PHYSICS

JEE–MAIN EXAMINATION – JUNE, 2022

27 June S - 02 Paper Solution

SECTION-A

1. The SI unit of a physical quantity is pascal-second. The dimensional formula of this quantity will be

(A) $[ML^{-1}T^{-1}]$ (B) $[ML^{-1}T^{-2}]$

(C) $[ML^{2}T^{-1}]$ (D) $[M^{-1}L^{3}T^{0}]$

Ans. (A)

Sol. Pascal second

$$\frac{F}{A}t = \frac{MLT^{-2}}{L^2}T = ML^{-1}T^{-1}$$

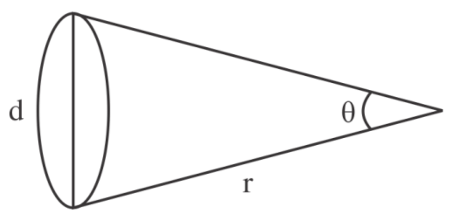
2. The distance of the Sun from earth is 1.5×10^{11} m and its angular diameter is (2000) s when observed from the earth. The diameter of the Sun will be :

(A) 2.45×10^{10} m (B) 1.45×10^{10} m

(C) 1.45×10^{9} m (D) 0.14×10^{9} m

Ans. (C)

Sol.



$$\theta = \frac{d}{r}$$

$$\frac{2000}{60 \times 60} \times \frac{\pi}{180} = \frac{d}{1.5 \times 10''}$$

$$\Rightarrow d = \frac{2000}{60 \times 60} \times \frac{\pi}{180} \times 1.5 \times 10''$$

$$= \frac{\pi \times 1.5}{3 \times 6 \times 18} \times 10'' = 1.45 \times 10^{9}$$

3. When a ball is dropped into a lake from a height 4.9 m above the water level, it hits the water with a velocity v and then sinks to the bottom with the constant velocity v. It reaches the bottom of the lake 4.0 s after it is dropped. The approximate depth of the lake is :

(A) 19.6 m (B) 29.4 m

(C) 39.2 m (D) 73.5 m

Ans. (B)

Sol. $V^2 = 2 \times 9.8 \times 4.9$

V = 9.8 m/s

Depth = distance travelled in 3 seconds

= 9.8 × 3 = 29.4 m

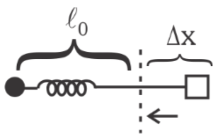
4. One end of a massless spring of spring constant k and natural length l_0 is fixed while the other end is connected to a small object of mass m lying on a frictionless table. The spring remains horizontal on the table. If the object is made to rotate at an angular velocity ω about an axis passing through fixed end, then the elongation of the spring will be:

(A) $\frac{k - m\omega^2 l_0}{m\omega^2}$ (B) $\frac{m\omega^2 l_0}{k + m\omega^2}$

(C) $\frac{m\omega^2 l_0}{k - m\omega^2}$ (D) $\frac{k + m\omega^2 l_0}{m\omega^2}$

Ans. (C)

Sol.



$K\,\Delta x = m(\ell_0 + \Delta x)w^2$

$K\,\Delta x = m\,\ell_0\,w^2 + mw^2\,\Delta x$

$$\Delta x = \frac{m\ell_0 w^2}{k - mw^2}$$

5. A stone tide to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of change in its velocity, as it reaches a position where the string is horizontal, is $\sqrt{x(u^2 - gL)}$. The value of x is

(A) 3 (B) 2

(C) 1 (D) 5

Ans. (B)

Sol. $v = \sqrt{u^2 - 2gL}$

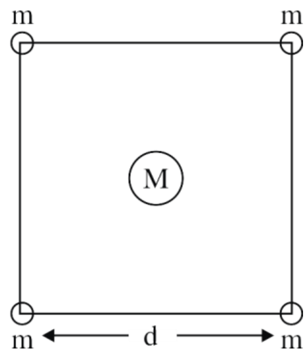
$\Delta v = \sqrt{u^2 + v^2}$

$\Delta v = \sqrt{u^2 + v^2 - 2gL}$

$\Delta v = \sqrt{2u^2 - 2gL}$

$\Delta v = \sqrt{2\left(u^2 - gL\right)}$ $x = 2$

6. Four spheres each of mass m form a square of side d (as shown in figure). A fifth sphere of mass M is situated at the centre of square. The total gravitational potential energy of the system is :



(A) $-\frac{Gm}{d}\left[(4+\sqrt{2})m + 4\sqrt{2}M\right]$

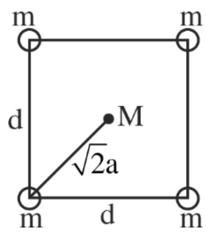
(B) $-\frac{Gm}{d}\left[(4+\sqrt{2})M + 4\sqrt{2}m\right]$

(C) $-\frac{Gm}{d}\left[3m^2 + 4\sqrt{2}M\right]$

(D) $-\frac{Gm}{d}\left[6m^2 + 4\sqrt{2}M\right]$

Ans. (A)

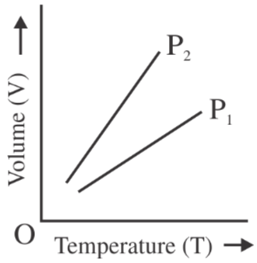
Sol.



$$-\frac{Gm^2}{d} \times 4 - \frac{Gm^2}{\sqrt{2}d} \times 2 - \frac{GMm}{d} \times 4\sqrt{2}$$

$$-\frac{Gm}{d}\left[(4+\sqrt{2})m + 4\sqrt{2}M\right]$$

7. For a perfect gas, two pressures P_1 and P_2 are shown in figure. The graph shows:



(A) $P_1 > P_2$

(B) $P_1 < P_2$

(C) $P_1 = P_2$

(D) Insufficient data to draw any conclusion

Ans. (A)

Sol. $PV = nRT$

$$\frac{V}{T} = \frac{nR}{P}$$

$$\frac{nR}{P_1} < \frac{nR}{P_2}$$

$$P_2 < P_1$$

8. According to kinetic theory of gases,

A. The motion of the gas molecules freezes at 0°C

B. The mean free path of gas molecules decreases if the density of molecules is increased.

C. The mean free path of gas molecules increases if temperature is increased keeping pressure constant.

D. Average kinetic energy per molecule per degree of freedom is $\frac{3}{2}k_BT$ (for monoatomic gases)

Choose the most appropriate answer from the options given below:

(A) A and C only (B) B and C only

(C) A and B only (D) C and D only

Ans. (B)

Sol. $\lambda = \frac{kT}{\sqrt{2}\pi d^2 P}$

9. A lead bullet penetrates into a solid object and melts. Assuming that 40% of its kinetic energy is used to heat it, the initial speed of bullet is:

(Given, initial temperature of the bullet = 127ºC, Melting point of the bullet = 327ºC,

Latent heat of fusion of lead = 2.5×10^4 J Kg^{-1},

Specific heat capacity of lead = 125J/kg K)

(A) 125 ms^{-1} (B) 500 ms^{-1}

(C) 250 ms^{-1} (D) 600 ms^{-1}

Ans. (B)

Sol. $m \times 125 \times 200 + m \times 2.5 \times 10^4 = \frac{1}{2}mv^2 \times \frac{40}{100}$

V = 500 m/s

10. The equation of a particle executing simple harmonic motion is given by $x = \sin\pi\left(t + \frac{1}{3}\right)$ m. At t = 1s, the speed of particle will be

(Given : $\pi = 3.14$)

(A) 0 cm s^{-1} (B) 157 cm s^{-1}

(C) 272 cm s^{-1} (D) 314 cm s^{-1}

Ans. (B)

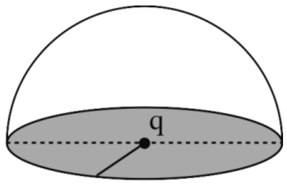
Sol. $x = \sin\pi\left(t + \frac{1}{3}\right)$

$$x = \sin\left(\pi t + \frac{\pi}{3}\right)$$

$$V = \frac{dx}{dt} = \cos\left(\pi t + \frac{\pi}{3}\right)\pi$$

$$= -\pi \times \frac{1}{2} = 157 \text{ cm/s}$$

11. If a charge q is placed at the centre of a closed hemispherical non-conducting surface, the total flux passing through the flat surface would be :

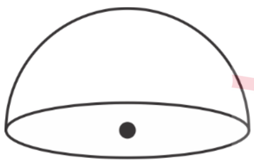


(A) $\frac{q}{\varepsilon_0}$ (B) $\frac{q}{2\varepsilon_0}$

(C) $\frac{q}{4\varepsilon_0}$ (D) $\frac{q}{2\pi\varepsilon_0}$

Ans. (B)

Sol.



Total flux through complete spherical surface is $\frac{q}{\varepsilon_0}$.

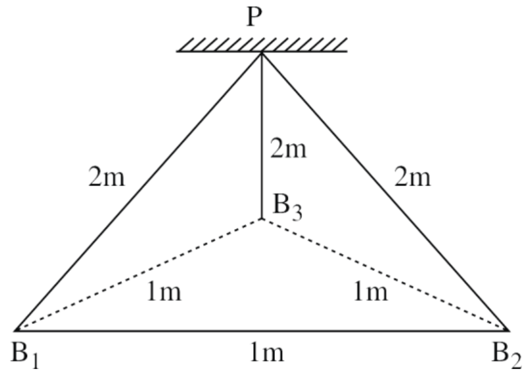
So the flux through curved surface will be $\frac{q}{2\varepsilon_0}$.

The flux through flat surface will be zero.

Remark : Electric flux through flat surface is zero but no option is given, option is available for electric flux passing through curved surface.

12. Three identical charged balls each of charge 2C are suspended from a common point P by silk threads of 2m each (as shown in figure). They form an equilateral triangle of side 1m.

The ratio of net force on a charged ball to the force between any two charged balls will be :

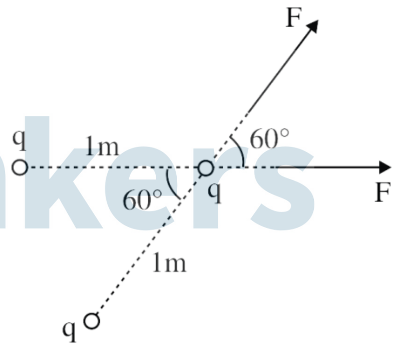


(A) 1 : 1   (B) 1 : 4

(C) $\sqrt{3}:2$ (D) $\sqrt{3}:1$

Ans. (D)

Sol.



$$F = \frac{k(2)(2)}{(1)^2}$$

(F = Force between two charges).

F = 4k

$$F_{net} = 2F\cos 30^\circ = 2\cdot F\cdot\frac{\sqrt{3}}{2} = F\sqrt{3}$$

(F_{net} = Net electrostatic force on one charged ball)

$$\frac{F_{net}}{F} = \frac{\sqrt{3}F}{F} = (\sqrt{3})$$

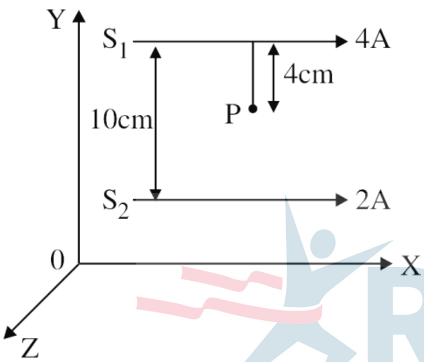
Remark: Net force on any one of the ball is zero. But no option given in options.

13. Two long parallel conductors S_1 and S_2 are separated by a distance 10 cm and carrying currents of 4A and 2A respectively. The conductors are placed along x-axis in X-Y plane. There is a point P located between the conductors (as shown in figure).

A charge particle of 3π coulomb is passing through the point P with velocity

$\vec{v} = (2\hat{i} + 3\hat{j})m/s$; where $\hat{i}$ & $\hat{j}$ represents unit vector along x & y axis respectively.

The force acting on the charge particle is $4\pi \times 10^{-5}(-x\hat{i} + 2\hat{j})N$. The value of x is :

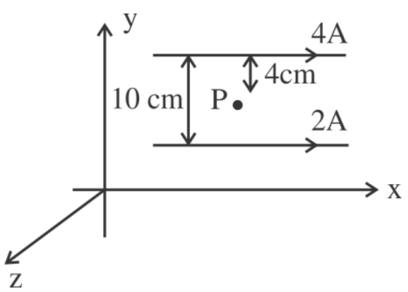


(A) 2 (B) 1

(C) 3 (D) –3

Ans. (C)

Sol.



$$B_{net} = B_1 - B_2 = \frac{\mu_0 \times 4}{2\pi[.04]} - \frac{\mu_0 \times 2}{2\pi[.06]}$$

$$\vec{B}_{net} = \frac{\mu_0}{2\pi}\left[\frac{200}{3}\right](-\hat{k})$$

$$\vec{F} = q\left[\vec{v} \times \vec{B}\right]$$

$$= [3\pi]\left[(2\hat{i} + 3\hat{j}) \times \left(\frac{\mu_0}{2\pi}\right)\left(\frac{200}{3}\right) - \hat{k}\right]$$

$$= 3\pi \times \frac{\mu_0}{2\pi}\left(\frac{200}{3}\right)\left[2 \times \hat{j} - 3(\hat{i})\right]$$

$$= (4\pi \times 10^{-7})(100)(-3\hat{i} + 2\hat{j})$$

$$= 4\pi \times 10^{-5} \times \left[-3\hat{i} + 2\hat{j}\right]$$

14. If L, C and R are the self inductance, capacitance and resistance respectively, which of the following does not have the dimension of time ?

(A) RC (B) $\frac{L}{R}$

(C) $\sqrt{LC}$ (D) $\frac{L}{C}$

Ans. (D)

Sol. $\left(\frac{L}{C}\right)$ does not have dimension of time.

RC, $\frac{L}{R}$ are time constant while $\sqrt{LC}$ is reciprocal of angular frequency or having dimension of time.

15. Given below are two statements:

Statement I : A time varying electric field is a source of changing magnetic field and vice-versa. Thus a disturbance in electric or magnetic field creates EM waves.

Statement II : In a material medium. The EM wave travels with speed $v = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$.

In the light of the above statements, choose the correct answer from the options given below:

(A) Both statement I and statement II are true.

(B) Both statement I and statement II are false.

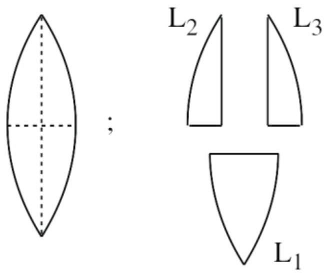
(C) Statement I is correct but statement II is false.

(D) Statement I is incorrect but statement II is true.

Ans. (C)

Sol. The statement II is wrong as the velocity of εm wave in a medium is $\frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$.

16. A convex lens has power P. It is cut into two halves along its principal axis. Further one piece (out of the two halves) is cut into two halves perpendicular to the principal axis (as shown in figure). Choose the incorrect option for the reported pieces.



(A) Power of $L_1 = \frac{P}{2}$

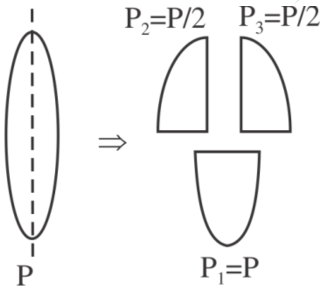
(B) Power of $L_2 = \frac{P}{2}$

(C) Power of $L_3 = \frac{P}{2}$

(D) Power of $L_1 = P$

Ans. (A)

Sol.



17. If a wave gets refracted into a denser medium, then which of the following is true?

(A) wavelength speed and frequency decreases.

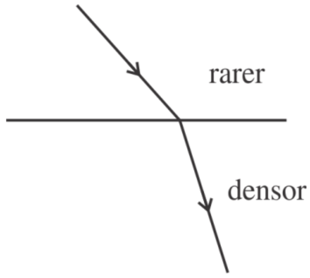
(B) wavelength increases, speed decreases and frequency remains constant.

(C) wavelength and speed decreases but frequency remains constant.

(D) wavelength, speed and frequency increases.

Ans. (C)

Sol.



No change in frequency but speed and wave-length decreases.

18. Given below are two statements:

Statement I : In hydrogen atom, the frequency of radiation emitted when an electron jumps from lower energy orbit (E_1) to higher energy orbit (E_2), is given as $hf = E_1 - E_2$.

Statement-II : The jumping of electron from higher energy orbit (E_2) to lower energy orbit (E_1) is associated with frequency of radiation given as $f = (E_2 - E_1)/h$

This condition is Bohr's frequency condition.

In the light of the above statements, choose the correct answer from the options given below:

(A) Both statement I and statement II are true.

(B) Both statement I and statement II are false

(C) Statement I is correct but statement II is false

(D) Statement I is incorrect but statement II is true.

Ans. (D)

Sol. When electron jump from lower to higher energy level, energy absorbed so statement-I incorrect.

When electron jump from higher to lower energy level, energy of emitted photon

$E = E_2 - E_1$

$hf = E_2 - E_1 \Rightarrow f = \frac{E_2 - E_1}{h}$

so statement-II is correct.

19. For a transistor to act as a switch, it must be operated in

(A) Active region

(B) Saturation state only

(C) Cut-off state only

(D) Saturation and cut-off state

Ans. (D)

Sol. Transistor act as a switch in saturation and cut of

region.

20. We do not transmit low frequency signal to long distances because

(a) The size of the antenna should be comparable to signal wavelength which is unreal solution for a signal of longer wavelength.

(b) Effective power radiated by a long wavelength baseband signal would be high.

(c) We want to avoid mixing up signals transmitted by different transmitter simultaneously.

(d) Low frequency signal can be sent to long distances by superimposing with a high frequency wave as well.

Therefore, the most suitable options will be :

(A) All statements are true

(B) (a), (b) and (c) are true only

(C) (a), (c) and (d) are true only

(D) (b), (c) and (d) are true only

Ans. (C)

Sol. (a) For low frequency or high wavelength size of antenna required is high.

(b) E P R is low for longer wavelength.

(c) yes we want to avoid mixing up signals transmitted by different transmitter simultaneously.

(d) Low frequency signals sent to long distance by superimposing with high frequency.

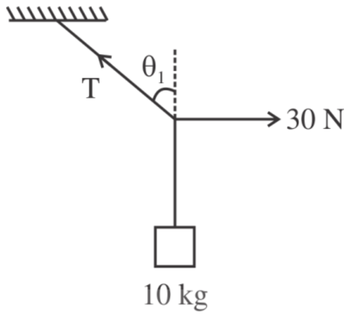
SECTION-B

1. A mass of 10 kg is suspended vertically by a rope of length 5m from the roof. A force of 30 N is applied at the middle point of rope in horizontal direction. The angle made by upper half of the rope with vertical is $\theta = \tan^{-1}(x \times 10^{-1})$. The value of x is ______ .

(Given $g = 10\ m/s^2$)

Ans. (3)

Sol.



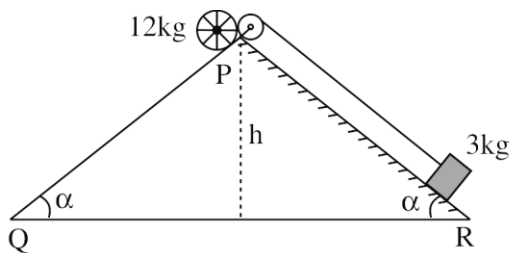
$T \sin\theta = 30$

$T \cos\theta = 100$

$\Rightarrow \tan\theta = 0.3$

2. A rolling wheel of 12 kg is on an inclined plane at position P and connected to a mass of 3 kg through a string of fixed length and pulley as shown in figure. Consider PR as friction free surface.

The velocity of centre of mass of the wheel when it reaches at the bottom Q of the inclined plane PQ will be $\frac{1}{2}\sqrt{xgh}$ m/s. The value of x is ______ .



Ans. (3)

Sol. Net loss in PE = Gain in KE

$$12\ gh - 3gh = \frac{1}{2}3v^2 + \frac{1}{2}12v^2 + \frac{1}{2}\left[12r^2\right]\left(\frac{v}{r}\right)^2$$

$$9gh = \frac{1}{2}\left[3+12+12\right]v^2$$

$$v^2 = \frac{2gh}{3} \Rightarrow v = \frac{1}{2}\sqrt{\frac{8}{3}gh}$$

$$x = \frac{8}{3} \simeq 3$$

3. A diatomic gas ($\gamma = 1.4$) does 400 J of work when it is expanded isobarically. The heat given to the gas in the process is _______ J.

Ans. (1400)

Sol. $$Q = nC_p\Delta T = \frac{n\nu}{\nu-1}R\Delta T$$

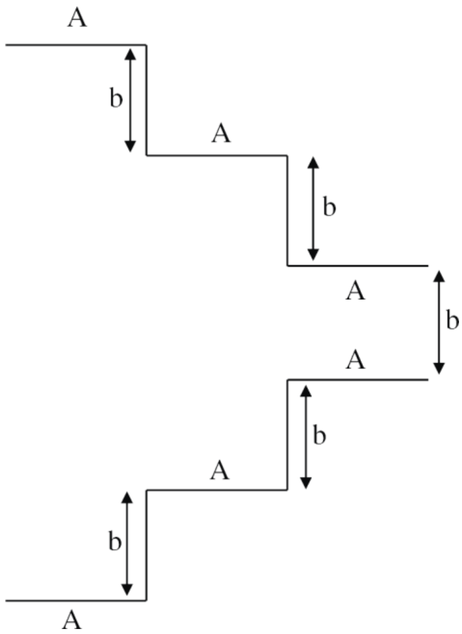
$$Q = \frac{\nu}{\nu-1}\omega = \frac{1.4}{0.4}\times 400 = 1400\ J$$

4. A particle executes simple harmonic motion. Its amplitude is 8 cm and time period is 6s. The time it will take to travel from its position of maximum displacement to the point corresponding to half of its amplitude, is ________ s.

Ans. (1)

Sol. $$t = \frac{\Delta\phi}{\omega} = \frac{\pi/2 - \pi/6}{2\pi/6} = \frac{\pi/3}{\pi/3} = 1\ \text{sec}$$

5. A paralle plate capacitor is made up of stair like structure with a palte area A of each stair and that is connected with a wire of length b, as shown in the figure. The capacitance of the arrangement is $\frac{x}{15}\frac{\varepsilon_0 A}{b}$. The value of x is _______ .



Ans. (23)

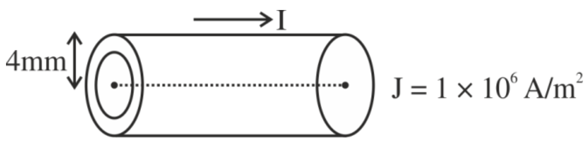
Sol. Parallel combination

$$c_{eq} = \varepsilon_0 A\left[\frac{1}{5b} + \frac{1}{3b} + \frac{1}{b}\right] = \frac{23}{15}\frac{\varepsilon_0 A}{b}$$

6. The current density in a cylindrical wire of radius r = 4.0 mm is 1.0×10^6 A/m^2. The current through the outer portion of the wire between radial distances r/2 and r is $x\pi$ A; where x is _______ .

Ans. (12)

Sol.



$$I = \int J dA$$

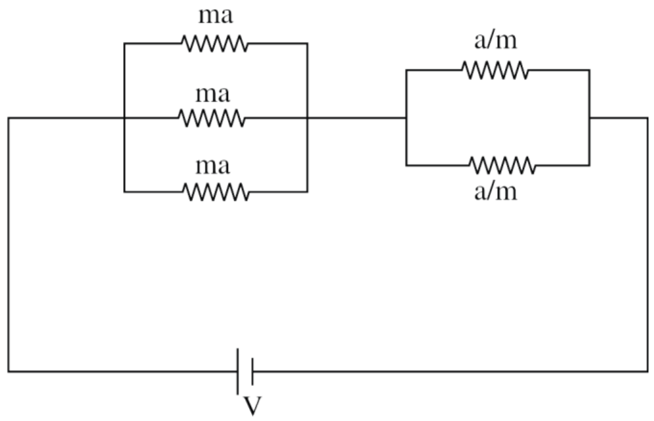
$$= \int 10^6 \times 2\pi x dx$$

$$= 10^6 \times 2\pi . \frac{x^2}{2}\Bigg]_{\frac{r}{2}}^{r}$$

$$= \pi \times 10^6\left[r^2 - \frac{r^2}{4}\right] = 12\pi$$

x = 12

7. In the given circuit 'a' is an arbitrary constant. The value of m for which the equivalent circuit resistance is minimum, will be $\sqrt{\frac{x}{2}}$. The value of x is _____ .



Ans. (3)

Sol. $R = \left(\frac{ma}{3}\right) + \left(\frac{a}{2m}\right)$

$$\frac{dR}{dm} = \frac{a}{3} - \frac{a}{2m^2} = 0$$

$$\frac{a}{3} = \frac{a}{2m^2}$$

$$m^2 = \frac{3}{2}$$

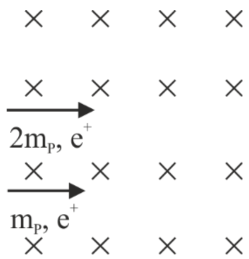
$$m = \sqrt{\frac{3}{2}}$$

$x = 3$

8. A deuteron and a proton moving with equal kinetic energy enter into to a uniform magnetic field at right angle to the field. If r_d and r_p are the radii of their circular paths respectively, then the ratio $\frac{r_d}{r_p}$ will be $\sqrt{x} : 1$ where x is ______ .

Ans. (2)

Sol.



$$R = \frac{mv}{q_B}$$

$$R_D = \frac{(2m_P)\,v_D}{e\,B}$$

$$R_P = \frac{(m_P)\,v_P}{e\,B}$$

$$\frac{R_D}{R_P} = \frac{2v_D}{v_P} = \frac{2v_D}{\sqrt{2}v_D} = \frac{\sqrt{2}}{1}$$

$$\frac{1}{2}(2mp)v_D^2 = \frac{1}{2}m_P.v_P^2$$

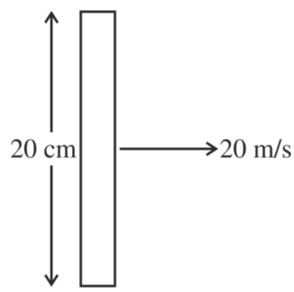
$$\sqrt{2}v_D = v_P$$

$x = 2$

9. A metallic rod of length 20 cm is palced in North-South direction and is moved at a constant speed of 20 m/s towards East. The horizontal component of the Earth's magnetic field at that place is 4×10^{-3} T and the angle of dip is 45°. The emf induced in the rod is _______ mV.

Ans. (16)

Sol.



$B_H = 4 \times 10^{-3}$ T

$\theta \to 45°$

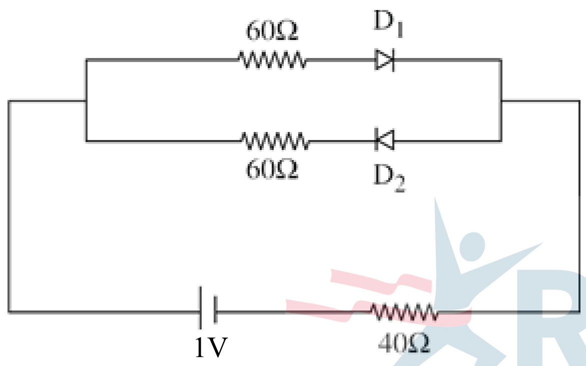
$B_V = B_H$

$\in = (\vec{V} \times \vec{B}) \cdot \vec{\ell}$

$= ((4 \times 10^{-3})(20)) \frac{20}{100}$

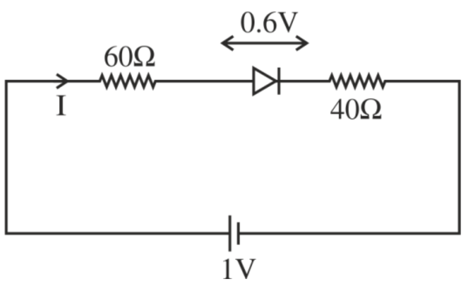
$= 16 \times 10^{-3}$ V $= 16$ mV

10. The cut-off voltage of the diodes (shown in figure) in forward bias is 0.6 V. The current through the resister of 40 Ω is ________ mA.



Ans. (4)

Sol.



$1 - I(60) - 0.6 - I(40) = 0$

$\frac{0.4}{100} = I$

$I = 4$ mA