response: D

Using the same coordinate system as in the previous situation,

$$v_y^2 - v_{0y}^2 = 2a(y - y_0) \quad \text{and} \quad v_{0y} = v_0 \sin\theta_0 \quad \Rightarrow$$

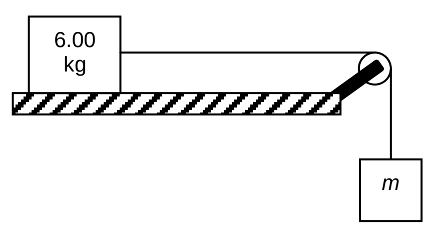
$$\Rightarrow \quad v_0 = \frac{\sqrt{v_y^2 - 2a(y - y_0)}}{\sin\theta_0} = \frac{\sqrt{0^2 - 2(-9.8\,\text{m/s}^2)(30.0\,\text{m})}}{\sin 50.0°} = 31.7\,\text{m/s}$$

9. Correct Response: A

$$F = \frac{\Delta p}{\Delta t} = m_{cart}a_{cart} + m_{person}a_{person} + m_{block}a_{block} \quad \Rightarrow \quad a_{cart} = \frac{F - m_{person}a_{person} - m_{block}a_{block}}{m_{cart}}$$

$$\Rightarrow \quad a_{cart} = \frac{1200\text{ N} - (100\text{ kg})(2.00\text{ m/s}^2) - (200\text{ kg})(2.00\text{ m/s}^2)}{800\text{ kg}} = 0.750\text{ m/s}^2$$

10. Correct Response: B



The only horizontal component of the force on the 6.00 kg block is the 30.0 N tension force. The horizontal acceleration of the 6.00 kg block is

$$a = \frac{F}{m} = \frac{30.0\text{ N}}{6.00\text{ kg}} = 5.00\text{ m/s}^2$$

The block of mass *m* has the same magnitude acceleration, but in the downward direction. The total vertical force on that block is the upward tension force and the downward gravitational force. By Newton's 2nd Law,

$$30.0\text{ N} - mg = ma \quad \Rightarrow \quad m = \frac{30.0\text{ N}}{a + g} = \frac{30.0\text{ N}}{-5.00\,\text{m/s}^2 + 9.80\,\text{m/s}^2} = 6.25\,\text{kg}$$

11. Correct Response: A

Using a coordinate system with the +x-axis downhill parallel to the incline,

$$\sum F_x = ma_x \quad \Rightarrow \quad F\sin 25^\circ + mg\sin 25^\circ = ma_x \quad \Rightarrow \quad F = \frac{ma_x}{\sin 25^\circ} - mg$$

$$\Rightarrow \quad F = \frac{\left(8.00\ \text{N}/9.80\ \text{m/s}^2\right)\left(6.00\ \text{m/s}^2\right)}{\sin 25^\circ} - \left(8.00\ \text{N}\right) = 3.59\ \text{N}$$

12. Correct Response: C

$$\sum F_x = ma_x = 0 \quad \Rightarrow \quad -F_{applied} + F\sin 25^\circ + mg\sin 25^\circ = ma_x = 0$$

But from problem 11,

$$F\sin 25^\circ + mg\sin 25^\circ = m\left(6.00\ \text{m/s}^2\right) \quad \Rightarrow \quad -F_{applied} + m\left(6.00\ \text{m/s}^2\right) = 0$$

$$\Rightarrow \quad F_{applied} = m\left(6.00\ \text{m/s}^2\right) = \frac{8.00\ N}{9.80\ \text{m/s}^2}\left(6.00\ \text{m/s}^2\right) = 4.90\ \text{N}$$

13. Correct Response: B

There are no external forces acting on the system, so the center of mass moves with constant velocity. From the initial conditions, the center of mass velocity is

$$v_{cm} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = \frac{(3.00\ \text{kg})(4.00\ \text{m/s}) + (2.00\ \text{kg})(-3.00\ \text{m/s})}{(3.00\ \text{kg}) + (2.00\ \text{kg})} = 1.20\ \text{m/s}$$

$$x_{cm} - x_{0cm} = v_{cm}t = (1.20\ \text{m/s})(5.00\ \text{s}) = 6.00\ \text{m}$$

14. Correct Response: A

In a perfectly elastic collision, the total kinetic energy is conserved.

$$\tfrac{1}{2}m_1 v_{1i}^2 + \tfrac{1}{2}m_2 v_{2i}^2 = \tfrac{1}{2}m_1 v_{1f}^2 + \tfrac{1}{2}m_2 v_{2f}^2 \quad \Rightarrow \quad v_{2f} = \sqrt{\frac{m_1}{m_2}\left(v_{1i}^2 - v_{1f}^2\right) + v_{2i}^2}$$

$$\Rightarrow \quad v_{2f} = \sqrt{\frac{5.00\ \text{kg}}{4.00\ \text{kg}}\left([30.0\ \text{m/s}]^2 - [10.0\ \text{m/s}]^2\right) + 0} = 31.6\ \text{m/s}$$

15. Correct Response: C

The metric prefix pico is equivalent to 10^{-12}.

16. Correct Response: B

$$P = \frac{W}{t} = \frac{\Delta K}{t} = \frac{600\ \text{J}}{12.0\ \text{s}} = 50.0\ \text{W}$$

17. Correct Response: B

$$T - m_1 g = m_1 a \quad and \quad T - m_2 g = -m_2 a$$
$$\Rightarrow \quad T = \frac{2m_1 m_2}{m_1 + m_2} g = \frac{2(4.00\,\text{kg})(6.00\,\text{kg})}{4.00\,\text{kg} + 6.00\,\text{kg}}\left(9.80\,\text{m/s}^2\right) = 47.0\ \text{N}$$

18. Correct Response: E

The entire original piece can be considered two masses, the mass m_1 that ends up with the hole in it and the mass m_2 circular piece that is moved.

$$\vec{r}_{cm} = \frac{\sum m_i \vec{r}_i}{\sum m_i} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2}{m_1 + m_2} = \frac{(10.0\,\text{kg})(\vec{0}) + (2.00\,\text{kg})(3.00\,\text{m}\,\hat{\mathbf{i}} + 2.00\,\text{m}\,\hat{\mathbf{j}})}{10.0\,\text{kg} + 2.00\,\text{kg}} = 0.500\,\text{m}\,\hat{\mathbf{i}} + 0.333\,\text{m}\,\hat{\mathbf{j}}$$

19. Correct Response: D

Assuming a Cartesian coordinate system with positive x horizontally to the right and positive y vertically downward. On the 45.0° line, the x coordinate is equal to the y coordinate.

$$x = v_{0x} t = v_{0y} t + \tfrac{1}{2} a t^2 \quad \Rightarrow \quad t = 2\frac{v_{0x} - v_{0y}}{a} = 2\frac{30.0\,\text{m/s} - 0.00\,\text{m/s}}{9.80\,\text{m/s}^2} = 6.122\text{s}$$
$$\Rightarrow \quad x = v_{0x} t = (30.0\,\text{m/s})(6.122\text{s}) = 184\,\text{m}$$

20. Correct Response: C

Calculate the moment of inertia of a solid circular plate of the same density and subtract the moment of inertia of four circles that are cut from the plate.

$$I = I_{solid} - 4I_{cutout} = \tfrac{1}{2} m_{solid} R^2 - 4\left(\tfrac{1}{2} m_{cutout} R^2_{cut-out} + m_{cutout}\left[\tfrac{2}{3} R\right]^2\right)$$

The mass of a solid circular plate of the same density and radius R as the object shown is

$$m_{solid} = \pi R^2 \sigma = \pi R^2 \frac{M}{\pi R^2 - 4\pi\left(\tfrac{1}{3} R\right)^2} = \tfrac{9}{5} M \quad \text{and} \quad m_{cut-out} = \pi\left(\tfrac{1}{3} R\right)^2 \sigma = \tfrac{1}{9} m_{solid} = \tfrac{1}{5} M$$
$$\Rightarrow \quad I = \tfrac{1}{2}\left(\tfrac{9}{5} M\right) R^2 - 4\left(\tfrac{1}{2}\left[\tfrac{1}{5} M\right]\left[\tfrac{1}{3} R\right]^2 + \left[\tfrac{1}{5} M\right]\left[\tfrac{2}{3} R\right]^2\right) = \left[\tfrac{9}{10} - 4\left\{\tfrac{1}{90} + \tfrac{4}{45}\right\}\right] M R^2 = \tfrac{1}{2} M R^2$$

21. Correct Response: B

$$\frac{G m_{star} m_{planet}}{R^2} = m_{planet} a = m_{planet} \omega^2 R = m_{planet} \frac{4\pi^2}{T^2} R \quad \Rightarrow$$
$$m_{star} = \frac{4\pi^2}{G T^2} R^3 = \frac{4\pi^2 \left(6.00\times 10^{11}\,\text{m}\right)^3}{\left(6.673\times 10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2\right)(20.0\,\text{yr})^2 \left(3.156\times 10^7\,\text{s/yr}\right)^2} = 3.21\times 10^{29}\,\text{kg}$$

22. Correct Response: C

$$PV = NkT \quad \Rightarrow \quad \frac{P_2 V_2}{P_1 V_1} = \frac{N T_2}{N T_1} \quad \Rightarrow \quad T_2 = \frac{P_2 V_2}{P_1 V_1} T_1 = \frac{(200\,\text{kPa})(5.00\,\text{m}^3)}{(300\,\text{kPa})(1.00\,\text{m}^3)} T_1 = 3.33 T_1$$

23. Correct Response: E

Work done by a gas is the area below the PV curve. That area can be partitioned into two trapezoids, one with a base from 1.0 m^3 to 2.0 m^3 and the second with a base from 2.0 m^3 to 5.0 m^3

$$W = \tfrac{1}{2}\left(300\times10^3\ \text{Pa} + 600\times10^3\ \text{Pa} +\right)\left(1.00\,\text{m}^3\right) + \tfrac{1}{2}\left(600\times10^3\ \text{Pa} + 200\times10^3\ \text{Pa} +\right)\left(3.00\,\text{m}^3\right)$$
$$= 1.65\times10^6\ \text{J}$$

24. Correct Response: C

$$R_{eq} = 4.00\,\Omega = 2.00\,\Omega + \frac{R(6.00\,\Omega)}{R + 6.00\,\Omega} \quad\Rightarrow\quad R = \frac{(4.00\,\Omega)(6.00\,\Omega) - (2.00\,\Omega)(6.00\,\Omega)}{6.00\,\Omega + 2.00\,\Omega - 4.00\,\Omega} = 3.00\,\Omega$$

25. Correct Response: B

$$Z = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$
$$= \sqrt{(9.00\,\Omega)^2 + \left[\left(1.20\times10^3\text{s}^{-1}\right)\left(30.0\times10^{-3}\ \text{H}\right) - 1/\left(\left(1.20\times10^3\text{s}^{-1}\right)\left(20.0\times10^{-6}\ \text{F}\right)\right)\right]^2} = 10.6\,\Omega$$

26. Correct Response: D

$$\sum\vec{F} = 0 \quad\Rightarrow\quad qE - mg = 0 \quad\Rightarrow\quad g = \frac{qE}{m} = \frac{\left(3.00\times10^{-3}\ \text{C}\right)\left(4000\,\text{V/m}\right)}{2.00\,\text{kg}} = 6.00\,\text{m/s}^2$$

27. Correct Response: B

$$m\lambda = \frac{dy}{L} \quad\Rightarrow\quad y = \frac{m\lambda L}{d} \quad\Rightarrow\quad y_2 - y_{-3} = [(2) - (-3)]\frac{\lambda L}{d}$$
$$\Rightarrow\quad d = \frac{5\lambda L}{y_2 - y_{-3}} = \frac{5\left(500\times10^{-9}\ \text{m}\right)(3.00\,\text{m})}{\left(7.00\times10^{-3}\ \text{m}\right)} = 1.07\times10^{-3}\ \text{m} = 1.07\,\text{mm}$$

28. Correct Response: A

$$\frac{1}{f_2} = \frac{1}{s_2} + \frac{1}{s_2'} \quad\Rightarrow\quad s_2 = \frac{f\,s_2'}{s_2' - f} = \frac{(-80.0\ \text{cm})(2.00\ \text{m} - 60.0\ \text{cm})}{(2.00\ \text{m} - 60.0\ \text{cm}) - (-80.0\ \text{cm})} = -50.91\,\text{cm}$$

Therefore, the image from the first lens is at *x* = 60.0 cm + 50.91 cm = 110.91 cm.

$$\frac{1}{f_1} = \frac{1}{s_1} + \frac{1}{s_1'} \quad\Rightarrow\quad s_1 = \frac{f\,s_1'}{s_1' - f} == \frac{(40.0\,\text{cm})(110.91\,\text{cm} - 10.0\,\text{cm})}{(110.91\,\text{cm} - 10.0\,\text{cm}) - (40.0\,\text{cm})} = 66.27\,\text{cm}$$

The source is 66.27 cm from the lens located at 10.0 cm, so the x position of the source is

$$x_{source} = 10.0\,\text{cm} - 66.27\,\text{cm} = -56.3\,\text{cm}$$

29. Correct Response: C

$$\sum F = 0 \quad \Rightarrow \quad F_{buoyant} - mg = 0 \quad \Rightarrow \quad \rho_{fluid} g V_{submerged} - \rho_{cylinder} g V_{cylinder} = 0$$

$$\Rightarrow \quad \rho_{cylinder} = \frac{V_{submerged}}{V_{cylinder}} \rho_{fluid} = \frac{\frac{2}{3}\pi R^2 L + 2\left(\frac{1}{2} R \cos 60° R \sin 60°\right) L}{\pi R^2 L} \rho_{fluid} = 0.804 \rho_{fluid}$$

30. Correct Response: B

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2 \quad \text{and} \quad A_1 v_1 = A_2 v_2 \quad \Rightarrow \quad v_2 = \frac{A_1}{A_2} v_1 = \frac{\pi R_1^2}{\pi R_2^2} v_1$$

$$\Rightarrow \quad \rho = \frac{2(P_1 - P_2)}{v_2^2 - v_1^2} = \frac{2(P_1 - P_2)}{v_1^2 \left(R_1^4 / R_2^4 - 1\right)} = \frac{2\left(2.00 \times 10^5 \text{ N/m}^2\right)}{(40.0 \text{ m/s})^2 \left((20.0 \text{ cm})^4 / (10.0 \text{ cm})^4 - 1\right)}$$

$$= 16.7 \text{ kg/m}^3$$

31. Correct Response: E

By definition of change in entropy,

$$\Delta S = \frac{Q}{T}$$

32. Correct Response: A

$$\Delta U + \Delta K = 0 \quad \Rightarrow$$

$$-mg\Delta h = \Delta K = mC\left(T_f - T_i\right) \quad \Rightarrow \quad T_f = T_i - \frac{g\Delta h}{C} = 40.0\ °\text{C} - \frac{\left(9.80 \text{ m/s}^2\right)(-20.0 \text{ m})}{80.0 \text{ J/}(\text{kg} \cdot \text{C°})} = 42.5\ °\text{C}$$

33. Correct Response: E

$$\Delta E = E_1 + E_2 = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = hc\left(\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right)$$

$$= \left(6.63 \times 10^{-34} \text{J} \cdot \text{s}\right)\left(3.00 \times 10^8 \text{ m/s}\right)\left(\frac{1}{400 \times 10^{-9} \text{ m}} + \frac{1}{600 \times 10^{-9} \text{ m}}\right) = 8.29 \times 10^{-19} \text{ J}$$

$$\Delta E = 8.29 \times 10^{-19} \text{ J} \times \frac{1 \text{eV}}{1.602 \times 10^{-19} J} = 5.17 \text{ eV}$$

34. Correct Response: B

$$K = E - mc^2 = Amc^2 - mc^2 = (A-1)mc^2$$

35. Correct Response: C

The neutron is a subatomic particle with a half-life 611 s.