2019 PhysicsBowl Answers and Solutions

1. A After converting all to decimal form, choice A) is the smallest

A) 0.015 B) 0.15 C) 0.15 D) 0.15 E) 0.15

2. C Their lifespans are:

Galileo (1564-1642) Newton (1643-1727) Cavendish (1731-1810)

3. C Electric potential (V) is uniform throughout

4. D An acceleration that is always perpendicular to the velocity is a centripetal acceleration and always causes a change in the object's direction.

5. B Weight (W)=Force due to gravity (F_g)=mg; $g_{moon}<g_{earth}$ so $W_{moon}<W_{earth}$

6. B or C After converting all to miles, choices B) & C) are not correct. The intended answer was C), however the conversion "1.00 yd=3.00 ft=12.0 in" that is given in the problem is incorrect. Thus, B) is also a valid answer.

A) 2.50 miles B) 2.50 miles C) 2497 miles D) 2.50 miles E) 2.50 miles

7. C By increasing the distance from the center of the Earth, the force of gravity decreases according to: $F_g = \frac{(G)(m_{person})(m_{Earth})}{(r_{Earth}+5000m)^2}$.

8. B $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$; Let $d_o = d_i = 2f \Longrightarrow f = (\frac{d_o}{2})$; $d_i = (72\ cm - d_o)$; $\frac{1}{(\frac{d_o}{2})} = \frac{1}{d_o} + \frac{1}{(72\ cm - d_o)}$

Solving for d_o gives 36 cm and solving for f we get 18 cm.

9. C $(1.0\ W)(365\ days)\left(24\ \frac{hours}{day}\right)\left(\frac{1.0\ kilowatt}{1000 watts}\right) = 8.76\ kilowatt\ hours$

$$(8.76\ kilowatt\ hours)\left(\frac{\$0.10}{kilowatt\ hours}\right) = \$0.876$$

10. E For mechanical waves, the speed of the wave depends upon the medium.

11. D The range equation: $R = \frac{(v_o^2)sin2\theta}{g}$ shows that doubling the launch speed (v_o) increases the range by a factor of 4. This equation results from combining the horizontal velocity component of a projectile launched at an angle: $v_o cos\theta$ and using it to solve for the horizontal distance $x_H = v_o cos\theta(t)$ with the vertical component of a projectile launched at an angle: $v_o sin\theta$ and using it to solve for time in flight: $t = \frac{2v_o sin\theta}{g}$.

12. B When the system reaches equilibrium, the net (centripetal) force will be provided by the spring. $kd = m\omega^2$; $\frac{k}{2m} = \omega^2$; $\omega = \sqrt{\frac{k}{2m}}$

13. D Based on the units in the constant (k) provided: $\Delta T = \frac{(Heat\ energy)(glass\ thickness)}{(k)(Area)(time)}$.

14. E After being excited and moving to a higher energy level, the electrons return to their original energy level and release the excess energy as light.

15. B The 2018 Nobel Prize in Physics was awarded to Arthur Ashkin, Gerard Mourou, and Donna Strickland *"for groundbreaking inventions in the field of laser physics"*.

16. D $F = ma = \frac{kg}{m \cdot s^2}$; $v^2 = v_o^2 + 2a\Delta y$; $v = 8.00\frac{m}{s}$; $120\ \frac{kg}{min} = 2.00\ \frac{kg}{s}$;
$F = (8.00\frac{m}{s})(\ 2.00\ \frac{kg}{s}) = 16.0\ \frac{kg}{m \cdot s^2} = 16.0\ N$

17. D For a number raised to a power, the uncertainty rule is to multiply the relative uncertainty by the power. $1.96 \pm 0.01\ m = 1.96\ m \pm 0.51\%$; $v = \frac{4}{3}\pi r^3 = 31.5\ m^3$; $(3)(0.51\%) = 1.53\%$; $31.5\ m^3 \pm 1.53\% = 31.5 \pm 0.5\ m^3$

18. B <u>Going up</u>: $\sum F = (F_{gravity} + F_{friction}) = ma$;
<u>Going down</u>: $\sum F = (F_{gravity} - F_{friction}) = ma$
A larger force acting on the block will result in a larger acceleration which will cause a larger change in velocity resulting in a steeper slope on the v-t graph.

19. D $F\Delta t = m\Delta v$; Impulse is $F\Delta t$; $\Delta v = v_2 - v_1$;
$F\Delta t = m(v_2 - v_1) = (0.500\ kg)[3.60\frac{m}{s} - (-4.80\frac{m}{s})] = 4.20\ kg\ \frac{m}{s} = 4.20\ Ns$

20. B For a standing transverse mechanical wave: 3 antinodes = 1.5λ and 4 antinodes = 2λ. v = λf and v is constant for waves traveling in the same medium. So, the longer the wavelength, the smaller the frequency. $\frac{1.5}{2} = \frac{12Hz}{x}$; $x = 16\ Hz$

21. D Magnification (M) is the ratio of the image size (h_i) to the object size (h_o) or the ratio of the image distance (d_i) to the object distance (d_o) according to: $M = \frac{d_i}{d_o} = -\frac{h_i}{h_o}$.
Choice (A) would form a virtual, enlarged, positive magnification image; choice (B) would form a virtual, smaller, positive magnification image; choice (C) would form a positive magnification image, and choice (E) will form a positive image of the same size.

22. C Because the two masses are connected by the string, they move as one mass and accelerate due to the net force: $\sum F_y = F_{m_1} - F_{m_2} = (m_1 + m_2)a = (6.0\ N - 4.0\ N) = (0.60\ kg + 0.40\ kg)a$; a=2.0 m/s^2

23. A $v^2 = v_o^2 + 2a\Delta x$; $a = \frac{v^2 - v_o^2}{2\Delta x} = 2.45\frac{m}{s^2}$
$\sum F_y = F_g - F_{AR} = ma$; $F_{AR} = F_g - ma = 30.0N - (3.0\ kg)\left(2.45\frac{m}{s^2}\right) = 22.65$ N

24. B Because there is no charge across the capacitor, there is no potential difference across the capacitor. Therefore, the potential at the junction between the 100 Ω resistor and the 300 Ω resistor is the same as the potential at the junction between the 400 Ω resistor and the 200 Ω resistor. As a result, the 100 ohm and 400 ohm resistors can be treated as a parallel combination connected in series to the parallel combination of the 300 Ω and 200 Ω resistors. This gives an equivalent resistance of 200 Ω and a total current of 60 mA. The potential difference across the top two resistors must be equal and their total current must add to 60 mA, resulting in a currents of 48 mA and 12 mA in the 100 Ω and 400 Ω resistors, respectively. Using the same reasoning, the currents in the 300 Ω and 400 Ω resistors are 24 mA and 36 mA, respectively. Using the junction to the left of the capacitor: I100 = Ix + I300, 48 mA = 24 mA + Ix. Ix = 24 mA

25. C At steady-state, no charge flows to or from the capacitor, so any current through the 100 Ω resistor continues to the 300 Ω resistor. The same is true for the 400 Ω resistor and the 200 Ω resistor. The potential drops across the 100 Ω and 300 Ω resistor must total 12 V. Because the current is the same in these resistors, the voltage drops are proportional to the resistances: 3 V for the 100 Ω and 9 V for the 300 Ω. By the same reasoning, the voltage drops across the 400 ohm and 200 ohm are 8 V and 4 V respectively. The resulting potential difference between the junction to the left of the capacitor and the junction to the right of the capacitor is 5 V. Using Q = CΔV = (15 μF)(5 V), gives 75 μC.

26. D The PDF version of this problem contained a typo in choice D). It should have been listed as 4.77 x 10^3 W/m^2. Therefore, all students that took the PDF version will receive credit for this problem, regardless of the answer given. This type was corrected for the WebAssign version of the exam and there will be no change to the scoring for those students. $Power = (Intensity)(Area); I = \frac{P}{A} = \frac{15\ x\ 10^{-3} W}{(\pi)(1.00\ x\ 10^{-3} m)^2}$

27. D Coulomb (C) measures electric charge, the Farad (F) measures capacitance, the Tesla (T) measures magnetic field, and the Henry (H) measures mutual inductance.

28. D On a banked curve the normal force on the car is no longer vertical and has a horizontal component. This component then acts as the centripetal force on the car while on the bank. $F_{NET} = F_{Centripetal}; mg \tan\theta = \frac{mv^2}{r};\ v^2 = rgtan\theta; v = \sqrt{rgtan\theta}$

29. A $M = \frac{d_i}{d_o} = -\frac{h_i}{h_o}; \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i};\ d_i = 3d_o$

30. C The torque is applied at the gear. $\tau = Fr = I\alpha\ and\ I = mr^2$ for a ring. As a result, α is 5.93 rad/s^2. Applying this acceleration to the wheel for 4.0s gives it an angular speed of 23.7 rad/s according to $\omega = \omega_o + \alpha\Delta t$. When the angular speed is multiplied by the radius, the resulting linear speed is 7.1 m/s.

31. E Using the sound intensity equation, $dB = 10log\frac{I}{I_o}; I_o = 1.0\ x\ 10^{-12}\frac{W}{m^2}$ and 60 dB, the Intensity (I) of the speaker is calculated to be 1.0 x 10^{-6} W/m^2 at 15 m.
Using $I = \frac{P}{A}\ and\ A = 4\pi r^2$, it is found that the power of the speaker is 2.8 x 10^{-3} W. At 2.0 m from the speaker, the intensity is 5.57 x 10^{-5} W.

32. C The blocks are floating so the buoyant force is equal to the weight of the blocks. $\sum F = 0\ so\ F_B = mg$. Because the mass remains the same in either arrangement of the blocks, the water level remains unchanged.

33. B When *Car 2* catches and passes *Car 1*, they will both have the same displacement from the starting point. $\Delta x_1 = \Delta x_2$. Use $\Delta x = v_o\Delta t + \frac{1}{2}a\Delta t^2$ for both cars, set the two equations equal to each other, then solve for Δt using the quadratic formula.

34. B Using $\bar{v} = \frac{\Delta x}{\Delta t}$, Michael Phelps had an average speed of 197.71 $\frac{cm}{s}$. Because only 0.01 s separated him from the second-place finisher and using these numbers gives 1.98 cm.

35. A The average kinetic energy of the molecules is directly related to both their mass and the temperature. $\overline{KE} = \frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$.

36. A Solve for V, I, & P for each resistor. $\underline{R_1}$=2.0V, 0.04A, 0.08W: $\underline{R_2}$=1.0V, 0.02A, 0.02W: $\underline{R_3}$=0.4V, 0.0067A, 0.0027W; $\underline{R_4}$=0.4V, 0.0133A, 0.0053W; $\underline{R_5}$=0.6V, 0.02A, 0.012W

37. A See resistor values for #36.

38. B The largest acceleration value from the graph is -10.4 m/s^2. The difference between this value and the constant velocity acceleration reading of -9.8 m/s^2 is 0.6 m/s^2 and this occurs for approximately 13.0 s. Then use $v = v_o + a\Delta t$.

39. A Find the wavelength using $v = \lambda f;\ \lambda = 0.5\ m$. Because it is initially a minimum sound intensity at point P, this means that the signals being received are 0.5λ out of phase. AP=2λ and BP=2.5λ. To receive a maximum sound intensity at point P, B needs to be moved far enough from A so that BP=3λ=1.5 m. Use $c^2 = a^2 + b^2$ to find the new distance between A and B.

40. D The mercury expands as the temperature increases. This new volume of mercury is the product of the original volume, the temperature increase, and the thermal expansion coefficient: 5.4 x 10^{-4} cm^3. Using $height = \frac{Volume}{cross\text{-}sectional\ area}$, it is found that the mercury rises 4.5 cm or 45 mm.

41. D The induced *emf* results from the changing area of the coil and accompanying changing flux that results from each breath and is calculated by: $\varepsilon = -N\frac{(\Delta A)(B)}{\Delta t}cos\theta$

42. B In an adiabatic process, no heat is allowed to flow into or out of the system, so Q=0. In an isochoric process, V is constant so Q=ΔU, and in an isobaric process, pressure is held constant so Q= ΔU+W.

43. A Treat the two blocks as one to find $F = (m_1 + m_2)a$; Using Newtons 2nd Law in the horizontal direction for Block 1: $F_{21} = m_1$a; $F_{21} = \mu m_1$g; m_1a= $\mu m_1 g$; $\mu = \frac{a}{g}$. Substitute for *a:* $\mu = \frac{F}{g(m_1+m_2)}$; Use $m_2 = 3m_1$: $\mu = \frac{F}{g(m_1+3m_1)} = \frac{F}{g(4m)}$.

44. A The speed of a wave on a stretched string or cord depends upon on the tension of the cord (T), and the cord's linear mass density (M/L). Examples include piano and guitar strings.

45. B The Carnot (ideal) efficiency for this engine is: $e_{ideal} = 1 - \frac{T_L}{T_H} = 0.52$.
60% of e_{ideal} is 0.31**.** $(60\ kW)(0.31) = 18.72\ kW$ is used by the engine and the remaining 41 kW are exhausted.

46. D The two most common types of cosmic rays that reach the experimental apparatus are muons and neutrinos.

47. E In both arrangements V is the same. $V = IR\ so\ I_{series}R_{series} = I_{parallel}R_{parallel}$

$$R_{series} = (R_1 + R_2);\ \frac{1}{R_{parallel}} = (\frac{1}{R_1} + \frac{1}{R_2})$$

48. D Choice (A) is accurate but incomplete, choice (B) is accurate but incomplete, choice (C) is inaccurate, choice (D) is accurate and complete, and choice (E) is inaccurate.

49. D The rest mass for each mass is 4.0 kg and they collide head-on with identical speeds pointing in opposite directions. This implies that the composite mass is at rest. So, recalling that the total energy is given by $E = \gamma mc^2$ and that the rest mass is given by $E = mc^2$, then $2\gamma mc^2 = Mc^2$ where *M* is the composite mass. The particle travels at $v = \frac{3}{5}c$ which yields $\gamma = \frac{5}{4}$. Plug this in to get $M = \frac{10}{4}x4 = 10\ kg$.

50. E An isothermal expansion of a gas occurs with no temperature change. Considering the 1st Law of Thermodynamics: $\Delta U = Q - W$, this means that with T constant, Q=W. The work done by a gas is $W = \int PdV$ and the Ideal Gas Law $PV = nRT \Rightarrow P = \frac{nRT}{V}$. Solving now for W we get: $W = \int \frac{nRT}{V}dV = nRTln(\frac{V_1}{V_2})$ and it is one mole of gas.