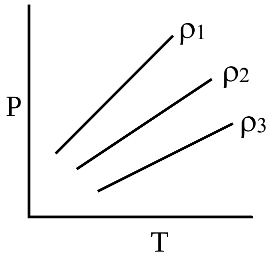
# JEE MAIN 2024 SESSION-2
## Paper with Solution

**PHYSICS | $04^{th}$ April 2024 _ Shift-1**

## SECTION – A

**31.** P-T diagram of an ideal gas having three different densities $\rho_1, \rho_2, \rho_3$ (in three different cases) is shown in the figure. Which of the following is correct:




(1) $\rho_1 > \rho_2$ (2) $\rho_2 < \rho_3$ (2) $\rho_1 < \rho_2$ (4) $\rho_1 = \rho_2 = \rho_3$

**Sol.** **1**

$P = \rho \frac{RT}{M_0}$

$\frac{P}{T} = \frac{\rho R}{M_0}$

i.e. $\boxed{\frac{P}{T} \alpha \rho}$

$\therefore \rho_1 > \rho_2 > \rho_3$

**32.** The equation of stationary wave is :

$y = 2a\sin\left(\frac{2\pi nt}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right).$

Which of the following is NOT correct :

(1) The dimensions of x is [L] (2) The dimensions of nt is [L]

(3) The dimensions of n is $[LT^{-1}]$ (4) The dimensions of $n/\lambda$ is [T]

**Sol.** **4**

$y = 2a \ \sin\left(\frac{\pi nt}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right)$

(i) [x] = L

(ii) $\left[\frac{\pi nt}{\lambda}\right] = 1 \Rightarrow [nt] = 1 \cdot [\lambda] = L$

(iii) $[nt] = L \Rightarrow [n] = LT^{-1}$

(iv) $\left[\frac{n}{\lambda}\right] = \frac{LT^{-1}}{L} = T^{-1}$

**33.** The electric field in an electromagnetic wave is given by $\vec{E} = \hat{i}\ 40\cos\omega\left(t - z/c\right) NC^{-1}$. The magnetic field induction of this wave is (in SI unit) :

(1) $\vec{B} = \hat{j} 40\cos\omega\left(t - z/c\right)$ (2) $\vec{B} = \hat{k}\frac{40}{c}\cos\omega\left(t - z/c\right)$

(3) $\vec{B} = \hat{i}\ \frac{40}{c}\cos\omega\left(t - z/c\right)$ (4) $\vec{B} = \hat{j}\ \frac{40}{c}\cos\omega\left(t - z/c\right)$

**Sol.** **4**

$\vec{E} = 40\cos\left(\omega t - \frac{\omega}{c}z\right) NC^{-1}\hat{i}$

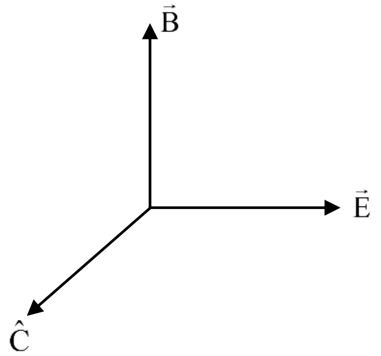
Direction of $\hat{c}$ is along +z

and Direction of $\hat{c}$ must be along $\vec{E} \times \vec{B}$.

$\therefore \vec{B}$ must be along $+\hat{j}$.

$E_0 = B_0 C$

$B_0 = \frac{E_0}{C} = \frac{40}{C}$




**34.** The resistances of the platinum wire of a platinum resistance thermometer at the ice point and steam point are 8 Ω and 10 Ω respectively. After inserting in a hot bath of temperature 400ºC, the resistance of platinum wire is :

(1) 8 Ω (2) 10 Ω (3) 16 Ω (4) 2 Ω

**Sol.** **3**

Given, $R_0 = 8\Omega$

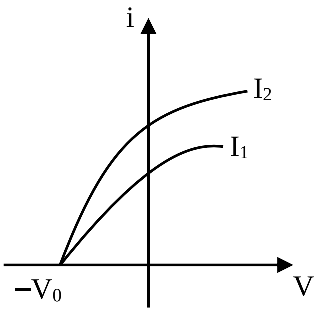
And $R_{100} = 10\Omega$

$\frac{C-0}{100} = \frac{R-R_0}{R_{100}-R_0}$

$\Rightarrow \frac{400}{100} = \frac{R-8}{2}$

$\Rightarrow R - 8 = 8 \Rightarrow R = 16\ \Omega$

**35.** Which figure shows the correct variation of applied potential difference (V) with photoelectric current (I) at two different intensities of light ($I_1 < I_2$) of same wavelengths:

(1)
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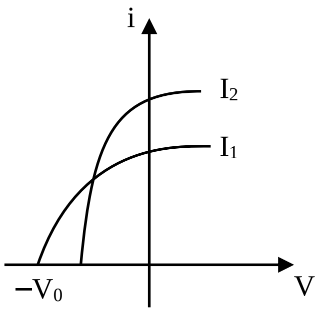


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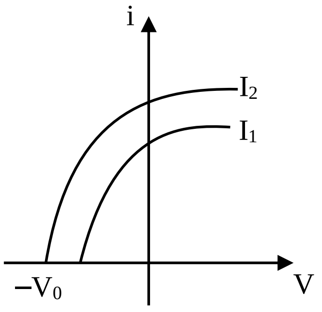


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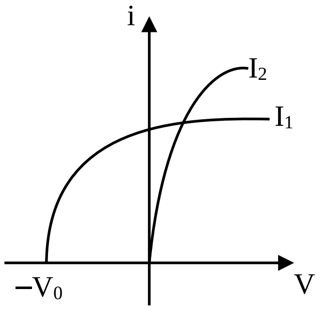


**Sol.** **1**

Saturation current depends on intensity of incident light.
Also according to question, both have same wavelength.
$\therefore$ There $KE_{max}$ will be same.
$\therefore$ There stopping potential will also be same.

**36.** To measure the internal resistance of a battery, potentiometer is used. For R = 10 Ω, the balance point is observed at *l* = 500 cm and for R = 1 Ω the balance point is observed at *l* = 400 cm. The internal resistance of the battery is approximately:

(1) 0.3 Ω (2) 0.4 Ω (3) 0.1 Ω (4) 0.2 Ω

**Sol.** **3**

$$i = \frac{\varepsilon}{r+R}$$

$$\varepsilon - ir = \varepsilon - \frac{\varepsilon}{r+R}\cdot r$$

$$= \frac{\varepsilon r + \varepsilon R - \varepsilon r}{r+R}$$

$$\varepsilon - ir = \frac{\varepsilon R}{r+R}$$

also, $\varepsilon - ir = \frac{V}{l}.x$

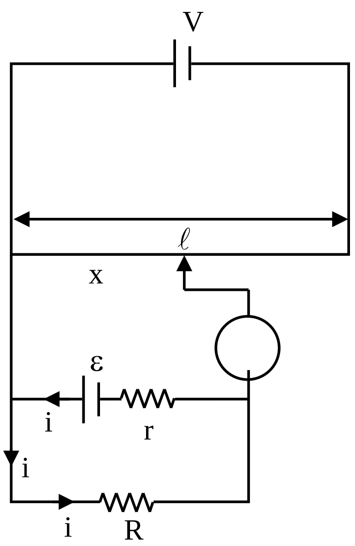
$$\therefore \frac{V}{l}x = \frac{\varepsilon R}{r+R}$$

Now, $\frac{x_1}{x_2} = \frac{R_1}{r+R_1} \times \frac{r+R_2}{R_2}$

r + 10 = 8r + 8

7r = 2

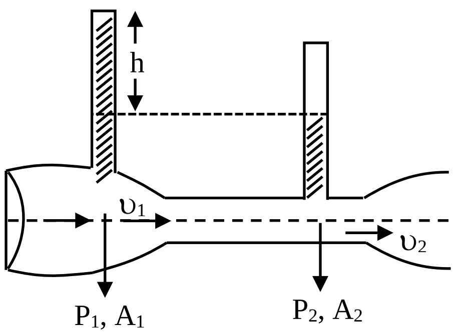
$r = \frac{2}{7} \approx 0.3$




**37.** Given below are two statements:

Statement I : When speed of liquid is zero everywhere, pressure difference at any two points depends on equation $P_1 - P_2 = \rho g(h_2 - h_1)$.

Statement II : In ventury tube shown $2gh = \upsilon_1^2 - \upsilon_2^2$




In the light of the above statements, choose the most appropriate answer from the options given below.

(1) Both Statement I and Statement II are correct.
(2) Both Statement I and Statement II are incorrect.
(3) Statement I is correct but Statement II is incorrect.
(4) Statement I incorrect but Statement II is correct.

**Sol.** 3

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$\rho gh = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$\boxed{v_2^2 - v_1^2 = 2gh}$$

statement II is incorrect

**38.** An electron is projected with uniform velocity along the axis inside a current carrying long solenoid. Then -

(1) The electron will continue to move with uniform velocity along the axis of the soldnoid

(2) the electron will be accelerated along the axis

(3) the electron path will be circular about the axis

(4) the electron will experience a force at 45° to the axis and execute a helical path.

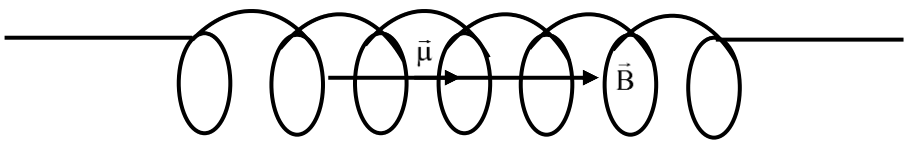
**Sol.** 1

$$\vec{F} = q\left(\vec{V} \times \vec{B}\right)$$

Both $\vec{V}$ & $\vec{B}$ will be in same direction

$\therefore$ Force on electron will be zero.

Option 1 is correct.




**39.** On celcius scale the temperature of body increases by 40°C. The increase in temperature on Fahrenheit scale is -

(1) 68°F (2) 70°F (3) 72°F (4) 75°F

**Sol.** 3

$$\frac{C - 0}{10\not{0}} = \frac{F = 32}{18\not{0}}$$

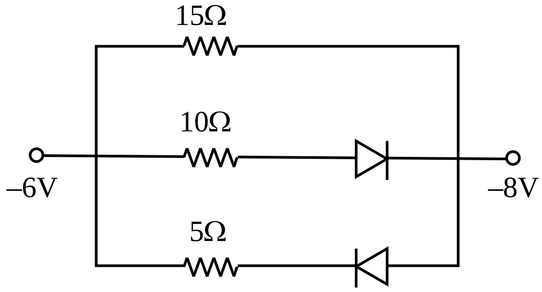
$$C = \frac{5}{9}(F - 32)$$

$$\Delta C = \frac{5}{9}\Delta F$$

$$40 = \frac{5}{9}\Delta F$$

$$\Rightarrow \Delta F = 72^{o} F$$

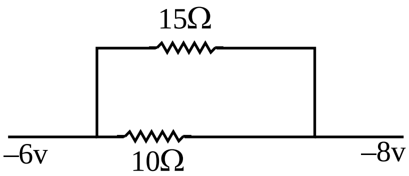
**40.** The value of net resistance of the network as shown in the given figure is –




(1) (5/2) Ω (2) (30/11) Ω (3) (15/4) Ω (4) 6 Ω

**Sol.** **4**

The circuit is equivalued to




$$\text{Rep} = \frac{15\times10}{25} = 6\Omega$$

**41.** An effective power of a combination of 5 identical convex lenses which are kept in contact along the principal axis is 25D. Focal length of each of the convex lens is -

(1) 20 cm (2) 50 cm (3) 25 cm (4) 500 cm

**Sol.** **1**

$$\frac{1}{f_q} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + \frac{1}{f_5}$$

$$25 = \frac{5}{f}$$

$$f = \frac{1}{5}\text{m} = 20\text{cm}$$

**42.** In an ac circuit, the instantanenous current is zero, when the instantanenous voltage is maximum. In this case, the source may be connected to –

A. Pure inductor.

B. pure capacitor.

C. pure resistor.

D. combination of an inductor and capacitor.

Choose the correct answer from the options given below -

(1) B,C and D only (2) A,B and D only (3) A and B only (4) A,B and C only

**Sol.** **2**

It can only be possible if phase difference b/w current and voltage is $\pi/2$.

**43.** Which of the following nuclear fragments corresponding to nuclear fission between neutron $\left({}_0^1n\right)$ and uranium isotope $\left({}_{92}^{235}U\right)$ is correct.

(1) ${}_{56}^{144}Ba + {}_{36}^{89}Kr + 3{}_0^1n$

(2) ${}_{56}^{144}Ba + {}_{36}^{89}Kr + 4{}_0^1n$

(3) ${}_{51}^{153}Sb + {}_{41}^{99}Nb + 3{}_0^1n$

(4) ${}_{56}^{140}Xe + {}_{38}^{94}Sr + 3{}_0^1n$

**Sol.** 1

The original fission reaction is given by

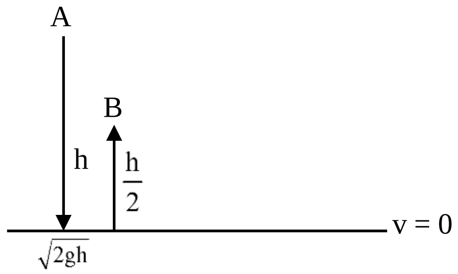
$^{235}U + n \rightarrow {}^{141}Ba + {}^{92}kr + 3n + \text{energy}$

All the given options can also be checked by balancing number of neutrons on both sides.

**44.** If a rubber ball falls from a height h and rebounds upto the height of h/2. The percentage loss of total energy of the initial system as well as velocity ball before it strikes the ground, respectively, are -

(1) $40\%, \sqrt{2gh}$ (2) $50\%, \sqrt{\frac{gh}{2}}$ (3) $50\%, \sqrt{2gh}$ (4) $50\%, \sqrt{gh}$

**Sol.** 3

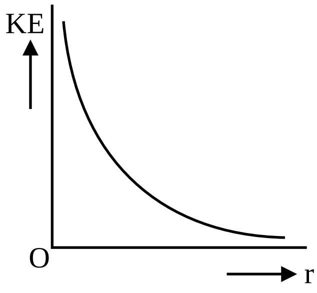



$E_A = Mgh$

$E_B = \frac{Mgh}{2}$

i.e. 50% loss.

**45.** An infinitely long positively charged straight thread has a linear charge density $\lambda$ $Cm^{-1}$. An electron revolves along a circular path having axis along the length of the wire. The graph that correctly represents the variation of the kinetic energy of electron as a function of radius of circular path from the wire is -

(1)
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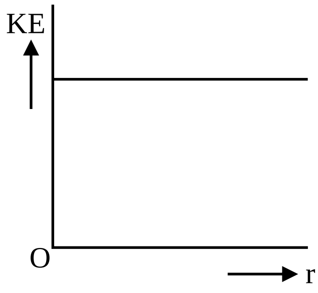
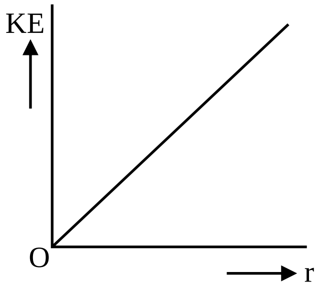



(3)
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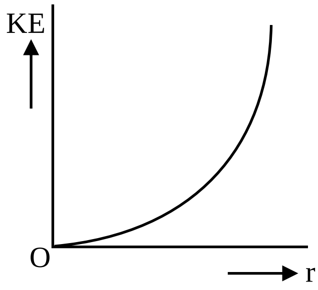
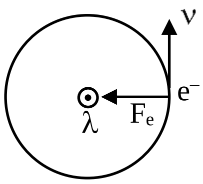


**Sol.** **2**

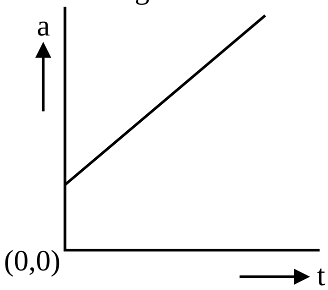
$$\frac{2Ke\lambda}{\cancel{r}} = \frac{mv^2}{\cancel{r}}$$

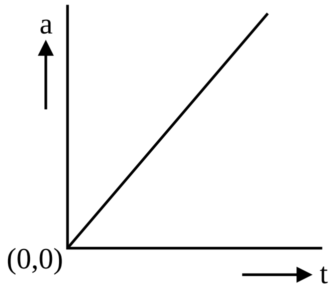
$mv^2 = 2Ke\lambda$

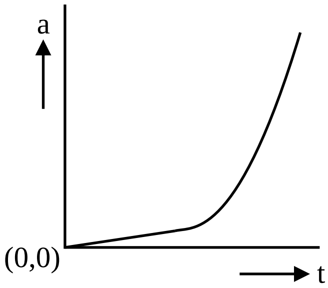
$\frac{1}{2}mv^2 = 2Ke\lambda = \text{constant}$




**46.** A wooden block, initially at rest on the ground, is pushed by a force which increases linearly with time t. Which of the following curve best describes acceleration of the block with time -

(1)



(2)



(3)
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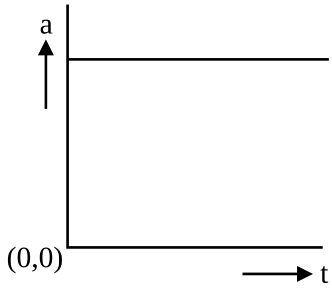
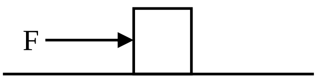



**Sol.** **2**




let $F = \alpha t$

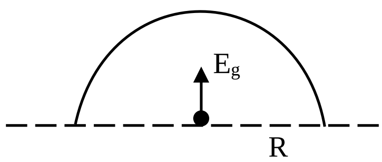
$$a = \frac{F}{m} = \frac{\alpha}{m}t$$

**47.** A metal wire of uniform mass density having length L and mass M is bent to form a semicircular arc and a particle of mass m is placed at the centre of the arc. The gravitational force on the particle by the wire is -

(1) 0 (2) $\frac{GMm\pi}{2L^2}$ (3) $\frac{2GMm\pi}{L^2}$ (4) $\frac{GMm\pi^2}{L^2}$

**Sol.** **3**

$$E_g = \frac{2\cdot G\cdot\lambda}{R} = \frac{2GM}{L\cdot R}$$




also, $\pi R = L$

$$R = \frac{L}{\pi}$$

$$\therefore E_g = \frac{2GM}{L\cdot\frac{L}{\pi}} = \frac{2GM\pi}{L^2}$$

$$F = mE_g = \frac{2GMm\pi}{L^2}$$

**48.** A body travels 102.5 m in $n^{th}$ second and 115.0 m in $(n + 2)^{th}$ second. The acceleration is -
(1) 5 $m/s^2$ (2) 12.5 $m/s^2$ (3) 6.25 $m/s^2$ (4) 9 $m/s^2$

**Sol.** **3**

$$S_{nth} = u + \frac{a}{2}(2n-1)$$

$$102.5 = u + \frac{a}{2}(2n-1) \quad ...(i)$$

$$115 = u + \frac{a}{2}(2n+4-1) \quad ...(ii)$$

Equation (ii) - (i)

$$115 - 102.5 = \frac{a}{2}\{2n+3-2n+1\}$$

$$= \frac{a}{2} \times 4 = 2a$$

$$\Rightarrow a = \frac{12.5}{2} = 6.25\ m/s^2$$

**49.** The co-ordinates of a particle moving in x-y plane are given by –
$x = 2 + 4t$, $y = 3t + 8t^2$
The motion of the particle is -
(1) uniform motion along a straight line
(2) uniformly accelerated having motion along a parabolic path
(3) non-uniformly accelerated
(4) uniformly accelerated having motion along a straight line

**Sol.** **2**

$x = 2 + 4t$
$y = 3t + 8t^2$

$$v_x = \frac{dx}{dt} = 4 = \text{constant}$$

$v_y = 3 + 16t$
$a_x = 0$
$a_y = +16$
$a_{net} = +16$ i.e. uniformly accelerated

Also, $t = \dfrac{x-2}{4}$

$$\therefore y = 3\frac{(x-2)}{4} + 8\left(\frac{x-2}{4}\right)^2$$

$$= \frac{3}{4}x - \frac{3}{2} + \frac{1}{2}\left(x^2 + 4 - 4x\right)$$

$$y = \frac{3}{4}x - \frac{3}{2} + \frac{x^2}{2} + 2 - 2x$$

$\Rightarrow 4y = 3x - 6 + 2x^2 + 4 - 4x$

$$\Rightarrow \boxed{4y = 2x^2 - x - 2}$$

i.e. parabolic path.

**50.** In an experiment to measure focal length (f) of convex lens, the least count of the measuring scales for the position of object (u) and for the position of image (v) are $\Delta u$ and $\Delta v$, respectively. The error in the measurement of the focal length of the convex lens will be -

(1) $2f\left[\frac{\Delta u}{u}+\frac{\Delta v}{v}\right]$ (2) $f\left[\frac{\Delta u}{u}+\frac{\Delta v}{v}\right]$ (3) $\frac{\Delta u}{u}+\frac{\Delta v}{v}$ (4) $f^2\left[\frac{\Delta u}{u^2}+\frac{\Delta v}{v^2}\right]$

**Sol.** **4**

$\frac{1}{v}-\frac{1}{4}=\frac{1}{f}$

$\frac{-1}{v^2}dv+\frac{1}{u^2}du=\frac{-1}{f^2}df$

$$\boxed{\Delta f=f^2\left(\frac{\Delta v}{v^2}+\frac{\Delta u}{u^2}\right)}$$

## SECTION – B

**51.** A soap bubble is blown to a diameter of 7 cm. 36960 erg of work is done in blowing it further. If surface tension of soap solution is 40 dyne/cm then the new radius is _____ cm. Take $\left(\pi=\frac{22}{7}\right)$

**Sol.** **7**

$\Delta w = 2T.4\pi r_2^2 - 2T.\ 4\pi r_1^2$

$r_2^2 - r_1^2 = \frac{\Delta w}{8T\pi} = \frac{36960\times 7}{8\times 40\times 22} = 36.75$

$r_2^2 = 36.75 + \frac{49}{4}$

$= 36.75 + 12.25$

$= 49$

$r = 7$ cm

**52.** Two forces $\vec{F}_1$ and $\vec{F}_2$ are acting on a body. One force has magnitude thrice that of the other force and the resultant of the two forces is equal to the force of larger magnitude. The angle between $\vec{F}_1$ and $\vec{F}_2$ is $\cos^{-1}\left(\frac{1}{n}\right)$. The value of $|n|$ is _______ .

**Sol.** **6**

let $F_1 = F_0$

then, $F_2 = 3F_0$

also, $R = 3F_0$

$\therefore 3F_0 = \sqrt{F_0^2 + 9F_0^2 + 6F_0^2\cos\theta}$

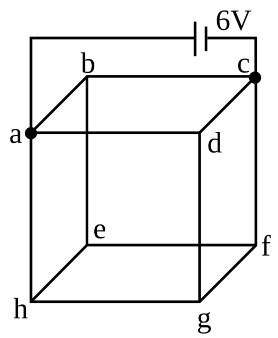
$3F_0 = F_0\sqrt{10+6\cos\theta}$

$9 = 10 + 6\cos\theta$

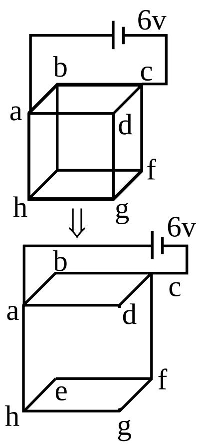
$\cos\theta = -\frac{1}{6}$

$|n| = 6$

**53.** Twelve wires each having resistance 2Ω are joined to form a cube. A battery of 6V emf is joined across point a and c. The voltage difference between e and f is _______ V.

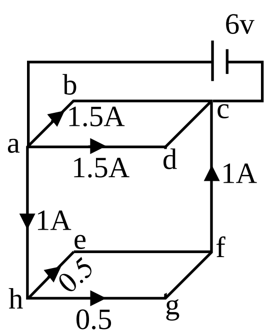



**Sol.** **1**




$R_{eq} = \frac{6 \times 2}{8} = \frac{3}{2}$

$i = \frac{v}{R_{eq}} = \frac{6}{3} \times 2 = 4A$




$V_{ef} = i_{ef} - R_{ef} = 0.5 \times 2 = 1V$

**54.** Two wavelengths $\lambda_1$ and $\lambda_2$ are used in Young's double slit experiment. $\lambda_1$ = 450 nm and $\lambda_2$ = 650 nm. The minimum order of fringe produced by $\lambda_2$ which overlaps with the fringe produced by $\lambda_1$ is n. The value of n is _______.

**Sol.** **9**

$m_2\lambda_2 = m_1\lambda_1$

$$\frac{m_2}{m_1} = \frac{\lambda_1}{\lambda_2} = \frac{450}{650} = \frac{9}{13}$$

i.e. $9^{th}$ maxima of l2 overlaps with $13^{th}$ maxima of $l_1$.

$\therefore$ n = 9

**55.** An infinite plane sheet of charge having uniform surface charge density $+\sigma_s$ C/m$^2$ is placed on x-y plane. Another infinitely long line charge having uniform linear charge density $+\lambda_e$ C/m is placed at z = 4 m plane and parallel to y-axis. If the magnitude values $|\sigma_s| = 2\,|\lambda_e|$ then at point (0,0,2), the ratio of magnitudes of electric field values due to sheet charge to that of line charge is $\pi\sqrt{n}:1$. The value of n is _______.

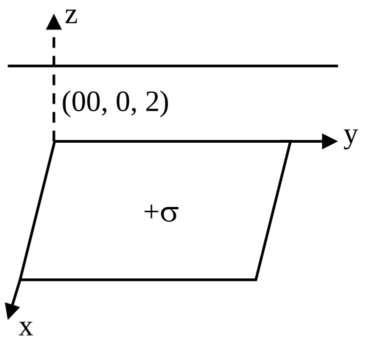
**Sol.** **16**

$$\vec{E}_{sheet} = \frac{\sigma}{2\epsilon_0}\hat{k} = \frac{\lambda}{\epsilon_0}\hat{k}$$

$$\vec{E}_{wire} = \frac{2k\lambda}{r}\left(-\hat{k}\right)$$

$$= \frac{2k\lambda}{2}\left(-\hat{k}\right)$$

$$= k\lambda\left(-\hat{k}\right)$$



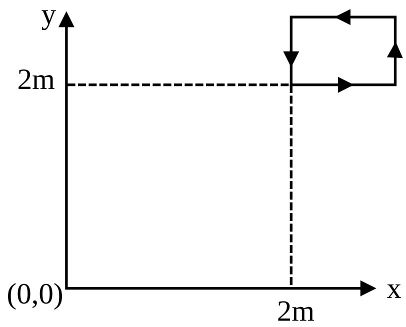

$$\frac{\left|\vec{E}_{sheet}\right|}{\left|\vec{E}_{wire}\right|} = \frac{\lambda}{\epsilon_0}\times\frac{1}{k\lambda} = \frac{1}{\epsilon_0 k} = \frac{1}{\epsilon_0\times\frac{1}{4\pi\epsilon_0}}$$

$= 4\pi$

$\Rightarrow 4\pi = \pi\sqrt{n}$

n = 16

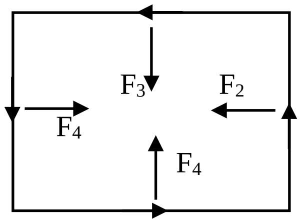
**56.** The magnetic field existing in a region is given by $\vec{B} = 0.2\left(1+2x\right)\hat{k}T$. A square loop of edge 50 cm carrying 0.5 A current is placed in x-y plane with its edges parallel to the x-y axes, as shown in figure. The magnitude of the net magnetic force experienced by the loop is _______ mN.



**Sol.** **50**

$\vec{F} = i\left(\vec{\ell} \times \vec{B}\right)$

$\rightarrow$ $F_3$ and $F_4$ will cancel each other.




$\vec{F}_1 = 0.5 \times \frac{50}{100} \times \{0.2(1+4)\}\hat{i}$

$= \frac{1}{2} \times \frac{1}{2} \times 1\hat{i} = \frac{1}{4}\hat{i} = 0.25\hat{i}$

$\vec{F}_2 = -0.5 \times \frac{50}{100} \times \{0.2(1+5)\}\hat{i}$

$= -\frac{1}{2} \times \frac{1}{2}\{1.2\}\hat{i}$

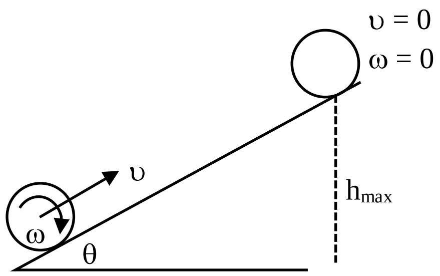
$= -0.3\hat{i}$

$\vec{F}_{net} = -0.05\hat{i}(N)$

$= -50(mN)\hat{i}$

**57.** A solid sphere and a hollow cylinder roll up without slipping on same inclined plane with same initial speed $\upsilon$. The sphere and the cylinder reaches upto maximum heights $h_1$ and $h_2$, respectively, above the initial level. The ratio $h_1 : h_2$ is $\frac{n}{10}$. The value of n is ______

**Sol.** **7**




Energy consevation

$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = mgh$

for pure rolling; v = ωR

$\frac{1}{2}mv^2 + \frac{1}{2}I\frac{v^2}{R^2} = mgh$

$\frac{1}{2}v^2\left(m + \frac{kmR^2}{R^2}\right) = mgh$

$\frac{1}{2}mv^2(1+k) = mgh$

$\frac{h_1}{h_2} = \frac{(k_1+1)\cdot r_1^2}{(k_2+1)r_2^2} = \frac{\frac{2}{5}+1}{1+1} = \frac{7}{5} \times \frac{1}{2} = \frac{7}{10}$

n = 7

**58.** A hydrogen atom changes its state from n = 3 to n = 2. Due to recoil, the percentage change in the wave length of emitted light is approximately $1 \times 10^{-n}$. The value of n is _______.
[Given Rhc = 13.6 eV, hc = 1242 eV nm, h = $6.6 \times 10^{-34}$ Js mass of the hydrogen atom = $1.6 \times 10^{-27}$ kg]

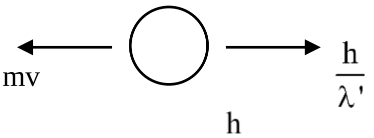
**Sol.** **7**

for n = 3 to n = 2

$$\Delta E = 13.6\left(\frac{1}{4}-\frac{1}{9}\right) = 13.6\times\frac{5}{36} = \frac{68}{36} = 1.88\text{eV}$$

if recoil takes place

$$\text{then, } \Delta E = \frac{hc}{\lambda'} + E_R$$




$$mv = \frac{h}{\lambda'}$$

$$v = \frac{h}{m\lambda'}$$

$$\frac{hc}{\lambda'} = \Delta E - E_R$$

$$= \Delta E - \frac{1}{2}m\cdot\frac{h^2}{m^2\lambda'^2}$$

$$= \Delta E - \frac{h^2}{2m\lambda'^2}$$

$$\frac{hc}{\lambda} - \frac{hc}{\lambda'} = \frac{h^2}{2m\lambda^2}$$

$$\frac{\lambda'-\lambda}{\lambda} = \frac{h}{2mc\lambda'} = \frac{hc}{2mc^2\lambda'} \approx \frac{\Delta E}{2mc^2}$$

$$\frac{\Delta\lambda}{\lambda} = \frac{1.88\times1.6\times10^{-19}}{2\times1.6-10^{-27}\times9\times10^{16}}$$

$$\approx 0.100\times10^{-8}$$

$$\frac{\Delta\lambda}{\lambda}\times100 = 10\times10^{-8} = 1\times10^{-7}$$

**59.** A alternating current at any instant is given by $i = [6+\sqrt{56}\sin(100\pi t+\pi/3)]\text{ A}$. The rms value of the current is __________ A.

**Sol.** **8**

If i = a + b sin (ωt + θ)

$$i_{rms} = \sqrt{a^2+\frac{b^2}{2}}$$

$$\therefore i_{rms} = \sqrt{36+\frac{56}{2}}$$

$$= \sqrt{36+28} = \sqrt{64} = 8\text{A}$$

**60.** An elastic spring under tension of 3 N has a length a. Its length is b under tension 2 N. For its length (3a – 2b), the value of tension will be ________ N.

**Sol.** **5**

$k(a - x_0) = 3$

$\Rightarrow a = \frac{3}{k} + x_0$ ....(i)

$k(b - x_0) = 2$

$\Rightarrow b = \frac{2}{k} + x_0$ ....(ii)

Now, $3a - 2b = \frac{9}{k} + 3x_0 - \frac{4}{k} - 2x_0$

$= \frac{5}{k} + x_0$

$\Rightarrow \{(3a - 2b) - x_0\} = \frac{5}{k}$

$\Rightarrow K\{(3a - 2b) - x_0\} = 5$

$\therefore T = 5\ N$