2023 PhysicsBowl Answers and Solutions

1. D $\frac{v^2}{r} = \frac{GM}{r^2}$

2. B Newton's 3rd Law

3. D See: https://www.thoughtco.com/metric-units-base-units-604140; a Volt is a derived unit.

4. E Sound speed is independent of the sound source.

5. C $N = \frac{6.02\ X\ 10^{23}\ atoms}{12.0\ g} = 5.02\ X\ 10^{22}\ atoms; t = \frac{5.02\ X\ 10^{22}\ atoms}{1\frac{atom}{s}} = 5.02\ X\ 10^{22}\ s$

$t = \frac{5.02\ X\ 10^{22}\ s}{3.15\ X\ 10^{7}\ s/year} = 1.59\ X\ 10^{15}\ years$

6. B The normal vector has a greater magnitude than its vertical component (magnitude of mg). The magnitude of the normal vector is also greater than the horizontal component, the net force directed to the center of circular motion.

7. B $v^2 = v_0^2 + 2a\Delta x$

8. D See: https://forumautomation.com/t/what-is-a-venturi-meter-and-how-does-it-work/8455. A Venturi meter measures fluid flow.

9. D $F = mg + 2mg = 3mg$

10. A $T = \frac{6.50\ s}{10\ cycles} = 0.65\ s;\ T = 2\pi\sqrt{\frac{m}{k}}$

11. A When floating: $F_b = F_g$; As force is applied vertically down, the buoyant force will increase to balance the total downward force.

12. D $v = v_0 + at$

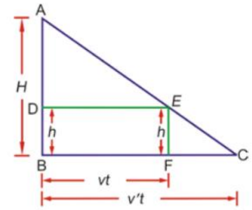
13. B $\tau = RF\sin\theta = R_\perp F = RF_\perp$

14. A See: https://www.epa.gov/radiation/radiation-basics

15. A $\frac{v^2}{r} = \frac{GM_{sun}}{r^2}$; The mass of the sun stays the same after collapse.

16. E Nobel prizes are awarded in six categories: physics, chemistry, literature, physiology or medicine, economics, and peace.

17. C BF=vt; BC=v′t; EFC and ABC are similar triangles, so $\frac{FC}{BC}=\frac{EF}{AB}=\frac{h}{H}=\frac{v't-vt}{v't}; v'=10\ m/s$



18. D $t_{air}=\sqrt{\frac{2(5.0\ m)}{10\frac{m}{s^2}}}=1.0\ s; v=gt=10\frac{m}{s}; t_{water}=5.0\ s-1.0\ s=4.0\ s;$

$x=(10\frac{m}{s})$(4.0 s)=40 m

19. B $\Delta x=v_0t+\frac{1}{2}at^2$

20. B Resolve forces into x & y components

$F_x=-80cos35^o+60+40cos45^o=22.75\ N$

$F_y=80sin35^o+0-40sin45^o=17.6\ N$

$F_{net}=\sqrt{(22.75)^2+(17.6)^2}=28.76\ N=ma$

21. C $\mu mgcos\theta=0.7mgxsin\theta;\ \mu=0.7tan\theta=0.40$

22. A $\frac{G_mM_E}{x^2}=\frac{G_mM_S}{(d-x)^2}$

23. E Let g_o be the acceleration due to gravity at the ground and g at some height above ground. At the ground: $T_o=2\pi\sqrt{\frac{L}{g_o}}$. At height h, $T=2\pi\sqrt{\frac{L}{g}}$.

$T=T_o\sqrt{\frac{g_o}{g}}=T_o\left(1+\frac{h}{R}\right)=2\left(1+\frac{320\ m}{6.4\ X10^6\ m}\right)=2.0001\ s;$

$2.0001\ s-2.000\ s=0.0001\ s; (43{,}200\ cycles)\left(0.0001\ \frac{s}{cycle}\right)=4.32\ s$

24. C If the width of the valley is *d* and the M-80 is detonated a distance *x* from one of the mountains, then the echoes will be heard in times t_1 and t_2.

$t_1=\frac{2x}{v}; t_2=\frac{2(d-x)}{v}; t_1+t_2=2+4=\frac{2d}{v}.$

25. A $W=qV; q=\frac{W}{V}=2.0\ X\ 10^{-12}\ C; N=\frac{q}{e}$

26. E $\omega=2\pi f=1.26\ X\ 10^{13}\ s^{-1};\ v_{max}=\omega A=138\frac{m}{s}$

27. B $\Delta h\ at\ 60^o=1.0\ m; PE_g=KE; mg\Delta h=\frac{1}{2}mv^2; v=\sqrt{2gh}=4.47\frac{m}{s}.$

$T=mg+\frac{mv^2}{r}; m=\frac{(g+\frac{v^2}{r})}{T}=1.0\ kg$

28. D Giga (G) $=10^9$; 4.0 X 10^{-3} GN = 4.0 X 10^6 N

29. D $\Delta p = -mv - mv = -2mv; v = \sqrt{2gh} = 5.66\frac{m}{s}. F = 2mnv;$
$F = 2(0.10\ kg)\left(\frac{441}{60}\right)\left(5.66\frac{m}{s}\right) = 8.32\ N;\ \frac{8.32\ N}{10\frac{m}{s^2}} = 0.83\ kg$

30. A T = 23 h 56 min = 86,160 s; $f = \frac{1}{T};\ \omega = 2\pi f$

31. C $F_{seat} - mg = \frac{mv^2}{r};\ F_{seat} = 1.5\ mg; 0.5\ mg = \frac{mv^2}{r}; v = \sqrt{(0.5)(g)(r)}$

32. D $\Delta P = \frac{1}{2}\rho(v_1^2 - v_2^2)$

33. C R = $\left(0.7\frac{\Omega}{km}\right)(30\ km) = 21\ \Omega;$ I = $\frac{10^7 W}{10^5 V} = 100\ A;\ P_{dissapated} = 2.1\ X\ 10^5\ W$

34. B $\Delta U = Q - W; Some\ work\ is\ done\ since\ it\ it\ not\ an\ isochoric\ process.$

35. E In the simplified circuit, the 18 Ω and the 9 Ω resistors both drop 72 V.

36. D Frequency is determined by the light source and will not change when passing to a new medium.

37. D $F_g = G\frac{m_1 m_2}{r^2}$; Decreasing the radius by a factor of 10 increases the force by 100.

38. A $PE_{elastic} = PE_{gravitational}; \frac{1}{2}kx^2 = mg\Delta h$

39. D $P = P_{O_2} + P_{N_2};\ P_i V_i = P_f V_f;\ P_{O_2} = \frac{V_i}{V_f}P_i = 0.20\ P_{atm};\ P_{N_2} = \frac{V_i}{V_f}P_i = 0.60\ P_{atm}$

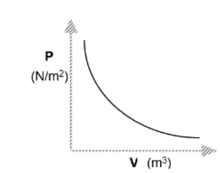
40. A The two 10 μC charges are opposite each other and cancel out the electric field produced by each since they point in opposite directions. Therefore, we get the value of the electric field from the 2 μC charge.
Line BM = (5 cm)sin 45° = 3.5 cm. $E = \frac{kq}{r^2}$

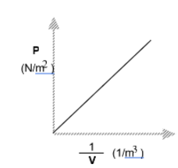
41. B $F = BIL;$ B is perpendicular to I; $\sin 90^o = 1$

42. C $\frac{v^2}{r} = \frac{GM}{r^2}$; Satellite orbital speed is independent of satellite mass.

43. C $\sum F = F_{down\ the\ ramp} - F_{friction} - F_{spring} = 0;\ F_{down\ the\ ramp} = mgsin\ 50^o =$
$11.5\ N;\ F_{friction} = \mu mgsin\ 50^o = 6.3\ N;\ F_{spring} = 5.2\ N;\ \vec{F} = -k\vec{x}$

44. B For a pressure & volume relationship:





45. A $qvB = \frac{mv^2}{r}; v = 1.0\ X\ 10^7\frac{m}{s}; v = \frac{2\pi r}{t}; t = 1.19\ X\ 10^{-6}\ s; f = \frac{1}{t}$

46. D $F(cos\theta)r = I\alpha;\ \alpha = 0.94\ \frac{rad}{s^2};\ \omega = \omega_o + \alpha t$

47. C $F_{total} = 3m_{rocket}g = 150{,}000\ N; Rate = \frac{150{,}000\frac{kgm}{s^2}}{1000\frac{m}{s}} = 150\frac{kg}{s}$

48. B $\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f_0}; Final\ image\ distance = x; x = -d_o(\frac{f_e}{f_o})^2 = 10^4(\frac{1}{8})^2 = 156.2\ m$

49. B Inductors have a voltage related to change… as driving frequency increases, the inductor reacts more strongly. Hence, the circuit is said to be more inductive. From AC circuit theory, a higher frequency increases the inductive reactance and makes the phase angle more positive. As the reactance increases, the impedance must be increasing as the current decreases, and the current decreases, so does the power associated with the resistor (and hence the source).

50. D The moving electron has momentum, *p*, along the positive x-axis and kinetic energy, *K*. The total energy, *E*, of the electron and the stationary positron before the collision is $E = K + 2mc^2 = 2.022$ MeV. The two photons emerge from the collision each with energy $E_\gamma = ½ E = 1.011$ MeV as given by conservation of energy, and each with magnitude of momentum $p_\gamma = E_\gamma/c = 1.011$ MeV/c. The momentum vectors of the photons make angles $\pm\theta$ with the x-axis. Conservation of momentum in the x-direction is $p = 2p\gamma \cos \theta$ from which $\theta = 45.3^o$.