IIT PHYSICS CENTRE
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ANSWERS AND SOLUTIONS

Ques.	1	2	3	4	5	6	7	8	9
Ans.	B	A	D	B	C	A	A,B	A,BC	A,D
Ques.	10	11	12	13	14	15	16	17	18
Ans.	A,B	A,C,D	B,C,D	2	6	6	3	4	1

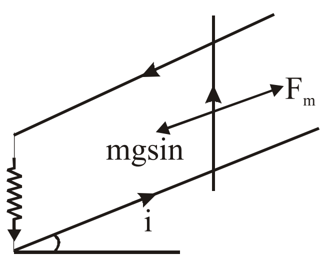
1. Terminal velocity is attained when magnetic force is equal to mg sinθ

$$F_m = mg\sin\theta$$

Or $iIB = mg\sin\theta$ Or $\left(\frac{e}{R}\right)IB = mg\sin\theta$ $\therefore$

Or $\frac{(Bv_T I)}{R} IB = mg\sin\theta$

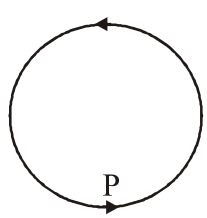
$$\therefore \quad v_T = \frac{mgR\sin\theta}{B^2 I^2}$$



2. $EI = \frac{d\phi}{dt} \therefore \quad E(2\pi R) = (\pi R^2)\frac{dB}{dt} \therefore$

$$E = \frac{R}{2}\frac{dB}{dt} \qquad q = \frac{qE}{m} = \frac{eR}{2m}\frac{dB}{dt}$$

At 'P' inducted electric lines towards right, force on electron will be towards left



3. L : R

$$0.6 = \frac{R}{\sqrt{R_1^2 + X_L^2}} \qquad ...(1)$$

$$0.5 = \frac{R_2}{\sqrt{R_2^2 + X_C^2}} \qquad ...(2)$$

$$I = \frac{R_1 + R_2}{\sqrt{(R_1 + R_2)^2 + (X_L + X_C)^2}} \qquad ...(3)$$

Solving these three equations we get,

$$\frac{R_1}{R_2} = \frac{3\sqrt{3}}{4}$$

4. Frequency $f \propto \sqrt{mg}$ or $f \propto \sqrt{g}$

In water $f_m = 0.8\, f_{air}$

$$\therefore \quad \frac{g'}{g} = (0.8)^2 = 0.64 \text{ Or } 1 - \frac{\rho_w}{\rho_m} = 0.64$$

$$\text{Or } \frac{\rho_w}{\rho_m} = 0.36$$

In liquid $\frac{g'}{g} = (0.6)^2 = 0.36 \therefore 1 - \frac{\rho_L}{\rho_m} = 0.36$

$$\text{Or } \frac{\rho_L}{\rho_m} = 0.64$$

From Eqs. (1) and (2)

$\frac{\rho_L}{\rho_W} = \frac{0.64}{0.36} \therefore \rho_L = 1.77$ Here, ρ_W = relative density of water = 1

ρ_m = relative density of m ass

And ρ_L = relative density of liquid.

5 We consider a small portion D*l* of the loop.
For equilibrium,

$$F = 2T\frac{\sin\theta}{2} = 2T\frac{\theta}{2} = T\theta$$

or $ID\textit{l}B = Tq$

6 $R = \frac{mv}{qB} = \frac{P}{qB}$

But kinetic energy $T = \frac{P^2}{2m}$ \ $P = \sqrt{2mT}$

$\therefore \quad R = \frac{\sqrt{2mT}}{qB}$

$\therefore \quad R' = \frac{\sqrt{2m(2T)}}{q(3B)}$

$$R' = \frac{\sqrt{2}}{3}R = \sqrt{\frac{2}{9}}R$$

Hence, option (C) is correct.

7. $X_C = \frac{1}{2\pi fC} = \frac{1}{(2\pi)(50/\pi)(0.02\times10^{-3})}$

$= 500\Omega$

$X_L = 2\pi f L = (2\pi)\ (50/\pi)\ (1) \qquad = 100\Omega$

$Z = \sqrt{R^2 + (X_C - X_L)^2} \qquad = 500\Omega$

$i_{rms} = \frac{E_{rms}}{Z} = 0.1A \quad (V_C)_{rms} = i_{rms}X_C = 50V$

8. $|e| = \left|\frac{d\phi}{dt}\right| = 4t \therefore \qquad i = \frac{|e|}{R} = 0.4t$

At $t = 2s, i = 0.8$ A

$i - t$ graph is straight line passing through origin.

$$\Delta q = \int_0^2 idt = \int_0^2 0.4t = 0.8C$$

9. This is a L-C circuit. Therefore,

$q = q_0 \cos \omega t$

And $V = V_0 \cos\omega t$

Where $\omega = \frac{1}{\sqrt{LC}}$

Or $T = 2\pi/\sqrt{LC}$

$i = \frac{dq}{dt} = -q_\theta\omega\sin(\omega t)$

(a) maximum current in the circuit is

$$i_{max} = q_\theta\omega = (CV_0)\frac{1}{\sqrt{LC}} = V_0\sqrt{\frac{C}{L}}$$

(b) potential across capacitor becomes zero after time $t = \frac{T}{4} = \frac{\pi}{2}\sqrt{LC}$

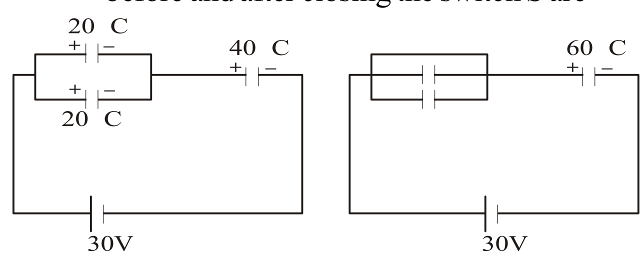
(c) at time $t = \frac{\pi}{2}\sqrt{LC}$ or T/4 energy stored in the capacitor is zero. Thus, the energy $\frac{1}{2}CV_0^2$ will be stored in the inductor.

(d) the maximum energy stored in the inductor will be $\frac{1}{2}CV_0^2$.

10. $\vec{\tau} = \vec{P}\times\vec{E} \qquad U = -\vec{P}.\vec{E}$

$U_{max} = PE$

11. The charges stored in different capacitors before and after closing the switch S are



$$\frac{40\times\cancel{2}}{\cancel{6}_3} = \frac{4}{\cancel{3}}(3\cancel{0})^{10}$$

The amount of charge flown through the battery is q = 20μC

$\therefore$ Energy S supplied by the battery is

U = qV = (20 × 10^{-6}) (30)J

$U = 0.6$ mJ

Energy stored in all the capacitors before closing the switch S is

$$U_i = \frac{1}{2}C_{net}V^2 = \frac{1}{2}\left(\frac{4}{3}\times 10^{-6}\right)(30)^2$$

$= 0.6$ mJ

And after closing the switch

$$U_f = \frac{1}{2}C_{net}V^2 = \frac{1}{2}(2\times 10^{-6})(30)^2 = 0.9\,mJ$$

$\therefore$ Heat generated $H = U - (U_f - U_i) = 0.3$ J

And charge flown through the switch is 60 μC

12. $\tau_{C_1} = \tau_{C_2} = 2CR = \tau_C$ (say)

$$q_1 = (EC)(1 - e^{-t/\tau_C})$$

And $q_2 = (2EC)(1 - e^{-t/\tau_C})$

$$\frac{q_1}{q_2} = \frac{1}{2} \quad \text{(at any time)}$$

$\therefore$ The ration of steady state charge is also 1 : 2

$$\left(\frac{dq_1}{dt}\right) = \frac{EC}{\tau_C}e^{-t/\tau_C}$$

And $\left(\frac{dq_2}{dt}\right) = \frac{2EC}{\tau_C}e^{-t/\tau_C}$

$\therefore$ $\left(\frac{dq_1}{dt}\right) \neq \left(\frac{dq_2}{dt}\right)$

$\therefore$ Option (a) is wrong.

13. $\frac{di}{dt} = \omega^2 q$

$$= \frac{q}{LC} = \frac{3.0\times 10^{-5}}{0.6\times 25\times 10^{-6}} = 2\,A/s$$

14. $i^2_{rms} = \frac{\int i\,dt}{\int dt}$

$$= \frac{\int_2^4 (4t)dt}{\int_2^4 dt} = \frac{4\int_2^4 t\,dt}{2} = 2\left[\frac{t^2}{2}\right]_2^4$$

$= 12\ A^2$

$i_{rms} = 2\sqrt{3}A$

15. $q = (2\mu F)(60V) = 12\ \mu C$,

$q_0 = (2\mu F)(12V) = 24\mu C$

$$\omega = \frac{2}{\sqrt{LC}} = \frac{1}{\sqrt{0.6\times 10^{-3}\times 2\times 10^{-6}}}$$

$= 2.9\times 10^4$ rad/s

$$i = \omega\sqrt{q_0^2 - q^2}$$

$$= (2.9\times 10^4)(10^{-6})\sqrt{(24)^2 - (12)^2} = 0.6A$$

16 Before connecting with wire, the total electrical energy is

$$U_i = \frac{q^2}{8\pi\varepsilon_0 a}$$

After connection with wire, all charges are transferred on outer sphere.

$\therefore$ $U_f = \frac{q^2}{8\pi\varepsilon_0 b}$

$\omega = 3$ rad/s.

17 If radii of spherical capacitor are 'a' and 'b' and air is filled between them, then

$$C = \frac{4\pi\varepsilon_0 ab}{b-a}$$

Given, $b - a = x = 1\text{ mm} = 10^{-3}$ m

$a = b - x,\ C = 10^{-6}$ F

$\therefore$ $10^{-6} = \frac{(b-x)b}{9\times 10^9\times 10^{-3}}$

or $b(b-x) = 9 \quad (\because \quad x << b)$

or $b^2 = 9$

$\therefore$ $b = 3$

18. $\lambda_\alpha - \lambda_m' = 3(\lambda_\alpha - \lambda_m)$

$$\therefore \frac{12375}{10.2(z-1)^2} - \frac{12375}{20\times 10^3} = 3\left[\frac{12375}{10.2(z-1)^2} - \frac{12375}{10\times 10^3}\right]$$

Solving we get z = 29