WYSE – Academic Challenge
Physics Solutions (Regional) – 2019

1. **Correct Response: D**

$$\mathbf{0.5ft^3} \times \left[\left\{\frac{\mathbf{12in}}{\mathbf{1ft}}\right\}^3 \times \left\{\frac{\mathbf{2.54cm}}{\mathbf{1in}}\right\}^3 \times \frac{\mathbf{1l}}{\mathbf{1000cm^3}}\right] = \mathbf{14.16l}$$

But upon reading the question carefully this is asking what the factor in the square brackets is [ ]? That factor is 28.3

2. **Correct Response: D**

$\mathbf{A} + \mathbf{B} = \mathbf{C}$ So we are looking for $\mathbf{B} = \mathbf{C} - \mathbf{A}$

Where $\mathbf{A} = \mathbf{0\hat{x} + 150\hat{y}}$ and $\mathbf{C} = \mathbf{46\hat{x} - 23\hat{y}}$

So now $\mathbf{B} = \mathbf{46\hat{x} - 173\hat{y}}$

and it is easy to calculate the magnitude: $\mathbf{B} = \sqrt{(\mathbf{46})^2 + (-\mathbf{173})^2} = \mathbf{179m}$

3. **Correct Response: C**

$Q = \kappa A(\Delta T/L)t \Rightarrow \kappa = QL/(At\Delta T)$

So κ is measured in units of J·m/(m^2·s·K) = J/(m·s·K) = W/(m·K)

4. **Correct Response: E**

Displacement is equal to the area under the *v*-versus-*t* curve.

From t = 0.00 s to t = 2.00 s, Δx = (4.00 m/s)(2.00 s)/2 = 4.00 m
From t = 2.00 s to t = 4.00 s, Δx = (– 4.00 m/s)(2.00 s)/2 = – 4.00 m

Overall displacement, Δx = 4.00 m + (– 4.00 m) = 0 m

5. **Correct Response: D**

The particle moves 4.00 m in the +*x* direction and then moves another 4.00 m in the –*x* direction.

Total distance, d = 4.00 m + 4.00 m = 8.00 m

6. **Correct Response: C**

Two forces act on the object: the downward force of gravity and the upward tension in the string.

Apply Newton's 2nd Law (net force equals mass times acceleration) in the vertical direction and choose the positive direction to be upward:

$$T - mg = ma \rightarrow T = m(g + a) = (0.200 \text{ kg})(9.80 \text{ m/s}^2 + 0.700 \text{ m/s}^2) = 2.10 \text{ N}$$

7. Correct Response: A

The forces that act on the box are: force of gravity (downward), force **F** (parallel the inclined plane, pointing uphill), normal force (perpendicular to the inclined plane, going up), and the force of static friction (parallel to the inclined plane, pointing uphill).

Set the *xy* coordinate system: Choose the *x* axis to be parallel to the inclined plane, with the +*x* direction pointing uphill; choose the *y* axis to be perpendicular to the inclined plane, with the +*y* direction pointing up.

Apply Newton's 2nd Law in the y direction:

$$N - mg \cos \theta = 0 \rightarrow N = mg \cos \theta$$

Apply Newton's 2nd Law in the x direction:

$$F + f_s - mg \sin \theta = 0 \rightarrow F = mg \sin \theta - f_s$$

Since $f_s \leq f_{s,\,max}$ and $f_{s,\,max} = \mu_s N = \mu_s mg \cos \theta$, $F \geq mg \sin \theta - \mu_s mg \cos \theta$

So the minimum value for *F* is:

$$F_{min} = mg(\sin \theta - \mu_s \cos \theta) = (40.0 \text{ kg})(9.80 \text{ m/s}^2)(\sin 20.0° - 0.300 \cos 20.0°) = 23.6 \text{ N}$$

8. Correct Response: B

The density is given by the equation: $\rho = \frac{M}{V}$ The volume depends on the radius to the third power. We are only interested in which has more density so the factor multiplying this dependence does not impact the answer. So all we have to check is $\rho \boldsymbol{\alpha} \frac{M}{R^3}$ for each of the 5 planets. When we check all of these we find that the largest number in this calculation comes from Earth.

9. Correct Response: A

$$W = Fd \cos \theta = (100 \text{ N})(6.00 \text{ m}) \cos 20.0° = 564 \text{ J}$$

10. Correct Response: C

$$X_{cm} = \frac{\sum m_i x_i}{\sum m_i} = \frac{2 \times 0 + 3 \times 2 + 4 \times 4}{2 + 3 + 4} = 2.44m$$

11. Correct Response: A

$$\boldsymbol{F = \sum G \frac{m_1 m_2}{r^2} = -G \frac{2 \times 3}{2^2} + G \frac{3 \times 4}{2^2} = G \frac{3}{2}}$$

12. Correct Response: C

At the highest point in a trajectory the x component of velocity is the velocity and the y component is zero. Throughout the trajectory the acceleration is g in the negative y direction. Therefore, the velocity is not zero and the acceleration is also not zero.

13. Correct Response: D

This is a conservation of mechanical energy problem. $PE_o + KE_o = PE_f + KE_f$

$$\boldsymbol{m_8 gh = m_5 gh + \frac{1}{2} m_8 v^2 + \frac{1}{2} m_5 v^2 + \frac{1}{2} I \omega^2}$$

$$\boldsymbol{(m_8 - m_5) gh = \frac{1}{2} \left\{ m_8 + m_5 + \frac{\frac{1}{2} m_6 R^2}{R^2} \right\} v^2}$$

$$\boldsymbol{v = \sqrt{\frac{2 \times (m_8 - m_5) \times gh}{m_8 + m_5 + \frac{1}{2} m_6}} = \sqrt{\frac{3}{8} gh}}$$

14. Correct Response: A

This is a conservation of mechanical energy problem. $PE_o + KE_o = PE_f + KE_f$

$$\boldsymbol{m_5 g h_1 + \frac{1}{2} m_5 v^2 = m_5 g h_2}$$

Where h_1 is h from the previous problem and h_2 is the height at the top of the trajectory, h_{max}. Solving for h_{max} we obtain:

$$\boldsymbol{h_{max} = h + \frac{v^2}{2g}}$$

15. Correct Response: E

The particle has a constant positive velocity until 3 seconds which means a straight line with positive slope. At that point the velocity decreases linearly which implies a constant negative acceleration and therefore a parabolic shape with downward curvature. That is graph E.

16. Correct Response: A

Recall question. The meaning of Aphelion is the farthest point in an elliptical orbit around the sun.

17. Correct Response: B

The object is in uniform circular motion on a plane perpendicular to the center axis. The normal force exerted by the container wall provides the centripetal force, while the force of static friction between the object and the wall balances the downward force of gravity.

Applied Newton's 2nd Law in the radial direction:

$$N = mv^2/r = m(r\omega)^2/r = mr\omega^2$$

Apply Newton's 2nd Law in the direction perpendicular to the object's plane of motion:

$$mg = f_s$$

Since $f_s \le f_{s,\,max}$ and $f_{s,\,max} = \mu_s N = \mu_s m r\omega^2$, $mg \le \mu_s m r\omega^2$ and $\omega \ge (g/\mu_s r)^{1/2}$

So the minimum value for ω is:

$$\omega_{min} = (g/\mu_s r)^{1/2} = [(9.80\text{ m/s}^2)/(0.200 \times 0.500\text{ m})]^{1/2} = 9.90\text{ rad/s}$$

18. Correct Response: D

During a collision, whether it is elastic or inelastic, the total momentum is conserved, while the total kinetic energy is conserved only if the collision is elastic.

19. Correct Response: E

Apply Conservation of Momentum during a collision:

$$(7.00\text{ kg})(4.00\text{ m/s}) = (7.00\text{ kg})(3.00\text{ m/s}) + (2.00\text{ kg})v$$

$$v = 3.50\text{ m/s}$$

20. Correct Response: C

To open a revolving door, a certain minimum amount of torque is required. Torque is force times the lever arm. The farther away you push from the axis of rotation, the longer the lever arm, and thus the lesser the force required.

21. Correct Response: B

The stick is in static equilibrium in a horizontal position. According to the conditions for static equilibrium, both the total torque and the total force must be zero.

Since the total torque equals zero, $T_1L_1 = T_2L_2$, where $T_2 = m_2g$

$$T_1 = m_2gL_2/L_1 = (0.300 \text{ kg})(9.80 \text{ m/s}^2)(0.600 \text{ m})/(0.400 \text{ m}) = 4.41 \text{ N}$$

22. Correct Response: C

Three forces act on the 500-g block: force of gravity (downward), tension in the string (upward), and buoyant force (upward). Choose the positive direction to be upward. Since the block has zero acceleration, the net force is zero:

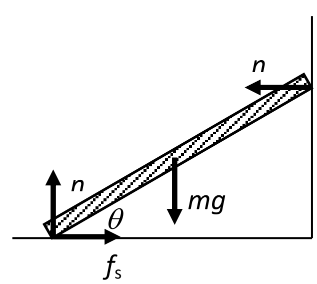
$$T_1 + F_B - m_1g = 0, \text{ where } F_B = \rho gV$$

$$T_1 + \rho gV - m_1g = 0$$

$$V = (m_1g - T_1)/(\rho g) = [(0.500 \text{ kg})(9.80 \text{ m/s}^2) - 4.41 \text{ N}]/[(1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)]$$
$$= 5.00 \times 10^{-5} \text{ m}^3 = 50.0 \text{ cm}^3$$

23. Correct Response: E

The ladder is in static equilibrium, so both the total force and the total toque are zero.



In the vertical direction, choose the positive direction to be upward. Total force equals zero:

$$n_2 - mg = 0 \Rightarrow n_2 = mg$$

Choose the point where the ladder is in contact with the wall as the axis of rotation. Total torque equals zero:

$$mg(L/2)\cos\theta + f_sL\sin\theta - n_2L\cos\theta = 0$$

$$f_s = [n_2L\cos\theta - mg(L/2)\cos\theta]/(L\sin\theta) = [mgL\cos\theta - mg(L/2)\cos\theta]/(L\sin\theta)$$
$$= mg\cos\theta/(2\sin\theta)$$

Since $f_s \le f_{s,\max}$ and $f_{s,\max} = \mu_s n_2 = \mu_s mg$,

$$mg \cos\theta/(2\sin\theta) \le \mu_s mg \quad \text{and} \quad \mu_s \ge \cos\theta/(2\sin\theta)$$

24. Correct Response: D

In the hollowed out interior of the conductor the lines of electric field must start on the charge and end perpendicular to the surface of the conductor. Inside the conductor there can be no electric field. And on the surface of a spherical conductor the induced charge will be evenly distributed so the field outside will appear as if it comes from the center of the system. Figure D is the one that satisfies all of these conditions.

25. Correct Response: C

This is a static equilibrium problem. Use as the axis the rope on the window washer's side of the platform. This gives a torque equation of:

$$-0.500m \times g \times 78.0kg - 1.05m \times g \times 25.0kg + 2.1m \times T = 0$$

Solving gives T=305N

26. Correct Response: B

Conservation of Momentum:

$$p_{1x} = m_1 v_1 \cos(45) = .5303 \frac{kg * m}{sec}$$

$$p_{2x} = m_2 v_2 \cos(45) = .5975 \frac{kg * m}{sec}$$

$$p_{1y} = -m_1 v_1 \sin(45) = -.5303 \frac{kg * m}{sec}$$

$$p_{2y} = m_2 v_2 \sin(45) = .5975 \frac{kg * m}{sec}$$

$$p_{fx} = 1.1278 \frac{kg*m}{sec} \text{ and } p_{fy} = 0.0672 \frac{kg*m}{sec}$$

Solving for the angle of the final momentum gives: $\theta = \arctan\left\{\frac{p_{fy}}{p_{fx}}\right\} = 3.41°$

27. Correct Response: D

Optics recall. As a light wave crosses a boundary the frequency remains constant but the index of refraction requires the speed to change (higher index means it moves slower) and by $v = \lambda f$ if v becomes less and f remains constant then the wavelength must be smaller.

28. Correct Response: A

$$P = I^2R, \quad Q = P\Delta t = I^2R\Delta t = cm\Delta T$$

$$\Delta T = I^2R\Delta t/(cm) = (0.800\text{ A})^2(400\ \Omega)(180\text{ s})/[(4186\text{ J/kg}\cdot°\text{C})(0.500\text{ kg})] = 22.0\text{ C°}$$

29. Correct Response: B

According the First Law of Thermodynamics, $\Delta U = Q - W$, where ΔU is the change in the internal energy of a system, Q is the heat, and W is the work.

30. Correct Response: D

Sound is a mechanical wave and it cannot travel in a vacuum. Sound waves need a medium in order to propagate.

31. Correct Response: A

$hf_c = \phi$, where h is the Planck's constant, f_c is the cut-off frequency, and ϕ is the work function.

32. Correct Response: C

The uncertainty principle states: $\Delta x \Delta p \geq \frac{h}{4\pi}$ realizing that $\Delta p = m\Delta v$ allows us to solve for Δv

$$\Delta v \geq \frac{h}{4\pi m \Delta x} = \frac{6.626 \times 10^{-34}}{4\pi(9.109 \times 10^{-31})[5.12 \times 10^{-11}]} = 1.13 \times 10^6 \frac{m}{s}$$

33. Correct Response: E

The magnetic flux through the coil is given by $\varphi_m = 3\pi r^2 B = 3\pi(0.35m)^2\{2t^3 - 5t + 1\}$

The magnitude of the emf is the time derivative of the flux:

$$\left|\frac{d\varphi_m}{dt}\right| = 3\pi(0.35m)^2\{6t^2 - 5\}$$

Which gives an emf at the time of 2 seconds of 21.9V.

34. Correct Response: D

The 700 and 200 ohm resistors are in parallel and have an equivalent resistance of

$$\frac{1}{700\Omega} + \frac{1}{200\Omega} = \frac{1}{x}$$

This resistance is in series with the 300 ohm resistor to create the total load for the circuit. Resistors in series add so this becomes $300\Omega + x = 300\Omega + 155.6\Omega = 455.6\Omega$

Power is given by $P = \frac{V^2}{R} = \frac{12.5^2}{455.6} = 0.343W$

35. Correct Response: C

The activity of a sample is given by:

$$A = N\lambda = N\frac{ln2}{t_{1/2}}$$

Solving for N and converting the activity to decays/sec as well as the half-life to seconds results in:

$$N = \frac{At_{1/2}}{ln2} = \frac{2.3 \times 10^{-6} \times 3.7 \times 10^{10} \times 25.0 \times 60}{0.693} = 1.84 \times 10^{8} atoms$$