JEE Main 2020 Paper

Date : 6th September 2020

Time : 02 : 00 pm - 05 : 00 pm

Subject : Physics

Q.1 For a plane electromagnetic wave, the magnetic field at a point x and time t is $\vec{B}(x,t) = \left[1.2\times10^{-7}\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)\hat{k}\right]T$

The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is :
(speed of light $c = 3 \times 10^8\ ms^{-1}$)

(1) $\vec{E}(x,t) = \left[36\sin\left(1\times10^{3}x+1.5\times10^{11}t\right)\hat{i}\right]\frac{V}{m}$

(2) $\vec{E}(x,t) = \left[36\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)\hat{k}\right]\frac{V}{m}$

(3) $\vec{E}(x,t) = \left[36\sin\left(1\times10^{3}x+0.5\times10^{11}t\right)\hat{j}\right]\frac{V}{m}$

(4) $\vec{E}(x,t) = \left[-36\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)\hat{j}\right]\frac{V}{m}$

Sol. **4**

$|\vec{E}| = |\vec{B}|C$

$\Rightarrow 1.2\times10^{-7}\times\sin|\,0.5\times10^{3}x + 1.5\times10^{11}t\,)\times 3\times10^{8}$

$\Rightarrow\ 36\sin(0.5\times10^{3}x+1.5\times10^{11}t)$

$\lambda \rightarrow$ Not change $\rightarrow$ Answer 1, 3 incorrect

$\vec{E}$ and $\vec{B}$ $\rightarrow$ not same direction $\rightarrow$ 2nd incorrect

Q.2 Particle A of mass m_1 moving with velocity $\left(\sqrt{3}\hat{i}+\hat{j}\right)ms^{-1}$ collides with another particle B of mass m_2 which is at rest initially. Let $\vec{V}_1$ and $\vec{V}_2$ be the velocities of particles A and B after collision respectively. If $m_1 = 2m_2$ and after collision $\vec{V}_1 = \left(\hat{i}+\sqrt{3}\hat{j}\right)ms^{-1}$, the angle between $\vec{V}_1$ and $\vec{V}_2$ is :

(1) 105° (2) 15° (3) –45° (4) 60°

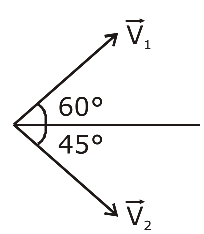
Sol. **1**

From momentum conservation

$(2m)\ (\sqrt{3}\,\hat{i}+\hat{j}) + 0 = 2m\ (\hat{i}+\sqrt{3}\hat{j}) + m\vec{v}_2$

$\vec{V_2} = \left(2(\sqrt{3}-1)\right)(\hat{i}-\hat{j})$

and $\vec{V_1} = \hat{i}+\sqrt{3}\,\hat{j}$



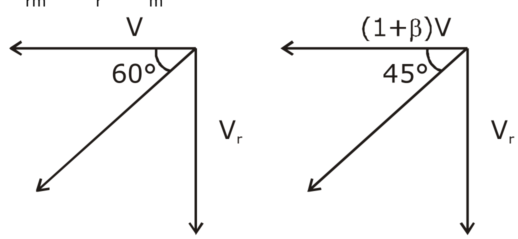
so angle b/w $\vec{v_1}$ and $\vec{V_2}$ is 105°.

Q.3 When a car is at rest, its driver sees rain drops falling on it vertically. When driving the car with speed v, he sees that rain drops are coming at an angle 60° from the horizontal. On further increasing the speed of the car to $(1 + \beta)v$, this angle changes to 45°. The value of β is close to:

(1) 0.50 (2) 0.73 (3) 0.37 (4) 0.41

Sol. **2**

$\overrightarrow{V_{rm}} = \overrightarrow{V_r} - \overrightarrow{V_m}$



(Ist case) (IInd case)

$\tan 60 = \frac{v_r}{v}$ ...(1)

$\tan 45 = \frac{v_r}{(1+\beta)v}$ ...(2)

from (1)/(2)

$\frac{\sqrt{3}}{1} = \frac{1/4}{1/(1+\beta)v}$

$\sqrt{3} = 1 + \beta \Rightarrow \beta = 0.732$

Q.4 A charged particle going around in a circle can be considered to be a current loop. A particle of mass m carrying charge q is moving in a plane with speed v under the influence of magnetic field $\vec{B}$. The magnetic moment of this moving particle:

(1) $\frac{mv^2\vec{B}}{2B^2}$ (2) $-\frac{mv^2\vec{B}}{2\pi B^2}$ (3) $-\frac{mv^2\vec{B}}{2B^2}$ (4) $-\frac{mv^2\vec{B}}{B^2}$

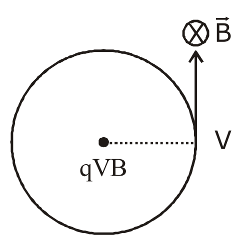
Sol. **3**

Magnetic dipole moment

M = iA

$\therefore$ i = qF, A = πR^2

$F = \frac{qB}{2\pi m}$, $R = \frac{mv}{qB}$



$M = q\left(\frac{qB}{2\pi m}\right) \times \pi\left(\frac{m^2v^2}{q^2B^2}\right)$

$M = \frac{mV^2}{2B}$

dir^n of $\vec{M}$ and $\vec{B}$ is opposite.

$\vec{M} = \frac{mV^2}{2B}.\left(-\hat{B}\right)$

$\rightarrow \frac{-mV^2}{2B^2}\vec{B}$

Q.5 A double convex lens has power P and same radii of curvature R of both the surfaces. The radius of curvature of a surface of a plano-convex lens made of the same material with power 1.5 P is:

(1) $\frac{R}{3}$ (2) $\frac{3R}{2}$ (3) $\frac{R}{2}$ (4) 2R

Sol. **1**

$$P = \left(\frac{\mu_\ell}{\mu_s} - 1\right)\left(\frac{2}{R}\right) \qquad ...(1)$$

$$\frac{3}{2}P = \left(\frac{\mu_\ell}{\mu_S} - 1\right)\left(\frac{1}{R_1}\right) \qquad ...(2)$$

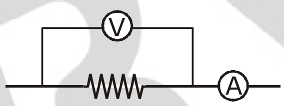
from (1)/(2)

$$\frac{P}{\frac{3}{2}P} = \frac{2/R}{1/R_1}$$

$R_1 = R/3$

Q.6 A circuit to verify Ohm's law uses ammeter and voltmeter in series or parallel connected correctly to the resistor. In the circuit:
(1) Ammeter is always connected in series and voltmeter in parallel
(2) Both, ammeter and voltmeter must be connected in series
(3) Both ammeter and voltmeter must be connected in parallel
(4) ammeter is always used in parallel and voltmeter is series

Sol. **1**

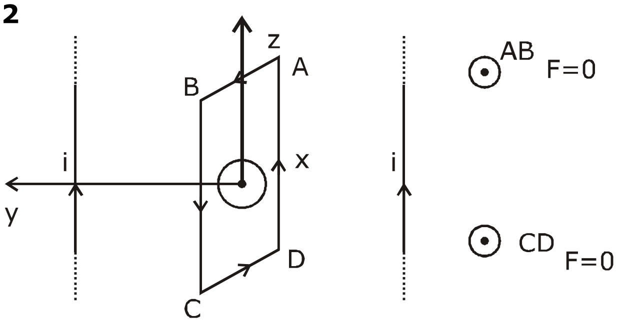


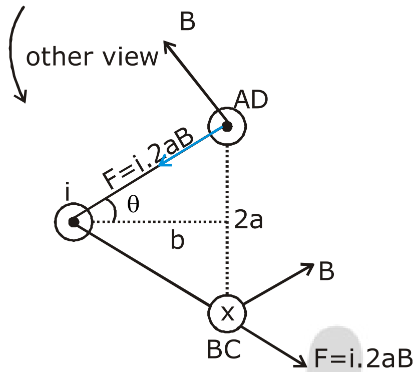
By theory
In order for a voltmeter to measure a device's voltage, it must be connected in parallel to that device. This is necessary because objects in parallel experience the same potential difference.
A voltmeter measures the potential difference of the circuit and it has high internal resistance. When the voltmeter is connected in parallel with a circuit component, the amount of current passing through the voltmeter is very less. Therefore, the current through the circuit is unaltered.
In order for an ammeter to measure a device's current, it must be connected in series to that device. This is necessary because objects in series experience the same current.

Q.7 A square loop of side 2a and carrying current I is kept in xz plane with its centre at origin. A long wire carrying the same current I is placed parallel to z-axis and passing through point (0, b, 0), (b >> a). The magnitude of torque on the loop about z-axis will be:

(1) $\frac{2\mu_0 I^2 a^2}{\pi b}$ (2) $\frac{2\mu_0 I^2 a^2 b}{\pi\left(a^2 + b^2\right)}$ (3) $\frac{\mu_0 I^2 a^2}{2\pi b}$ (4) $\frac{\mu_0 I^2 a^2 b}{2\pi\left(a^2 + b^2\right)}$

Sol. **2**





$$B = \frac{\mu_0 i}{2\pi\sqrt{a^2 + b^2}}$$

$\therefore$ torque = F cos θ . 2 a

$$= \frac{i.2a.\mu_0 i}{2\pi\sqrt{a^2 + b^2}} \frac{b}{\sqrt{a^2 + b^2}}.2a$$

$$= \frac{2\mu_0 i^2 a^2 b}{\pi(a^2 + b^2)}$$

Q.8 In a dilute gas at pressure P and temperature T, the mean time between successive collisions of a molecule varies with T as:

(1) $\sqrt{T}$ (2) $\frac{1}{T}$ (3) T (4) $\frac{1}{\sqrt{T}}$

Sol. **4**

$$V_{avg.} \propto \sqrt{T}$$

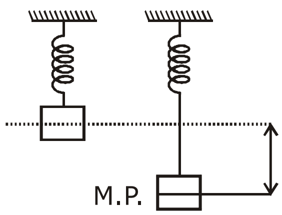
$$T_{mean} = \frac{\lambda}{V_{avg}}$$

$$T_{mean} \propto \frac{1}{\sqrt{T}}$$

Q.9 When a particle of mass m is attached to a vertical spring of spring constant k and released, its motion is described by $y(t) = y_0\sin^2\omega t$, where 'y' is measured from the lower end of unstretched spring. Then ω is:

(1) $\sqrt{\frac{g}{y_0}}$ (2) $\frac{1}{2}\sqrt{\frac{g}{y_0}}$ (3) $\sqrt{\frac{2g}{y_0}}$ (4) $\sqrt{\frac{g}{2y_0}}$

9. **4**



$$y(t) = \frac{y_0}{2}\,(1 - \cos(2\omega t))$$

From comparing standard equation of SHM Amplitude $A = \frac{y_0}{2}$

At equilibrium situation $\frac{mg}{k} = \frac{y_0}{2}$

$$\frac{2g}{y_0} = \frac{k}{m}$$

$$2\omega = \sqrt{\frac{k}{m}}$$

$$\omega = \frac{1}{2}\sqrt{\frac{k}{m}}$$

$$\omega = \frac{1}{2}\sqrt{\frac{2g}{y_0}}$$

$$\omega = \frac{1}{\sqrt{2}}\sqrt{\frac{g}{y_0}}$$

Q.10 The linear mass density of a thin rod AB of length L varies from A to B as $\lambda(x) = \lambda_0\left(1 + \frac{x}{L}\right)$, where x is the distance from A. If M is the mass of the rod then its moment of inertia about an axis passing through A and perpendicular to the rod is:

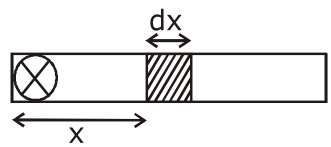
(1) $\frac{2}{5}ML^2$ (2) $\frac{5}{12}ML^2$ (3) $\frac{7}{18}ML^2$ (4) $\frac{3}{7}ML^2$

Sol. **3**

$$dm = \lambda_0\left(1 + \frac{x}{L}\right)dx$$

$$\int_0^M dm = \int_0^L \lambda_0\left(1+\frac{x}{L}\right)dx$$

$$M = \frac{3\lambda_0 L}{2} \qquad ...(1)$$



$dI = dm\, x^2$

$$\int dI = \int dm x^2$$

$$I = \int_0^L \lambda_0\left(1+\frac{x}{L}\right)dx\ x^2$$

$$I = \frac{7\lambda_0 L^3}{12}$$

from (1) $\lambda_0 = \frac{2M}{3L}$

$$I = \frac{7ML^2}{18}$$

Q.11 A fluid is flowing through a horizontal pipe of varying cross-section, with speed v ms^{-1} at a point where the pressure is P pascal. At another point where pressure is $\frac{P}{2}$ Pascal its speed is V ms^{-1}. If the density of the fluid is ρ kg m^{-3} and the flow is streamline, then V is equal to:

(1) $\sqrt{\frac{P}{2\rho}+v^2}$ (2) $\sqrt{\frac{P}{\rho}+v^2}$ (3) $\sqrt{\frac{2P}{\rho}+v^2}$ (4) $\sqrt{\frac{P}{\rho}+v}$

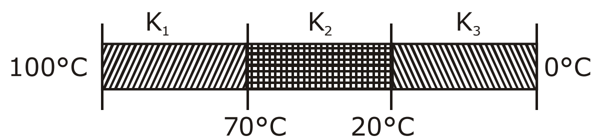
Sol. **2**

From Bernoulli's eq^n.

$$P+\frac{1}{2}\rho v^2 = \frac{P}{2}+\frac{1}{2}\rho V_1^2$$

$$V_1 = \sqrt{\frac{P}{\rho}+V^2}$$

Q.12 Three rods of identical cross-section and lengths are made of three different materials of thermal conductivity K_1, K_2 and K_3, respectively. They are joined together at their ends to make a long rod (see figure). One end of the long rod is maintained at 100°C and the other at 0°C (see figure). If the joints of the rod are at 70°C and 20°C in steady state and there is no loss of energy from the surface of the rod, the correct relationship between K_1, K_2 and K_3 is:



(1) $K_1 : K_2 = 5:2$, $K_1 : K_3 = 3:5$ (2) $K_1 < K_2 < K_3$ (3) $K_1 : K_3 = 2:3$, $K_2 : K_3 = 2:5$ (4) $K_1 > K_2 > K_3$

Sol. **3**

Heat current same

$$\frac{K_1(100-70)}{R_1} = \frac{K_2(70-20)}{R_2} = \frac{K_3(20-0)}{R_3}$$

$\therefore\ \ell_1$ A = same

$30k_1 = 50k_2 = 20k_3$

$$\frac{K_1}{k_2} = \frac{5}{3}, \frac{K_2}{k_3} = \frac{2}{5}$$

$$\frac{K_1}{K_3} = \frac{2}{3}$$

Q.13 Assuming the nitrogen molecule is moving with r.m.s. velocity at 400 K, the de-Broglie wavelength of nitrogen molecule is close to : (Given : nitrogen molecule weight : 4.64×10^{-26} kg, Boltzman constant: 1.38×10^{-23} J/K, Planck constant : 6.63×10^{-34} J.s)

(1) 0.44 Å (2) 0.34 Å (3) 0.20 Å (4) 0.24 Å

Sol. **4**

$$\lambda = \frac{\lambda}{mv_{r.m.s.}}$$

$$\therefore v = \sqrt{\frac{3kT}{M}}$$

$$\lambda = \frac{h}{\sqrt{3mkT}}$$

$$\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{3 \times 4.6 \times 10^{-26} \times 1.38 \times 10^{-23} \times 400}}$$

$\lambda = 2.4 \times 10^{-11}$ M

$\Rightarrow$ 0.24Å

Q.14 Consider the force F on a charge 'q' due to a uniformly charged spherical shell of radius R carrying charge Q distributed uniformly over it. Which one of the following statements is true for F, if 'q' is placed at distance r from the centre of the shell?

(1) $\frac{1}{4\pi \epsilon_0}\frac{qQ}{R^2} > F > 0$ for $r < R$

(2) $F = \frac{1}{4\pi \epsilon_0}\frac{qQ}{r^2}$ for $r > R$

(3) $F = \frac{1}{4\pi \epsilon_0}\frac{qQ}{r^2}$ for all r

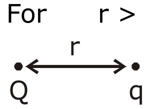
(4) $F = \frac{1}{4\pi \epsilon_0}\frac{qQ}{R^2}$ for $r < R$

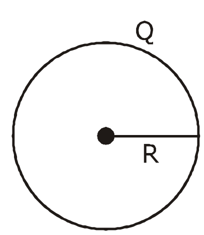
Sol. **2**

For r < R

E = 0

For r > R



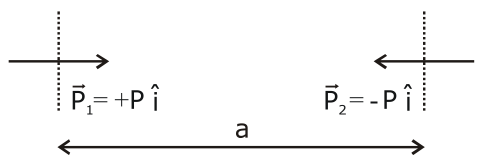


$$F = \frac{kQq}{r^2}$$

Q.15 Two identical electric point dipoles have dipole moments $\vec{p}_1 = p\hat{i}$ and $\vec{p}_2 = -p\hat{i}$ and are held on the x axis at distance 'a' from each other. When released, they move along the x-axis with the direction of their dipole moments remaining unchanged. If the mass of each dipole is 'm', their speed when they are infinitely far apart is:

(1) $\frac{p}{a}\sqrt{\frac{3}{2\pi \in_0 ma}}$ (2) $\frac{p}{a}\sqrt{\frac{1}{\pi \in_0 ma}}$ (3) $\frac{p}{a}\sqrt{\frac{1}{2\pi \in_0 ma}}$ (4) $\frac{p}{a}\sqrt{\frac{2}{\pi \in_0 ma}}$

Sol. **3**



interaction energy of dipole is

$$= P\frac{dv}{dr} \Rightarrow P\frac{d\left(\frac{Kp}{r^2}\right)}{dr} \Rightarrow \frac{-2kP}{r^3}$$

Now from E.C.

$$\frac{2kP}{r^3} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$$

$$V = \sqrt{\frac{2kp^2}{mr^3}}$$

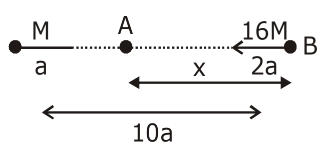
$$\therefore r = a$$

$$V = \frac{P}{a}\sqrt{\frac{1}{2\pi\varepsilon_0 ma}}$$

Q.16 Two planets have masses M and 16 M and their radii are a and 2a, respectively. The separation between the centres of the planets is 10a. A body of mass m is fired from the surface of the larger planet towards the smaller planet along the line joining their centres. For the body to be able to reach at the surface of smaller planet, the minimum firing speed needed is:

(1) $2\sqrt{\frac{GM}{a}}$ (2) $\sqrt{\frac{GM^2}{ma}}$ (3) $\frac{3}{2}\sqrt{\frac{5GM}{a}}$ (4) $4\sqrt{\frac{GM}{a}}$

Sol. **3**



A → Where $F_{net} = 0$

$$\frac{G(16M)(m)}{x^2} = \frac{G(M)(m)}{(10a - x)^2}$$

$x = 8a$

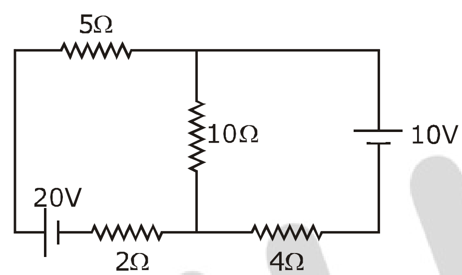
So if particle reaches A it will automatically reaches to smaller planet.

Now E – C b/w B and A.

$$\frac{1}{2}mv^2 - \frac{G(16M)(m)}{2a} - \frac{GMm}{8a} = \frac{-G(16M)(m)}{8a} - \frac{G(M)(m)}{2a}$$

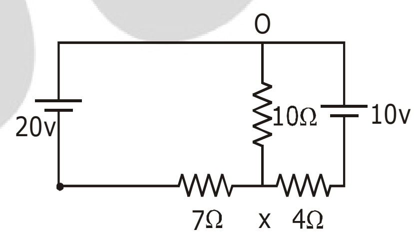
$$V = \frac{3}{2}\sqrt{\frac{5GM}{a}}$$

Q.17 In the figure shown, the current in the 10 V battery is close to:



(1) 0.21 A from positive to negative terminal
(2) 0.36 A from negative to positive terminal
(3) 0.42 A from positive to negative terminal
(4) 0.71 A from positive to negative terminal

Sol. **1**



$$\frac{x+20}{7} + \frac{x+10}{4} + \frac{x}{10} = 0$$

$$x = \frac{-1500}{138} = -10.87$$

current through 10 v .

$$i = \frac{10.87 - 10}{4} \Rightarrow 0.21\text{Amp.}$$

Q.18 A student measuring the diameter of a pencil of circular cross-section with the help of a vernier scale records the following four readings 5.50 mm, 5.55 mm, 5.45 mm, 5.65 mm. The average of these four readings is 5.5375 mm and the standard deviation of the data is 0.07395 mm. The average diameter of the pencil should therefore be recorded as:

(1) (5.54 ± 0.07) mm
(2) (5.5375 ± 0.0740) mm
(3) (5.5375 ± 0.0739) mm
(4) (5.538 ± 0.074) mm

Sol. **1**

Significant rule says that reading should has same significant figure as that of reading given.

5.5375 → rounded to → 5.54

Q.19 Given the masses of various atomic particles m_p = 1.0072 u, m_n = 1.0087 u, m_e = 0.000548 u, $m_{\bar{\nu}}$ = 0, m_d = 2.0141 u, where p ≡ proton, n ≡ neutron, e ≡ electron, $\bar{\nu}$ ≡ antineutrino and d ≡ deuteron. Which of the following process is allowed by momentum and energy conservation?

(1) n + n → deuterium atom (electron bound to the nucleus)

(2) $e^+ + e^- \to \gamma$

(3) $p \to n + e^+ + \bar{\nu}$

(4) $n + p \to d + \gamma$

Sol. **4**

Answer - 1 → incorrect

(because n + p → d)

Answer - 2 → incorrect

(because $e^- + e^- \to \gamma$)

Answer - 3 → incorrect

(because mass ↑)

Q.20 A particle moving in the xy plane experiences a velocity dependent force $\vec{F} = k\left(v_y\hat{i} + v_x\hat{j}\right)$, where v_x and v_y are the x and y components of its velocity $\vec{v}$. If $\vec{a}$ is the acceleration of the particle, then which of the following statements is true for the particle?

(1) kinetic energy of particle is constant in time

(2) quantity $\vec{v} \times \vec{a}$ is constant in time

(3) quantity $\vec{v}.\vec{a}$ is constant in time

(4) $\vec{F}$ arises due to a magnetic field

Sol. **2**

given $\vec{F} = k\left(V_y\hat{i} + V_x\hat{j}\right)$

$m\vec{a} = k(V_y\hat{i} + V_x\hat{j})$

$a_x = \frac{kv_y}{m}, a_y = \frac{kv_x}{m}$

option -1 is incorrect. (K.E. ≠ const.)

option -2 is correct.

$\vec{V} \times \vec{a} = 0$ $\qquad$ $\vec{a} = \frac{k\vec{v}}{m}$

because $\vec{v}$ and $\vec{a}$ in same direction.

option - 3 → $\vec{v}.\vec{a} = \frac{k}{m}[v_x^2 + v_y^2]$ (incorrect)

option - 4 → incorrect.

Q.21 A Young's double-slit experiment is performed using monochromatic light of wavelength λ. The intensity of light at a point on the screen, where the path difference is λ, is K units. The intensity of light at a point where the path difference is $\frac{\lambda}{6}$ is given by $\frac{nK}{12}$, where n is an integer. The value of n is __________.

Sol. **9**

From Ist case

$I_{net} = 4I\cos^2\frac{\Delta\phi}{2}$

$\therefore \Delta\phi = \frac{2\pi}{\lambda}\times\lambda \Rightarrow 2\pi$

$I_{net} = 4I = k$ (given)

from IInd case

$I_{net} = 4I\cos^2\frac{\Delta\phi}{2}$

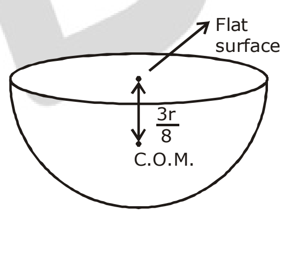
$\therefore \Delta\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{6} \Rightarrow \frac{\pi}{3}$

$I_{net} = 4I\times\frac{3}{4} \Rightarrow \frac{3}{4}k = \frac{nk}{12}$

n = 9

Q.22 The centre of mass of solid hemisphere of radius 8 cm is x from the centre of the flat surface. Then value of x is __________.

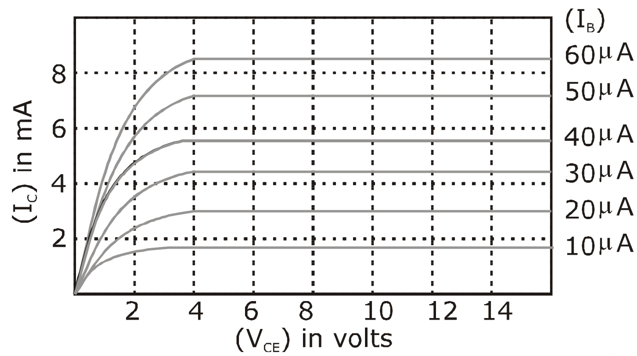
Sol. **3**



As we know c.o.m. or hemisphere = $\frac{3r}{8}$

r = 8cm (given) $\Rightarrow \frac{3\times 8}{8} \Rightarrow$ 3cm

Q.23 The output characteristics of a transistor is shown in the figure. When V_{CE} is 10V and I_C = 4.0 mA, then value of β_{ac} is __________.



Sol. **150**

$\beta = \frac{\Delta I_C}{\Delta I_B}$

ΔI_B = 30 – 20 $\qquad$ I_C = 4mA (refrence value given)

= 10 μA

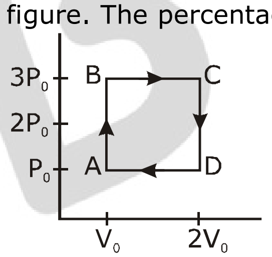
ΔI_C = 4.5 – 3

= 1.5mA

$\beta = \frac{1.5 \times 10^{-3}}{10 \times 10^{-6}}$

= 150

Q.24 An engine operates by taking a monoatomic ideal gas through the cycle shown in the figure. The percentage efficiency of the engine is close to __________.



Sol. **19%**

% efficiency of carnot engine $\eta = \frac{W}{Q} \times 100$

work = Area of ABC D = $(2P_0)(V_0)$

Heat = $Q_{AB} + Q_{BC}$

(input)

Q_{AB} = isochoric process

= $nc_V \Delta T$ $\qquad$ $\therefore$ PV = n R T

$\Rightarrow nc_V (T_B - T_A)$ $\qquad$ $T = \frac{PV}{nR}$

$$Q_{Ab} = 1 \times \frac{3}{2}k(3P_0V_0 - P_0V_0) \Rightarrow 3P_0V_0$$

Q_{BC} = isobaric process
= $n\,C_P\,\Delta T$

$$\Rightarrow 1 \times \frac{5}{2}K\left(6P_0V_0 - 3P_0V_0\right) \Rightarrow 7.5P_0V_0$$

$$\eta = \frac{2P_0V_0}{3P_0V_0 + 7.5P_0V_0} \times 100 \approx 19\%$$

Q.25 In a series LR circuit, power of 400W is dissipated from a source of 250 V, 50 Hz. The power factor of the circuit is 0.8. In order to bring the power factor to unity, a capacitor of value C is added in series to the L and R. Taking the value of C as $\left(\frac{n}{3\pi}\right)\mu F$, then value of n is __________.

Sol. **400**
given
in Ist case
power factor of LR CKT

$$\cos\phi = 0.8 = \frac{R}{\sqrt{R^2 + X_L^2}}$$

where $\sqrt{R^2 + X_L^2} = z$ ...(1)

$$\therefore\ P = VI\cos\theta$$

$$\Rightarrow 400 = (250)^2 \times \frac{R}{Z^2}$$

$$400 = (250)^2 \times \frac{0.8}{z}$$

$z = 125$ ...(2)

$$R = \frac{(250)^2 \times 0.8 \times 0.8}{400} \Rightarrow 100\Omega \quad ..(3)$$

from (1), (2) and (3)

$$(100)^2 + X_L^2 = (125)^2$$

$$X_L^2 = 15625 - 10000$$

$$X_L^2 = 5625$$

$X_L = 75$ ...(4)

in IInd case given.
Power factor = 1
that means
$X_L = X_C$ (Resonance condition)

$$X_L = \frac{1}{\omega_C} \Rightarrow 75 = \frac{1}{(2\pi F)C}$$

$$C = \frac{1}{2\pi \times F \times 75}$$

$$C = \frac{1}{2\pi \times 50 \times 75} F \quad ....(5)$$

$$C = \frac{n}{3\pi} \mu F \text{ given} \quad ...(6)$$

From (5) & (6)

$$\frac{1}{2\pi \times 50 \times 75} = \frac{n \times 10^{-6}}{3\pi}$$

$$n = \frac{10^6}{7500} \Rightarrow \frac{3 \times 10^4}{75} \Rightarrow \frac{30000}{75}$$

n = 400