JEE-MAIN-2020 (3rd September-First Shift)-PCM-2

PART –A (PHYSICS)

***Questions*: 1:-** A uniform thin rope of length 12 m and mass 6 kg hangs vertically from a rigid support and a block of mass 2 kg is attached to its free end. A transverse short wave-train of wavelength 6 cm is produced at the lower and the rope. What is the wavelength of the wave train (in cm) when it reaches the top of the tope?

(A) 6 **(B)** 12

(C) 3 **(D)** 9

***Ans*: - B**

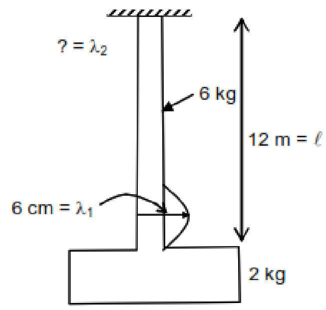
At lower end

$$T_1 = 20 \Rightarrow v_1 = \sqrt{\frac{T_1}{\mu}} = \sqrt{\frac{20}{\mu}} \quad ...(1)$$

At upper end

$$T_2 = 80 \Rightarrow v_2 = \sqrt{\frac{T_2}{\mu}} = \sqrt{\frac{80}{\mu}}$$

$$= 2\mu \quad ...(2)$$



$\therefore$ frequency remaining same

$$f = f_2$$

$$\Rightarrow \frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2} \Rightarrow \lambda_2 = \lambda_1 \frac{v_2}{v_1}$$

$$= 2\lambda = 12 \text{ cm}$$

***Questions*: 2:-** When the wavelength of radiation falling on a metal is charged from 500 nm to 200 nm the maximum kinetic energy of the photoelectrons becomes three times larger. The work function of the metals is close to:

(A) 1.02 eV **(B)** 0.61 eV

(C) 0.52 eV **(D)** 0.81 eV

***Ans*:- B**

If work function of metal be ϕ, then K.E. of emitted photo electron,

$$k = h\nu\phi = \frac{hc}{\lambda} - \phi \qquad \ldots(1)$$

$\therefore$ at $\lambda_1 = 500$ nm

$$k_1 = \frac{hc}{\lambda_1} - \phi \qquad \ldots(2)$$

At $\lambda_2 = 200$ nm

$$k_2 = \frac{hc}{\lambda_2} - \phi = 3k_1 \text{ (given)}$$

$$= 3\left(\frac{hc}{\lambda_1} - \phi\right)$$

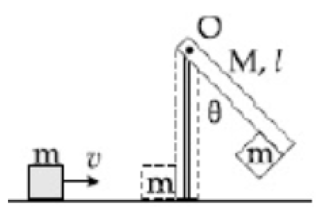
$$\Rightarrow \quad \frac{hc}{1}\left(\frac{3}{\lambda_1} - \frac{1}{\lambda_2}\right) = 2\phi$$

$$\Rightarrow \quad \phi = \frac{hc}{2}\left(\frac{3}{\lambda_1} - \frac{3}{\lambda_2}\right)$$

$$= \frac{hc}{2 \times 100 \text{ nm}}\left(\frac{3}{5} - \frac{1}{2}\right)$$

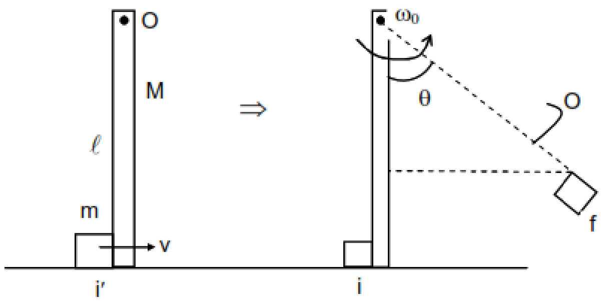
$$= \frac{1240}{2 \times 100}\,\frac{1}{10} = 0.62 \text{ eV.}$$

***Questions*: 3:-** A block of mass m = 1 kg slides with velocity v = 6 m/s on a frictionless horizontal surface and collides with a uniform vertical rod and sticks to its as shown. The rod is pivoted about O and swings as a result of the collision-making angle θ before momentarily coming to rest. If the rod has mass M = 2 kg, and length ℓ = 1 m, the value of θ is approximately: (take g = 10 m/s^2)



(A) 49° **(B)** 55°
(C) 69° **(D)** 63°

***Ans*:- D**



COAM about O between (i) and (f)

$$mv\ell = \left(\frac{M\ell^2}{3} + m\ell^2\right)w_0$$

$$\frac{3mv}{(M\ell + 3m\ell)} = ab \qquad ...(1)$$

COTME between (i) and (f) positrons

$$\frac{1}{2}\left(m\ell^2 + \frac{M\ell^2}{3}\right)\left(\frac{3mv_o}{M\ell + 3m\ell}\right)^2 = mg(\ell - \ell\cos\theta) + Mg\left(\frac{\ell}{2} - \frac{\ell}{2}\cos\theta\right)$$

$$\Rightarrow \frac{\ell}{2}\times\frac{1}{3}\frac{9m^2v_0^2}{(M\ell + 3m\ell)} = \ell(1-\cos\theta)\left(mg + \frac{Mg}{2}\right)$$

$$\Rightarrow \frac{3}{2}\times\frac{(1)^2\times(1)\times 6^2}{(2\times 1 + 3\times 1\times 1)} = (1)(1-\cos\theta)(10+10)$$

$$\Rightarrow \frac{27\times 2}{20\times 5} = 0.54 = (1-\cos\theta)$$

$$\Rightarrow \cos\theta = 0.46$$

$$\Rightarrow \theta \approx 63°$$

***Questions*: 4:-** An elliptical loop having resistance R, of semi major axis a and semi minor axis b is placed in a magnetic field as shown in the figure. If the loop is rotated about the x-axis with angular frequency ω, the average power loss in the loop due to joule heating is:

(A) $\frac{\pi^2a^2b^2B^2\omega^2}{R}$ **(B)** zero

(C) $\frac{\pi abB\omega}{R}$ **(D)** $\frac{\pi^2a^2b^2B^2\omega^2}{2R}$

***Ans*:- D**

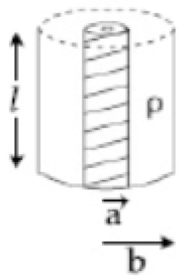
For rotating loop

$\varepsilon_0 = BA\omega = B(\pi ab)\omega$

∴ Average power loss

$$P_{avg} = \frac{E_0^2}{2R} = \frac{\pi^2a^2b^2B^2\omega^2}{2R}$$

***Questions*: 5:-** Model a torch battery of length ℓ to be made up of a thin cylindrical bar of radius 'a' and a concentric thin cylindrical shell of radius 'b' filled in between with an electrolyte of resistivity p (see figure). If the battery is connected to a resistance of value R, the maximum joule heating in R will take place for:



(A) $R=\frac{\rho}{\pi\ell}\ell n\left(\frac{b}{a}\right)$ **(B)** $R=\frac{\rho}{2\pi\ell}\left(\frac{b}{a}\right)$

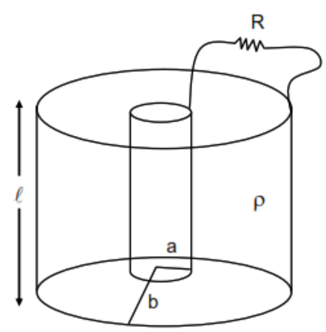
(C) $R=\frac{2\rho}{\pi\ell}\ell n\left(\frac{b}{a}\right)$ **(D)** $R=\frac{\rho}{2\pi\ell}\ell n\left(\frac{b}{a}\right)$

***Ans*:- D**

For maximum joule heating,
$R = R_{eq}$ of cylinder

$$= \int \frac{\rho dx}{(2\pi x\ell)}$$

$$= \frac{\rho}{2\pi\ell}\ell n\left(\frac{b}{a}\right)$$



***Questions*: 6:-** In a radioactive material, fraction of active material remaining after time t is 9/16. The fraction that was remaining after t/2 is

(A) 3/5 **(B)** 3/4

(C) 7/8 **(D)** 4/5

***Ans*:- B**

$$\frac{9}{16}N_o = N = N_o \quad e^{-\lambda t} \qquad \ldots(1)$$

$$\therefore \quad N' = N_o\, e^{-\frac{\lambda t}{2}}$$

$$= N_o\left(e^{-\lambda t}\right)^{1/2}$$

$$\Rightarrow \quad \frac{N'}{N_o} = \left(\frac{9}{16}\right)^{1/2} = \frac{3}{4}$$

***Questions*:7:-**

A charged particle carrying charge 1 μC is moving with velocity $\left(2\hat{i}+3\hat{j}+4j\hat{k}\right)$ ms^{-1}. If an external magnetic field of $\left(5\hat{i}+3\hat{j}-6j\hat{k}\right)\times 10^{-3}$ T exists in the region where the particle is moving then the force on the particle is $\vec{F}\times 10^{-9}$ N. The vector $\vec{F}$ is:

(A) $-30\hat{i}+32\hat{j}-9\hat{k}$ **(B)** $-3.0\hat{i}+3.2\hat{j}-0.9\hat{k}$

(C) $-300\hat{i}+320\hat{j}-90\hat{k}$ **(D)** $-0.30\hat{i}+0.32\hat{j}-0.09\hat{k}$

***Ans*:- A**

Coulomb's law

$\vec{F} = q\vec{V} \times \vec{B}$

$= (10^{-6})\ (2\hat{i} + 3\hat{j} + 4\hat{k}) \times (5\hat{i} + 3\hat{j} - 6\hat{k}) \times 10^{-3}$

$= (10^{-9})\ \left[-30\hat{i} + 32\hat{j} - 9\hat{k}\right]$

***Questions*: 8:-** In a Young's double slit experiment, light of 500 nm is used to produce an interference pattern. When the distance between the slits is 0.05 mm, the angular width (in degree) of the fringes formed on the distance screen is close to:

(A) 1.7° **(B)** 0.07°

(C) 0.57° **(D)** 0.17°

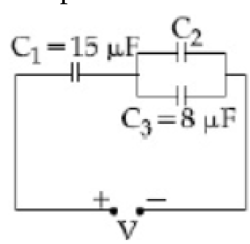
***Ans*:- C**

Angular width of a fringe is YDSE

$= \frac{\lambda}{d} = \frac{500 \times 10^{-9}}{0.05 \times 10^{-3}}\text{rad}$

$= 10^{-2} \times \left(\frac{180}{3.14}\right) \approx 0.57^{\circ}$

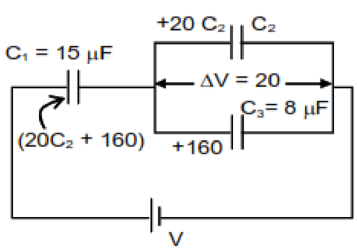
***Questions*: 9:-** In the circuit shown in the figure, the total charge is 750 μC_2 and the voltage across capacitor C_2 is 20 V. Then the charge on capacitor C is



(A) 160 μC **(B)** 650 μC

(C) 590 μC **(D)** 450 μC

***Ans*:- C**



Total charge on all cap (left plates)

$\Delta V = 20$ V

$\Rightarrow \quad 750 = (20\ C_2 + 660) \times 1$

$\Rightarrow \quad 20\ C_2 = 590\ \mu C$

***Questions*: 10:-** A 750 Hz, 20 V (rms) source is connected to a resistance of 100 Ω an inductance of 0.1803 H and a capacitance of 10 μF all in series. The time in which the resistance (heat capacity 2 J/°C) will get heated by 10°C. (assume no loss of heat to the surroundings) is close to:

(A) 348 s **(B)** 365 s

(C) 418 s **(D)** 245 s

***Ans*:- B**

Power loss in AC

$$P = \varepsilon_{rms}^2 R = \frac{\varepsilon_{rms}^2 R}{Z^2}$$

$\therefore \quad \Delta Q = Pt$

$$\Rightarrow \quad 2 \times 10 = \frac{(20)^2 \times 100 \times t}{(715600)}$$

$\Rightarrow \quad t = 358$ sec.

***Questions*: 11:-** Pressure inside two soap bubbles are 1.01 and 1.02 atmosphere, respectively. The ratio of their volumes is

(A) 4 : 1 **(B)** 0.8 : 1

(C) 2 : 1 **(D)** 8 : 1

***Ans*:- D**

$$\Delta P_1 = \frac{4T}{R_1} = 0.01 \qquad \ldots(1)$$

$$\& \quad \Delta P_2 = \frac{4T}{R_2} = 0.02 \qquad \ldots(2)$$

$$\therefore \quad \text{Ratio of volumes} \times \frac{R_1^3}{R_2^3} = \frac{1}{\left(\frac{1}{2}\right)^3} = 8:1$$

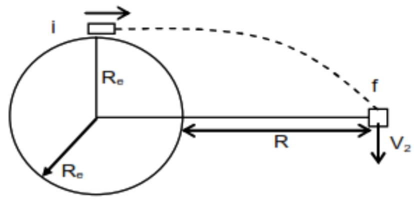
***Questions*: 12:-** A satellite is moving in a low nearly circular orbit around the earth. Its radius is roughly equal to that of the earth's radius R_e. By firing rockets attached to it, its speed is instantaneously increased in the direction of its motion so that it become $\sqrt{\frac{3}{2}}$ times larger. Due to this the farthest distance from the centre of the earth that the satellite reaches is R. Value of R is:

(A) $2.5R_e$ **(B)** $3R_e$

(C) $2R_e$ **(D)** $4R_e$

***Ans*:- C**

$$V = \sqrt{\frac{3}{2}}\sqrt{\frac{GMe}{R_e}} = \sqrt{\frac{36}{2R_e}}$$



Between two positions

COAM

$$m\sqrt{\frac{36\,M_e}{2\,R_e}}\,R_e = m(R_e + R)V_2 \quad ...(1)$$

COTME

$$-\frac{GM_e m}{R_e} + \frac{1}{2}m\frac{3GM_e}{2R_e} = \frac{-GMm}{(R_e + R)} + \frac{1}{2}mv_2^2 \quad ...(2)$$

Solving:

$$\Rightarrow \quad -\frac{GM_e m}{4R_e} = -\frac{GM_e m}{(R_e + R)} + \frac{m}{2}\frac{\left(\frac{36\,M_e}{2\,R_e}\right)R_e^2}{(R_e + R)^2}$$

Let $R_e + R = x$

$$-\frac{1}{4R_e} = -\frac{1}{x} + \frac{3R_e}{4x^2}$$

$$\Rightarrow \quad -x^2 = -4R_e n + 3R_e^2 \quad ; \quad x^2 + 4\,R_e x + R_e^2 = 0$$

$$\Rightarrow \quad x = \frac{4\,R_e + \sqrt{16\,R_e^2 + 12\,R_e^2}}{2}$$

$= (2R_e + R_e)$

$= R = 2R_e$

***Questions*: 13:-** Magnitude of magnetic field (in SI units) at the centre of a hexagonal shape coil of side 10 cm. 50 turns and carrying current I (Ampere) in units of $\frac{\mu_0 I}{\pi}$ is:

(A) $500\sqrt{3}$ **(B)** $50\sqrt{3}$

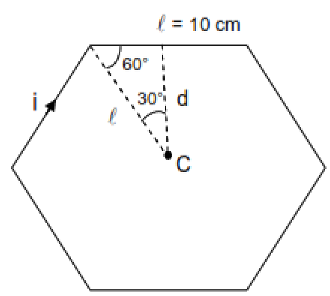
(C) $5\sqrt{3}$ **(D)** $250\sqrt{3}$

***Ans*:- A**

$$\vec{B}(\text{at C}) = 6 \times \frac{\mu_0 i}{4\pi d}(\sin 30^\circ \times 2) \times 50$$

$$= \frac{\mu_0 i}{\pi} \times \frac{3}{2 \times \left(0.1 \times \frac{\sqrt{3}}{2}\right)} \times 50$$

$$= \frac{\mu_0 i}{\pi} \times (500\sqrt{3})$$



***Questions*: 14:-**

The magnetic field of a plane electromagnetic wave is

$\vec{B} = 3 \times 10^{-8} \sin[200\,\pi(y + ct)]\,\hat{i}\,T$

where $c = 3 \times 10^8\ ms^{-1}$ is the speed of light.

The corresponding electric field is

(A) $\vec{E} = 9\sin[200\,\pi(y + ct)]\,\hat{k}\ V/m$ **(B)** $\vec{E} = -9\sin[200\,\pi(y + ct)]\,\hat{k}\ V/m$

(C) $\vec{E} = 3 \times 10^{-8}\sin[200\,\pi(y + ct)]\,\hat{k}\ V/m$ **(D)** $\vec{E} = -10^{-6}\sin[200\,\pi(y + ct)]\,\hat{k}\ V/m$

Ans:- **B**

$E_o = CB_o = 3 \times 10^8 \times 3 \times 10^{-8} = 9$ V/m

$\therefore \quad \vec{E} = -9 \sin[200\,\pi(y + ct)]\,\hat{k}$

<u>Direction of travel</u>

$\frac{d}{dt}(y + ct) = 0$

$\Rightarrow \quad \frac{ds}{dt} = -C \rightarrow \text{along } (-\hat{j})$

$\because \quad \vec{E} \times \vec{B}$ should be along $(-\hat{j})$

***Questions*: 15:-** Using screw gauge of pitch 0.1 cm and 50 divisions on its circular scale, the thickness of an object is measured. It should correctly be recorded as

(A) 2.121 cm **(B)** 2.123 cm

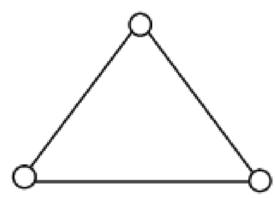
(C) 2.124 cm **(D)** 2.125 cm

Ans:- **C**

$LC = \frac{p}{N} = \frac{0.1\,\text{cm}}{50} = 0.02 \text{ mm} = 0.002 \text{ cm}$

Hence, measurement should be a multiple of LC

***Questions*: 16:-** Consider a gas of triatomic molecules. The molecules are assumed to be triangular and made of massless rigid rods whose vertices are occupied by atoms. The internal energy of a mole of the gas at temperature T is:



(A) $\frac{5}{2}RT$ **(B)** $\frac{3}{2}RT$

(C) 3RT **(D)** $\frac{9}{2}RT$

Ans:- **C**

$U = \frac{nfRT}{2}$

$= (1)(6)\frac{RT}{2} = 3RT$

***Questions*: 17:-** Two isolated conducting spheres S_1 and S_2 of radius 2/3R and 1/3R have 12 μC and –3 μC charges, respectively, and are at a large distance from each other. A conducting wire now connects them. A long time after this is done the charges on S_1 and S_2 are respectively:

(A) +4.5 μC and –4.5 μC **(B)** 4.5 μC on both

(C) 6 μC and 3 μC **(D)** 3 μC and 6 μC

Ans:- **C**

Spheres are in parallel.
So, $C_{aq} = C1 + C2 = 4\pi e_0(R_1 + R_2)$

$\therefore$ Potential, $V = \left(\dfrac{q_1 + q_2}{c_1 + c_2}\right)$

$\therefore$ $q_1 = Gv = \dfrac{2}{3}R \times \dfrac{(q)}{(R)} = 6\ \mu C$

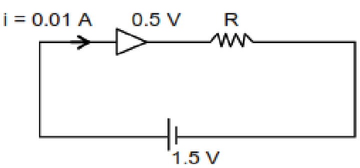
& $q_2 = 3\ \mu C$

***Questions*: 18:-** When a diode is forward biased, it has a voltage drop of 0.5 V. The safe limit of current through the diode is 10 mA. If a battery of emf 1.5 V is used in the circuit, the value of minimum resistance to be connected in series with the diode so that the current does
not exceed the safe limit is

(A) 100 Ω **(B)** 200 Ω

(C) 50 Ω **(D)** 300 Ω

***Ans*:- A**



KVL
$1.5 - 0.5 - 0.01\ R = 0$
$\Rightarrow$ $R = 100\ \Omega$

***Questions*: 19:-**

Moment of inertia of a cylinder of mass M, length L and radius R about an axis passing through its centre and perpendicular to the axis of the cylinder is $I = M\left(\dfrac{R^2}{4} + \dfrac{L^2}{12}\right)$. If such a cylinder is to be made for a given mass of a material, the ratio L/R for it to have minimum possible I is

(A) 2/3 **(B)** $\sqrt{3/2}$

(C) 3/2 **(D)** $\sqrt{2/3}$

***Ans*:- B**

Mass of material = CONSTANT

$\Rightarrow$ $(\pi R^2 L \rho) = M$ ...(1)

$\therefore$ $I = M\left(\dfrac{R^2}{4} + \dfrac{L^2}{12}\right) = M\left(\dfrac{M}{4\pi\rho L} + \dfrac{L^2}{12}\right)$

$\therefore$ For I maximum / minimum

$0 = \dfrac{dI}{DL} = M\left(-\dfrac{M}{4\pi\rho L^2} + \dfrac{L}{6}\right)$

$\Rightarrow$ $\dfrac{M}{\pi\rho L} = \dfrac{4}{6}L^2$

$\Rightarrow$ $R^2 = \dfrac{2}{3}L^2$ $\Rightarrow$ $\dfrac{L}{R} = \sqrt{\dfrac{3}{2}}$

***Questions*: 20:-** A balloon filled with helium (32°C and 1.7 atm.) bursts. Immediately afterwards the expansion of helium can be considered as:

(A) Irreversible adiabatic **(B)** reversible isothermal

(C) Reversible adiabatic **(D)** irreversible isothermal

Ans:- **D**
After burning, heat exchange occurs between helium and atmospheric. Hence, irreversible, isothermal process.