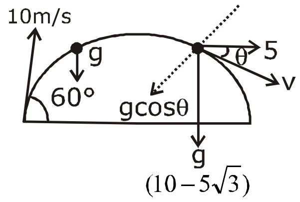
PHYSICS
JEE-MAIN (January-Attempt) 11 January (Shift-1) Paper

SECTION - A

1. A body is projected at t = 0 with a velocity 10 ms^{-1} at an angle of 60º with the horizontal. The radius of curvature of its trajectory at t = 1s is R. neglecting air resistance and taking acceleration due to gravity g = 10ms^{-2}, the value of R is :
(A) 2.8 m (B) 5.1 m (C) 10.3 m (D) 2.5 m

Sol. **A**



$V_x = 10\cos 60^\circ = 5m/s$

V_y = 10 cos30º = $5\sqrt{3}m/s$

velocity after t = 1 sec.

V_x = 5 m/s

$v_y = \left|\left(5\sqrt{3} - 10\right)\right| m/s = 10 - 5\sqrt{3}$

$a_n = \frac{v^2}{R} \Rightarrow R = \frac{v_x^2 + v_y^2}{a_n} = \frac{25 + 100 + 75 - 100\sqrt{3}}{10\cos\theta}$

$\tan\theta = \frac{10 - 5\sqrt{3}}{5} = 2 - \sqrt{3} \Rightarrow \theta = 15^\circ$

$R = \frac{100\left(2 - \sqrt{3}\right)}{10\cos 15} = 2.8m$

2. Ice at - 20ºC is added to 50 g of water at 40º C, when the temperature of the mixture reaches 0ºC it is found that 20 go ice is still emulated. The amount of ice added to the water was close to
(Specific heat of water = 4.2 J/g/ºC
Speciffic heat of ice = 2.1j/g/ºC
Heat of fusion of water at 0ºC = 334 j/g)
(A) 40 g (B) 60 g (C) 100 g (D) 50 g

Sol. **A**
Let amount of ice is m gm.
According to principal of calorimeter heat taken by ice = heat given by water
$\therefore$ 20×2.1×m+(m-20)×334 = 50×4.2×40
376 m = 8400 + 6680
m = 40.1
$\therefore$ correct answer is (B)

3. Equation of travelling wave on a stretched string of linear density 5 g/m is y = 0.03 sin (450t–9x) where distance and time are measured in SI units. THe tension in the string is :
(A) 12.5 N (B) 10 N (C) 5 N (D) 7.5 N

Sol. **A**
y = 0.03 sin (450 t–9x)

$v = \frac{\omega}{k} = \frac{450}{9} = 50m/s$

$v = \sqrt{\frac{T}{\mu}} \Rightarrow \frac{T}{\mu} = 2500$

$\Rightarrow T = 2500 \times 5 \times 10^{-3}$ = 12.5 N

4. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic field of the wave before and after entering into the medium are respectively, given by :

(A) $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$ (B) $\left(\frac{1}{\sqrt{n},} \sqrt{n}\right)$ (C) $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$ (D) $\left(\sqrt{n}, \sqrt{n}\right)$

Sol. **A**

$$C = \frac{1}{\sqrt{\mu_0 \in_0}}$$

$$V = \frac{1}{\sqrt{K \in_0 \mu_0}}$$ [For transparent medium $\mu_r \approx \mu_0$]

$$\therefore \frac{C}{V} = \sqrt{k} = n$$

$$\frac{1}{2} \in_0 E_0^2 C = \text{intensity} = \frac{1}{2} \in_0 kE^2 v$$

$$\therefore E_0^2 C = kE^2 v$$

$$\Rightarrow \frac{E_0^2}{E^2} = \frac{kV}{C} = \frac{n^2}{n} \Rightarrow \frac{E_0}{E} = \sqrt{n}$$

similarly

$$\frac{B_0^2 C}{2\mu_0} = \frac{B^2 v}{2\mu_0} \Rightarrow \frac{B_0}{B} = \frac{1}{\sqrt{n}}$$

5. Two equal resistances when connected in series to a battery, consume electric in series to a battery, consume electric power of 60 W. If these resistances are now connected in parallel combination to the same battery, the electric power consumed will be :

(A) 30 W (B) 240 W (C) 60 W (D) 120 W

Sol. **B**

In series condition, equivalent resistance is 2R thus power consumed is $60W = \frac{\varepsilon^2}{2R}$

In parallel condition equivalent resistance is R/2 thus new power is

$$P' = \frac{\varepsilon^2}{(R/2)}$$ or P' = 4P = 240W

6. The force of interaction between two atoms is given by $F = \alpha\beta \exp\left(-\frac{x^2}{\alpha kt}\right)$; where x is the distance, k is the Boltzmann constant and T is temperature and α and β are two constants. The dimension of β is :

(A) M^2LT^{-4} (B) MLT^{-2} (C) $M^2L^2T^{-2}$ (D) $M^0L^2T^{-4}$

Sol. **A**

$$F = \alpha\beta e^{\left(\frac{-x^2}{\alpha KT}\right)}$$

$$\left[\frac{x^2}{\alpha KT}\right] = M^\circ L^\circ T^\circ$$

$$\frac{L^2}{[\alpha] ML^2T^{-2}} = M^\circ L^\circ t^\circ$$

$$\Rightarrow [\alpha] = M^{-1}T^2$$

$[F] = [\alpha][\beta]$

$MLT^{-2} = M^{-1}T^2[\beta] \Rightarrow [\beta] = M^2LT^{-4}$

7. An amplitude modulated signal is given by $V(t) = 10[1 + 0.3\cos(2.2 \times 10^4 t)] \sin(5.5 \times 10^5 t)$. Here t is in seconds. The sideband freqencies (in KHz) are, (Given π =22/7]

(A) 892.5 and 857.5
(B) 178.5 and 171.5
(C) 89.25 and 85.75
(D) 178.5 and 171.5

Sol. **C**

$$V(t) = 10 + \frac{3}{2}\left[2\cos A \sin B\right]$$

$$= 10 + \frac{3}{2}[\sin(A+B) - \sin(A-B)]$$

$$= 10 + \frac{3}{2}[\sin(57.2 \times 10^4 t) - \sin(52.8 \times 10^4 t)]$$

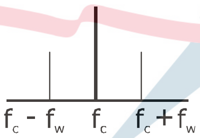
$$\omega_1 = 57.2 \times 10^4 = 2\pi f_1$$

$$f_1 = \frac{57.2 \times 10^4}{2 \times \left(\frac{22}{7}\right)} = 9.1 \times 10^4$$

$$\simeq 91\text{KHz}$$

$$f_2 = \frac{52.8 \times 10^4}{2 \times \left(\frac{22}{7}\right)}$$

$$\simeq 84\text{KHz}$$

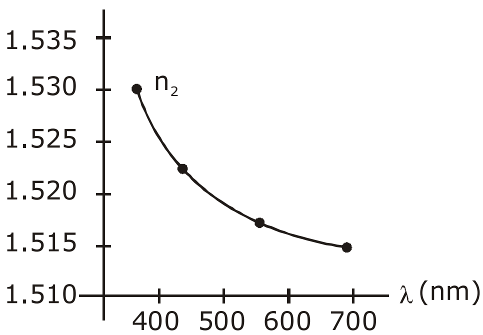


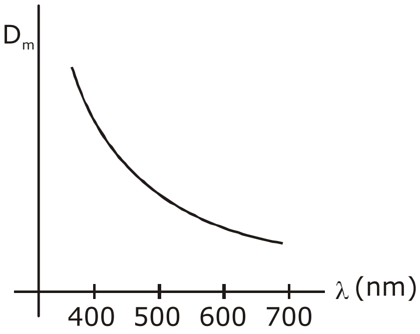
Side band frequency are

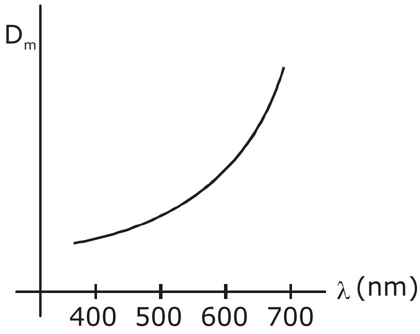
$$f_1 = f_c - f_w = \frac{52.8 \times 10^4}{2\pi} \approx 85.00\text{kHz}$$

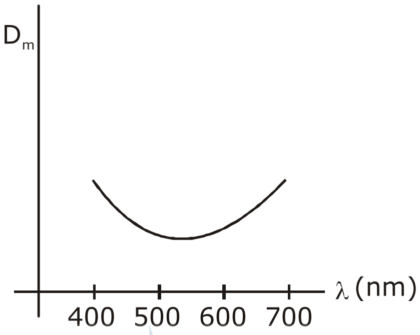
$$f_2 = f_c - f_w = \frac{57.2 \times 10^4}{2\pi} \approx 90.00\text{kHz}$$

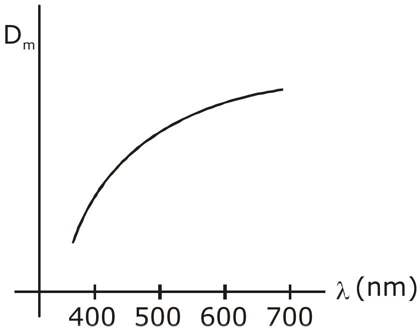
8. The variation of refractive index of a crown glass thin prism with wavelength of the incident light is shown. Which of the following graphs is the correct one, if D_m is the angle of minimum deviation ?



(A)


(B)


(C)


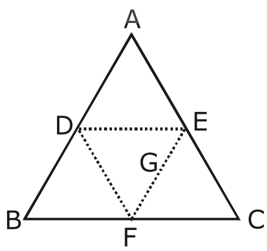
(D)


Sol. **A**

Since $D_m = (\mu-1)A$

& on increasing the wavelength, μ decreases & hence D_m decreases. Therefore correct answer is (A)

9. An equilateral triangle ABC is cut from a thin solid sheet of wood. (See figure) D, E and F are the mid-points of its sides as shown and G is the centre of the triangle. The moment of inertia of the triangle about an axis passing through G and perpendicular to the plane of the triangle is I_0. If the smaller triangle DEF is removed from ABC, the moment of inertia of the remaining figure about the same axis is I. Then :



(A) $I = \frac{3}{4} I_0$ (B) $I = \frac{9}{16} I_0$ (C) $I = \frac{I_0}{4}$ (D) $I = \frac{15}{16} I_0$

Sol. **D**

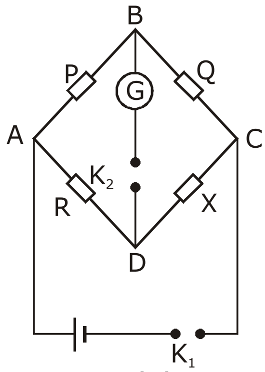
Suppose M is mass and a is side of larger triangle, then $\frac{M}{4}$ and $\frac{a}{2}$ will be mass and side length of smaller triangle.

$$\frac{I_{removed}}{I_{original}} = \frac{\frac{M}{4}}{M} \cdot \frac{\left(\frac{a}{2}\right)^2}{(a)^2}$$

$$I_{removed} = \frac{I_0}{16}$$

So, $I = I_0 - \frac{I_0}{16} = \frac{15 I_0}{16}$

10. In a Wheatstone bridge (see fig.), Resistances P and Q are approximately equal. When R = 400 Ω , the bridge is balanced. On interchanging P and Q, the value of R, for balance, is 405Ω. THe value of X is close to :



(A) 401.5 ohm (B) 403.5 hom (C) 404.5 ohm (D) 402.5 Ohm

Sol. **D**

$\frac{P}{Q} = \frac{400}{x}$

$\frac{Q}{P} = \frac{405}{x}$

$x = \sqrt{400 \times 405} = 402.5\Omega$

11. A liquid of density ρ is coming out of a hose pipe of radius a with horizontal speed v and hits a mesh. 50% of the liquid passes through the the mesh unaffected. 25% Iooses all of its momentum and 25% comes back with the same speed. The resultant pressure on the mesh will be:

(A) pv^2 (B) $\frac{3}{4}pv^2$ (C) $\frac{1}{4}pv^2$ (D) $\frac{1}{2}pv^2$

Sol. **B**

Momentum per second carried by liquid per second is $\rho a v^2$

Net force due to reflected liquid $= 2 \times \left[\frac{1}{4}\rho a v^2\right]$

net force due to stopped liquid $= \frac{1}{4}\rho a v^2$

Total force $= \frac{3}{4}\rho a v^2$

net pressure $= \frac{3}{4}\rho v^2$

12. A body of mass 1 kg falls freely from a height of 100 m, on a platform of mass 3kg which is mounted on a spring having spring constant k = 1.25 $\times 10^6$ N/m. The body sticks to the platform and the spring's maximum compression is found to be x. Given that g = 10 ms^{-2}, the value of x will be close to :

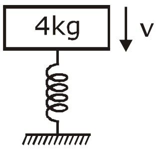
(A) 8 cm (B) 4 cm (C) 40 cm (D) 80 cm

Sol. **B**

Velocity of 1 kg block just before it collides with 3 kg block = $\sqrt{2gh} = \sqrt{2000}m/s$

Applying momentum conversation just before and just after collision.

$1 \times \sqrt{2000} = 4v \Rightarrow v = \frac{\sqrt{2000}}{4}m/s$



initial compression of spring

$1.25\times 10^{6}\ x_0 = 30 \Rightarrow x_0 = 0$

applying work energy theorem, $W_g + WE_{sp} = \Delta KE$

$$\Rightarrow 40 \times x + \frac{1}{2} \times 1.25 \times 10^{6}(0^{2} - x^{2})$$

$$= 0 - \frac{1}{2} \times 4 \times v^{2}$$

solving $x \approx 4\text{cm}$

13. A hydrogen atom, initially in the ground state is excited by absorbing a photon of wavelength 980Å. The radius of the atom in the excited state, in terms of Bohr radius a_0, will be -
(hc = 12500 eV-Å)

(A) $4a_0$ (B) $16\ a_0$ (C) $25\ a_0$ (D) $9\ a_0$

Sol. **B**

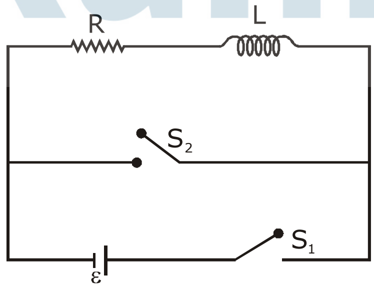
Eneregy of photon $= \frac{12500}{980} = 12.75\text{eV}$

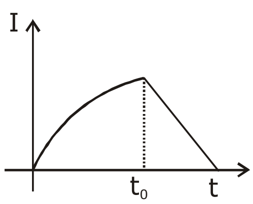
$\therefore$ Electron will excite to n = 4

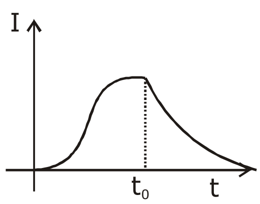
Since 'R' $\propto n^2$

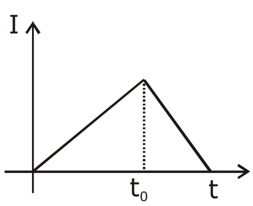
$\therefore$ Radius of atom will be $16a_0$

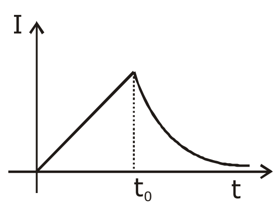
14. In the circuit shown, the switch S_1 is closed at time t = 0 and the switch S_2 is kept open. At some later time (t_0), the switch S_1 is opened and S_2 is closed. The behavior of the current I as a function of time 't' is given by -



(A)


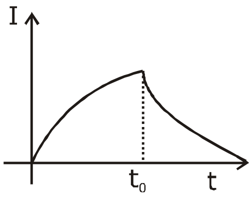
(B)


(C)


(D)


Sol. **B**

From time t = 0 to $t = t_0$, growth of current takes place and after that decay of current takes place.

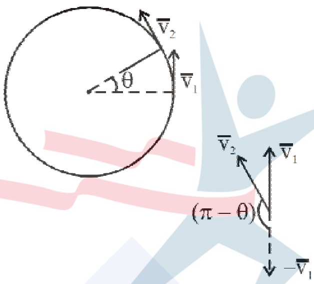


most appropriate is (B)

15. A particle is moving along a circular path with a constant speed of 10 ms^{-1}. What is the magnitude of the change in velocity of the particle, when it moves through an angle of 60° around the centre of the circle ?

(A) zero (B) 10 m/s (C) $10\sqrt{3}m/s$ (D) $10\sqrt{2}m/s$

Sol. **B**



$$|\Delta \bar{V}| = \sqrt{v_1^2 + v_2^2 + 2v_1v_2\cos(\pi - \theta)}$$

$= 2v\sin\frac{\theta}{2}$ since $\left[|\bar{v}_1| = |\bar{v}_2|\right]$

$= (2 \times 10) \times \sin(30°)$

= 10 m/s

16. There are two long co-axial solenoids of same length l. The inner and outer coils have radii r_1 and r_2 and number of turns per unit length n_1 and n_2, respectively. The ratio of mutual inductance to the self-inductance of the inner-coil is -

(A) $\frac{n_2}{n_1}\cdot\frac{r_1}{r_2}$ (B) $\frac{n_2}{n_1}\cdot\frac{r_2^2}{r_1^2}$ (C) $\frac{n_1}{n_2}$ (D) $\frac{n_2}{n_1}$

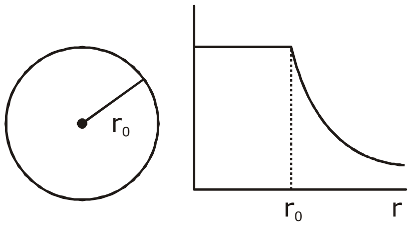
Sol. **D**

$M = \mu_0 n_1 n_2 \pi r_1^2$

$L = \mu_0 n_1^2 \pi r_1^2$

$\Rightarrow \frac{M}{L} = \frac{n_2}{n_1}$

17. The given graph shows variation (with distance r from centre) of -



(A) Potential of a uniformly charged sphere
(B) Potential of a uniformly charged spherical shell
(C) Electric field of a uniformly charged sphere
(D) Electric field of a uniformly charged spherical shell

Sol. **B**

18. If the de-Broglie wavelength of an electron is equal to 10^{-3} times the wavelength of a photon of frequency 6×10^{14} Hz, then the speed of electron is equal to -
(Speed of light = 3×10^8 m/s
Planck's constant = 6.63×10^{-34} J.s
Mass of electron = 9.1×10^{-31} kg)

(A) 1.1×10^6 m/s (B) 1.8×10^6 m/s (C) 1.7×10^6 m/s (D) 1.45×10^6 m/s

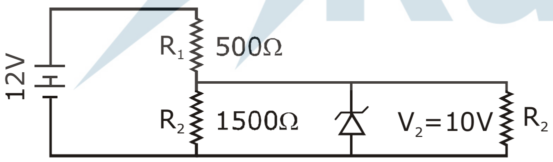
Sol. **D**

$$\frac{h}{mv} = 10^{-3}\left(\frac{3 \times 10^8}{6 \times 10^{14}}\right)$$

$$v = \frac{6.63 \times 10^{-34} \times 6 \times 10^{14}}{9.1 \times 10^{-31} \times 3 \times 10^5}$$

$v = 1.45 \times 10^6$ m/s

19. In the given circuit the current through Zener Diode is close to -



(A) 6.7 mA (B) 0.0 mA (C) 6.0 mA (D) 4.0 mA

Sol. **B**

Since voltage across zener diode must be less than 10V therefore it will not work in breakdown region, & its resistance wil be infinite & current through it = 0

20. An object is at a distance of 20 m from a convex lens of focal length 0.3 m. The lens forms an image of the object. if the object moves away from the lens at a speed of 5m/s, the speed and direction of the image will be -

(A) 3.22×10^{-3} m/s towards the lens (B) 2.26×10^{-3} m/s away from the lens
(C) 0.92×10^{-3} m/s away from the lens (D) 1.16×10^{-3} m/s towards the lens

Sol. **D**

From lens equation $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{v} - \frac{1}{(-20)} = \frac{1}{(.3)} = \frac{10}{3}$$

$$\frac{1}{v} = \frac{10}{3} - \frac{1}{20}$$

$$\frac{1}{v} = \frac{197}{60}; v = \frac{60}{197}$$

$$m = \left(\frac{v}{u}\right) = \frac{\left(\frac{60}{197}\right)}{20}$$

velocity of image wrt. to lens is given by $v_{I/L} = m^2 v_{O/L}$

direction of velocity of image is same as that of object

$$v_{O/L} = 5m/s$$

$$v_{I/L} = \left(\frac{60 \times 1}{197 \times 20}\right)^2 (5) = 1.16\times10^{-3} \text{ m/s towards the lens.}$$

21. In a Young's double slit experiment, the path difference, at a certain point on the screen, between two interfering waves is $\frac{1}{8}$ the of wavelength. The ratio of the intensity at this point to that at the centre of a bright fringe is close to -

(A) 0.94 (B) 0.80 (C) 0.85 (D) 0.74

Sol. **C**

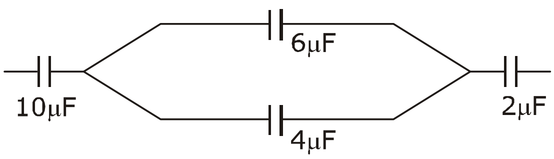
$$\Delta x = \frac{\lambda}{8}$$

$$\Delta\phi = \frac{(2\pi)}{\lambda}\frac{\lambda}{8} = \frac{\pi}{4}$$

$$I = I_0 \cos^2\left(\frac{\pi}{8}\right)$$

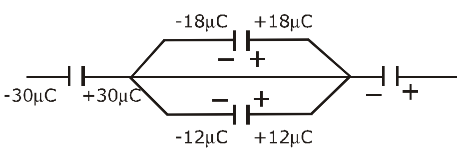
$$\frac{I}{I_0} = \cos^2\left(\frac{\pi}{8}\right) = \frac{1+\cos\frac{\pi}{4}}{2} = .85$$

22. In the figure shows below, the charge on the left plate of the 10μF capacitor is −30μC. The charge on the right plate of the 6μF capacitor is -



(A) −12μC (B) +12μC (C) −18μC (D) +18μC

Sol. **C**



23. A particle undergoing simple harmonic motion has time dependent displacement given by $x(t) = A \sin\frac{\pi t}{90}$. The ratio of kinetic to potential energy of this particle at t = 210 s will be -

(A) 1 (B) 3 (C) 2 (D) $\frac{1}{9}$

Sol. **B**

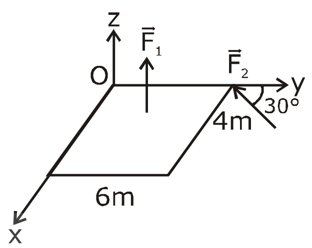
$K = \frac{1}{2}m\omega^2A^2\cos^2\omega t$

$U = \frac{1}{2}m\omega^2A^2\sin^2\omega t$

$\frac{k}{U} = \cot^2\omega t = \cot^2\frac{\pi}{90}(210) = \frac{1}{3}$

Hence ratio is 3 (most appropriate)

24. A slab is subjected to two forces $\vec{F}_1$ and $\vec{F}_2$ of same magnitude F as shown in the figure. Force $\vec{F}_2$ is in XY-plane while force F_1 acts along z-axis at the point $\left(2\vec{i} + 3\vec{j}\right)$. The moment of these forces about point O will be :



(A) $\left(3\hat{i} - 2\hat{j} - 3\hat{k}\right)F$ (B) $\left(3\hat{i} + 2\hat{j} - 3\hat{k}\right)F$ (C) $\left(3\hat{i} + 2\hat{j} + 3\hat{k}\right)F$ (D) $\left(3\hat{i} - 2\hat{j} + 3\hat{k}\right)F$

Sol. **D**

Torque for F_1 force

$\vec{F}_1 = \frac{F}{2}\left(-\hat{i}\right) + \frac{F\sqrt{3}}{2}\left(-\hat{j}\right)$

$\vec{r}_1 = 0\hat{i} + 6\hat{j}$

$\vec{\tau} = \vec{r}_1 \times \vec{F}_1 = 3F\hat{k}$

Torque for F_2 force

$\vec{F}_2 = F\hat{k}$

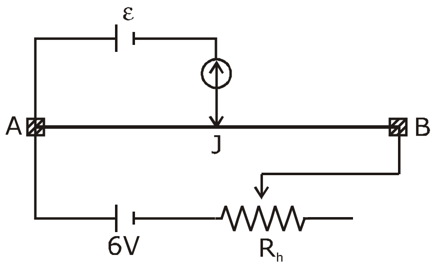
$\vec{r}_2 = 2\hat{i} + 3\hat{j}$

$\vec{\tau}_{F_2} = \vec{r}_2 \times \vec{F}_2 = 3F\hat{i} + 2F(-\hat{j})$

$\vec{\tau}_{net} = \vec{\tau}_{F_1} + \vec{\tau}_{F_2}$

$= 3F\hat{i} + 2F\left(-\hat{j}\right) + 3F(\hat{k})$

25. The resistance of the meter bridge AB in given figure is 4Ω. With a cell of emf ε=0.5V and rheostat resistance R_h = 2Ω the null point is obtained at some point J. When the cell is replaced by another one of emf $\varepsilon=\varepsilon_2$ the same null point J is found for R_h = 6 Ω. The emf ε_2 is, :



(A) 0.5 V (B) 0.4 V (C) 0.6 V (D) 0.3 V

Sol. **D**

Potential gradient with R_h = 2Ω

is $\left(\frac{6}{2+4}\right) \times \frac{4}{L} = \frac{dV}{dLl}; L = 100cm$

Let null point be at ℓ cm

thus $\varepsilon_1 = 0.5V = \left(\frac{6}{2+4}\right) \times \frac{4}{L} \times \ell$ ...(1)

Now with R_h = 6Ω new potential gradient is $\left(\frac{6}{4+6}\right) \times \frac{4}{L}$ and at null point

$\left(\frac{6}{4+6}\right) \times \left(\frac{4}{L}\right) \times \ell = \varepsilon_2$ ...(2)

dividing equation (1) by (2) we get

$\frac{0.5}{\varepsilon_2} = \frac{10}{6}$ thus $\varepsilon_2 = 0.3$

26. A satellite is revolving in a circular orbit at a height h from the earth surface, such that h<<R where R is the radius of the earth. Assuming that the effect of earth's atmosphere can be neglected the minimum increase in the speed required so that the satellite could escape from the gravitational field of earth is :

(A) $\sqrt{2gR}$ (B) $\sqrt{gR}$ (C) $\sqrt{\frac{gR}{2}}$ (D) $\sqrt{gR}\left(\sqrt{2}-1\right)$

Sol. **D**

$v_0 = \sqrt{g(R+h)} \approx \sqrt{gR}$

$v_e = \sqrt{2g(R+h)} \approx \sqrt{2gR}$

$\Delta v = v_e - v_0 = \left(\sqrt{2}-1\right)\sqrt{gR}$

27. In an experiment, electrons are accelerated, from rest, by applying a voltage of 500 V. Calculate the radius of the path if a magnetic field 100 mT is then applied. [Charge of the electron = 1.6×10^{-19} C Mass of the electron = 9.1×10^{-3} kg]

(A) 7.5 m (B) 7.5×10^{-2} m (C) 7.5×10^{-3} m (D) 7.5×10^{-4} m

Sol. **D**

$$r = \frac{\sqrt{2mg}}{eB} = \frac{\sqrt{2me\Delta v}}{eB}$$

$$r = \frac{\sqrt{\frac{2m}{e}.\Delta v}}{B} = \frac{\sqrt{\frac{2 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19}}(500)}}{100 \times 10^{-3}}$$

$$r = \frac{\sqrt{\frac{9.1}{0.16} \times 10^{-10}}}{10^{-1}} = \frac{3}{4} \times 10^{-4} = 7.5 \times 10^{-4}$$

28. A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Considering only translational and rotational modes, the total internal energy of the system is :

(A) 4 RT (B) 12RT (C) 15 RT (D) 20 RT

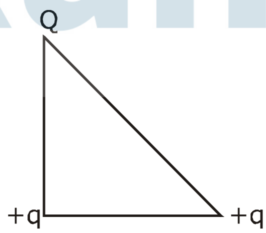
Sol. **C**

$$U = \frac{f_1}{2}n_1RT + \frac{f_2}{2}n_2RT$$

$$= \frac{5}{2}(3RT) + \frac{3}{2} \times 5RT$$

$$U = 15RT$$

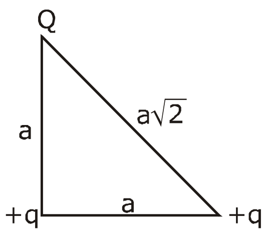
29. Three charges Q, +q and +q are placed at the vertices of a right-angle isosceles triangle as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is :



(A) $-2q$ (B) $\frac{-\sqrt{2}q}{\sqrt{2}+1}$ (C) $\frac{-q}{1+\sqrt{2}}$ (D) $+q$

Sol. **B**

$$U = K\left[\frac{q^2}{a} + \frac{Qq}{a} + \frac{Qq}{a\sqrt{2}} = 0\right]$$



$$\Rightarrow q = -Q\left[1 + \frac{1}{\sqrt{2}}\right]$$

$$\Rightarrow Q = \frac{-q\sqrt{2}}{\sqrt{2}+1}$$

30. A rigid diatomic ideal gas undergoes an adiabatic process at room temperature. The relation between temperature and volume for this process is TV^x = constant, then x is :

(A) $\frac{3}{5}$ (B) $\frac{2}{3}$ (C) $\frac{2}{5}$ (D) $\frac{5}{3}$

Sol. **C**

For adiabatic process : $TV^{\gamma-1}$ = constant

For diatomic process : $\gamma - 1 = \frac{7}{5} - 1$

$\therefore x = \frac{2}{5}$