2021 PhysicsBowl Answers and Solutions

1. D A Joule is the SI unit of work or energy, equal to the work done by a force of one newton when its point of application moves one meter in the direction of action of the force. $J = Nxm = kg\left(\frac{m}{s^2}\right)m$

2. C Applied force and direction of motion need to be the same for work to be done.

3. A $KE = \frac{1}{2}mv^2$, the mass ratio is based upon the ratio of the squares of the velocities.

4. D At these points, the object is traveling in the opposite direction of the starting direction.

5. C $\rho gh = \frac{1}{2}\rho v^2$

6. A John Bardeen was awarded this prize in 1956 (transistors) 1972 (superconductors). See: https://en.wikipedia.org/wiki/List_of_Nobel_laureates_in_Physics for details.

7. E P=$\frac{W}{t} = \frac{F\Delta x}{t}$ $Both\ cranes\ do\ 320{,}000\ J\ of\ work. Crane\ 2\ does\ it\ in\ less\ time.$

8. D W= $F\Delta x$

9. E $KE = \frac{1}{2}mv^2$; $v^2 = v_0^2 + 2a\Delta x$; $\sum \vec{F} = m\vec{a}$

10. A $\rho = \frac{m}{V}$; $m = \rho V$

11. B $v = v_0 + at$

12. E A glass has a natural resonance, a frequency at which the glass will vibrate easily.

13. C $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$; $d_i = -60\ cm$

14. C $dB = 10log\frac{I}{I_0}$; 65 dB for I, so 2I = 68 dB.

15. D There is force provided by the electric field on the charged drop.

16. C Smallest area = 12 cm^2; Largest area = 60 cm^2; $P = \frac{F}{A}$

17. E $v_{rms} = \sqrt{\frac{3kT}{m}}$; Inversely proportional relationship

18. D $T = 2\pi\sqrt{\frac{L}{g}}$; $f = \frac{1}{T}$

19. A Ball 1 starts with a positive velocity and is rolling on the same ramp as Ball 2, therefore, they have the same acceleration (slope of v-t graph).

20. D The Earth's gravity is constantly providing the necessary centripetal force and changing the direction according to Newton's 1st Law.

21. D $F = \frac{kQ^2}{r^2} = 177nC$

22. C $a = \frac{v^2}{r}$

23. C $\rho = \frac{m}{V}$

24. A $v^2 = v_0^2 + 2a\Delta x$

25. C $T_A = 0.174v$ & $T_B = 0.202v$; $\frac{T_B}{T_A} = 1.15$

26. D $x = \frac{v_0^2 sin2\theta}{g}$; $x_A = 0.087v^2$ & $x_B = 0.35v^2$

27. E A) 3 parallel; B) 2 parallel; C) 2 parallel, 1 series; D) 2 series; E) Not possible

28. C Fission yields energy density on a MeV scale while chemical energy density is eV scale.

29. D $a^2 + b^2 = c^2$; $a_c = \sqrt{(27.7\ \frac{m}{s^2})^2 - (10\ \frac{m}{s^2})^2}$

30. C Falling: $x_{fall} = v_o t + \frac{1}{2}at^2$; Sound: $x_{sound} = (v_{sound})t$; $x_{fall} = x_{sound}$;
$\frac{1}{2}\left(10\ \frac{m}{s^2}\right)t^2 = 340\frac{m}{s}(2.5s - t)$; t = 0.085 s.

31. A Both decays change the number of protons in the nucleus.

32. B $PE_g = KE + TE_{friction}$; With no friction, child would be traveling at 7.75 m/s at bottom of slide. $PE_g = mgh = 30m$; $KE = \frac{1}{2}mv^2 = 3.18m$; $\frac{3.18m}{30m}(100) = 10.6\%$

33. A The sticks are the same length and will have the same period.

34. C $x = \frac{v_0^2 sin2\theta}{g}$; maximum range achieved at launch angle of 45°.

35. B $KE_{Translational} = \frac{1}{2}mv^2$; $KE_{Rotational} = \frac{1}{2}I\omega^2$

36. D $PE_E = KE$; $PE_E = \frac{1}{2}kx^2$ & $KE = \frac{1}{2}mv^2$;
$k\ \&\ m\ don't\ change, so\ the\ speed\ is\ directly\ proportional\ to\ the\ compression.$

37. B Final combination of resistors offers 2/3 of the resistance of each individual resistor and 1.5 times more current can move through this combined resistor circuit.

38. D $KE = \frac{1}{2}mv^2$; $\frac{1}{2}Mv^2 + \frac{1}{2}m(\frac{M}{m}v)^2 = \frac{1}{2}(M + \frac{M^2}{m})v^2$

39. A An adiabatic process transfers energy to the surroundings only as work. In an adiabatic process, no heat is allowed to flow into or out of the system, so Q=0. $\Delta U = Q - W$. Because the gas does work, it cools.

40. B $P = e\sigma A(T_1^4 - T_2^4)$

41. D In a pure (intrinsic) Si or Ge semiconductor, each nucleus uses its four valence electrons to form four covalent bonds with its neighbors and there are no excess electrons or holes. Now, if one of the atoms in the semiconductor lattice is replaced by an element with three valence electrons, such as a Group 3 element like Boron (B) or Gallium (Ga), the electron-hole balance will be changed.

42. C $\boldsymbol{N(t) = N_0(\frac{1}{2})^{\frac{t}{half\ life\ t}}}$

43. B After reducing and solving this circuit, the current and voltage for each resistor is as follows: R_1=0.5 A, 2.0 V; R_2=0.25 A, 1.0 V; R_3=0.25 A, 2.0 V; R_4=0.25 A, 2.5 V; R_5=0.125 A, 0.5 V; R_6=0.125 A, 0.25 V; R_7=0.125 A, 0.25 V

44. B See solution for #43

45. D $\varepsilon = vBL$

46. A Efficiency is: $e = 1 - \frac{T_L}{T_H}$ (T in Kelvins)=0.8; (0.8)(2000J)=400J

47. C Since there is no resistance in the circuit, no energy is lost through Joule heating; thus, the maximum energy stored in the capacitor is equal to the maximum energy stored at a later time in the inductor. This is analogous to the mechanical oscillations of a mass at the end of a spring. Energy is transferred back and forth between the mass, which has kinetic energy and the spring which has potential energy.

48. C $F_e = k\frac{q_1 q_2}{r^2}$; $F_g = mg$; $k\frac{q_1 q_2}{r^2} = mg(tan\theta)$

49. E Since there are two convex lenses, the set-up can be treated as a telescope. The lens closest to the laser is the objective while the other is the eyepiece. This can then be solved using $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ and $M = \frac{f_{obj}}{f_{eye}}$

50. C $E^2 = p^2c^2 + m_0^2c^4$