WYSE – Academic Challenge
Physics Test (State) – 2015

1. **Correct Response: A**

Angular momentum is the product of mass (M), velocity (L/T), and radius (L).

2. **Correct Response: E**

$$\text{Average speed} = \frac{\text{path length}}{\text{time interval}} = \frac{6.0\ \text{m}}{2.0\ \text{s}} = 3.0\ \text{m/s}$$

3. **Correct Response: D**

$$\text{Average speed} = \frac{\text{path length}}{\text{time interval}} = \frac{9.0\ \text{m}}{6.0\ \text{s}} = 1.5\ \text{m/s}$$

4. **Correct Response: D**

$$t = \sqrt{\frac{2y_0}{g}} = \sqrt{\frac{2\left(\frac{1}{2}g(2.00\ \text{s})^2 + 40.0\ \text{m}\right)}{g}} = \sqrt{\frac{2\left(\frac{1}{2}\left(9.80\ \text{m/s}^2\right)(2.00\ \text{s})^2 + 40.0\ \text{m}\right)}{\left(9.80\ \text{m/s}^2\right)}} = 3.49\ \text{s}$$

5. **Correct Response: E**

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.

$$x = v_{0x}t = v_{0y}t + \tfrac{1}{2}at^2 \quad \Rightarrow \quad t = 2\frac{v_{0x} - v_{0y}}{a} = 2\frac{20.0\ \text{m/s} - 0.00\ \text{m/s}}{9.80\ \text{m/s}^2} = 4.08\ \text{s}$$

$$\Rightarrow \quad x = v_{0x}t = (20.0\ \text{m/s})(4.08\ \text{s}) = 81.6\ \text{m}$$

6. **Correct Response: E**

With a coordinate system with the positive x direction parallel to and up the incline and the y direction perpendicular to plane and directed upward:

$$\sum F_x = F\cos 20.0° - (m_4 + m_2)g\sin 20.0° = (m_4 + m_2)a \quad \Rightarrow$$

$$\Rightarrow \quad F = \frac{(m_4 + m_2)a + (m_4 + m_2)g\sin 20.0°}{\cos 20.0°} =$$

$$= \frac{\left[(4.00\ \text{kg}) + (2.00\ \text{kg})\right]\left(2.00\ \text{m/s}^2\right) + \left[(4.00\ \text{kg}) + (2.00\ \text{kg})\right]\left(9.80\ \text{m/s}^2\right)\sin 20.0°}{\cos 20.0°}$$

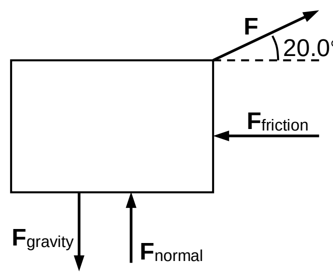
$$= 34.2\ \text{N}$$

7. **Correct Response: B**

With a coordinate system with the positive x direction parallel to and up the incline and the y direction perpendicular to plane and directed upward:

$$\sum F_x = F - m_2 g \sin 20.0^\circ = m_2 a = 0 \quad \Rightarrow$$
$$\Rightarrow \quad F = m_2 g \sin 20.0^\circ = (2.00\,\text{kg})(9.80\,\text{m/s}^2)\sin 20.0^\circ = 6.70\text{ N}$$

8. **Correct Response: C**



$$\mathbf{F}_{gravity} + \mathbf{F}_{normal} + \mathbf{F}_{friction} + \mathbf{F} = 0 \quad \Rightarrow \quad F_{gravity\,y} + F_{normal\,y} + F_{friction\,y} + F_y = 0 \quad \Rightarrow$$
$$F_{normal\,y} = -F_{gravity\,y} - F_{friction\,y} - F_y = -(-20.0\,\text{kg})(9.80\,\text{m/s}^2) - 0 - 60.0\,\text{N}\sin 20.0^\circ = 175.\text{N}$$
$$F_{gravity\,x} + F_{normal\,x} + F_{friction\,x} + F_x = 0 \quad \Rightarrow \quad 0 + 0 - \mu F_{normal} + F\cos 20.0^\circ = 0 \quad \Rightarrow$$
$$\mu = \frac{F\cos 20.0^\circ}{F_{normal}} = \frac{(60.0\,\text{N})\cos 20.0^\circ}{175.\text{N}} = 0.321$$

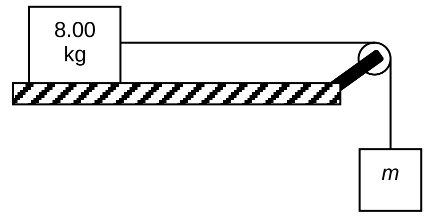
9. **Correct Response: A**

$$W_{friction} = \Delta K + \Delta U_{gravity} \quad \Rightarrow \quad -\mu mgd\cos 30^\circ = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2 + mg(h_2 - h_1)$$
$$\Rightarrow \quad \mu = -\frac{\tfrac{1}{2}v_2^2 - \tfrac{1}{2}v_1^2 + g(h_2 - h_1)}{gd\cos 30^\circ}$$
$$= -\frac{v_2^2 - v_1^2 - 2gd\sin 30^\circ}{2gd\cos 30^\circ} = -\frac{(4.00\,\text{m/s})^2 - (2.00\,\text{m/s})^2 - 2(9.80\,\text{m/s}^2)(1.50\,\text{m})\sin 30^\circ}{2(9.80\,\text{m/s}^2)(1.50\,\text{m})\cos 30^\circ}$$
$$= 0.106$$

10. **Correct Response: C**

$$\mathbf{a} = \frac{\mathbf{F}}{m} = \frac{\mathbf{F}_A + \mathbf{F}_B}{m} \quad \Rightarrow \quad a_x = \frac{F_{Ax} + F_{Bx}}{m} = \frac{(2.00\,\text{N})\sin 50.0^\circ - (4.00\,\text{N})\cos 20.0^\circ}{3.00\,\text{kg}} = -0.7422\,\text{m/s}^2$$
$$\Rightarrow \quad a_y = \frac{F_{Ay} + F_{By}}{m} = \frac{(2.00\,\text{N})\cos 50.0^\circ + (4.00\,\text{N})\sin 20.0^\circ}{3.00\,\text{kg}} = 0.8846\,\text{m/s}^2$$
$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{(-0.7422\,\text{m/s}^2)^2 + (0.8846\,\text{m/s}^2)^2} = 1.15\,\text{m/s}^2$$

11. **Correct Response: C**



The only horizontal component of the force on the 8.00 kg block is the 40.0 N tension force. The horizontal acceleration of the 8.00 kg block is

$$a = \frac{F}{m} = \frac{40.0\ \text{N}}{8.00\ \text{kg}} = 5.00\ \text{m/s}^2.$$

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,

$$40.0\ \text{N} - mg = ma \quad \Rightarrow \quad m = \frac{40.0\ \text{N}}{a+g} = \frac{40.0\ \text{N}}{-5.00\ \text{m/s}^2 + 9.80\ \text{m/s}^2} = 8.33\ \text{kg}$$

12. **Correct Response: C**

No. The constant acceleration, initial velocity, and initial position must all be known to determine the postion at future times.

13. **Correct Response: D**

$$a = \sqrt{a_c^2 + a_t^2} = \sqrt{\left(\omega^2 r\right)^2 + (\alpha r)^2} = \sqrt{\left(\left(2.00\ \text{s}^{-1}\right)^2 (0.200\ \text{m})\right)^2 + \left(\left(3.00\ \text{s}^{-2}\right)(0.200\ \text{m})\right)^2} = 1.00\ \text{m/s}^2$$

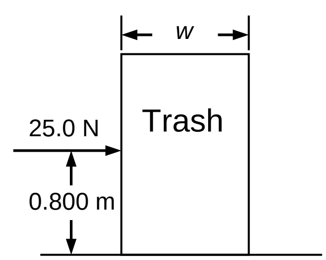
14. **Correct Response: E**

A conservative force results in no net work done on an object as it traverses a closed path. In this case, there is a change in speed as the object completes a closed path, so work must have been done on the object. The force is not conservative.

15. **Correct Response: B**

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2)v' \quad \Rightarrow \quad v' = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = \frac{(500\ \text{kg})(8.00\ \text{m/s}) + (80.0\ \text{kg})(0)}{500\ \text{kg} + 80.0\ \text{kg}} = 6.90\ \text{m/s}$$

16. **Correct Response: C**



If the trash can tips, it will rotate about the lower right-most point of the trash can. Calculating torque about that point with an axis of rotation perpendicular to the page,

$$\sum \tau = mg\frac{w}{2} - F_{horizontal}(0.800\ \text{m}),$$

where positive torque is counterclockwise and negative torque is clockwise. The trash can will tip if the total torque about the lower right corner is clockwise (i.e. less than zero).

$$\sum \tau = mg\frac{w}{2} - F_{horizontal}(0.800\,\text{m}) < 0$$

$$\Rightarrow \quad w < \frac{2F_{horizontal}(0.800\,\text{m})}{mg} = \frac{2(25.0\,\text{N})(0.800\,\text{m})}{(6.00\,\text{kg})(9.80\,\text{m/s}^2)} = 0.680\,\text{m}$$

17. **Correct Response: A**

$$x_{cm} = \frac{m_1 x_{cm1} + m_2 x_{cm2}}{m_1 + m_2} = \frac{(2.00\text{ m})(20.0\text{ kg}) + (8.00\text{ m})(24.0\text{ kg})}{(20.0\text{ kg}) + (24.0\text{ kg})} = 5.27\text{ m}$$

$$y_{cm} = \frac{m_1 y_{cm1} + m_2 y_{cm2}}{m_1 + m_2} = \frac{(2.50\text{ m})(20.0\text{ kg}) + (1.50\text{ m})(24.0\text{ kg})}{(20.0\text{ kg}) + (24.0\text{ kg})} = 1.95\text{ m}$$

18. **Correct Response: E**

$$I_{zz} = I_1 + I_2 = \left(I_{cm1} + m_1 d_1^2\right) + \left(I_{cm2} + m_2 d_2^2\right)$$

$$= \tfrac{1}{12}(20.0\,\text{kg})\left((4.00\,\text{m})^2 + (5.00\,\text{m})^2\right) + (20.0\,\text{kg})\left((2.00\,\text{m})^2 + (2.50\,\text{m})^2\right)$$

$$+ \tfrac{1}{12}(24.0\,\text{kg})\left((8.00\,\text{m})^2 + (3.00\,\text{m})^2\right) + (24.0\,\text{kg})\left((8.00\,\text{m})^2 + (1.50\,\text{m})^2\right)$$

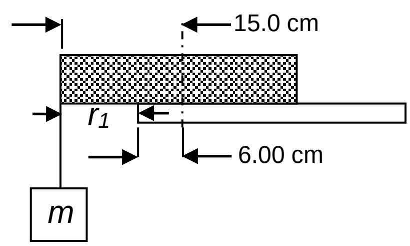
$$= 2.01\times 10^3\text{ kg}\cdot\text{m}^2$$

19. **Correct Response: A**

$$I_f \omega_f = I_i \omega_i \quad \Rightarrow \quad I_f = \frac{I_i \omega_i}{\omega_f} = \frac{(3.00\text{ kg}\cdot\text{m}^2)(2\pi 1.0\text{ s}^{-1})}{(2\pi 2.5\text{ s}^{-1})} = 1.20\text{ kg}\cdot\text{m}^2$$

$$W = \Delta K = \tfrac{1}{2} I_f \omega_f^2 - \tfrac{1}{2} I_i \omega_i^2 = \tfrac{1}{2}(1.20\text{ kg}\cdot\text{m}^2)(2\pi 2.5\text{ s}^{-1})^2 - \tfrac{1}{2}(3.00\text{ kg}\cdot\text{m}^2)(2\pi 1.0\text{ s}^{-1})^2 = 88.8\text{ J}$$

20. **Correct Response: A**



The maximum mass without tipping results in a zero net torque on the object. If the torque about the edge of the table is used,

$$+r_1 mg - r_{cm\,block} m_{block} g = 0. \quad \Rightarrow$$

$$+(9.00\,\text{cm})m(9.80\,\text{m/s}^2) - (6.00\,\text{cm})(4.00\,\text{kg})(9.80\,\text{m/s}^2) = 0 \quad \Rightarrow$$

$$m = \frac{(6.00\,\text{cm})(4.00\,\text{kg})(9.80\,\text{m/s}^2)}{(9.00\,\text{cm})(9.80\,\text{m/s}^2)} = 2.67\,\text{kg}$$

21. **Correct Response: A**

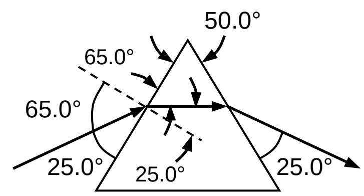
$$F_{average} = \frac{\Delta P}{\Delta t} = \frac{(m_1 v_{1f} + m_2 v_{2f}) - (m_1 v_{1i} + m_2 v_{2i})}{\Delta t_1}$$

Using a coordinate system with north positive and south negative,

$$F_{average} = \frac{((100.\text{ kg})(0) + (80.0\text{ kg})(0)) - ((100.\text{ kg})(-6.00\text{ m/s}) + (80.0\text{ kg})(7.00\text{ m/s}))}{(0.400\text{ s})} = 100.\text{ N}$$

This is the force on the players, so by Newton's 3rd Law, the force on the ground is 100. N south.

22. **Correct Response: E**



The symmetry of the direction of the entering ray and the exiting ray imply that the ray within the prism forms an isoceles triangle with the apex of the triangle with base angle 65.0°. Therefore, the incident angle and the refracted angle are 65.0° and 25.0°, respectively.

$$n_i \sin\theta_i = n_r \sin\theta_r \quad \Rightarrow \quad n_r = \frac{n_i \sin\theta_i}{\sin\theta_r} = \frac{1.000 \sin 65.0^\circ}{\sin 25.0^\circ} = 2.14$$

23. **Correct Response: C**

$$\frac{P_1 V_1}{P_2 V_2} = \frac{n_1 T_1}{n_2 T_2} \quad \Rightarrow \quad P_2 = \frac{P_1 V_1 n_2 T_2}{V_2 n_1 T_1} = \frac{P_1 T_2}{T_1} = \frac{(1.00\,\text{atm})([400. + 273.]\text{K})}{([200. + 273.]\text{K})} = 1.42\,\text{atm}$$

24. **Correct Response: E**

$$U = \tfrac{3}{2} nRT \quad \Rightarrow \quad \Delta U = \tfrac{3}{2} nR\Delta T$$
$$= \tfrac{3}{2}(4.00\text{ moles})(8.3145\text{ J/(mole}\cdot\text{K)})([400. + 273.]\text{K} - [200. + 273.]\text{K}) = 9.98\,\text{kJ}$$

25. **Correct Response: B**

$$Q = m_{ice} c_{ice} \Delta T_{ice} + m_{ice} L_{fusion} + m_{ice} c_{water} \Delta T_{melted\ ice} + m_{water} c_{water} \Delta T_{water}$$
$$= (20.0\text{ g})(2.11\text{ J/(g}\cdot\text{C}^\circ))(0.00\ ^\circ\text{C} - [-5.00\ ^\circ\text{C}]) + (20.0\text{ g})(334.\text{ J/g})$$
$$+ (20.0\text{ g})(4.18\text{ J/(g}\cdot\text{C}^\circ))(20.0\ ^\circ\text{C-}0.00\ ^\circ\text{C})$$
$$+ (100.0\text{ g})(4.18\text{ J/(g}\cdot\text{C}^\circ))(20.0\ ^\circ\text{C-}0.00\ ^\circ\text{C}) = 16.9\text{ kJ}$$

26. **Correct Response: E**

Given a wave represented by a function of x and t that can be written in the form

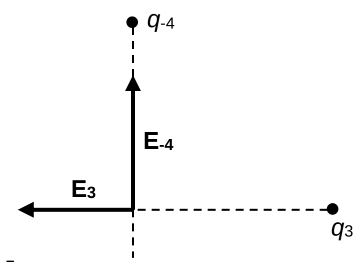
$$y(x,t) = f(x - vt),$$

where the velocity of the wave is *v*. The given function that describes the wave can be put in this form

$$y(x,t) = A\cos(3kx - 9\omega t) + 2A\sin(2kx - 6\omega t) = A\cos\left[3k\left(x - \frac{3\omega}{k}t\right)\right] + 2A\sin\left[2k\left(x - \frac{3\omega}{k}t\right)\right],$$

which implies the velocity of the waves is $3\omega / k$.

27. **Correct Response: B**



$$\mathbf{E} = \mathbf{E}_3 + \mathbf{E}_{-4} \quad \Rightarrow \quad E_x = E_{3x} + E_{-4x} \quad \text{and} \quad E_y = E_{3y} + E_{-4y}$$

$$E_x = -\frac{k|q_3|}{d_3^2} + 0 = -\frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(3.00\times10^{-6}\ \text{C}\right)}{(0.200\ \text{m})^2} + 0 = -6.74\times10^5\ \text{N/C}$$

$$E_y = 0 + \frac{k|q_{-4}|}{d_{-4}^2} = 0 + \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(4.00\times10^{-6}\ \text{C}\right)}{(0.200\ \text{m})^2} = 8.99\times10^5\ \text{N/C}$$

$$E = \sqrt{E_x^2 + E_y^2} = \sqrt{\left(-6.75\times10^5\ \text{N/C}\right)^2 + \left(9.00\times10^5\ \text{N/C}\right)^2} = 1.12\times10^6\ \text{N/C}$$

28. **Correct Response: A**

$$E = -\frac{\Delta V}{\Delta x} \quad \Rightarrow \quad \Delta V = -E\Delta x \quad \Rightarrow \quad V_2 - V_1 = -E\Delta x \quad \Rightarrow$$

$$V_2 = V_1 - E\Delta x = 2.00\ \text{V} - (5.00\ \text{N/C})(1.00\ \text{m}) = -3.00\ \text{V}$$

29. **Correct Response: C**

Application of the right hand rule for the force on a positive charge, gives a resulting force direction into the page. As the moving charge is negative, the force is in the opposite direction, out of the page.

30. **Correct Response: D**

$$R_{equivalent} = 18.0\ \Omega + \frac{(20.0\ \Omega)(30.0\ \Omega)}{(20.0\ \Omega) + (30.0\ \Omega)} = 30.0\ \Omega$$

$$P = \frac{V^2}{R_{equivalent}} = \frac{(150.\ \text{V})^2}{30.0\ \Omega} = 750.\ \text{W}$$

31. **Correct Response: E**

Applying Faraday's Law, during the time the flux is changing there is an induced EMF proportional to the rate of change of the flux. When the flux is constant, the induced EMF is zero. The polarity of the induced EMF when the flux is decreasing is opposite in polarity to when the flux is increasing.

32. **Correct Response: B**

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{V_{rms}}{\sqrt{R^2 + \omega^2 L^2}} = \frac{10.0\text{ V}}{\sqrt{(40.0\ \Omega)^2 + \left(1.00 \times 10^4\ \text{s}^{-1}\right)^2 \left(3.00 \times 10^{-3}\ \text{H}\right)^2}} = 0.200\ \text{A}$$

33. **Correct Response: D**

$$I = \frac{E}{A \cdot t} = \frac{\frac{hc}{\lambda}\frac{N}{t}}{L \cdot W} = \frac{\frac{\left(6.626 \times 10^{-34}\,\text{J}\cdot\text{s}\right)\left(3.00. \times 10^{8}\,\text{m/s}\right)}{\left(600. \times 10^{-9}\,\text{m}\right)}\left(2.00 \times 10^{20}\,\text{s}^{-1}\right)}{(0.200\text{ m})(0.300\text{ m})} = 1.10\,\text{kW/m}^2$$

34. **Correct Response: B**

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}} \quad \Rightarrow \quad v = \sqrt{1 - \frac{L^2}{L_0^2}}\,c = \sqrt{1 - \left(\frac{75.0\,\text{m}}{100.0\,\text{m}}\right)^2}\,c = 0.661c$$

35. **Correct Response: D**

A beta decay results in an atom with an atomic number one greater than the original atom. The element with atomic number 7 is nitrogen.