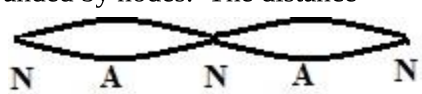
2013 PhysicsBowl Solutions

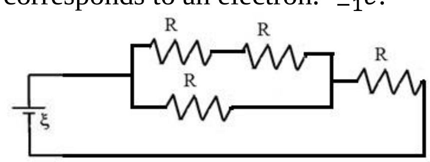
#	Ans	#	Ans	#	Ans	#	Ans	#	Ans
1	C	11	E	21	E	31	D	41	A
2	B	12	C	22	B	32	E	42	C
3	D	13	E	23	D	33	A	43	A
4	E	14	B	24	B	34	A	44	E
5	A	15	D	25	A	35	C	45	C
6	C	16	D	26	B	36	C	46	E
7	D	17	D	27	C	37	A	47	B
8	B	18	A	28	E	38	B	48	A
9	D	19	C	29	B	39	A	49	D
10	E	20	D	30	B	40	E	50	B

1. **C…** The prefixes for the answers given are A) milli, B) micro, C) nano, D) pico, E) femto
2. **B…** Using constant acceleration kinematics, we have $v = v_0 + at \Rightarrow v = (-10)(2.5) = -25\frac{m}{s}$. Speed is always positive.
3. **D…** Using constant acceleration kinematics, we have $x = x_0 + v_0 t + \frac{1}{2}at^2 \Rightarrow$
   $0 = H + 0 + \frac{1}{2}(-10)(2.5^2) \Rightarrow H = 31.3\ m.$
4. **E…** A light-year is the distance that light travels in one year.
5. **A…** Linear momentum is computed as the mass multiplied by the velocity.
6. **C…** A string vibrating in the 2nd harmonic will have 2 antinodes surrounded by nodes. The distance between consecutive nodes is ½ of a wavelength. Hence, we have a full wavelength here, as seen in the figure.



7. **D…** Using Coulomb's Law, we have $F = \frac{kQ_1Q_2}{r^2}$ with $Q_1 = Q_2 = Q$.
   This leads to $3 = \frac{9\times10^9 Q^2}{0.5^2}$ or $|Q| = \sqrt{\frac{(3)(0.5^2)}{9\times10^9}} = \sqrt{8.33\times10^{-11}} = 9.13\times10^{-6}C$.
8. **B…** LED's are Light Emitting Diodes
9. **D…** The expression for the period of a simple pendulum at small angles is $T = 2\pi\sqrt{\frac{L}{g}}$. So, $2 = 2\pi\sqrt{\frac{L}{10}}$ leads to $\frac{1}{\pi} = \sqrt{\frac{L}{10}} \Rightarrow L = \frac{10}{\pi^2} = 1.0\ m$
10. **E…** For an object launched upward and then returning to its initial position, the initial velocity is upward and the final velocity is downward. This means that half of the time, the velocity is positive with it being negative the other half of the time (by symmetry). Of the graphs shown, only (E) has this property (and the velocity has a constant slope indicating a constant acceleration).
11. **E…** The announcement of the discovery of a particle consistent with the Higgs Boson took place last summer from the LHC (Large Hadron Collider).
12. **C…** The Moon does rotate on its axis. Because of this rotation rate, there is a "dark side of the Moon" which is always directed away from the Earth.
13. **E…** The significant digits are not counted until the first non-zero value is encountered. For the choices given, the number of sig figs is A) 3, B) 3, C) 2, D) 2, E) 6
14. **B… METHOD #1: 2D kinematics**. For the vertical motion, one can use constant acceleration kinematics to find $v_{yf}^2 = v_{yo}^2 + 2a_y\Delta y \Rightarrow \Delta y = \frac{0-(20\sin 30^\circ)^2}{2(-10)} = \frac{10^2}{2(10)} = 5.0\ m$
    METHOD #2: energy. From mechanical energy conservation, we write $\Delta KE + \Delta PE = 0 \Rightarrow$
    $\frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2 + mg\Delta y = 0 \Rightarrow \frac{1}{2}(v\cos 30^\circ)^2 - \frac{1}{2}v^2 + (10)\Delta y = 0 \Rightarrow \Delta y = \frac{\frac{1}{2}(300)-\frac{1}{2}(400)}{-10} = 5.0m$

15. **D…** The total number of coulombs of charge in 3.0 hr to pass through the circuit is $Q = It = (3.20A)(3.0hr) = (3.20A)\left(3.0\ hr \times \frac{3600\ s}{1\ hr}\right) = 3.456 \times 10^4 C$. The charge of an electron has magnitude $1.6 \times 10^{-19} C$, so we have from charge quantization $Q = Ne \Rightarrow N = \frac{Q}{e} = \frac{3.456 \times 10^4}{1.6 \times 10^{-19}} = 2.16\ \times 10^{23}$.
16. **D…** First, we need to find the acceleration of the block which is done from kinematics as $v_f^2 = v_0^2 + 2a\Delta x$ yielding $0^2 = 8^2 + 2a(12) \Rightarrow a = \frac{-64}{24} = -2.67\frac{m}{s^2}$. Now, from the free body diagram of the block, we find 3 total forces (gravitational acting downward, normal from the surface acting upward, and the friction opposite to the motion here). Since there is no vertical acceleration from Newton's Second Law we have, $F_{net_y} = ma_y \Rightarrow n - mg = 0 \Rightarrow n = mg$. For the horizontal direction, we have $F_{net_x} = ma_x \Rightarrow -f_k = m(-2.67)$. Knowing that $f_k = \mu_k n$, we have $\mu = \frac{f_k}{n} = \frac{m(2.67)}{mg} = 0.267$.
17. **D…** Given the position vs. time, we see that we start at position 8.0 m and stay there for 3 seconds. We then move at a constant rate to the 0 m mark traveling 8.0 m. After stopping for 1 second, we walk at a constant rate 8 more meters to -8 m. Finally, we travel from -8 m to 10 m during the last second for a total of 18 m. Hence, for the entire trip, we moved 8 + 8 + 18 = 34 meters.
18. **A…** Any time the velocity changes (magnitude or direction), there is acceleration. Consequently, since the speed changes in I & III, there is tangential acceleration. As the direction of motion changes in II & III, there is radial (centripetal) acceleration here. Hence, there is acceleration in all cases presented.
19. **C…** Albert Einstein won his Nobel Prize partly for his work explaining the photoelectric effect.
20. **D…** Using the ideal gas equation leads to $PV = Nk_BT$ and we need to convert the units of a few quantities to give $P = 0.50\ atm \times \frac{1.013 \times 10^5 Pa}{1\ atm} = 50650\ Pa$ and $T = 40 + 273 = 313\ K$. Hence, $N = \frac{PV}{k_BT} = \frac{(50650)(3.5 \times 10^{-2})}{(1.38 \times 10^{-23})(313)} = 4.10 \times 10^{23} molecules$.
21. **E…** To balance the equation, ${}^A_ZX$ needs to be replaced with ${}^{\ 0}_{-1}X$. This corresponds to an electron. ${}^{\ 0}_{-1}e$.
22. **B…** The equivalent resistance is computed by working through the words… Two resistors in series have an equivalent resistance of $R + R = 2R$. Putting this in parallel with a resistor gives a total resistance of $\frac{1}{R_{123}} = \frac{1}{R} + \frac{1}{2R} \Rightarrow R_{123} = \frac{2}{3}R$. Finally, putting another resistor in series gives $R_{total} = \frac{2}{3}R + R = \frac{5}{3}R$. The figure shows the resistor combination for which we solved the equivalent value.

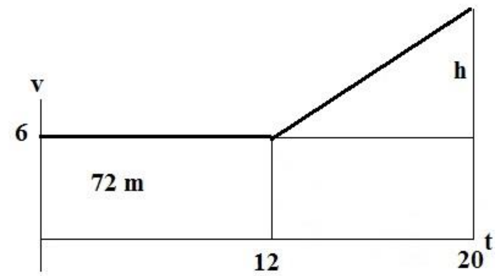


23. **D…** As the object is moving in a circle with increasing angular speed, there are both tangential and radial accelerations. These are computed as $a_{tan} = r\alpha = (0.30m)\left(4.5\frac{rad}{s^2}\right) = 1.35\frac{m}{s^2}$ and $a_r = \frac{v_t^2}{r} = r\omega^2 = r(\alpha t)^2 = (0.30m)\left(\left(4.5\frac{rad}{s^2}\right)\left(\frac{1}{3}s\right)\right)^2 = 0.675\frac{m}{s^2}$. The total acceleration is computed using the Pythagorean Theorem (the tangential and radial accelerations are at right angles to each other) to give $a_{total} = \sqrt{a_{tan}^2 + a_{rad}^2} = 1.51\frac{m}{s^2}$. So, finally, $F_{net} = ma = (0.011\ kg)\left(1.51\frac{m}{s^2}\right) = 1.66 \times 10^{-2} N$
24. **B…** Huygens's Principle is related to wave phenomena and that one can treat each point on a wave front to be the sources of new spherical wave fronts (sometimes called wavelets).
25. **A…** Using Bernoulli's Principle, we have $P + \frac{1}{2}\rho v^2 + \rho g y = C$. Since the tube is horizontal, there is no change in y as the fluid enters the narrower region. However, from continuity, as the size of the opening decreases, the fluid speed must increase (what goes in, must come out). Using the Bernoulli expression now with the second term increasing and the third term unchanged, this means that the pressure of the fluid has to decrease as it enters the narrow region.
26. **B…** In order to have the required average speed of the trip, a total of 200 meters needs to be covered. In the first stage, a total of $x = x_0 + v_0 t + \frac{1}{2}at^2\ \Rightarrow 0 + (6)(12) + 0 = 72\ m$ is covered, leaving $200 - 72 = 128\ m$ for the second stage.

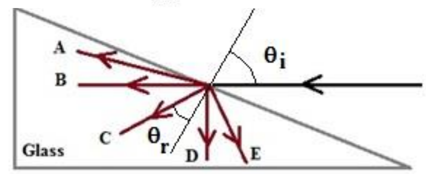
METHOD #1: By writing the constant acceleration kinematics expression, we have

$$x = x_0 + v_0 t + \frac{1}{2}at^2 \Rightarrow 200 = 72 + (6)(8) + \frac{1}{2}a(8^2) \Rightarrow 128 = 48 + 32a \Rightarrow a = \frac{80}{32} = 2.5\frac{m}{s^2}$$

METHOD #2: By graphing the velocity as a function of time, we can compute the area under the curve during the last 8 seconds to obtain $128\ m$. For the rectangle shown, we have an area of $\left(6\frac{m}{s}\right)(8\ s) = 48\ m$ leaving $80\ m$ for the area of the triangle. For the triangle, we have $\frac{1}{2}bh = \frac{1}{2}(8\ s)(h) = 80 \Rightarrow h = 20\frac{m}{s}$. This represents the change in velocity of the object during the last 8 seconds… hence, $\Delta v = at \Rightarrow 20 = a(8) \Rightarrow a = \frac{20}{8} = 2.5\frac{m}{s^2}$.



27. C… As the light enters a medium with a higher index of refraction, it bends toward the normal. We need to look at the figure to determine which way that is directed. Since the angles are measured from normal to the surface, that angle must decrease in the glass, meaning that the ray travels along C.



28. E… Imagine an object dropped from rest and let it attain a final downward speed of $10\frac{m}{s}$. If the object is stopped in 2.0 seconds, the magnitude of the (average) acceleration is $|a| = \left|\frac{\Delta v}{\Delta t}\right| = \left|-\frac{10}{2}\right| = 5\frac{m}{s^2} < g$.

If the object is stopped in time $1.0\ s$, the acceleration is $|a| = \left|\frac{\Delta v}{\Delta t}\right| = \left|\frac{-10}{1}\right| = 10\frac{m}{s^2} = g$

If the object is stopped in time $0.50\ s$, the acceleration is $|a| = \left|\frac{\Delta v}{\Delta t}\right| = \left|\frac{-10}{0.50}\right| = 20\frac{m}{s^2} > g$

29. B… METHOD #1: Energy Using mechanical energy conservation for the particle-field system as the particle crosses the region between the plates, we write $\Delta KE + \Delta PE = 0$ where $\Delta PE = q\Delta V$. Since the potential difference between the plates will be the same for each charge, the change in PE of the charge-field system is the same in each case, meaning that the change in KE is the same for each charge. Hence, each charge reaches the other side with the same speed.

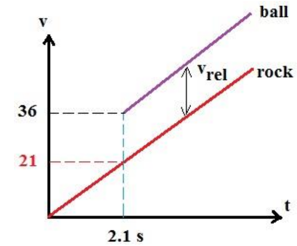
METHOD #2: Kinematics/Force: This approach is a bit messier, but also works. The force on a charge is $F = qE$ and by Newton's Second Law, $qE = ma \Rightarrow a = \frac{qE}{m}$. We will treat all motion "to the left" to be "positive". Consequently, using constant acceleration kinematics, we have for the x-component of velocity at the left-hand plate to be $v_f^2 = v_0^2 + 2a\Delta x \Rightarrow v_{fx}^2 = (v\cos\theta)^2 + 2\left(\frac{qE}{m}\right)d$ where θ will be the arbitrary angle below the horizontal at which the electron is launched. Combining this result with the y-component of the velocity (which is constant), we have $v^2 = v_x^2 + v_y^2 = (v\sin\theta)^2 + (v\cos\theta)^2 + 2\left(\frac{qE}{m}\right)d = v^2 + \frac{2qEd}{m}$. This final result for the speed is independent of the angle of launch!!

30. B… Conventional current is in the direction of positive charge flow, so that is directed to the right in the wire. Using the right-hand rule, the direction of the magnetic field associated with this current is out of the plane of the page at the location of the proton (thumb to the right, fingers curl around the thumb). Now, we use the right-hand rule that the force on a charged particle can be found by pointing the right fingers along the velocity (up the plane) and curling them into the direction of the field (out of the plane), resulting in the thumb pointing to the right, in the direction of the force.

31. D… An ideal gas during an isothermal process has a constant temperature (that is the meaning of isothermal). Since internal energy depends on the temperature, there is no internal energy change.

32. E… While this looks like this is the acceleration for simple harmonic oscillation, at time $= 0$, when the speed should be maximum, the object is at rest. So, this is not SHO. Instead, we need to find the area under the curve to give the velocity as a function of time. For the first 2.5 seconds, the acceleration is positive, so the velocity is becoming more positive. For the next 2.5 seconds, the acceleration is negative, indicating that the object is now slowing down, but still moving forward (velocity is still positive) until it comes back to rest at time t = 5 seconds. The process begins again for the next 5 seconds with the object again having positive velocity. Hence, the object is getting further from its starting position during this motion and achieves its greatest displacement from the origin at $t = 10\ s$.

33. A… METHOD #1: Acceleration is the rate of change in velocity in time. When both objects are moving, they each have the same acceleration and so each has the same change in velocity. This means that whatever the difference in speed was when the second object was launched is the relative speed of the ball with respect to the rock at all times during the fall. At launch, the rock had fallen for $2.10\ s$ giving it a downward speed of $= v_0 + at \Rightarrow v = (10)(2.1) = 21\frac{m}{s}$. The ball had downward speed of $36.0\frac{m}{s}$. This means that from the rock's point of view, the ball is always moving at $36 - 21 = 15.0\frac{m}{s}$ relative to it.



METHOD #2: Graph the velocity vs. time for each object. We note on the graph that at any instant of time, the lines are the same distance apart, representing the relative speed between the objects.

METHOD #3: Kinematics We can set up kinematics tables of variables to determine the speeds of the objects for the condition needed, choosing downward as the positive direction. For the rock, we have $x = x_0 + v_0 t + \frac{1}{2}at^2$ giving $X = 0 + 0 + 5T^2$. For the ball, the expression becomes $X + 28 = 36(T - 2.1) + 5(T - 2.1)^2$. Substituting the ball's expression for X, we have $5T^2 + 28 = 36T - 75.6 + 5T^2 + 4.41 - 21T \ \Rightarrow\ 15T = 99.19 \ \Rightarrow T = 6.61\ s$. Using this in the velocity equations, we get $v_{Rock} = 0 + (10)(6.61) = 66.1\frac{m}{s}$ and $v_{Ball} = 36 + (10)(4.51) = 81.1\frac{m}{s}$. The relative speed therefore is $81.1 - 66.1 = 15.0\frac{m}{s}$.

34. A… Intensity is power (in Watts) divided by area (in m^2). So, we have for the analysis:

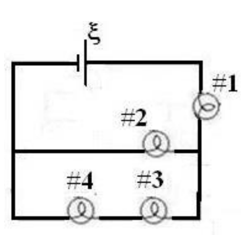
$$\frac{W}{m^2} = \frac{\frac{J}{s}}{m^2} = \frac{J}{sm^2} = \frac{Nm}{sm^2} = \frac{kg\frac{m}{s^2}}{sm} = \frac{kg}{s^3}$$

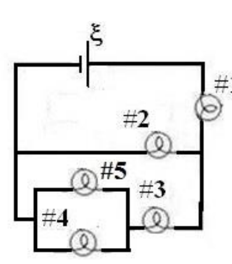
35. C… The current of the inner circuit is oriented counterclockwise. By the right hand rule, this means that the field is directed out of the plane in the interior of the circuit, but since field lines for closed loops, they would enter into the plane of the page exterior to the loop. Since not all of the field lines coming back into the plane are interior to the outer loop, the net magnetic flux is directed out of the plane of the page for the outer loop, but decreasing in strength. By Lenz's Law, this means that there is an induced current directed counterclockwise around the outer loop. Hence, this is generated by pushing electrons from left to right from X to Y in the upper branch.

36. C… The principal quantum number allows one to find the azimuthal quantum number, l as $l = 0,1,2,3,4$. The magnetic quantum number is then found as $m_l = -l, \ldots - 1,0,1, \ldots, l$. Since $l = 4$, the values of m_l are $m_l = -4,-3,-2,-1,0,1,2,3,4$ which is a total of 9 possible values.

37. A… When an object in air is placed in front of a concave glass lens, the result is a virtual image that is smaller than the object. This means that the lens must be convex. Now, for locations between the radius of curvature and the focal length of the lens, the resulting image is larger than the object. Further, the image is real. Now, if the object is placed inside the focal length of the convex lens, the result is a magnified, but virtual image. Without more information as to exactly where the object was placed, it is not possible to determine whether a real or virtual image is formed.

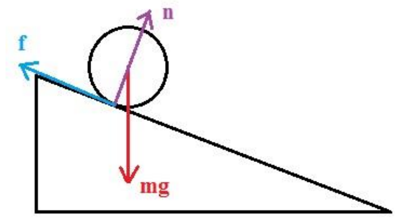
38. B… The equivalent circuit before and after the switch is closed for the resistors is shown in the figure. In words, by closing the switch the resistance of the entire circuit goes down since the resistance of the bottom branch drops from $2R$ to $\frac{3}{2}R$. Since there is less resistance in the circuit, there is more current, meaning that there is more current through bulb #1 directly connected to the battery. Bulb #1 gets brighter and has more potential difference. Consequently, there is less potential difference now for bulb #2 from Kirchhoff's Loop Rule with the battery and bulb #1. Bulb #2 is dimmer. Finally, since the resistance of the bottom branch decreased, it now gets a higher percentage of a





slightly higher current. With the switch closed, bulbs #4 and #5 now share the current equally, resulting in less current through bulb #4, thereby making it dimmer than before. At the same time, all of the slightly higher current is now through #3, thereby making it brighter.

39. A… METHOD #1: In the experiment in which two objects like this race, the disk reaches the bottom of the incline first as it has a smaller moment of inertia. Well, by looking at the free body diagram of each object, there are three forces acting. Each has the same gravitational and normal forces, but since the disk accelerates at a greater rate down the incline, it must therefore have a greater net force down the incline. Since the gravitational forces are equal, this means that the friction force must be less for the disk than for the ring!



METHOD #2: mathematical analysis. Using energy conservation for the object-Earth system of each, one has $\Delta KE + \Delta PE = 0 \Rightarrow \left(\frac{1}{2}mv_{cm}^2 + \frac{1}{2}I_{cm}\omega^2\right)_f - \left(\frac{1}{2}mv_{cm}^2 + \frac{1}{2}I_{cm}\omega^2\right)_i + mg\Delta y = 0$. Since both objects start at rest, we have $\frac{1}{2}mv_{cm}^2 + \frac{1}{2}I_{cm}\omega^2 = -mg\Delta y$. Using the moments of inertia of the objects and that $v_{cm} = \omega R$ for objects rolling, we have: $\omega_{ring}^2 = \frac{-g\Delta y}{R^2}$ and $\omega_{disk}^2 = \frac{-4g\Delta y}{3R^2}$. For the masses rolling down the same distance on the incline, we see that $\omega_{disk} > \omega_{ring}$ which means $\alpha_{disk} > \alpha_{ring}$ and so $a_{disk} > a_{ring}$ and since the gravitational force is the same, the friction must be greater for the ring.

40. E… METHOD #1: Continuing with the mathematical analysis in #39, we can now write $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$ and compare these quantities after rolling for the same angle (distance down incline). This gives $\frac{\omega_{ring}^2}{\omega_{disk}^2} = \frac{\omega_0^2 + 2\alpha_{ring}\Delta\theta}{\omega_0^2 + 2\alpha_{disk}\Delta\theta} \Rightarrow \frac{\frac{-g\Delta y}{R^2}}{\frac{-4g\Delta y}{3R^2}} = \frac{\alpha_{ring}}{\alpha_{disk}} \Rightarrow \frac{\alpha_{ring}}{\alpha_{disk}} = \frac{3}{4}$.

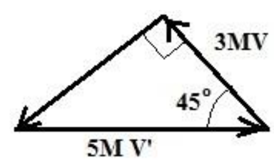
METHOD #2: Using the Free Body Diagram and writing $F_{net} = ma$ and $\tau_{net} = I\alpha$, we have $F_{net_x} = ma_x \Rightarrow mg\sin\theta - f_s = ma$ and $\tau_{net} = I\alpha \Rightarrow f_sR = I\alpha$. Using $a = R\alpha$, we have $f_sR = I\alpha \Rightarrow f_s = I\frac{\alpha}{R}$ and $mg\sin\theta - f_s = mR\alpha$. Substituting the friction expression gives us $mg\sin\theta - I\frac{\alpha}{R} = mR\alpha$ which leads to $mgR\sin\theta = (I + mR^2)\alpha \Rightarrow \alpha = \frac{mgR\sin\theta}{I+mR^2}$. So,

$$\frac{\alpha_{ring}}{\alpha_{disk}} = \frac{\frac{mgR\sin\theta}{I_{ring} + mR^2}}{\frac{mgR\sin\theta}{I_{disk} + mR^2}} = \frac{I_{disk} + mR^2}{I_{ring} + mR^2} = \frac{\frac{3}{2}mR^2}{2mR^2} = \frac{3}{4}$$

Alternatively: The approach using the FBD can also be done using the point of contact of the rolling objects with the incline (instantaneous axis of rotation).

41. A… Carnot efficiency is computed as $e_{Carnot} = 1 - \frac{T_c}{T_h}$ where all temperatures are in Kelvin. Converting those here gives $e_{Carnot} = 1 - \frac{(273+273)}{(546+273)} = 1 - \frac{2(273)}{3(273)} = 1 - \frac{2}{3} = \frac{1}{3}$.

42. C… METHOD #1: Vector Addition: Since $\vec{p}_{3M} + \vec{p}_{4M} + \vec{p}_{5M} = 0$ as the object was initially at rest, $\vec{p}_{3M} + \vec{p}_{4M} = -\vec{p}_{5M}$. Since p_{3M} and p_{4M} form a right angle with p_{5M} as the hypotenuse, we use right-triangle trig to obtain $\cos 45^\circ = \frac{p_{3M}}{p_{5M}} \Rightarrow \frac{1}{\sqrt{2}} = \frac{3MV}{5MV'} \Rightarrow V' = \frac{3\sqrt{2}}{5}V$



METHOD #2: Momentum components: By writing linear momentum conservation in both the x and y directions, we have $\Delta p_x = 0 \Rightarrow \Delta p_{3M_x} + \Delta p_{4M_x} + \Delta p_{5M_x} = 0 \Rightarrow$

$$3M(-V\cos 45^\circ - 0) + 4M(-V'\cos 45^\circ - 0) + 5M(V'' - 0) = 0$$

$$-\frac{3V}{\sqrt{2}} - -\frac{4V'}{\sqrt{2}} + 5V'' = 0 \Rightarrow 5\sqrt{2}\,V'' = 3V + 4V'$$

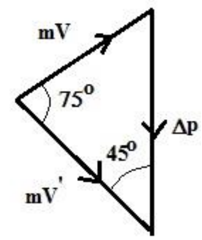
$$\Delta p_y = 0 \Rightarrow \Delta p_{3M_y} + \Delta p_{4M_y} + \Delta p_{5M_y} = 0 \Rightarrow$$

$$3M(-V\cos 45^\circ - 0) + 4M(-V'\cos 45^\circ - 0) + 5M(V'' - 0) = 0$$

$$3M(V\sin 45^\circ - 0) + 4M(-V'\sin 45^\circ - 0) + 5M(0-0) = 0$$
$$V' = \frac{3}{4}V$$

So, by substituting this result into the y-expression gives $5\sqrt{2}\,V'' = 3V + 3V \Rightarrow V'' = \frac{6}{5\sqrt{2}}V = \frac{3\sqrt{2}}{5}V$

43. A… METHOD #1: Knowing the velocity directions and that it is in free fall allows us to recognize that the horizontal component of velocity is unchanged. Therefore, $V\cos 30^\circ = V_f \cos 45^\circ \Rightarrow V_f = \frac{\sqrt{3}\,\sqrt{2}}{2}\,V$. As for the impulse, we know that $\Delta\vec{p}$ is the impulse. Since the x-component of motion is constant, we need only consider the y-component. $\Delta p_y = m(v_{fy} - v_{0y}) = (1)\left((-V_f\sin 45^\circ) - (V\sin 30^\circ)\right) = -\left(\left(\frac{\sqrt{3}\,\sqrt{2}}{2}\,V\right)\left(\frac{1}{\sqrt{2}}\right) + V\left(\frac{1}{2}\right)\right)$. So, the magnitude of this quantity is $\frac{1}{2}(\sqrt{3}+1)V$.



METHOD #2: By drawing a picture of the momentum before and after the motion, we note that the change is only in the vertical direction. Using the Law of Sines, we write $\frac{\Delta p}{\sin 75^\circ} = \frac{mV}{\sin 45^\circ} \Rightarrow \Delta p = mV\,\frac{\sin 75^\circ}{\sin 45^\circ}$. One can write $\sin 75^\circ = \sin 45^\circ\cos 30^\circ + \cos 45^\circ\sin 30^\circ = \sin 45^\circ(\cos 30^\circ + \sin 30^\circ)$ since $\sin 45^\circ = \cos 45^\circ$. Hence, $\Delta p = mV\,\frac{\sin 75^\circ}{\sin 45^\circ} = V\left(\frac{\sqrt{3}}{2} + \frac{1}{2}\right)$.

44. E… Young's modulus deals with extension/compression of materials.

45. C… There are several similar approaches to solving this question. To obtain the required voltages, this means that $\Delta V_R = 3.0\ V$ and $\Delta V_C = 9.0\ V$. Using that $\Delta V_R = RI = RI_{max}e^{-\frac{t}{\tau}}$ we note that $I_{max} = 12\ V$ immediately after the switch is closed. Also, $\tau = RC = (10\ \Omega)(2.2\ F) = 22.0\ s$. So, we find $\Delta V_R = RI_{max}e^{-\frac{t}{\tau}} \Rightarrow 3 = (12)e^{-\frac{t}{22}} \Rightarrow \ln\frac{1}{4} = -\frac{t}{22} \Rightarrow t = 22\ln 4$. This evaluates to 30.5 seconds.

46. E... The top quark was confirmed experimentally in 1995.

47. B… The angular momentum of the Earth on its axis is computed as $L = I\omega = \left(\frac{2}{5}MR^2\right)\omega$ since we approximate the Earth as a solid sphere. The mass and radius of the Earth are on the constants sheet while the value of $\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi\ rad}{1\ dy} \times \frac{1\ dy}{24\ hr} \times \frac{1\ hr}{3600\ s} = 7.27\times 10^{-5}\,\frac{rad}{s}$. So, we find $L = \frac{2}{5}(6.0\times 10^{24})(6.4\times 10^{6})^2(7.27\times 10^{-5}) = 7\times 10^{33}\,\frac{kg\cdot m^2}{s} \approx 10^{34}\,\frac{kg\cdot m^2}{s}$.

48. A… METHOD #1: Using that the heat for the processes are $Q_p = nc_p\Delta T$ and $Q_v = nc_v\Delta T$ with an identical number of moles and temperature change (doubled in both cases), we need to compare specific heats. For ideal monatomic ideal gases, we have $c_p = \frac{5}{2}R$; $c_v = \frac{3}{2}R$. Hence, $Q_p > Q_v$.

METHOD #2: Since the gases are identical ideal monatomic gases, using the ideal gas equation, we see that the temperature doubles in both cases. Hence, $\Delta U = \frac{3}{2}nR\Delta T$ is the same for both gases. However, the isochoric process (constant volume) has no work done while the isobaric process with an increasing volume will have negative work done onto the gas. Using $\Delta U = Q + W$, with the same ΔU and a negative W for the isobaric process, that process will have a larger Q

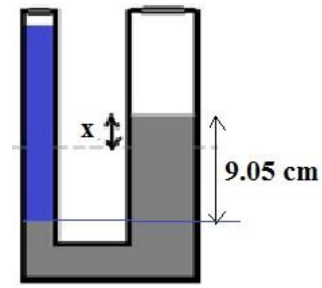
49. D... Taking the ratio of the momenta gives $\frac{p_2}{p_1} = 2 = \left(\frac{\gamma_2 m v_2}{\gamma_1 m v_1}\right) \Rightarrow 4 = \left(\frac{\gamma_2 m v_2}{\gamma_1 m v_1}\right)^2 = \frac{1-\frac{v_1^2}{c^2}}{1-\frac{v_2^2}{c^2}}\frac{v_2^2}{v_1^2}$ where $v_1 = 0.4\ c$ leading to $4 = \frac{1-(0.4)^2}{c^2 - v_2^2}\frac{v_2^2}{(0.4)^2} \Rightarrow 4 = 5.25\,\frac{v_2^2}{c^2 - v_2^2} \Rightarrow \frac{4}{5.25} = \frac{\beta^2}{1-\beta^2}$ where $\beta = \frac{v_2}{c}$. Solving for β gives $\frac{4}{5.25} = \frac{9.25}{5.25}\,\beta^2 \Rightarrow \beta = \sqrt{\frac{4}{9.25}} \Rightarrow v_2 = 0.657c = 1.97\times 10^8\,\frac{m}{s}$.

Alternatively: The slow electron has a linear momentum of $p = \gamma m v = \frac{mv}{\sqrt{1 - v^2/c^2}} = \frac{(9.11\times 10^{-31})(0.4\times 3\times 10^8)}{\sqrt{1-(0.4)^2}} = 1.19\times 10^{-22}\ kg\cdot\frac{m}{s}$. Doubling this gives

$$2.38 \times 10^{-22} = \frac{mv}{\sqrt{1-v^2/c^2}} \Rightarrow 6.83 \times 10^{16} = \frac{v^2}{1-\frac{v^2}{c^2}} \Rightarrow$$

$$6.83 \times 10^{16} - 0.759v^2 = v^2 \Rightarrow v = \sqrt{\frac{6.83 \times 10^{16}}{1.759}} = 1.97 \times 10^8 \frac{m}{s}$$

50. B… We note that at the interface of the water/mercury in the left tube, the pressure there must match the pressure at that depth in the mercury-only side. So, we write $P_0 + \rho_w g h_w = P_0 + \rho_{Hg} g h_{Hg}$. Since there are 800 grams of water and an area of 6.50 cm^2 for the tube that it is in, we know the depth of the water column as $800\ cm^3 = 6.50\ cm^2(h) \Rightarrow h = 123.1\ cm$. The density of water is $1.0 \frac{g}{cm^3}$ leading to the conclusion of 800 cm^3 of water. So, the amount of mercury is $\rho_w g h_w = \rho_{Hg} g h_{Hg} \Rightarrow h_{Hg} = \frac{\rho_w}{\rho_{Hg}} h_w$. This gives $h_{Hg} = 9.05\ cm$.



Finally, we use that the volume of mercury displaced upward from the original equilibrium must match the volume of water displacing it below that line. This means from the picture that $A_{right} x = A_{left}(9.05 - x)$. Solving for x gives $15x = 6.5(9.05 - x) \Rightarrow 21.5x = 58.825 \Rightarrow x = 2.74\ cm$