2024 PhysicsBowl Answers and Solutions

1. B $v = \frac{\Delta x}{\Delta t}$; $\Delta x = v\Delta t + v\Delta t =$ (8.0 $\frac{m}{s}$)(12 s) + (- 6.0 $\frac{m}{s}$)(16 s)=
96m + 96 m=192 m. Speed is a scalar quantity so, $v_{avg} = \frac{\Delta x}{\Delta t} = \frac{192\ m}{28s} = 6.9\ \frac{m}{s}$.

2. C Velocity is a vector quantity. The displacement is 96 m + -96 m=0, so $v_{avg} = 0$.

3. A $\tau = rFsin\Theta = (0.8\ m)(15\ N) = 12\ Nm$

4. B Total mechanical energy for this situation is KE + PE_g and since energy is conserved, it stays constant.

5. C $p = mv;\ \Delta p_{before} = \Delta p_{after}; (60\ kg)\left(2.0\ \frac{m}{s}\right) = (40\ kg)v_2$

6. B $\left(\frac{km}{hr}\right)\left(\frac{1000\ m}{1\ km}\right)\left(\frac{1\ hr}{3600\ s}\right)\left(\frac{1\ hr}{3600\ s}\right) = 7.72 \text{ x } 10^{-5}$

7. E $(3963\ miles)\left(\frac{1609\ m}{mile}\right) = 6.38\ x\ 10^6\ m; A = 4\pi r^2 = 5.1 \text{ x } 10^{14}\ m^2$

8. B $v_2^2 = v_1^2 + 2a\Delta x; a = -1.0\frac{m}{s^2}; F_f = \mu F_N; ma = \mu mg;\ \mu = 0.10$

9. C Statement III is not correct because there is no force directed vertically upward. Only Statements I & II are correct.

10. B $v_2^2 = v_1^2 + 2a\Delta x;\ \Delta x = 20.0\ m$

11. E $v = \lambda f;\ f_1 = f_2;\ \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{1450\frac{m}{s}}{331\frac{m}{s}} = 4.38$

12. C $\Delta x = v_1 t + \frac{1}{2}at^2$; t for dive from 16.0 m is 1.79 s. After 1.59 s (leaving the fish 0.2 s to take evasive action) the pelican has dived 12.63 m. Therefore, 16.0 m – 12.63 m = 3.37 m above the surface of the water.

13. A Momentum is conserved in this collision, so
$m_1v_1 + m_2v_2 = m_1v_{1f} + m_2v_{2f}; 0.5 = 0.5(v_{1f} + 2v_{2f}); \mathbf{1 = v_{1f} + 2v_{2f}}$
And since kinetic energy is conserved in elastic collisions
$\frac{1}{2}m_1{v_1}^2 + \frac{1}{2}m_2{v_2}^2 = \frac{1}{2}m_1{v_{1f}}^2 + \frac{1}{2}m_2{v_{2f}}^2; \mathbf{1 = {v_{1f}}^2 + 2{v_{2f}}^2}$
Solving this system of two equations (in bold) gives -3.3 $\frac{m}{s}$ and +6.7 $\frac{m}{s}$.

14. A See: http://oisc.net/Speed_of_Light.htm

15. C The period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{L}{g}}$; Decreasing the moment of inertia (statement 1) and the torque (statement 2) both lead to a decrease in the period of the pendulum.

16. A See: https://bigthink.com/hard-science/dark-matter-evidence

17. B $F_{Normal} = 500\ N - T sin30^o$
$F_{Horizontal} = 0.500(500\ N - T sin30^o) = T cos30^o; T = 224\ N$

18. D $Open\ both\ ends: f_1 = \frac{v}{2L}; L = 0.394\ m$
$Closed\ one\ end: f_1 = \frac{v}{4L} = 216\ Hz; Fifth\ harmonic = 5f_1 = 1080\ Hz$

19. B See: https://en.wikipedia.org/wiki/Orbital_speed

20. E $sin\theta = \frac{opposite}{hypotenuse}; hypotenuse = sin6^o(120\ m) = 1148\ m$

21. E $W = mgh = (80\ kg)\left(10\ \frac{m}{s^2}\right)(120\ m)$ =96,000 J

22. A $\frac{1148\ m}{4.9\frac{m}{rev}} = 234.3\ revolutions;\ \frac{96{,}000\ J}{234.3\ rev} = 409.7\ \frac{J}{rev}$
$\Delta x = \pi d = 1.07\ m; W = F\Delta x; F = 383\ N$

23. C $Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

For disk:

$$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\omega^2$$
$$Mgh = \frac{1}{2}Mv^2 + \frac{1}{4}M(R\omega^2)$$
$$Mgh = \frac{1}{2}Mv^2 + \frac{1}{4}Mv^2\ (rolling\ without\ slipping\ implies\ v = R\omega)$$
$$Mgh = \frac{3}{4}Mv^2$$
$$\frac{4}{3}gh = v^2$$

For solid sphere:

$$Mgh' = \frac{1}{2}Mv^2 + \frac{1}{2}\left(\frac{2}{5}MR^2\right)\omega^2$$
$$Mgh' = \frac{1}{2}Mv^2 + \frac{1}{5}M(R\omega)^2$$

$Mgh' = \frac{1}{2}Mv^2 + \frac{1}{5}Mv^2$ $(rolling\ without\ slipping\ implies\ v = R\omega)$

$Mgh' = \frac{7}{10}Mv^2$

$Mgh' = \frac{7}{10}M\left(\frac{4}{3}gh\right)$

$h' = \frac{14}{15}gh$

24. B In an isothermal process, the temperature of the gas remains constant. Since internal energy, *U*, of an ideal gas depends only on its temperature, and the temperature is constant throughout the process, the change in internal energy *ΔU* is zero. However, heat, *Q*, can still be transferred to or from the gas during the process. This transfer of heat is necessary to maintain the constant temperature. Therefore, *Q* is not zero.

25. B $m_1: (m_1 g) - T = m_1 a; 50 - T = 5a$

$m_2: T - (m_2 g) = m_2 a; T - 70 = 7a$

a=1.67 $\frac{m}{s^2}$; T=58.4 N

26. B $F = -k\Delta x; k = 400\ \frac{N}{m}; T = 2\pi\sqrt{\frac{m}{k}} = 0.444\ s; f = \frac{1}{T} = 2.25\ Hz$

27. C $F = \frac{Gm_{Mars}m_{person}}{r^2} = 244\ N$

28. A $PE_g\ at\ top = KE\ on\ mat; mgh = \frac{1}{2}mv^2$

29. B In an inelastic collision, momentum is conserved but kinetic energy is not.

30. D Sonar relies on reflection to detect an object and uses the Doppler Effect to determine both the speed and direction of the object.

31. C $Q = \frac{kA\Delta T}{d} = \frac{(0.1)(10)(10)}{0.02} = 500\ W$

32. E $q = (q_0)(\frac{1}{2})^5$

33. C $Speeding\ up: v_2^2 = v_1^2 + 2a\Delta x;\ v_2 = 116.9\ \frac{m}{s}$

$After\ 350\ m\ of\ slowing: v_2^2 = v_1^2 + 2a\Delta x;\ v_2 = 96.9\ \frac{m}{s}$

34. C See: https://en.wikipedia.org/wiki/Relativistic_mechanics

35. A V is the same across all branches of a parallel circuit and V=IR, so I = 2 A.

36. C $200\ x\ 10^{-6}\ m^3$ *need to be displaced by wood.* $\rho_{water} = 1000\ \frac{kg}{m^3}$.
This means that $200\ g$ *of water needs to be displaced.*
Mass of the wood must equal the mass of water displaced.

37. A $r = L sin\theta;\ F_{net} = ma = T sin\theta; a = \frac{T sin\theta}{m};\ a_c = \frac{v^2}{r} = \frac{T sin\theta}{m}; v = \sqrt{\frac{TL sin\theta}{m}}$

38. B Choose appropriate speeds and accelerations and solve.
$v_1 = 2\ \frac{m}{s};\ v_2 = 1\ \frac{m}{s};\ a_1 = 1\ \frac{m}{s^2};\ a_2 = 2\ \frac{m}{s^2};\ v_f = v_i + aT$
$v_{1f} = v_{2f}; 2 + 1T = 1 + 2T; T = 1\ s$
$\Delta x_1 = v_1 T + \frac{1}{2} a_1 T^2 = 2.5\ m;\ \Delta x_2 = v_2 T + \frac{1}{2} a_2 T^2 = 2\ m$
$\frac{\Delta x_2}{\Delta x_1} = \frac{2\ m}{2.5\ m} = 4:5$

39. C When the average speed of the gas molecules increases, the kinetic energy of the molecules also increases. This corresponds to an increase in the temperature of the gas. According to the ideal gas law (PV = nRT), when the temperature of a gas increases while the volume remains constant (as in the case of a rigid cylinder), the pressure of the gas also increases. Therefore, both the temperature and the pressure of the gas increase when the average speed of the gas molecules increases.

40. E We know that the electric potential due to a point charge is directly proportional to the magnitude of the charge and inversely proportional to the distance from the charge as shown by: $V = \frac{kQ}{r}$; We also know that the electric potential due to a charged spherical shell is constant at all points outside the shell, and it's zero inside the shell. So, the order is $V_W < V_X = V_Y = V_Z$.

41. D For the smaller box: $T_{in\ rope}$=ma; For the larger box: F-$T_{in\ rope}$=2ma;
Solve equations simultaneously to get F=3ma, so $T_{in\ rope} = \frac{F}{3}$.

42. B When the original circuit reaches steady state, the voltage drop across the resistor and capacitor are both equivalent to the emf of the source. When the switch is opened, we have an RC discharging circuit. Taking a Kirchhoff loop around this circuit (where the only devices are the capacitor and the resistor), the voltage gained across one device must always be equivalent to the voltage lost across the other device.

43. B According to Wien's displacement law, the wavelength of electromagnetic radiation emitted by a black body is inversely proportional to the temperature of the black body. So as temperature increases, the wavelength decreases.

44. D Conservation of Energy: $KE_1 + PE_g = KE_2 + W_{Air\ Resistance}$

$$W_{Air\ Resistance} = F\Delta x;\ \Delta x = \frac{3500\ m}{sin\ 10^o}$$

$$\frac{1}{2}mv_1^2 + mgh = \frac{1}{2}mv_2^2 + F\left(\frac{3500\ m}{sin\ 10^o}\right)$$

45. E $t = 27.3\ days = 2.36\ x\ 10^6\ s; r = 3.84\ x\ 10^5\ km = 3.84\ x\ 10^8\ m$

$$v = \frac{2\pi r}{t} = 1022\ \frac{m}{s};\ a_c = \frac{v^2}{r}$$

46. D As the object is moved from point P to point Q, the size of the image produced by the concave mirror will initially increase. This is because the object moves closer to the focal point of the mirror, resulting in the image moving further away from the mirror and becoming larger. However, as the object moves past the focal point and closer to the mirror, the image size will then decrease. At this point, the image will become larger than the object, virtual, and erect.

47. D $f = 401\frac{rev}{min} = 6.683\frac{rev}{sec};\ \omega = 2\pi f = 42\frac{rad}{s}$

$$I = \frac{1}{3}mL^2; KE_{total} = (2)\left(\frac{1}{2}I\omega^2\right)$$

48. A $V = \frac{kQ}{r} = 0.018\ V$

$$If\ R\ is\ radius\ of\ new\ drop, then\ \frac{4}{3}\pi R^3 = n\frac{4}{3}\pi r^3; R = n^{\frac{1}{3}}r = \ 1.26\ x\ 10^{-3}\ m$$

$$V = \frac{kQ}{r} = 0.0143\ V$$

49. B $F = \frac{\mu_o I_1 I_2 L}{2\mu d};\ \mu_o\ is\ permeability\ of\ free\ space, I\ is\ current\ in\ each\ wire, L\ is\ length\ of\ wire\ and\ d\ is\ distance\ between\ wires. F = mg,$

$$so: mg = \frac{\mu_o I_1 I_2 L}{2\mu d}$$

50. A After one time constant of decay, there are 3678 particles of gas in the sample Using: $N = N_o e^{-t/\tau}$ =(10000)e^{-1} = 3678. Then, adding 10000 more gas particles gives a total of 13678 particles, meaning:

10000=13678$e^{-t/\tau} = \frac{10000}{13678}e^{-t/\tau}; t = -\tau ln\left(\frac{10000}{13678}\right) = (0.313)\tau$