JEE Main September 2020

Question Paper With Text Solution

2 September| Shift-2

PHYSICS

MATRIX

JEE Main & Advanced | XI-XII Foundation| VI-X Pre-Foundation

JEE MAIN SEP 2020 | 2 SEP SHIFT-2

1. If momentum (P), area (A) and time (T) are taken to be the fundamental quantities then the dimensional formula for energy is :

    (A) $[PA^{-1}T^{-2}]$ (B) $[PA^{\frac{1}{2}}T^{-1}]$ (C) $[P^{\frac{1}{2}}AT^{-1}]$ (D) $[P^2AT^{-2}]$

Ans.   (B)

Sol. $E = A^x T^y P^z$

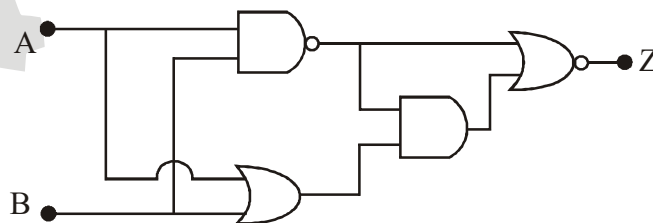$ML^2T^{-2} = (L^2)^x (T)^y (MLT^{-1})^z$

(i) $z = 1$

(ii) $2x + z = 2$

(iii) $y - z = -2$

From equation (i), (ii) & (iii)

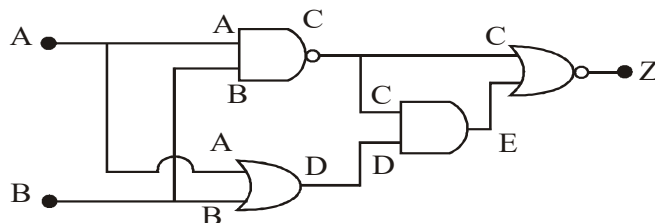$x = \frac{1}{2}, y = -1, z = 1$

$E = A^{1/2} T^{-1} P^1$

2. In the following digital circuit, what will be the output at 'Z', when the input (A, B) are (1, 0), (0, 0) (1,1), (0, 1):

    (A) 0, 1, 0, 0   (B) 1, 0, 1, 1   (C) 1, 1, 1, 1   (D) 0, 0, 1, 0

Ans.   (D)

Sol.

$C = \overline{AB}$

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D = A + B

E = CD

$Z = \overline{(C + E)} = \overline{(C + CD)}$

$Z = \overline{[C(1 + D)]}$

we know that. 1 + A = 1

So $Z = = \overline{C} = \left(\overline{\overline{\overline{AB}}}\right) = AB$

A	B	C
1	0	0
1	0	0
1	1	1
0	4	0

3. An ideal gas in a closed container is slowly heated. As its temperature increases, which of the follwing statements are ture?

(a) the mean free path of the molecules decreases.

(b) the mean collision time between the molecules decreases.

(c) the mean free path remains unchanged.

(d) the mean collision time remains unchanged.

(A) (b) and (c)　　　(B) (c) and (d)　　　(C) (a) and (d)　　　(D) (a) and (b)

Ans.　(A)

Sol.　Mean free path = $l = \dfrac{1}{\sqrt{2}\left(\dfrac{N}{V}\right)\pi d^2}$

here N = no of molecule, d $\Rightarrow$ diameter of molecule
V $\Rightarrow$ Vol. of container.
N, V, d is remain same so mean free path remain same due to increase in temperature, no of collision increase so relaxation time decrease.

4. A wire carrying current I is bent in the shape ABCDEFA as shown, where rectangle ABCDA and ADEFA are perpendicular to each other. If the sides of the rectangles are of lenths a and b, then the magnitude and direction of magnetic moment of the loop ABCDEFA is ;

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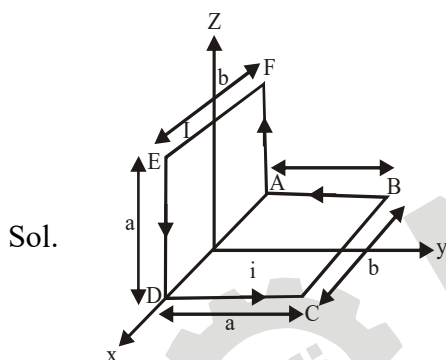**Website :** www.matrixedu.in ; Email : smd@matrixacademy.co.in

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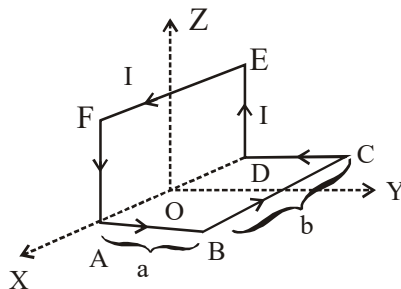
(A) abI, along $\left(\dfrac{\hat{j}}{\sqrt{2}}+\dfrac{\hat{k}}{\sqrt{2}}\right)$

(B) abI, along $\left(\dfrac{\hat{j}}{\sqrt{5}}+\dfrac{2\hat{k}}{\sqrt{5}}\right)$

(C) $\sqrt{2}$ abI, along $\left(\dfrac{\hat{j}}{\sqrt{2}}+\dfrac{\hat{k}}{\sqrt{2}}\right)$

(D) $\sqrt{2}$ abI, along $\left(\dfrac{\hat{j}}{\sqrt{5}}+\dfrac{2\hat{k}}{\sqrt{5}}\right)$

Ans.   (C)

Sol.

Add a wire AD in which we will assume current *i* is flowing in both directions. Now, this loop can be considered as a combination of 2 loops i.e. ABCD & DEFA

$\overline{m}_{ABCD} = i\text{ab}(\hat{k})$

$\overline{m}_{DEFA} = i\text{ab}(\hat{j})$

$\overline{m}_{total} = i\text{ab}(\hat{k}+\hat{j})$

Magnitude = $\sqrt{2}\text{abI}$

direction is $\left(\dfrac{\hat{j}}{\sqrt{2}}+\dfrac{\hat{k}}{\sqrt{2}}\right)$

5.   A charge Q is distributed over two concentric conducting thin spherical shells radii r and R (R > r). If

the surface charge densities on the two shells are equal, the electric potential at the common centre is:

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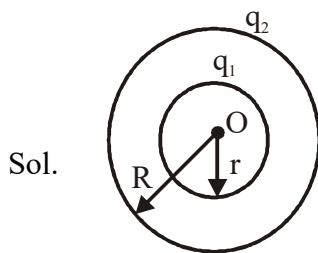**Office : Piprali Road, Sikar (Raj.) | Ph. 01572-241911**
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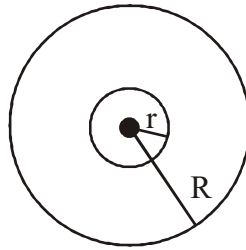
(A) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{(R+r)}{(R^2+r^2)}Q$ (B) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{(2R+r)}{(R^2+r^2)}Q$ (C) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{(R+2r)Q}{2(R^2+r^2)}$ (D) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{(R+r)}{2(R^2+r^2)}Q$

Ans. (A)

Sol.

(i) $q_1 + q_2 = Q$

$\dfrac{q_1}{4\pi r^2} = \dfrac{q_2}{4\pi R^2}$

(ii) $\dfrac{q_1}{q_2} = \dfrac{r^2}{R^2}$

From (i) & (ii)

$q_1 = \dfrac{Q \times r^2}{R^2 + r^2}, \quad q_2 = \dfrac{QR^2}{R^2 + r^2}$

$V_0 = \dfrac{kq_1}{r} + \dfrac{kq_2}{R}$

Putting values of q_1 and q_2

$V_0 = \dfrac{kQ(r+R)}{R^2 + r^2}$

6. When the temperature of a metal wire is increased from 0°C to 10°C, its length increases by 0.02%. The

    percentage change in its mass density will be closest to:

    (A) 0.8   (B) 2.3   (C) 0.06   (D) 0.008

Ans. (C)

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Sol. $\dfrac{\Delta L}{L} \times 100 = 0.02$ and $\Delta T = 10^{\circ}C$

$\dfrac{\Delta L}{L} = 2 \times 10^{-4} = \alpha \Delta T$
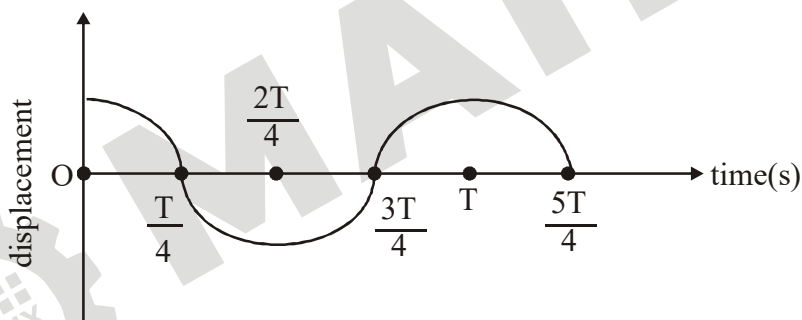
$\alpha = 2 \times 10^{-5}$

$\gamma = 3\alpha = 6 \times 10^{-5}$

$\rho = \dfrac{m}{v}$

$\dfrac{\Delta \rho}{\rho} = \dfrac{-\Delta v}{v} = -\gamma \Delta T = -6 \times 10^{-5} \times 10$

$\dfrac{\Delta \rho}{\rho} \times 100 = -6 \times 10^{-2}$

7.   The displacement time graph of a particle executing S.H.M. is given in figure : (sketch is schematic and not to scale)

Which of the following statements is/are true for this motion?

(a) The force is zero at t = $\dfrac{3T}{4}$

(b) The acceleration is maximum at t = T

(c) The speed is maximum at t = $\dfrac{T}{4}$

(d) The P. E. is equal to K.E. of the oscillation at t = $\dfrac{T}{2}$

(A) (a), (b) and (c)   (B) (b), (c) and (d)   (C) (a) and (d)   (D) (a), (b) and (d)

Ans.   (A)

Sol.   As seen from graph, equation of SHM will be given by
x = Acos(ωt)

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At time $\dfrac{T}{4}$ & $\dfrac{3T}{4}$ particle is at mean position.

this means,

$F = -kx = 0$

$a = -\omega^2 x = 0$

$v = \omega\sqrt{A^2 - x^2} = \omega A = \text{max imum}$

At $t = \dfrac{T}{8}$, $\quad x = A\cos\left(\omega \times \dfrac{T}{8}\right)$

$= A\cos\left(\dfrac{2\pi}{T} \times \dfrac{T}{8}\right) = \dfrac{A}{\sqrt{2}}$

$v = \dfrac{1}{2}kx^2 = \dfrac{1}{4}\left(m\omega^2\right)A^2$

$k = \dfrac{1}{2}mv^2 = \dfrac{1}{2}m\omega^2\left(A^2 - \dfrac{A^2}{2}\right) = \dfrac{1}{4}m\omega^2A^2$

$U = k$

8. Two uniform circular discs are rotating independently in the same direction around their common axis passing through their centres. The moment of inertia and angular velocity of the first disc are 0.1 kg-m^2 and 10 rad s^{-1} respectively while those for the second one are 0.2 kg-m^2 and 5 rad s^{-1} respectively. At some instant they get stuck together and start rotating as a single system about their common axis with some angular speed. The Kinetic energy of the combined system is :

(A) $\dfrac{20}{3}$ J   (B) $\dfrac{10}{3}$ J   (C) $\dfrac{2}{3}$ J   (D) $\dfrac{5}{3}$ J

Ans. (A)

Sol. Using angular momentum conservation

$I_1\omega_1 + I_2\omega_2 = \left(I_1 + I_2\right)\omega$

$w = \dfrac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2} = \dfrac{0.1 \times 10 + 0.2 \times 5}{0.1 + 0.2} = \dfrac{20}{3}$

Final K.E. $= \dfrac{1}{2}I_1\omega^2 + \dfrac{1}{2}I_2\omega^2$

$= \dfrac{\omega^2}{2}\left(I_1 + I_2\right) = \left(\dfrac{20}{3}\right)^2 \times \dfrac{1}{2} \times \left(0.3\right) = \dfrac{20}{3}$ J
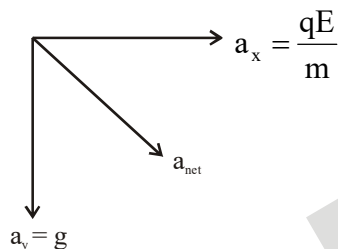
9. A small point mass carrying some positive charge on it, is released from the edge of a table. There is a uniform electric field in this region in the horizontal direction,. Which of the following options then correctly describe the trajectory of the mass ? (Curves are drawn schematically and are not to scale).
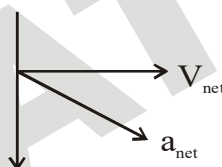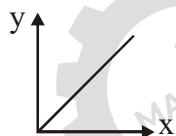

(A) (B) (C) (D)

Ans. (A)

Sol.

$a_x = \dfrac{qE}{m}$

and

$a_y = g$
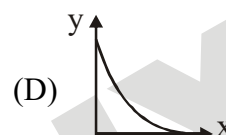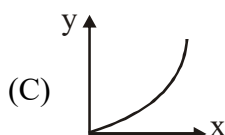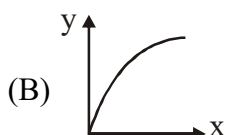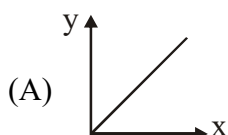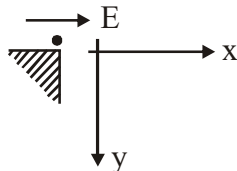
so path of particle is straight line

10. A capillary tube made of glass of radius 0.15 mm is dipped vertically in a beaker filled with methylene iodide (surface tension = 0.05 Nm^{-1}, density = 667 kg m^{-3}) which rises to height h in the tube. It is observed that the two tangents drawn from liquid-glass interfaces (from op. sides of the capillary) make an angle of 60° with one another. Then h is close to (g = 10 ms^{-2}).

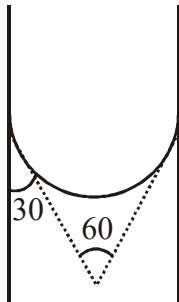(A) 0.087 m (B) 0.137 m (C) 0.049 m (D) 0.172 m

Ans. (A)

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Sol.

$$h = \frac{2s\cos\theta}{\rho gr} = \frac{2 \times \frac{1}{20} \times \cos 30^\circ}{667 \times 10 \times 15 \times 10^{-5}} = 0.087m$$

11. In a hydrogen atom the electron makes a transition from $(n+1)^{th}$ level to the nth level. If n>>1, the frequency of radiation emitted is proportional to:

(A) $\dfrac{1}{n^4}$ (B) $\dfrac{1}{n^2}$ (C) $\dfrac{1}{n^3}$ (D) $\dfrac{1}{n}$

Ans. (C)

Sol. $h\nu = (13.6\text{ eV})\left(\dfrac{1}{n^2} - \dfrac{1}{(n+1)^2}\right)$

$= (13.6\text{ eV})\left(\dfrac{2n+1}{n^2(n+1)^2}\right)$

$= (13.6\text{ eV})\left(\dfrac{2+\dfrac{1}{n}}{n^3(1+\dfrac{1}{n})^2}\right)$

n>>1

$h\nu = (13.6\text{ eV})\dfrac{2}{n^3}$

$\nu \propto \dfrac{1}{n^3}$

12. In a Young's double slit experiment, 16 fringes are observed in a certain segment of the screen when light of wavelength 700 nm, is used. IF the wavelength of light is changed to 400 nm, the number of fringes observed in the same segement of the screen would be :

(A) 28   (B) 30   (C) 24   (D) 18

Ans. (A)

Sol. for $\lambda = 700$ nm $y = \dfrac{(16)D(700)}{d}$ (1)

for $\lambda = 400$ nm $y = \dfrac{n\,D(400)}{d}$ (2)

form (1) & (2) $\Rightarrow n = \dfrac{700 \times 16}{400} = 28$

13. A heat engine is involved with exchange of heat of 1915J, –40J, + 125J and – QJ, during one cycle achieving an efficiency of 50.0%. The value of Q is :

(A) 980J   (B) 40J   (C) 400J   (D) 640J

Ans. (A)

Sol. efficiency $= \dfrac{\text{work done}}{\text{heat supplied}}$

$= \dfrac{150}{100} = \dfrac{1915 - 40 + 125 - Q}{1915 + 125}$

$= \dfrac{1}{2} = \dfrac{2000 - Q}{2040}$

Q = 980 J

14. The height 'h' at which the weight of a body will be the same as that at the same depth 'h' from the surface of the earth is (Radius of teh earth is R and effect of the rotation of the earth is neglected):

(A) $\dfrac{\sqrt{5}}{2}R - R$ (B) $\dfrac{\sqrt{3}R - R}{2}$ (C) $\dfrac{R}{2}$ (D) $\dfrac{\sqrt{5}R - R}{2}$

Ans. (D)

Sol. $\Rightarrow \dfrac{GM}{(R + h)^2} = \dfrac{GM}{R^3}$

$\Rightarrow R^3 = (R+h)^2 (R-h)$

$\Rightarrow R^3 = R^3 - h^3 - h^2 R + hR^2$

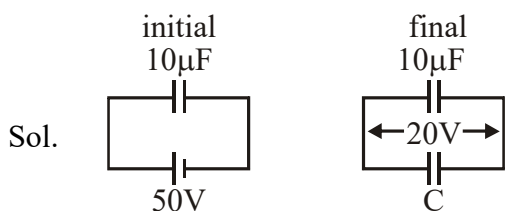$\Rightarrow h^3 + h^2 R - hR^2 = 0$

$h(h^2 + hR - R^2) = 0$

$$h = 0, \frac{-R \pm \sqrt{5}R}{2}$$

$$h = \frac{-R + \sqrt{5}R}{2}$$

15. A 10μF capacitor is fully charged to a potential difference of 50V. After removing the source voltage it is connected to an uncharged capacitor in parallel. Now the potential difference across them becomes 20V. The capacitance of the second capacitor is :

    (A) 15 μF   (B) 10 μF   (C) 20 μF   (D) 30 μF

Ans. (A)

Sol.

$Q_{10} = 10 \times 50 \ \mu \ C = 500 \ \mu \ C$

Now charge on $10 \ \mu \ F = Q_{10}^1 = 20 \times 10 = 200 \ \mu \ F$

charge on $C = Q_{10} - Q_{10}^1 = 500 - 200 = 300 \ \mu \ F$

$300 = C \times 20$

$C = 15 \ \mu \ F$

16. In a plane electromagnetic wave, the directions of electric and magnetic field are represented by $\hat{k}$ and $2\hat{i} - 2\hat{j}$, respectively. What is the unit vector along direction of propagation of the wave.

    (A) $\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$ (B) $\frac{1}{\sqrt{5}}(\hat{i} + 2\hat{j})$ (C) $\frac{1}{\sqrt{5}}(2\hat{i} + \hat{j})$ (D) $\frac{1}{\sqrt{2}}(\hat{j} + \hat{k})$

Ans. (A)

Sol. $\hat{E} = \hat{k}$ $\vec{B} = 2\hat{i} - 2\hat{j}$

$$\vec{B} = \frac{2\hat{i} - 2\hat{j}}{\sqrt{144}} = \frac{\hat{i}}{\sqrt{2}} = \frac{\hat{j}}{\sqrt{2}}$$

direction fo propagation fo wave $= \hat{E} \times \hat{B}$

$$= \hat{k} \times \left[\frac{1}{\sqrt{2}} (\hat{i} - \hat{j}) \right]$$

$$= \frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}} = \frac{1}{\sqrt{2}} \left(\hat{i} + \hat{j} \right)$$

17. A particle is moving 5 times as fast as an electron. The ratio of the de-Broglie wavelength of the particle to the particle to that of the electron is 1.878×10^{-4}. The mass of the particle is close to:

(A) 4.8×10^{-27}kg (B) 1.2×10^{-28}kg (C) 9.7×10^{-28}kg (D) 9.1×10^{-31}kg

Ans. (C)

Sol. Let speed of $e^- = V_0$
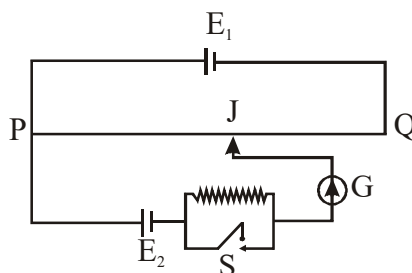
then speed of particle $= 5V_0$

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

$$= \frac{\lambda \, \text{particle}}{\lambda \, \text{electron}} = \frac{m_e v_e}{m_p v_p} = 1.87 \times 10^{-4}$$

$$= \frac{9.1 \times 10^{-31} \times V_0}{m_p \times 5V_0} = 1.87 \times 10^{-4}$$

$$\Rightarrow m_p = 9.7 \times 10^{-28} \text{ kg}$$

18. A potentiometer wire PQ of 1 m length is connected to a standard cell E_1. Another cell E_2 of emf 1.02 V is connected with a resistance 'r' and switch S (as shown in figure). With switch S open, the null position is obtained at a distance of 49 cm from Q. The potential gradient in the potentiometer wire is :

(A) 0.03V/cm (B) 0.01 V/cm (C) 0.02 V/cm (D) 0.04 V/cm

Ans. (C)

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Sol.   Balance length from P = 100 – 49 = 51 cm

Potential gradient = $\dfrac{dv}{dx} = \dfrac{1.02V}{51cm} \Rightarrow 0.02 v/cm$

19.   An inductance coil has a reactance of 100Ω. When an AC signal of frequency 1000Hz is applied to the coil, the applied voltage leads the current by 45°. The self-inductance of the coil is:

(A) 5.5×10^{-5}H   (B) 6.7×10^{-7}H   (C) 1.1×10^{-1}H   (D) 1.1×10^{-2}H

Ans.   (D)

Sol. $Z = \sqrt{R^2 + X_L^2} = 100$ ....(1)

Voltage leads the current by 45º

So $\tan 45º = \dfrac{X_L}{R} = 1 \Rightarrow R = X_L = \omega L$
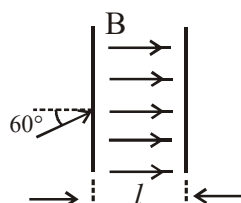
From (1) $\sqrt{X_L^2 + R^2} = 100$

$X_L = 50\sqrt{2}$

$\omega L = 50\sqrt{2}$

$L = \dfrac{50\sqrt{2}}{2000\pi}$ H

$L = 1.125 \times 10^{-2}$ H

20.   The figure shows a region of length 'l' with a uniform magnetic field of 0.3 T in i and a proton entering the region with velocity 4×10^5 ms^{-1} making an angle 60° with the field. If the proton completes 10 revolution by the time it cross the region shown, 'l' is close to (mass of proton = 1.67×10^{-27} kg, charge of the proton = 1.6×10^{-19}C)

(A) 0.44   (B) 0.88   (C) 0.11   (D) 0.22 m

Ans.   (A)

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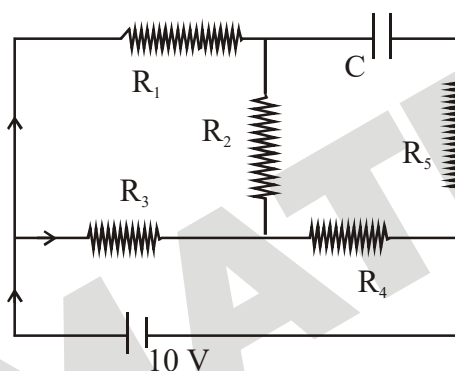**Website :** www.matrixedu.in ; Email : smd@matrixacademy.co.in

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Sol. $l = 10$ (pitch)

$$10 \left[v \cos 60 \times \frac{2\pi m}{eB} \right]$$

$$= 10 \times 4 \times 10^5 \times \frac{1}{2} \times \frac{2\pi \times 1.67 \times 10^{-27}}{1.6 \times 10^{-19} \times 0.3}$$
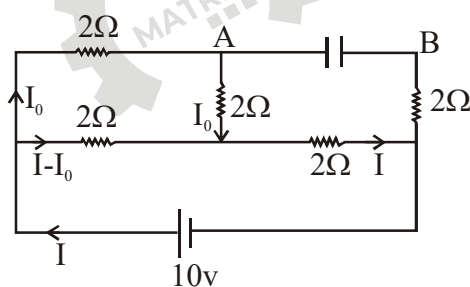
$$\approx 0.44 m$$

21. An ideal cell of emf 10 V is connected in circuit shown in figure. Each resistance is 2Ω. The potential difference (in V) across the capacitor when it is fully charged is _____.

Ans. 8

Sol. In steady state

from KVL ⇒ $\quad -2(I - I_0) - 2I + 10 = 0$

$\quad\quad\quad\quad\quad 2I - I_0 = \quad\quad\quad\quad (1)$

⇒ $\quad\quad\quad\quad -2I_0 - 2I_0 + 2(I - I_0) = 0$

$\quad\quad\quad\quad\quad I = 3I_0 \quad\quad\quad\quad\quad (2)$

from (1) & (2) $\quad I_0 = 1A, I = 3A$

$\quad\quad\quad\quad\quad V_{AB} = 2I_0 + 2I$

$\quad\quad\quad\quad\quad = 2 \times 1 + 2 \times 3 = 8V$

22. A wire of density 9×10^{-3} kg cm^{-3} is stretched between two clamps 1 m apart. The resulting strain in the

wire is 4.9×10^{-4}. the lowest frequency of the transverse vibrations in the wire is (Young's modulus of

wire $Y = 9 \times 10^{10}$ Nm^{-2}), (to the nearest integer),_____.
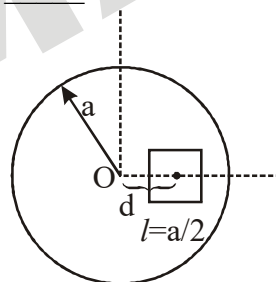
Ans. 35 Hz

Sol. $f = \dfrac{1}{2\ell}\sqrt{\dfrac{T}{\mu}}$ and $\mu = \rho A$, $Y = \dfrac{T/A}{\Delta\ell/\ell} \Rightarrow \dfrac{T}{A} = \dfrac{Y\Delta\ell}{\ell}$

So $f = \dfrac{1}{2\ell}\dfrac{\sqrt{Y\Delta\ell}}{\rho\ell}$

$= \dfrac{1}{2\times 1}\sqrt{\dfrac{9\times 10^9 \times 4.9 \times 10^{-4}}{100}}$

$= \dfrac{70}{2} = 35\text{Hz}$

23. A square shaped hole of side $l = \dfrac{a}{2}$ is carved out at a distance $d = \dfrac{a}{2}$ from the centre 'O' of a uniform

circular disk of radius a. If the distance of the centre of mass of the remaining portion from O is $-\dfrac{a}{X}$,

value of X (to the nearest integer) is_____.

Ans. 23

Sol. $X = \dfrac{M_{complete}\, X_{complete} - M_{removed}X_{removed}}{M_{complete} - M_{removed}}$

$= \dfrac{(\sigma\pi a^2)(0) - (\sigma\dfrac{a^2}{4})\times\dfrac{a}{2}}{\sigma(\pi a^2) - (\sigma\dfrac{a^2}{4})}$
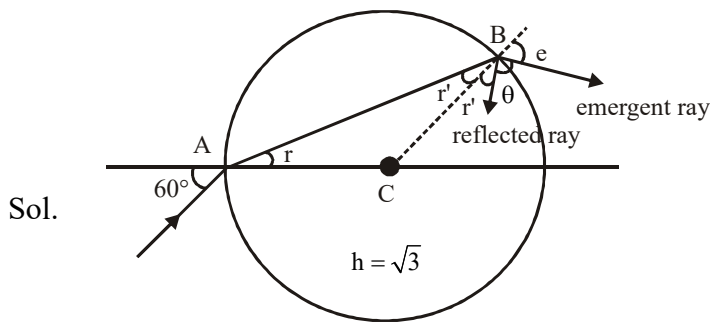
$= \dfrac{-a^3/8}{(\pi - 1/4)} = \dfrac{-a}{8\pi - 2}$

$8\pi - 2 \sim 23.1$

So, answer is 23

24. A light ray enters a solid glass sphere of refractive index $\mu = \sqrt{3}$ at an angle of incidence 60°. The ray is both reflected and refracted at the farther surface of the sphere. The angle (in degrees) between the reflected and refracted rays at this surface is_____.

Ans. $\theta = 90°$

Sol.

Apply Snell's law at A

$1 \sin 60° = \sqrt{3} \ \sin r$

$\qquad r = 30°$

In $\triangle ABC \quad AC = BC \quad$ So $r = r' = 30°$

Again apply snell's law on B

$\sqrt{3} \ \sin r' = 1 \sin e$

$e = 60°$

from geometry $r' + \theta + e = 180°$

$\theta = 90°$

25. A particle of mass m is moving along the x-axis with initial velocity $u\hat{i}$. It collides elastically with a particle of mass 10 m at rest and then moves with half its initial kinetic energy (see figure). If $\sin\theta_1 = \sqrt{n} \ \sin\theta_2$ then value of n is _____.
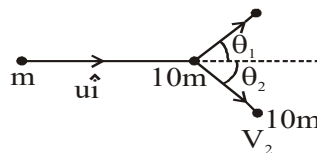
Ans. 10

Sol.   Linear momentum conservation in y direction $\Rightarrow$

$O = m\,V_1 \sin\theta_1 - mv_2 \sin\theta_2$

$\Rightarrow v_1 \sin\theta_1 = 10V_2 \sin\theta_2$ ....(1)

for m mass $\Rightarrow KE_f = \dfrac{KE_i}{2}$

$mV_1^2 = \dfrac{1}{2} \times \dfrac{1}{2}\ mu^2$

$V_1 = \dfrac{u}{\sqrt{2}}$ ....(2)

elastic collision $\Rightarrow KE_i = KE_f$

$\dfrac{1}{2}\ mu^2 = \dfrac{1}{2}\ mv_1^2 + \dfrac{1}{2}\ (10\,m)\,V_2^2$

$u^2 = \dfrac{u^2}{2} + 10V_2^2$

$V_2 = \dfrac{u}{\sqrt{20}}$ ....(3)

Put (2), (3) in equation(1)

$\dfrac{u}{\sqrt{2}}\ \sin\theta_1 = \dfrac{10u}{\sqrt{20}}\ \sin\theta_2$

$\sin\theta_1 = \sqrt{10}\ \sin\theta_2$

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