WYSE – Academic Challenge
Physics Exam Solutions (Sectional) – 2018

1. **Correct Response: B**

This is a direct application of Kepler's Third Law,

$$T = \sqrt{\frac{4\pi^2}{GM_s}}a^{3/2} \quad \Longrightarrow \quad M_s = \frac{4\pi^2 a^3}{GT^2}$$

$$M_s = \frac{4\pi^2(1.50\times10^{11}\text{ m})^3}{(6.67\times10^{-11}\ N\cdot\text{m}^2/\text{kg}^2)(3.15\times10^7\text{ s})^2} = 2.01\times10^{30}\text{ kg}$$

Note:

$$T = 1.00\text{ yr} = 1.00\text{ yr}\left(\frac{365.24\text{ days}}{1.00\text{ yr}}\right)\left(\frac{24.0\text{ hr}}{1.00\text{ day}}\right)\left(\frac{3600\text{ s}}{1.00\text{ hr}}\right) = 3.15\times10^7\text{ s}$$

2. **Correct Response: C**

$$d = |y(t_2) - y(t_1)| \quad \Longrightarrow$$

$$d = \left|\left(y_o + v_o t_2 + \tfrac{1}{2}at_2^2\right) - \left(y_o + v_o t_1 + \tfrac{1}{2}at_1^2\right)\right| = \left|v_o(t_2 - t_1) + \tfrac{1}{2}a(t_2^2 - t_1^2)\right| \quad \Longrightarrow$$

$$d = \left|(0.00\text{ m/s})(3.83\text{ s} - 1.31\text{ s}) + \tfrac{1}{2}(6.27\text{ m/s}^2)([3.83\text{ s}]^2 - [1.31\text{ s}]^2)\right| = 40.6\text{ m}$$

3. **Correct Response: A**

$$\mathbf{F}_{net} = M\mathbf{a} \quad \Longrightarrow \quad \mathbf{a} = \frac{\mathbf{F}_{net}}{M}$$

4. **Correct Response: C**

$$\mathbf{A}+\mathbf{B} = (1.36\hat{\mathbf{i}} - 2.10\hat{\mathbf{j}}) + (1.49\cos 224°\,\hat{\mathbf{i}} + 1.49\sin 224°\,\hat{\mathbf{j}}) = 0.288\hat{\mathbf{i}} - 3.14\hat{\mathbf{j}}$$

$$|\mathbf{A}+\mathbf{B}| = \sqrt{(\mathbf{A}+\mathbf{B})_x^2 + (\mathbf{A}+\mathbf{B})_y^2} = \sqrt{(0.288)^{\mathbf{2}} + (3.14)^{\mathbf{2}}} = 3.15$$

$$\theta_{\mathbf{A+B}} = \tan^{-1}\frac{(\mathbf{A}+\mathbf{B})_y}{(\mathbf{A}+\mathbf{B})_x} = \tan^{-1}\frac{-3.14}{0.288} = -85° \text{ (or } +275°)$$

5. **Correct Response: D**

$$a = \sqrt{a_r^2 + a_t^2} = \sqrt{\left(\frac{v^2}{r}\right)^2 + a_t^2} = \sqrt{\left(\frac{(15.0\text{ m/s})^2}{(37.5\text{ m})}\right)^2 + (8.00\text{ m/s}^2)^2} = 10.0\text{ m/s}^2$$

6. **Correct Response: D**

$$\omega = \omega_o + \alpha t \quad \Longrightarrow \quad \alpha = \left|\frac{\omega - \omega_o}{t}\right| = \left|\frac{0.75\frac{\text{rev}}{\text{s}}\cdot 2\pi\frac{\text{rad}}{\text{rev}} - 3.00\frac{\text{rev}}{\text{s}}\cdot 2\pi\frac{\text{rad}}{\text{rev}}}{14.3\text{ s}}\right| = 0.989\ \frac{\text{rad}}{\text{s}^2}$$

7. **Correct Response: A**

$$W = \Delta K = \tfrac{1}{2}I\omega_f^2 - \tfrac{1}{2}I\omega_o^2 = \tfrac{1}{2}I\left(\omega_f^2 - \omega_o^2\right)$$

$$W = \tfrac{1}{2}(0.0176\ \text{kg}\cdot\text{m}^2)\left\{\left(0.75\frac{\text{rev}}{\text{s}}\cdot 2\pi\frac{\text{rad}}{\text{rev}}\right)^2 - \left(3.00\frac{\text{rev}}{\text{s}}\cdot 2\pi\frac{\text{rad}}{\text{rev}}\right)^2\right\} = -2.93\ \text{J}$$

8. **Correct Response: E**

$$\Delta K + \Delta U = 0 \quad \Longrightarrow \quad \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2 - mgh = 0 \quad \Longrightarrow \quad v_f = \sqrt{2gh + v_o^2}$$

9. **Correct Response: B**

$$W = \Delta K \quad \Longrightarrow \quad -\mu_k mgd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2 \quad \Longrightarrow \quad v_f = \sqrt{v_o^2 - 2\mu_k gd} \quad \Longrightarrow$$

$$v_f = \sqrt{(5.23\ \text{m/s})^2 - 2(0.150)(6.11\ \text{m})(9.80\ \text{m/s}^2)} = 3.06\ \text{m/s}$$

10. **Correct Response: B**

$$W = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r}$$

For the first segment of the motion, the path is parallel to the *y* axis,

$$d\mathbf{r} = dy\hat{\mathbf{j}} \quad \Longrightarrow \quad W_1 = \int_{y_i}^{y_f} \mathbf{F}\cdot dy\hat{\mathbf{j}} = \int_{y=1.00\ \text{m}}^{y=4.00\ \text{m}} \{(3.00\ \text{N/m})x\hat{\boldsymbol{\imath}} + (1.00\ \text{N/m}^2)xy\hat{\mathbf{j}}\}\cdot dy\hat{\mathbf{j}}$$

$$= \int_{y=1.00\ \text{m}}^{y=4.00\ \text{m}} (1.00\ \text{N/m}^2)xy\,dy = \tfrac{1}{2}(1.00\ \text{N/m}^2)xy^2\Big|_{y=1.00\ \text{m}}^{y=4.00\ \text{m}} =$$

$$= \tfrac{1}{2}(1.00\ \text{N/m}^2)(1.00\ \text{m})[(4.00\ \text{m})^2 - (1.00\ \text{m})^2] = 7.50\ \text{J}$$

For the second segment of the motion, the path is parallel to the *x* axis,

$$d\mathbf{r} = dx\hat{\mathbf{i}} \quad \Longrightarrow \quad W_2 = \int_{x_i}^{x_f} \mathbf{F}\cdot dx\hat{\mathbf{i}} = \int_{x=1.00\ \text{m}}^{x=5.00\ \text{m}} \{(3.00\ \text{N/m})x\hat{\mathbf{i}} + (1.00\ \text{N/m}^2)xy\hat{\mathbf{j}}\}\cdot dx\hat{\mathbf{i}}$$

$$= \int_{x=1.00\ \text{m}}^{x=5.00\ \text{m}} (3.00\ \text{N/m})x\,dx = \tfrac{1}{2}(3.00\ \text{N/m})x^2\Big|_{x=1.00\ \text{m}}^{x=5.00\ \text{m}} =$$

$$= \tfrac{1}{2}(3.00\ \text{N/m})[(5.00\ \text{m})^2 - (1.00\ \text{m})^2] = 36.0\ \text{J}$$

$$W = W_1 + W_2 = 7.5\ \text{J} + 36.0\ J = 43.5\ \text{J}$$

11. **Correct Response: B**

$$\omega = \frac{2\pi}{T} = \sqrt{\frac{g}{l}} \quad \Longrightarrow \quad g = \frac{4\pi^2 l}{T^2} = \frac{4\pi^2(1.78\ \text{m})}{(6.94\ \text{s})^2} = 1.46\ \text{m/s}^2$$

12. **Correct Response: C**

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_f \quad \Longrightarrow$$

$$v_f = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = \frac{(785\ \text{kg})(8.21\ \text{m/s}) + (2410\ \text{kg})(4.67\ \text{m/s})}{785\ \text{kg} + 2410\ \text{kg}} = 5.54\ \text{m/s}$$

13. **Correct Response: C**

$$\frac{P_1 V_1}{P_2 V_2} = \frac{n_1 T_1}{n_2 T_2} \quad \Longrightarrow \quad P_2 = \frac{P_1 V_1 n_2 T_2}{V_2 n_1 T_1} = \frac{(1.33\ \text{atm})([500\ + 273.15]\ \text{K})}{([200 + 273.15]\ \text{K})} = 2.17\ \text{atm}$$

14. **Correct Response: E**

$$U = \frac{3}{2} nRT \quad \Longrightarrow$$

$$\Delta U = \tfrac{3}{2} nR\Delta T = \tfrac{3}{2}(3.00\ \text{moles})(8.3145\ \text{J/(mole}\ \cdot \text{K))}([500 - 200]\ \text{K}) = 11.2\ \text{kJ}$$

15. **Correct Response: B**

First, using the right hand rule, the magnetic field direction at the location of interest created by both currents is in the positive *y* direction.

$$\mathbf{B} = \frac{\mu_o I_1}{2\pi d_1}\hat{\mathbf{j}} + \frac{\mu_o I_2}{2\pi d_2}\hat{\mathbf{j}} = \frac{(4\pi \times 10^{-7}\ \text{T} \cdot \text{m/A})(0.768\ \text{A})}{2\pi(1.56 \times 10^{-2}\ \text{m})}\hat{\mathbf{j}} + \frac{(4\pi \times 10^{-7}\ \text{T} \cdot \text{m/A})(0.768\ \text{A})}{2\pi(1.56 \times 10^{-2}\ \text{m})}\hat{\mathbf{j}}$$

$$\mathbf{B} = 1.97 \times 10^{-5}\ \text{T}\ \hat{\mathbf{j}}$$

16. **Correct Response: E**

In General Relativity, the surface of the sphere of radius equal to the Schwarzschild radius is known as the event horizon.

17. **Correct Response: D**

Gamma rays are electromagnetic radiation and therefore energetic photons.

18. **Correct Response: E**

$$p = mv \quad \Longrightarrow \quad m = \frac{p}{v} \quad \Longrightarrow \quad \text{units of mass} = \frac{\text{units of momentum}}{\text{units of velocity}} = \frac{\text{su}}{\text{duper}}$$

19. **Correct Response: B**

Using a coordinate system with the x-direction toward the east and the y-direction toward the north,

$$d_x = d\cos\theta \quad \Longrightarrow \quad d = \frac{d_x}{\cos\theta}$$

$$d_y = d\sin\theta = \frac{d_x \sin\theta}{\cos\theta} = \frac{(200.\text{ miles})\sin 50.0°}{\cos 50.0°} = 238\text{ miles}$$

20. **Correct Response: E**

Using East as the positive $x$ coordinate,

$$v_f^2 - v_i^2 = 2a(x_f - x_i) \quad \Longrightarrow$$

$$a = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{(-8.00\text{ m/s})^2 - (4.00\text{ m/s})^2}{2(-2.00\text{ m/s} - 0.00\text{ m/s})} = -12.0\text{ m/s}^2$$

21. **Correct Response: A**

Using East as the positive $x$ coordinate,

$$W = \mathbf{F}\cdot\mathbf{d} = (20.0\text{ N})(-2.00\text{ m} - 0.00\text{ m}) = -40.0\text{ J}$$

22. **Correct Response: E**

Either recall

$$\text{Range} = \frac{2v_0^2 \cos\theta \ \sin\theta}{g}$$

or derive this range equation. Using $x$ as the horizontal component and upward $y$ as the vertical component,

$$y = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 = y_0 + v_0 \sin\theta\, t - \tfrac{1}{2}gt^2$$

As $y = y_0$,

$$t = 0 \quad or \quad t = \frac{2v_0 \sin\theta}{g}$$

The horizontal component of motion is constant velocity motion,

$$x = x_0 + v_{0x}t \quad \Longrightarrow \quad \text{Range} = x - x_0 = v_0\cos\theta\, t = \frac{2v_0^2\cos\theta \ \sin\theta}{g}$$

23. **Correct Response: A**

Using a coordinate system with horizontally to the right as the +x-direction and vertically upward as the +y-direction,

$$\sum F_y = ma_y \quad \Longrightarrow \quad -mg - (20.0\text{ N})\sin 30.0° + F_N = 0 \quad \Longrightarrow$$

$$F_N = mg + (20.0\text{ N})\sin 30.0° = (5.00\text{ kg})(9.80\text{ m/s}^2) + (20.0\text{ N})\sin 30.0° = 59.0\text{ N}$$

$$\sum F_x = ma_x \quad \Longrightarrow \quad (20.0\text{ N})\cos 30.0° - \mu F_N = ma_x \quad \Longrightarrow$$

$$\mu = \frac{(20.0\text{ N})\cos 30.0° - ma_x}{F_N} = \frac{(20.0\text{ N})\cos 30.0° - (5.00\text{ kg})(2.00\text{ m/s}^2)}{59.0\text{ N}} = 0.124$$

24. **Correct Response: B**

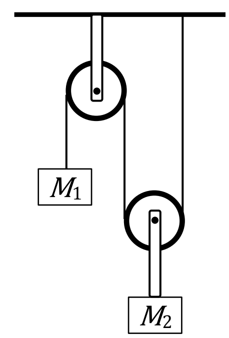
$$\sum F_x = ma_x \quad \Rightarrow \quad (20.0\text{ N})\cos 30.0° - \mu F_N + F_a = ma_x = 0 \quad \Rightarrow$$

$$F_a = -\{(20.0\text{ N})\cos 30.0° - \mu F_N\} = -ma_{no\,F_a} = -(5.00\text{ kg})\left(2.00\frac{\text{m}}{\text{s}^2}\right) = -10.0\text{ N}$$

25. **Correct Response: D**

$$\tau = r_1 F_1 \sin\theta_1 + r_2 F_2 \sin\theta_2 = (0.60\text{ m})(60.0\text{ N})\sin(-70.0°) + (1.00\text{ m})(80.0\text{ N})\sin(245°)$$
$$= -106\text{ N}\cdot\text{m}$$

26. **Correct Response: D**




Using a coordinate system with vertically upward as the $+y$ direction and the $T$ as the magnitude of the tension force,

$$\sum F_{y1} = T - M_1 g = M_1 a_1 \quad\text{and}\quad \sum F_{y2} = 2T - M_2 g = M_2 a_2$$

If $M_1$ moves, then $M_2$ will move one-half the distance and in the opposite vertical direction $\Rightarrow a_2 = -\frac{1}{2}a_1$. Using this relationship and solving the left equation above for $T$ and substituting for $T$ in the right equation above,

$$2(M_1 a_1 + M_1 g) - M_2 g = -\tfrac{1}{2}M_2 a_1$$

Solving for $a_1$,

$$a_1 = -\frac{4M_1 - 2M_2}{4M_1 + M_2}g \quad\text{or}\quad |a_1| = \left|\frac{4M_1 - 2M_2}{4M_1 + M_2}\right| g$$

27. **Correct Response: D**

$$0 = \Delta K + \Delta U = K_f - K_i + M_1 g\Delta h_1 + M_2 g\Delta h_2$$

As in previous solution, $M_2$ will move one-half the distance and in the opposite vertical direction to $M_1 \quad \Rightarrow \quad \Delta h_2 = -\frac{1}{2}\Delta h_1$

$$K_f = K_i - M_1 g\Delta h_1 - M_2 g\Delta h_2 = 0 - M_1 g\Delta h_1 + \tfrac{1}{2}M_2 g\Delta h_1 = -\left(M_1 - \tfrac{1}{2}M_2\right)g\Delta h_1$$

As $K_f$ must be non-negative, $\Delta h_1$ must be negative, so $M_1$ is the mass that falls.

$$K_f = \left(M_1 - \tfrac{1}{2}M_2\right)gd$$

28. **Correct Response: B**

Set the tension in the cable to the maximum tension, 400 N, and solve for the mass $M$ that creates static equilibrium. Solving for the torque about the pin at point A,

$$\tau = (0.700)L\,(400\text{ N})\sin 150.° - (1.00)LMg\sin 90.0° - (0.500)Lm_{beam}g\sin 90.0° = 0$$

$$\Longrightarrow \quad M = \frac{(0.700)\,(400\text{ N})\sin 150.° - (0.500)(10.0\text{ kg})\left(9.80\,\frac{\text{m}}{\text{s}^2}\right)\sin 90.0°}{(1.00)\left(9.80\,\frac{\text{m}}{\text{s}^2}\right)\sin 90.0°} = 9.28\text{ kg}$$

29. **Correct Response: B**

As the total impulse acting on a system is identical to the total change in momentum of the system, response b. is an alternate statement of the law of conservation of momentum.

30. **Correct Response: A**

$$\bar{K} = \tfrac{3}{2}k_BT = \tfrac{1}{2}mv_{rms}^2 \quad \Longrightarrow \quad \frac{v_{rms2}^2}{v_{rms1}^2} = \frac{T_2}{T_1}$$

$$\Longrightarrow \quad v_{rms2} = \sqrt{\frac{T_2}{T_1}}\,v_{rms1} = \sqrt{\frac{80.0 + 273.15}{20.0 + 273.15}}\;v = 1.10\;v$$

31. **Correct Response: C**

Within the described fields, the electrostatic force on the electron is directed toward the top of the page, and, using the right-hand rule, the magnetic force on the electron is toward the bottom of the page. For the electron to move with constant velocity, the net force must be zero, implying that the magnitude of the electrostatic force equals the magnitude of the magnetic force.

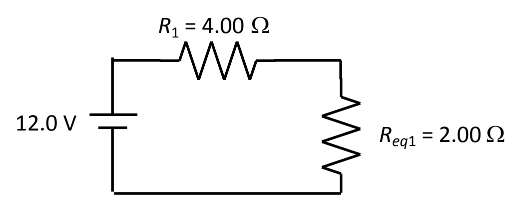
$$qE = qvB\sin\theta \quad \Longrightarrow \quad v = \frac{E}{B\sin\theta} = \frac{300.\,\frac{\text{V}}{\text{m}}}{2.00\text{ T}\sin 90°} = 150.\text{ m/s}$$

32. **Correct Response: B**

Taking an approach of reducing the circuit to a single equivalent resistance, the equivalent resistance of $R_2$ and $R_3$ in parallel is

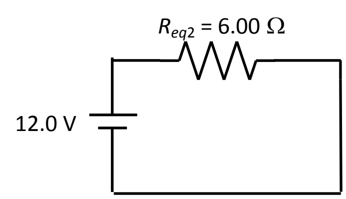
$$R_{eq1} = \frac{R_2R_3}{R_2 + R_3} = \frac{(3.00\ \Omega)(6.00\ \Omega)}{(3.00\ \Omega) + (6.00\ \Omega)} = 2.00\ \Omega$$

This results in an equivalent circuit shown to the right with the $R_1$ in series with $R_{eq1}$. These two resistances




in series have an equivalent resistance

$$R_{eq2} = R_1 + R_{eq1} = (4.00\ \Omega) + (2.00\ \Omega) = 6.00\ \Omega$$




Ohm's Law may now be used directly to determine the current from the voltage source,

$$V = IR_{eq2} \quad \Longrightarrow \quad I = \frac{V}{R_{eq2}} = \frac{12.0\text{ V}}{6.00\ \Omega} = 2.00\text{ A}$$

33. **Correct Response: D**

$$E_{Z,n} = -13.6\text{ eV}\,\frac{Z^2}{n^2} \quad \Longrightarrow \quad \frac{E_{3Z,2}}{E_{Z,1}} = \frac{(3Z)^2/2^2}{Z^2/1^2} = \frac{9}{4} \quad \Longrightarrow \quad E_{3Z,2} = \frac{9}{4}E_{Z,1}$$

34. **Correct Response: A**

$$E = \gamma E_0 \quad \Longrightarrow \quad \gamma = \frac{E}{E_0} = \frac{6.0\ \times 10^{12}\text{eV}}{9.38\ \times 10^{8}\text{eV}} = 6.397 \times 10^3$$

$$L = \frac{L_0}{\gamma} = \frac{21.6\text{ m}}{6.397 \times 10^3} = 3.38\ \times 10^{-3}\text{m} = 3.38\text{ mm}$$

35. **Correct Response: E**

$$A = A_0 e^{-t/\tau} \quad \Longrightarrow \quad \tau = \frac{-t}{\ln\frac{A}{A_0}} = \frac{-3.00\text{ hr}}{\ln\frac{1.00\ \mu\text{Ci}}{4.00\ \mu\text{Ci}}} = 2.16\text{ hr}$$