WYSE – Academic Challenge
Physics Test (Sectional) – 2016

1. **Correct Answer: A**

Conservation of Energy

$$mgH = mgR + \frac{1}{2}mv^2$$

Solving for *v* gives:

$$v = \sqrt{2g(H-R)}$$

2. **Correct Answer: D**

The pressure at depth is atmospheric plus the pressure of the water.

$$P = P_A + \rho g D$$

Plugging in the numbers gives

$$P = 1.01 \times 10^5 \text{Pa} + 1 \times 10^3 \frac{\text{kg}}{\text{m}^3} \times 9.8 \frac{\text{m}}{\text{s}^2} \times 12 \text{ m} = 2.18 \times 10^5 \text{Pa}$$

Converting to atm means dividing by P_A

$$P = \frac{2.18 \times 10^5 \text{Pa}}{1.01 \times 10^5 \frac{\text{Pa}}{\text{atm}}} = 2.16 \text{ atm}$$

3. **Correct Answer: B**

$$F = ma$$

$$m_1 + m_2 + m_3 = \frac{F}{a} = 2.29 \text{ kg}$$

$$m_3 = 2.29 \text{ kg} - 0.54 \text{ kg} - 0.79 \text{ kg} = 0.96 \text{ kg}$$

4. **Correct Answer: D**

First convert the final angular velocity to rad/s.

$$1000 \frac{\text{rev}}{\text{s}} \times 2\pi \frac{\text{rad}}{\text{rev}} = 6283 \frac{\text{rad}}{\text{s}}$$

Now we have two equations and two unknowns

$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$\omega = \omega_o + \alpha t$$

The unknowns are α and *t*. Solving for α in the second equation and plugging it in to the first results in an equation with only t as the unknown:

$$5000 \text{ rad} = 0 + \frac{1}{2}\frac{6283 \frac{\text{rad}}{\text{s}}}{t} t^2$$

$$t = \frac{5000 \text{ rad}}{3140 \frac{\text{rad}}{\text{s}}} = 1.6 \text{ s}$$

5. **Correct Answer: C**

Potential Energy of a Spring: $E_P = \frac{1}{2}kx^2 = \frac{1}{2} \times 211\frac{\text{N}}{\text{m}} \times (0.438\ \text{m})^2 = 20.2\ \text{J}$

6. **Correct Answer: D**

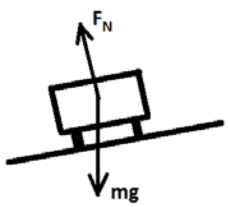
The energy given the mass by the spring will be equal to the work done on the mass from friction once the mass comes to rest.

$$\frac{1}{2}kx^2 = \frac{1}{2} \times 211\frac{\text{N}}{\text{m}} \times (0.438\ \text{m})^2 = 20.23\ \text{J} = mg\mu_k d$$

Solving for *d* gives:

$$d = \frac{20.23\ \text{J}}{18.2\ \text{kg} \times 9.8\frac{\text{m}}{\text{s}^2} \times 0.024} = 4.73\ \text{m}$$

7. **Correct Answer: E**



$\overrightarrow{F_N} + \overrightarrow{mg} = \overrightarrow{m\frac{v^2}{R}}$ And in the figure $\overrightarrow{mg}$ is in the ***y*** direction and $\overrightarrow{m\frac{v^2}{R}}$ is in the negative ***x*** direction. F_N is then the hypotenuse of a right triangle. So mg is the adjacent side and the angle is 15 degrees.

$$F_N = \frac{mg}{cos\theta} = 7507\ \text{N}$$

8. **Correct Answer: E**

Thrust, exit velocity, and the rate of change of the mass are related by

$$Thrust = \left(\frac{dm}{dt}\right)v$$

Solving for the rate of change of the mass:

$$\left(\frac{dm}{dt}\right) = \frac{Thrust}{v} = \frac{16000\ N}{3050\frac{\text{m}}{\text{s}}} = 5.2\ \frac{\text{kg}}{\text{s}}$$

9. **Correct Answer: C**

In elastic collisions momentum and mechanical energy are conserved.

10. **Correct Answer: C**

The force produces a tension in the string. The tension necessary to accelerate the mass upward with the given acceleration is found by the sum of the forces equalling the mass times the acceleration:

$$F - mg = ma$$
$$F = m(g + a) = 21.4\ \text{N}$$

11. **Correct Answer: D**

The kinetic energy is the initial kinetic energy plus the work that the force does on the object. So we must calculate

$$\int_0^7 F dx = \int_0^6 \left(-\frac{6}{4}x + 6\right) dx + \int_6^7 (-3) dx = \left(-\frac{6}{8}x^2 + 6x\right)\Big|_0^6 + (-3x)|_6^7 = 9\text{ J} - 3\text{ J} = 6\text{ J}$$

Of course there are other ways to calculate that integral including calculating the areas of triangles and squares in the figure. Finally adding the initial kinetic energy we get:

$$\frac{1}{2}mv^2 + 6\text{ J} = 24\text{ J} + 6\text{ J} = 30\text{ J}$$

12. **Correct Answer: B**

Conservation of momentum: $3 \times (12700\text{kg}) \times 1.79\frac{\text{m}}{\text{s}} = 68199\frac{\text{kg}\cdot\text{m}}{\text{s}} = m_T v_F$

Solving for v_F gives: $v_F = \frac{68199\frac{\text{kg}\cdot\text{m}}{\text{s}}}{3\times(12700\text{kg})+4\times(4290kg)} = 1.23\frac{\text{m}}{\text{s}}$

13. **Correct Answer: D**

Electric field is given by $E = k\frac{q}{r^2}$ in the radial direction either toward or away from the charge depending on the charge. In this case the 5μC charge is positive so the electric field from that charge will be in the negative *x* direction and the -2μC charge is negative so the electric field from that charge will be in the positive *y* direction. These are at right angles so we can now calculate the field (added as vectors)

$$E = \sqrt{\left(k\frac{q_1}{r_1^2}\right)^2 + \left(k\frac{q_2}{r_2^2}\right)^2} = [8.988 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2]\sqrt{\left(\frac{5\times10^{-6}\text{C}}{\{0.15\text{m}\}^2}\right)^2 + \left(\frac{2\times10^{-6}\text{C}}{\{0.10\text{m}\}^2}\right)^2} = 2.687 \times 10^6\frac{\text{N}}{\text{C}}$$

14. **Correct Answer: C**

For an object floating in a fluid the volume submerged, V_{sub}, is related to the volume of the object, V_o, and the densities of the fluid and the object by:

$$V_{sub} = V_o\left(\frac{\rho_o}{\rho_F}\right)$$

So the percentage of submerged material is given by:

$$\left(\frac{V_{sub}}{V_o}\right) \times 100 = \left(\frac{\rho_o}{\rho_F}\right) \times 100 = 74.0\%$$

This leaves the rest, or 26%, above the water.

15. **Correct Answer: C**

The electric field pointed radially inward means that the charge must be negative. The magnitude is given by:

$$E = k\frac{q}{r^2}$$

We solve this for *q* to get:

$$q = \frac{Er^2}{k} = \frac{130\frac{N}{C} \times (6.37 \times 10^6\mathrm{m})^2}{[8.988 \times 10^9\ \mathrm{N \cdot m^2/C^2}]} = 5.87 \times 10^5\mathrm{C}$$

16. **Correct Answer: B**

Conservation of mechanical energy:

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\frac{v^2}{r^2}$$

Where *r* is the radius of the spindle. Solving for *v* gives:

$$v = \sqrt{\frac{mgh}{\left(\frac{m}{2} + \frac{I}{2r^2}\right)}} = 0.80\frac{\mathrm{m}}{\mathrm{s}}$$

17. **Correct Answer: E**

This optical system has an image distance of 0.017m and an object distance of 0.55 m. The power of the lens is given by 1/*f* when *f* is in units of meters, which appears in the lens equation for the system:

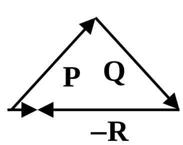
$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{0.017m} + \frac{1}{0.55m} = 60.6\mathrm{D}$$

18. **Correct Answer: A**

$$F = C\frac{v}{A} \quad \Rightarrow \quad C = \frac{FA}{v} \quad \Rightarrow \quad [C] = \frac{\frac{\mathrm{ML}}{\mathrm{T}^2}\cdot \mathrm{L}^2}{\frac{\mathrm{L}}{\mathrm{T}}} = \frac{\mathrm{ML}^2}{\mathrm{T}}$$

19. **Correct Answer: A**



20. **Correct Answer: E**

The magnitude of the average velocity is the distance between the starting point and ending point divided by the time of travel. The average speed is the length of the path followed divided by the time of travel. The only way for the distance between the starting point and ending point to be the same as the path length is for the path to be a straight line between the starting and ending points, which implies the direction of travel is constant.

21. **Correct Answer: C**

$$K_{final} - K_{initial} = W \quad \Rightarrow \tfrac{1}{2} m v_{final}^2 - \tfrac{1}{2} m v_{initial}^2 = W \quad \Rightarrow$$
$$v_{final} = \sqrt{\frac{2W}{m} + v_{initial}^2} = \sqrt{\frac{2(24.0\ \mathrm{J})}{3.00\ \mathrm{kg}} + (4.00\ \mathrm{m/s})^2} = 5.66\ \mathrm{m/s}$$

22. **Correct Answer: D**

The rate of change of speed is the tangential component of acceleration and the centripetal acceleration component is the speed squared divided by the radius of the track:

$$a = \sqrt{(6.00\ \mathrm{m/s^2})^2 + \left(\frac{(20.0\ \mathrm{m/s})^2}{50.0\ \mathrm{m}}\right)^2} = 10.0\ \mathrm{m/s^2}$$

23. **Correct Answer: B**

$$\sum \tau = \tau_{string} + \tau_{weight} = F_{string} r_{string} \sin\theta_{string} - mgr_{cm} \sin\theta_{mg} \quad \Rightarrow \quad F_{string} = \frac{mgr_{cm} \sin\theta_{mg}}{r_{string} \sin\theta_{string}}$$
$$F_{string} = \frac{(200.\ \mathrm{N})(1.50\ \mathrm{m})\sin 150^\circ}{(2.40\ \mathrm{m})\sin 120^\circ} = 72.2\ \mathrm{N}$$

24. **Correct Answer: E**

Moving the arm's away from the body increases the moment of inertia of the skater. Conservation of angular momentum thus requires slower rotation.

25. **Correct Answer: E**

$$\tau = F_1 r_1 \sin\theta_1 + F_2 r_2 \sin\theta_2 = (60.0\ \mathrm{N})(1.80\ \mathrm{m})\sin 75.0^\circ + (40.0\ \mathrm{N})(3.00\ \mathrm{m})\sin 70.0^\circ = 217.\ \mathrm{N\cdot m}$$

26. **Correct Answer: D**

The displacement is the area under the velocity versus time curve. From 0.0 s to 2.0 s, the area is 5.0 m, the area from 2.0 s to 4.0 s is 10.0 m, and the area from 4.0 s to 6.0 s is 8.0 m. The total displacement is 5.0 m + 10.0 m + 8.0 m = 23.0 m.

27. **Correct Answer: C**

$$\overline{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{(3.0\text{ m/s}) - (0.0\text{ m/}s)}{6.0\text{ s} - 0.0\text{ s}} = 0.50\text{ m/s}^2$$

28. **Correct Answer: D**

$$\Delta K = W \quad \Rightarrow \quad \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2 = (F_{rope} - F_{friction})d \quad \Rightarrow \quad F_{rope} = \frac{\tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2}{d} + F_{friction} \quad \Rightarrow$$

$$F_{rope} = \frac{\tfrac{1}{2}(8.00\text{ kg})(2.00\text{ m/s})^2 - \tfrac{1}{2}(8.00\text{ kg})(1.00\text{ m/s})^2}{3.00\text{ m}} + 12.0\text{ N} = 16.0\text{ N}$$

29. **Correct Answer: B**

$$F = \mu N = \mu mg \quad \Rightarrow \quad \mu = \frac{F}{mg} = \frac{12.0\text{ N}}{(8.00\text{ kg})(9.80\text{ m/s}^2)} = 0.153$$

30. **Correct Answer: C**

$$\frac{P_2V_2}{P_1V_1} = \frac{N_2T_2}{N_1T_1} \quad \Rightarrow \quad N_2 = \frac{P_2V_2N_1T_1}{P_1V_1T_2} = \frac{(6.00\text{ atm})V(3.00\text{ moles})(20.0 + 273.15)}{(2.00\text{ atm})V(40.0 + 273.15)} = 8.43\text{ moles}$$

$$\Delta N = N_2 - N_1 = 8.43\text{ moles} - 3.00\text{ moles} = 5.43\text{ moles}$$

31. **Correct Answer: B**

$$\Delta V = BLv\sin\theta = (25.0 \times 10^{-6}\text{ T})(16.0\text{ m})(200.\text{ m/s})\sin 90° = 0.08\text{ V} = 80\text{ mV}$$

32. **Correct Answer: C**

$$V(t) = V_{final} + (V_{initial} - V_{final})e^{-t/RC} \quad \Rightarrow \quad t = -RC\ln\frac{V(t) - V_{final}}{V_{initial} - V_{final}} \quad \Rightarrow$$

$$t = -(4.00\ \Omega)(2.00 \times 10^{-4}\text{ F})\ln\frac{3.00\text{ V} - 6.00\text{ V}}{0.00\text{ V} - 6.00\text{ V}} = 5.55 \times 10^{-4}\text{ s}$$

33. **Correct Answer: B**

Destructive interference between the waves from two sources occurs when the difference in path lengths from the two sources is an odd number of half wavelengths.

$$L_2 - L_1 = (2n - 1)\frac{\lambda}{2} \quad \Rightarrow$$

$$\lambda = \frac{2(L_2 - L_1)}{2n - 1} = \frac{2(4.00\text{ m} - 3.00\text{ m})}{2n - 1} = \frac{2.00\text{ m}}{2n - 1} \in (2.00\text{ m, } 0.67\text{ m, } 0.400\text{ m, } 0.286\text{ m, } ...)$$

34. **Correct Answer: E**

$$W = \Delta E = \frac{1}{\sqrt{1 - v_f^2 / c^2}} mc^2 - \frac{1}{\sqrt{1 - v_i^2 / c^2}} mc^2$$

$$= \left[\frac{1}{\sqrt{1 - (0.800)^2}} - \frac{1}{\sqrt{1 - (0.500)^2}} \right] (4.00 \times 10^5 \text{ kg})(3.00 \times 10^8 \text{ m/s})^2 = 1.84 \times 10^{22} \text{ J}$$

35. **Correct Answer: E**

$$A = N\lambda = \frac{N \ln 2}{t_{1/2}} \quad \Rightarrow$$

$$N = \frac{At_{1/2}}{\ln 2} = \frac{(2.00 \times 10^{-6} \text{ Ci})(3.7 \times 10^{10} \text{ s}^{-1} / \text{Ci})(20.0 \text{ m})(60 \text{ s/min})}{\ln 2} = 1.28 \times 10^8$$