WYSE – Academic Challenge
Physics Test (Regional) – 2016

1. **Correct Answer: A**

Torque is a vector and work is a scalar.

2. **Correct Answer: D**

Pascals are units of pressure. That is force per area. Since $L_o/\Delta L$ has units that cancel, D is the only answer that yields force per area.

3. **Correct Answer: C**

First we convert rev to radians.

$$6.2\ \text{rev}\left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right) = 38.96\ \text{rad}$$

The kinematic equation of motion in rotational systems is

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

With ω_o = 0, we can solve for α.

$$\alpha = \frac{2 \times 38.96\ \text{rad}}{(12\ \text{s})^2} = 0.541\frac{\text{rad}}{\text{s}^2}$$

4. **Correct Answer: D**

$$\rho = \frac{M}{V} = \frac{1.00\ \text{kg}}{(0.07\ \text{m})^3} = 2.92 \times 10^3 \text{kg/m}^3$$

5. **Correct Answer: E**

$$F_x = F\ cos\theta,\ \text{so}\ \ F_x = 1.93\ \text{N}$$
$$F_y = F\ sin\theta,\ \text{so}\ \ F_y = 2.56\ \text{N}$$

6. **Correct Answer: A**

Near the surface of the Earth the acceleration of an object in free fall is 9.8 m/s^2 at all times. When a ball is thrown upwards, it stops momentarily at the top of its flight. At that time the velocity is 0.0 m/s.

7. **Correct Answer: D**

The total time between release and hearing the sound is the sum of the time it takes the stone to drop the distance and the time it takes the sound to return from that distance. A stone dropped from rest will fall under free fall:
$y = \frac{1}{2}gt^2$. In this case, *y* = 207 m and *g* = 9.80 m/s². Solving for *t* gives

$$t = \sqrt{\frac{2y}{g}} = 6.50\text{ s}$$

Now we must solve for the sound returning. In this case, $y = vt$, where *v* is the speed of sound. Solving for *t* gives

$$t = \frac{y}{v} = 0.60\text{ s}.$$

The sum of the two times is 7.10 s.

8. **Correct Answer: E**

This graph shows a particle that begins with speed zero (horizontal slope) and, over the time, the slope (speed) becomes more and more negative. As the slope is the x component of velocity, this is the only graph among the responses for which the x component of velocity is decreasing with time.

9. **Correct Answer: B**

$$W = \mathbf{F}\cdot\mathbf{d} = -Fd = -\mu_k F_N = -\mu_k mgd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$$

Solving for v_f,

$$v_f = \sqrt{\frac{2\left(\frac{1}{2}mv_o^2 - \mu_k mgd\right)}{m}} = 3.00\text{ m/s}$$

10. **Correct Answer: A**

$$L = I\omega = mR^2\frac{v}{R} = mvR = 0.25\text{ kg}\ \ 0.824\frac{\text{m}}{\text{s}}\ (1.00\text{ m}\sin 15°) = 0.053\ {}^{\text{kg m}^2}/_{\text{s}}$$

11. **Correct Answer: B**

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}mR^2\right)\left(\frac{v}{R}\right)^2 = \frac{3}{4}mv^2$$

$$v = \sqrt{\frac{4gh}{3}} = 2.34\text{ m/s}$$

12. **Correct Answer: C**

Conservation of momentum: $m_T v_o = (m_T + m_C)v_f$ Solving for the final velocity,

$$v_f = \frac{m_T}{(m_T + m_C)}v_o = 10.7\frac{\text{m}}{\text{s}}.$$

13. **Correct Answer: E**

The center of mass is determined by the equation

$$X_{cm} = \frac{\sum_i x_i m_i}{\sum_i m_i},$$

where we consider all of the little pieces of mass. The weighted average of the position is then in the center going left to right. In the vertical direction, as you move up and down you want to find the place where there is as much mass moment above as below. That position is just outside of the boomerang but near the top.

14. **Correct Answer: D**

$$\frac{F_{D2}}{F_{D1}} = \frac{v_2^2}{v_1^2} \Longrightarrow F_{D2} = F_{D1}\,\frac{v_2^2}{v_1^2} = 53\text{ N}\,\frac{\left(12.1\,\frac{\text{m}}{\text{s}}\right)^2}{\left(9.0\,\frac{\text{m}}{\text{s}}\right)^2} = 96\text{ N}$$

15. **Correct Answer: B**

$$P = Fv = mgv = 1000\text{ kg} \times 9.8\frac{\text{m}}{\text{s}^2} \times 1.5\frac{\text{m}}{\text{s}} = 14700\text{ W} = 14.7\text{ kW}$$

16. **Correct Answer: C**

In the horizontal direction the velocity remains constant. In the vertical direction the bullet begins to fall under the acceleration of gravity. After 0.5 s in free fall the vertical component of velocity is (9.8 m/s^2) × (0.5s) = 4.9 m/s. Using vector addition of the horizontal and vertical velocities gives $v = \sqrt{v_x^2 + v_y^2} = 420.03\text{ m/s}$.

17. **Correct Answer: D**

In static equilibrium, $\sum \boldsymbol{\tau} = 0$, where the torque $\boldsymbol{\tau}$ = **r**×**F**. Using the axis of rotation through pivot point of the hinge and perpendicular to the page,

$$-(0.6\text{ m})(3.5\text{ kg})\left(9.8\frac{\text{m}}{\text{s}^2}\right) - (1.2\text{m})(15\text{ kg})\left(9.8\frac{\text{m}}{\text{s}^2}\right) + (1.2\text{ m})(T)\sin 20° = 0.00$$

Solving for the tension, T, yields the result 480N.

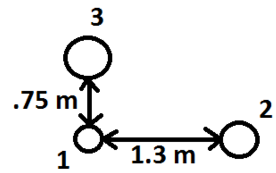
18. **Correct Answer: C**

$$\Delta KE = W = \mathbf{F}\cdot\mathbf{d} = -Fd = -\mu_k F_N = -\mu_k mgd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$$

Solving for μ_k, we get

$$\mu_k = \frac{v_o^2}{2gd} = 0.25.$$

19. **Correct Answer: C**



The equation $F = G\frac{m_1 m_2}{r^2}$ in the direction between the two objects is the gravitational force. We must consider objects 1 and 2 as well as objects 3 and 2. For the force between object 1 and 2, F_{12}, we see $F_{12} = G\frac{2kg \times 4kg}{(1.3m)^2} = 4.734G$ This force is applied to object 2 in the negative *x* direction. Now we move on to the force between 3 and 2. The vector between 2 and 3 is 30˚ clockwise from the negative *x* direction. The magnitude of the force is $F_{32} = G\frac{5kg \times 4kg}{(1.5m)^2} = 8.889G$ and it is directed along the 30˚ line. Breaking this vector down into its *x* and *y* components:

$$F_{32x} = -8.889G\cos 30 = -7.70G$$
$$F_{32y} = 8.889G\sin 30 = 4.44G$$

Adding the components gives $F_x = -4.734G - 7.70G = -12.434G$ and $F_y = 4.44G$ so the total magnitude of the force is $F_T = \sqrt{(-12.434G)^2 + (4.44G)^2} = 13.2\ G$

20. **Correct Answer: A**

$$a = \frac{F}{m} = \frac{\left\{-\left(283\frac{\mathrm{N}}{\mathrm{m}}\right)x + 85.6\ \mathrm{N}\right\}}{0.275\ \mathrm{kg}}\hat{x} = -131\hat{x}\ \mathrm{m/s^2}$$

21. **Correct Answer: C**

The electric force that charge A exerts on Charge C does not depend on the charge nor location of charge B. Electric force satisfy the principle of superposition.

22. **Correct Answer: E**

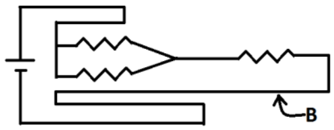
The definition of triple point is the point at which liquid, solid, and gas can coexist in equilibrium.

23. **Correct Answer: C**

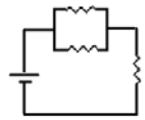
There is no difference in kinetic energy at the initial position and the position at which the 2.50 kg mass momentarily comes to rest, as the mass is at rest in both positions. The spring is compressed 3 cm initially and is extended 8 cm from that point, so it is stretched 5 cm from its equilibrium in the final position.

$$\frac{1}{2}k{x_o}^2 + mgh = \frac{1}{2}k{x_f}^2 \Rightarrow k = \frac{2mgh}{{x_f}^2 - {x_o}^2} = 24.5\ \mathrm{N/cm}$$

24. **Correct Answer: B**



is equivalent to



The parallel resistors in the equivalent circuit have a equivalent resistance

$$R_{eq} = \left(\frac{1}{6.00\ \Omega} + \frac{1}{6.00\ \Omega}\right)^{-1} = 3.00\ \Omega$$

The equivalent resistance is in series with the third resistor so the total resistance in series is

$$R = 3.00\ \Omega + 6.00\ \Omega = 9.00\ \Omega$$

This is the equivalent resistance that the battery encounters. Applying Ohm's Law,

$$V = IR \implies I = \frac{V}{R} = \frac{7.40\ \text{V}}{9.00\ \Omega} = 0.82\ \text{A}$$

25. **Correct Answer: D**

$x_{bus} = v_{bus}t$ and $x_{car} = \frac{1}{2}a_{car}t^2$. When the bus and the car are in the same position,

$$x_{Bus} = x_{Car} \implies v_{bus}t = \frac{1}{2}a_{car}t^2 \implies t = \frac{2v_{bus}}{a_{car}} \Rightarrow x_{Bus} = \frac{2v_{bus}^2}{a_{car}} = 212\ \text{m}$$

26. **Correct Answer: D**

Apply conservation of mechanical energy to find the velocity of the 1.1 kg mass (m_2) as the 3.0 kg mass (m_1) strikes the floor,

$$m_1gh + m_2g(-h) = m_2gh + \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$$\implies v_2 = \frac{2m_1gh + 2m_2g(-h)m_1gh + m_2g(-h) - m_1v_1^2}{m_2} = 2.78\ \text{m/s}$$

(Note that the constraint of the rope results in the speed of the two masses being identical before m_1 strikes the ground.) Use this as the initial velocity to find the height the mass would travel beyond this point (the mass m_2 is in free fall after m_1 strikes the ground).

$$\frac{1}{2}m_2v^2 = m_2gh_2 \implies h_2 = \frac{v^2}{2g} = 0.39\ \text{m}$$

The sum of 0.85 m and 0.39 m gives the total height reached by the second mass, 1.24 m.

27. **Correct Answer: A**

An engine running on the Carnot Cycle is the most efficient engine possible.

28. **Correct Answer: B**

Considering only the forces in the direction along the incline, we see that gravity has a component force of $F_{gx} = -mg\sin 25°$ and that component force of the push is $F_{px} = F_p \cos 25°$. The sum of the forces in the incline direction must equal the mass times the acceleration,

$$F_p \cos 25 - mg \sin 25 = ma \implies F_p = \frac{ma + mg\sin 25°}{\cos 25°} = 27.1\ \mathrm{N}$$

29. **Correct Answer: B**

Protons are baryons and are made up of three quarks.

30. **Correct Answer: D**

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \text{ and } m = -\frac{d_i}{d_o} \Rightarrow f = \left(\frac{1}{d_o} + \frac{1}{-md_o}\right)^{-1} = 33.3\ \mathrm{cm}$$

31. **Correct Answer: C**

$$L_I = 20\log\frac{I}{I_0} \implies L_{I2} - L_{I1} = 10\log\frac{I_2}{I_0} - 10\log\frac{I_1}{I_0} = 10\log\frac{I_2}{I_1} = 10\log\frac{d_1^2}{d_2^2}$$
$$\Rightarrow d_2 = d_1\sqrt{10^{\left(\frac{L_{I2}-L_{I1}}{10}\right)}} = 355\ \mathrm{m}$$

32. **Correct Answer: E**

$$\mathbf{a} = \frac{\mathbf{F}}{m} = \frac{1.1\ \mathrm{N}\hat{\mathbf{x}} - 0.8\ \mathrm{N}\hat{\mathbf{y}}}{1.0\ \mathrm{kg}} = 1.1\ \mathrm{m/s^2}\hat{\mathbf{x}} - 0.8\ \mathrm{m/s^2}\hat{\mathbf{y}}$$

$$\mathbf{r} = \mathbf{r_0} + \mathbf{v_0}t + \tfrac{1}{2}\mathbf{a}t^2 = \vec{0} + \vec{0} + \tfrac{1}{2}(1.1\ \mathrm{m/s^2}\hat{\mathbf{x}} - 0.8\ \mathrm{m/s^2}\hat{\mathbf{y}})(3.0\ \mathrm{s})^2 = 5.0\ \mathrm{m}\hat{\mathbf{x}} - 3.6\ \mathrm{m}\hat{\mathbf{y}}$$

33. **Correct Answer: D**

Using Kepler's 3rd Law,

$$T^2 = \frac{4\pi^2 r^3}{GM} \Rightarrow M = \frac{4\pi^2 r^3}{GT^2} = 1.51 \times 10^{22}\ \mathrm{kg}$$

34. **Correct Answer: E**

$$\sum \mathbf{p}_f = \sum \mathbf{p}_i \implies m_\alpha \mathbf{v}_{\alpha f} + m_p \mathbf{v}_{pf} = m_\alpha \mathbf{v}_{\alpha i} + m_p \mathbf{v}_{pi} \implies \mathbf{v}_{\alpha f} = \frac{m_\alpha \mathbf{v}_{\alpha i} + m_p \mathbf{v}_{pi} - m_p \mathbf{v}_{pf}}{m_\alpha}$$

$$\implies \mathbf{v}_{\alpha f} = 6.29 \times 10^4 \text{ m/s } \hat{\mathbf{x}} + 3.11 \times 10^4 \text{m/s } \hat{\mathbf{y}}$$

35. **Correct Answer: A**

Applying conservation of momentum in the horizontal direction,

$$\sum p_f = \sum p_i \implies (m_{boat} + m_{man}) v_f = m_{boat} v_i \Rightarrow v_f = \frac{m_{boat} v_i}{(m_{boat} + m_{man})} = 4.62 \ \frac{\text{m}}{\text{s}}$$