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# MOCK TEST PAPER # 2

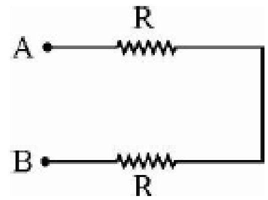
## SOLUTION

IITJEE (Main) PHYSICS

**1.(1)** The equivalent circuit is:

Rest of the resistors are shorted.

$\therefore \quad R_{AB} = 2R$




**2.(4)** For maximum current, net resistance of cells must be equal to $2.5\Omega$

i.e., $\dfrac{n(0.5)}{m} = 2.5$ ...(1)

and $m \times n = 45$ ...(2)

Solving, we get $n = 15$, $m = 3$

**3.(2)** When Jockey is not connected $I = \dfrac{E}{13r}$ ...(1)

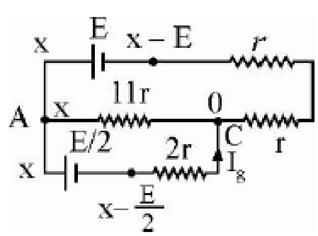
Resistance per unit length

$$\lambda = \frac{12r}{300}\,\Omega / cm$$

$\therefore \quad R_{AC} = \lambda l = \dfrac{12r}{300} \times 275$

$\therefore \quad R_{AC} = 11r$

Let potential at C is zero.

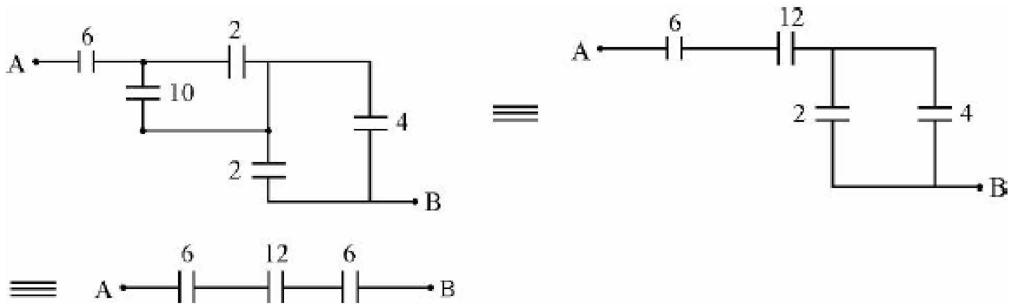



At A : $\dfrac{x-0}{11r} + \dfrac{x - \frac{E}{2} - 0}{2r} + \dfrac{(x - E - 0)}{2r} = 0$

$\Rightarrow \quad x = \dfrac{11E}{16}$

$$\therefore \quad I_g = \frac{x - \frac{E}{2}}{2r} = \frac{\left(\frac{11E}{16}\right) - \frac{E}{2}}{2r} = \frac{3E}{32r}$$

**4.(1)** The circuit is

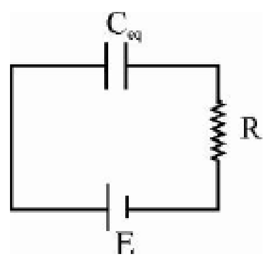



$\therefore \quad \frac{1}{C} = \frac{1}{6} + \frac{1}{12} + \frac{1}{6}$

$\Rightarrow \quad \frac{1}{C} = \frac{5}{12}$

$\therefore \quad C = \frac{12}{5}\mu F = 2.4\mu F$

**5.(3)** Charging of capacitor :




$$q = C_{aq}E\left[1 - e^{-\frac{t}{\tau}}\right]$$

Where, $\tau = RC_{eq}$

$$\therefore \quad q = C_{eq}E\left[1 - e^{-\frac{t}{RC_{eq}}}\right]$$

**6.(1)** Switch (1) : Final charge in charging = $C_1V$

$= 1\mu F \times 60 Volt = 60\mu C$

Switch (2) : $C_{23} = \frac{C_2C_3}{C_2 + C_3} = \frac{3\times 6}{3+6}\mu F = 2\mu F$


Charge is conserved $\quad \therefore \ q_1 + q_2 = 60\mu C$

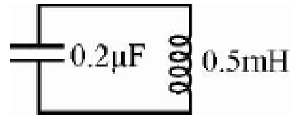
$V$ = common potential

$\therefore \quad V = \frac{q_1}{1} = \frac{q_2}{2} = \frac{q_1 + q_2}{1+2} = \frac{60}{3}$

$\therefore \quad q_2 = 40\mu C$

**7.(3)** Final charge on capacitor = $CV = 0.2\mu F \times 10\text{volt} = 2\mu C$

LC. Oscillation :




Initial charge = $Q_0 = 2\mu C$

$$Q = Q_0 \cos\omega t \text{ , where } \omega = \frac{1}{\sqrt{LC}}$$

$$V = \frac{Q}{C} = \frac{Q_0}{C} \cos\omega t \Rightarrow 5 = 10 \cos\omega t$$

$\therefore$ $\omega t = 60°$

$\therefore$ Current = I = $-\frac{dQ}{dt} = Q_0 \omega \sin\omega t$

$\Rightarrow$ $I = \frac{Q_0}{\sqrt{LC}} \sin 60°$ $\Rightarrow$ $I = \frac{2\times10^{-6}}{\sqrt{0.5\times10^{-3}\times0.2\times10^{-6}}} \times \frac{\sqrt{3}}{2} A$

$\therefore$ $I = 0.17A$

**8.(4)** Figure of merit $= \frac{I}{\theta} = 60\mu A$

$\Rightarrow$ $I = 9\times 60\mu A$

$\therefore$ $I = 540\mu A$

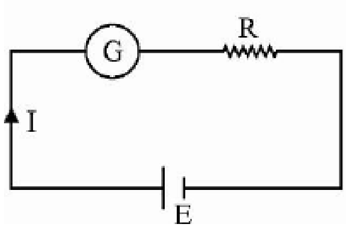
Also, $I = \frac{E}{R+G}$ ...(1)

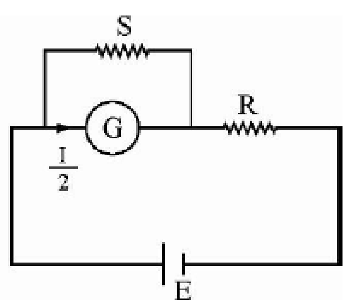
$\Rightarrow$ $540\times10^{-6} = \frac{6}{11000+G}$

$\therefore$ $G = 111\Omega$ ...(2)

Again, $\frac{I}{2} = \frac{E}{R+\frac{GS}{G+S}} \cdot \frac{S}{G+S}$

$\therefore$ $I = \frac{2SE}{RG+RS+GS}$ ...(3)



Equate (1) & (3),

$\Rightarrow \quad \frac{E}{R+G} = \frac{2SE}{RG+RS+GS} \quad \Rightarrow \quad RG+RS+GS = 2RS+2GS$

$\Rightarrow \quad RG = RS + GS \quad \Rightarrow \quad \boxed{S = \frac{RG}{R+G}}$

$\Rightarrow \quad S = \frac{11000 \times 111}{11111}\Omega$

$\therefore \quad S = 110\Omega$

**9.(2)** Average power $= <p> = \frac{1}{2}\varepsilon_0 i_0 \cos\phi$

Here, $\varepsilon_0 = 100,\ i_0 = 20, \phi = -\frac{\pi}{4}$

$\therefore \quad <p> = \frac{1}{2} \times 100 \times 20 \times \cos\frac{-\pi}{4}$

$<p> = \frac{1000}{\sqrt{2}}$

$|\text{Wattless current}| = I_{rms} \sin|\phi| = \frac{20}{\sqrt{2}}\sin\frac{\pi}{4} = \frac{20}{\sqrt{2}} \cdot \frac{1}{\sqrt{2}}$

$\therefore \quad |\text{Wattless current}| = 10.$

**10.(2)** Efficiency $= \eta = \frac{\text{output power}}{\text{Input power}}$

$\eta = \frac{\varepsilon_s I_s}{\varepsilon_p I_p}$

$\Rightarrow \quad I_s = \frac{\eta I_p \varepsilon_p}{\varepsilon_s} \quad \Rightarrow \quad I_s = \frac{0.9 \times 5 \times 2300}{230} A \quad \therefore \quad I_s = 45A$

**11.(3)** Magnetic flux, $\phi = n\vec{B}.\vec{A}$

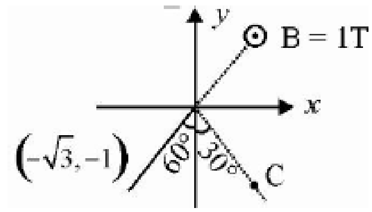
$\phi = nBA\cos\omega t$

$\therefore \quad |Induced\ emf| = |\varepsilon| = \left|\frac{d\phi}{dt}\right| \quad \Rightarrow \quad |\varepsilon| = nBA\ \omega|\sin\omega t|$

$\therefore \quad |\varepsilon|_{\max} = nBA\omega$

**12.(3)** By symmetry, the magnetic field at the centre P is zero.

**13.(3)** The centre will be at 'C' as shown:




Coordinates of the centre are $(r\cos 60°, -r\sin 60°)$

Where $r$ = radius of circle $= \frac{mv}{Bq} = \frac{1\times 1}{1\times 1} = 1$

i.e., $\left(\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$

**14.(2)** Magnetic field at the centre of loop due to straight wire is $B_0 = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0}{2\pi}$ tesla

Magnetic moment of the loop = M = NIA $= 100\times 2\times\pi\times 4\times 10^{-4}\ A.m^2$

$\therefore \quad M = 8\pi\times 10^{-2} A.m^2$

$\therefore \quad$ Torque acting on the loop $= |\vec{\tau}| = |\vec{M}\times\vec{B_0}| = MB_0\sin 90° = MB_0 = \frac{\mu_0}{25}$

**15.(1)** To demagnetise completely : $H = 100A/m = nI$

$\therefore \quad I = \frac{H}{n} = \frac{100}{1000}\times 10^{-2} A \quad \Rightarrow \quad I = 1\times 10^{-3} A$

$\therefore \quad I = 1mA$

**16.(4)** Assume a solid sphere without cavity.
Potential at A due to this solid sphere

$$\Rightarrow \quad V_A' = \frac{3}{2}\cdot\frac{1}{4\pi\varepsilon_0}\frac{\left(\frac{4}{3}\pi R^3\rho\right)}{R} = \frac{\rho R^2}{2\varepsilon_0}$$

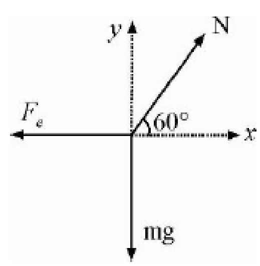
Now consider the cavity filled with negative charge

$$V_A'' = \frac{1}{4\pi\varepsilon_0}\frac{\frac{4}{3}\pi\left(\frac{R}{2}\right)^3(-\rho)}{\frac{R}{2}} = \frac{-\rho R^2}{12\varepsilon_0}$$

Now net value for the solid sphere with the cavity can be given by superposition of the above two cases.

Hence, $V_A = V_A' + V_A'' = \frac{\rho R^2}{\varepsilon_0}\left(\frac{1}{2}-\frac{1}{12}\right) = \frac{5\rho R^2}{12\varepsilon_0}$

**17.(1)** The bowl exerts a normal force N on each ball, directed along the radial line or at 60° above the horizontal. Consider the free-body diagram of the ball on the left with the electric force $F_e$ applied.




$$\sum F_y = N\sin 60° - mg = 0, \Rightarrow N = mg/\sin 60°$$

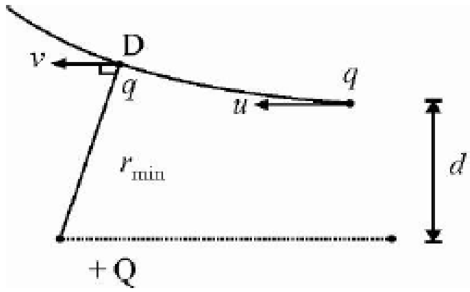
$$\sum F_x = -F_e + N\cos 60° = 0, \Rightarrow \frac{Kq^2}{R^2} = N\cos 60° = \frac{mg}{\tan 60°} = \frac{mg}{\sqrt{3}}$$

Thus, $q = R\left(\frac{mg}{K\sqrt{3}}\right)^{1/2}$

**18.(3)** The path of the particle will be as shown in the figure. At the point of minimum distance (D) the velocity of the particle will be $\perp$ to its position vector w.r.t to + Q.

Now by conservation of energy:

$$\frac{1}{2}mu^2 + 0 = \frac{1}{2}mv^2 + \frac{KQq}{r_{\min}} \qquad \ldots(1)$$




$\because$ Torque on q about Q is zero hence angular momentum about Q will be conserved

$\Rightarrow \quad m\,v r_{\min} = m\,ud \qquad \ldots(2)$

$$\text{By (2) in (1)} \Rightarrow \frac{1}{2}mu^2 = \frac{1}{2}m\left(\frac{ud}{r_{\min}}\right)^2 + \frac{KQq}{r_{\min}}$$

$$\Rightarrow \quad \frac{1}{2}mu^2\left(1 - \frac{d^2}{r_{\min}{}^2}\right) = \frac{mu^2 d}{r_{\min}} \qquad \{\because\ KQq = mu^2 d\,(\text{given})\}$$

$$\Rightarrow \quad r_{\min}^2 - 2r_{\min}d - d^2 = 0 \qquad \Rightarrow \qquad r_{\min} = \frac{2d \pm \sqrt{4d^2 + 4d^2}}{2} = d\left(1 \pm \sqrt{2}\right)$$

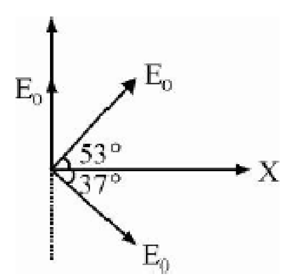
$\because$ Distance cannot be negative

$\therefore \quad r_{\min} = d\left(1 + \sqrt{2}\right)$

**19.(1)** Here, $E_x = E_0\cos 37^\circ + E_0\cos 53^\circ = \frac{4}{5}E_0 + \frac{3}{5}E_0 = \frac{7}{5}E_0$

and $E_y = E_0 + E_0\sin 53^\circ - E_0\sin 37^\circ = E_0 + \frac{4}{5}E_0 - \frac{3}{5}E_0 = E_0 + \frac{1}{5}E_0 = \frac{6F_0}{5}$

$\therefore \quad E_0' = \sqrt{E_x^2 + E_y^2} = \sqrt{\frac{49}{25} + \frac{36}{25}}E_0 = \sqrt{\frac{85}{25}}E_0 = \frac{\sqrt{85}}{5}E_0$

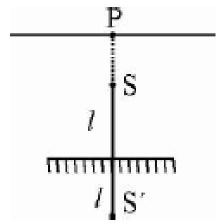



Here, $\tan\phi = \frac{E_y}{E_x} = \frac{\frac{6}{5}E_0}{\frac{7}{5}E_0} = \frac{6}{7}$

$\therefore \quad \phi = \tan^{-1}\left(\frac{6}{7}\right)$

Thus, $E = E_0'\sin(\omega t + \phi) = = \frac{\sqrt{85}}{5}E_0 \sin\left[\omega t + \tan^{-1}\left(\frac{6}{7}\right)\right]$

**20.(1)** The path difference at point P is




$$= 2l + SP + \frac{\lambda}{2} - SP$$

$$= 2l + \frac{\lambda}{2} = m\lambda$$

or $$2l = m\lambda - \frac{\lambda}{2}$$

$\therefore$ $$l = \frac{m\lambda}{2} - \frac{\lambda}{4} \quad \ldots\text{(i)}$$

When the mirror is shifted downward at distance, $l_0$

$$\Delta x' = 2(l + l_0) + \frac{\lambda}{2} = \left(m + \frac{1}{2}\right)\lambda$$

or $$l + l_0 = \left(m + \frac{1}{2}\right)\frac{\lambda}{2} - \frac{\lambda}{4}$$

or $$m\frac{\lambda}{2} - \frac{\lambda}{4} + l_0 = m\frac{\lambda}{2} + \frac{\lambda}{4} - \frac{\lambda}{4}$$

or $$l_0 = \frac{\lambda}{4} = \frac{600}{4} = 150\,nm$$

**21.(3)** At path difference $\frac{\lambda}{6}$, phase difference is $\frac{\pi}{3}$.

$$I = I_0 + I_0 + 2I_0 \cos\frac{\pi}{3} = 3I_0 \qquad I_{\max} = 4I_0$$

So the required ratio is $\frac{3I_0}{4I_0} = 0.75$

**22.(3)** For second minima, $\sin\theta = \frac{2\lambda}{a}$

$$\Rightarrow \quad \sin\theta = \frac{2 \times 550 \times 10^{-9}}{22 \times 10^{-7}} \quad \Rightarrow \quad \sin\theta = \frac{1}{2} \quad \Rightarrow \quad \theta = 30^\circ = \frac{\pi}{6}$$

**23.(3)** Let Angle between the direction of polarization and x-axis is $\alpha$.

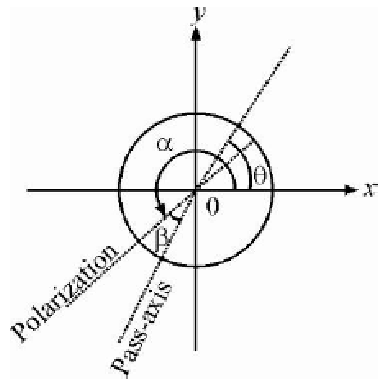
Let $\beta$ is angle between polarization and pass axis.

$$\beta = \alpha - \theta, \text{ if } 180° < \theta < 270°$$

Also, $\beta_1 = -\beta_2$ at $\theta_1 = 188°$ and $\theta_2 = 218°$

$\Rightarrow$ $\alpha - 188° = -(\alpha - 218°)$

$\therefore$ $\alpha = 203°$




**24.(2)** $\because$ $-\frac{1}{20} = (1.5-1)\left(-\frac{1}{R} - \frac{1}{R}\right)$

or $-\frac{1}{20} = -\frac{1}{R}$

$\therefore$ R = 20 cm

$\therefore$ The power of the silvered lens is P = $2P_l + P_m = -\frac{2}{20} - \frac{1}{10} = -\frac{2}{10} = -\frac{1}{5}$

The focal length of equivalent mirror is,

$$F = -\frac{1}{P} = 5cm$$

$\because$ $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

or $\frac{1}{v} - \frac{1}{40} = \frac{1}{5}$

$\therefore$ $v = \frac{40}{9} cm$

**25.(2)** $x = x_0 + A \sin \omega t$

$\therefore$ $x = 10 + 2 \sin \omega t$

$\therefore$ $u = -(10 + 2 \sin \omega t)$

(A) periodic motion

(C) Right amplitude $A_2 = \frac{40}{3} - 10 = \frac{10}{3} cm$,

Left amplitude $A_1 = 10 - \frac{60}{7} = \frac{10}{7} cm$

(D) $\therefore$ $v = \frac{fu}{u-f}, f = -5cm$

Image position :

When $x = 8cm$,

$$v_1 = \frac{(-5)\times(-8)}{-8+5} cm = -\frac{40}{3} cm$$

When $x = 12cm$,

$$v_2 = \frac{(-5)\times(-12)}{-12+5}cm = -\frac{60}{7}cm$$

$\therefore$ Distance between turning points $= |v_1| - |v_2| = \frac{40}{3} - \frac{60}{7} = \frac{100}{21}cm.$

$\therefore$ Correct options are A, C, D

**26.(2)** Total deviation $\delta = i - r + 180° - 2r + 180° - 2r + i - r$

$$\delta = 360° + 2i - 6r$$

For minimum $\delta, \frac{d\delta}{di} = 0$

$$\Rightarrow \quad 2 - 6\frac{dr}{di} = 0 \quad \Rightarrow \quad \frac{dr}{di} = \frac{1}{3} \quad \ldots(1)$$

Snell's' law

$$1\sin i = \mu \sin r \quad \Rightarrow \quad \cos i.\, di = \mu \cos r\, dr \quad \ldots(2)$$

$\therefore$ By (1) & (2)., $\cos i = \frac{\mu \cos r}{3}$

$$\Rightarrow \quad \cos i = \frac{\mu}{3}\sqrt{1-\sin^2 r} = \frac{\mu}{3}\sqrt{1-\frac{\sin^2 i}{\mu^2}}$$

$$\Rightarrow \quad \sqrt{\mu^2 - \sin^2 i} = 3\cos i \quad \Rightarrow \quad \mu^2 - 1 = 8\cos^2 i$$

$$\therefore \quad \cos i = \sqrt{\frac{\mu^2 - 1}{8}}$$

**27.(3)** Higher frequency causes photoemission of electron with largest kinetic energy

$$= f = \frac{\omega}{2\pi} = \frac{8\times10^{15}}{2\pi}s^{-1}$$

Maximum kinetic energy of photoelectrons is:

$$K_{max} = hf - \phi_0 = \frac{4.14\times10^{-15}\times8\times10^{15}}{2\pi} - 2.0 = 5.27 - 2.0 = 3.27eV$$

**28.(4)** After $t$ seconds, $\frac{N_A}{N_B} = \frac{N_0 e^{-10\lambda t}}{N_0 e^{-\lambda t}} = \frac{e^{-10\lambda\times1/9\lambda}}{e^{-\lambda\times1/9\lambda}} = \frac{e^{-\frac{10}{9}}}{e^{-\frac{1}{9}}} = e^{\left(-\frac{10}{9}+\frac{1}{9}\right)} = e^{-9/9} = e^{-1}$

**29.(4)** First we find the location of COM

$$Mx = m(r-x)$$

$$x = \left(\frac{m}{M+m}\right)r \qquad \ldots\text{(i)}$$

Centripetal force an electron is due to electrostatic attraction.

So, $m(r-x)\omega^2 = K.\frac{Ze^2}{r^2} \quad \Rightarrow \quad m\left(r - \frac{mr}{M+m}\right)\omega^2 = \frac{KZe^2}{r^2}$

$\Rightarrow \quad \left(\frac{m}{M+m}\right)Mr.\omega^2 = \frac{KZe^2}{r^2} \quad \Rightarrow \quad \left(\frac{Mm}{M+m}\right)r^3\omega^2 = KZe^2 \qquad \ldots\text{(ii)}$

Where, $\frac{Mm}{M+m} = \mu =$ reduced mass of system

Now, moment of inertia of system = $I = Mx^2 + m(r-x)^2$

Now, we substitute for $x$ from Equation (i) in above expression, we get

$$I = M\left(\frac{m}{M+m}\right)^2 .r^2 + m\left(r - \frac{mr}{M+m}\right)^2 = \frac{Mm^2r^2 + mM^2r^2}{(M+m)^2} = \left(\frac{Mm}{M+m}\right).r^2 = \mu r^2$$

$\therefore$ Angular momentum $= I\omega = \left(\frac{Mm}{M+m}\right)r^2\omega.$

**30.(1)** Current gain = $\beta = \frac{\Delta I_C}{\Delta I_B}$ ; Voltage gain = $\beta.\frac{R_L}{R_{BE}}$

Power gain = $\beta^2.\frac{R_L}{R_{BE}}$

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