Section A

1.

(d) 10^{-3} to 10^{6} Ω cm

Explanation:

Resistivity of a semiconductor at room temp, is in between 10^{-3} to 10^{6} Ω cm.

2.

(b) R

Explanation:

In the balanced condition, the resistance R of the galvanometer is ineffective. We now have (R + R) and (R + R) resistances in parallel.

$\therefore R_\alpha = \frac{2R \times 2R}{2R + 2R}$ = R

3.

(d) complete image will be formed

Explanation:

Image formed will be complete when upper half of lens is blocked. Intensity of the image will decrease as the incident rays from upper half are cut off.

4.

(c) 2 : 1

Explanation:

2 : 1

5.

(c) $\frac{2}{\ln(2)}\mathrm{M}\Omega$

Explanation:

$U = \frac{q_0^2}{2C}$

At t = 1 s, energy reduces to half, so

$q = \frac{q_0}{\sqrt{2}}$

Now $q = q_0 e^{-\frac{t}{\tau}}$

$\therefore \frac{q_0}{\sqrt{2}} = q_0 e^{-1}$

$\Rightarrow e^{\frac{1}{t}} = \sqrt{2} \Rightarrow \frac{1}{\tau} = \ln(\sqrt{2})$

$\Rightarrow \tau = \frac{2}{\ln(2)}$

$\Rightarrow RC = \frac{2}{\ln(2)}$

$R = \frac{2}{C\ln(2)} = \frac{2}{10^{-6}\ln(2)}\Omega = \frac{2}{\ln(2)}\mathrm{M}\Omega$

6. **(a)** $e\left(v_x B_y - v_y B_x\right)\hat{k}$

Explanation:

$e\left(v_x B_y - v_y B_x\right)\hat{k}$

7.

(d) $\tau \ln(10/9)$

Explanation:

$I = I_0\left(1 - e^{\frac{-t}{\tau}}\right)$
and $I = 0.1I_0$
$e^{\frac{-t}{\tau}} = \frac{9}{10}$
$\frac{t}{\tau} = \ln\frac{10}{9}$
$t = \tau\ln\frac{10}{9}$

8.

(c) Lead
Explanation:
as Lead is diamagnetic substance.

9.

(d) 9I and I
Explanation:
$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$
I_1 = I, I_2 = 4I
On putting these values,
$I_{max} = (\sqrt{I} + \sqrt{4I})^2$
I_{max} = 9I
$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$
$I_{min} = (\sqrt{I} - \sqrt{4I})^2$
I_{min} = I

10.

(b) a parabola
Explanation:
The path of an electron in an electric field is determined by the forces acting on it. When an electron has an initial velocity that is not aligned with the electric field, it experiences a force due to the electric field that changes its direction of motion. This results in a curved trajectory. The combination of the initial velocity and the constant acceleration from the electric field leads to a parabolic path, similar to the motion of a projectile under gravity. Thus, the correct answer is that the path of the electron is a parabola.

11.

(c) $\frac{2I_m}{\pi}$
Explanation:
Current waveform can be represented as, $I = I_m sin\omega t$ for $0 \leq \omega t \leq 2\pi$, where I_m = max load current
Average current, $I_{DC} = \frac{I_m}{\pi}\int_0^{\pi}\sin(\omega t)\,\mathrm{d}(\omega t)$
$= \frac{I_m}{\pi}[-cos(\omega t)]_0^{\pi} = \frac{2I_m}{\pi}$

12.

(b) Become infinite
Explanation:
$\frac{1}{f} = (\frac{\mu_2}{\mu_1} - 1)(\frac{1}{R_1} - \frac{1}{R_2})$
Since, $\mu_2 = \mu_1$,
$\frac{1}{f} = 0,\ hence\ f = \infty$

13. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
Both A and R are true and R is the correct explanation of A.

14. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation:

Both A and R are true and R is the correct explanation of A.

15.

(b) Both A and R are true but R is not the correct explanation of A.

Explanation:

Both A and R are true but R is not the correct explanation of A.

16. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation:

Both A and R are true and R is the correct explanation of A.

Section B

17. Given:

i. Magnetic field in plane electromagnetic wave $B_y = 12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$

Now $B_0 = 12 \times 10^{-8}$T

Speed of light c = 3×10^8 m/s

From the relation: $E_0 = B_0 c$

$= 12 \times 10^{-8} \times 3 \times 10^8$

$E_0 = 36$ V/m

Now Energy Density can be calculated using:

Energy Density of the electromagnetic waves = $\frac{1}{2}\varepsilon_0 E_0^2$

Energy Density of the electromagnetic waves= $\frac{1}{2} \times \left(8.85 \times 10^{-12}\right) \times (36)^2$

Energy Density of electromagnetic waves = 5.74×10^{-15} J/m^3

ii. Magnetic field in plane electromagnetic wave

$B_y = 12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$

Now k = 1.2×10^7

$\omega = 3.6 \times 10^{15}$

Since, $\lambda = \frac{2\pi}{k}$ and $f = \frac{\omega}{2\pi}$

Hence the speed of wave: v = $\lambda \times f$

$= \frac{\omega}{k} = 3 \times 10^8 \mathrm{m/s}$

18. Let Q be the energy dissipated per unit volume per hysteresis cycle in the given sample. Then the total energy lost by the volume V of the sample in time t will be

W = Q $\times$ V $\times$ ν $\times$ t

where v is the number of hysteresis cycles per second.

Here Q = 300 Jm^{-3} cycle^{-1}, ν = 50 cycle s^{-1}, t = 1 h = 3600s

Volume, V = $\frac{\text{Mass}}{\text{Density}} = \frac{12}{7500}$ m^3

$\therefore$ Hysteresis loss,

W = $300 \times \frac{12}{7500} \times 50 \times 3600$ J = 86400 J

OR

Here W = 3.2×10^4 J, v = 50 cycle s^{-1}, t = 30 min = 1800 s

Volume, V = $\frac{\text{Mass}}{\text{Density}} = \frac{8.4}{7200}$ = kg m^{-3}

Energy dissipated per unit volume per cycle,

Q = $\frac{W}{V \times v \times t} = \frac{3.2 \times 10^4 \times 7200}{8.4 \times 50 \times 1800}$

= 304.8 Jm^{-3} cycle^{-1}

19. Since $n_e > n_h$, the semiconductor is n-type. The conductivity of the semi conductor is $e(n_e\mu_e + n_h\mu_h)$

= 1.6×10^{19} ((8×10^{13})(24000) + (4×10^{13})(200))mho/cm

= 0.32 mho cm^{-1}

=320 m mho cm^{-1}

20. a. Impact parameter is the perpendicular distance of the initial velocity vector of the α – particle from the centre of the nucleus.
Distance of closest approach: It is the minimum distance between the projected α – particle and the nucleus of target atom at which the kinetic energy of the α – particle becomes equal to potential energy of α-particle in the field of nucleus.
Minimum: When α-particle rebounds back $(\theta = \pi)$
Very large: when α-particle goes nearly undeviated and has a small deflection $(\theta = 0^o)$
b. According to Bohr's second postulate electron revolves only in those orbit for which angular momentum is $\frac{\mathrm{nh}}{2\pi}$.

21. Force on a charge moving parallel or antiparallel to the direction of the magnetic field is zero $F = \ qvB \sin\theta$

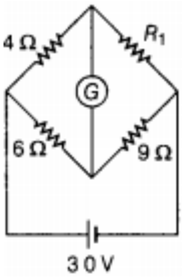
for (0^o or 180^o)

$\sin\theta\ = 0$

So Force =0

Section C

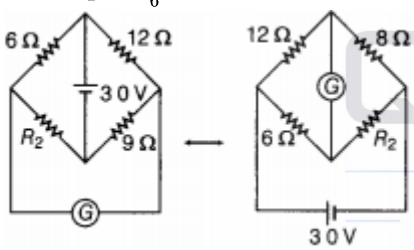
22. Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit current flows through it. The SI unit of current sensitivity is rad. A^{-1}. Current sensitivity is expressed as $\frac{\theta}{I} = \frac{NAB}{K}$ where N, A, B and K are number of turns, cross-sectional area, magnetic field intensity and galvanometer's constant respectively.



For balanced Wheatstone bridge, there will be no deflection in the galvanometer.

$\therefore \frac{4}{R_1} = \frac{6}{9}$

$\Rightarrow \quad R_1 = \frac{4\times 9}{6} = 6\Omega$



For the equivalent circuit. when the Wheatstone bridge is balanced, there will be no deflection in the galvanometer.

$\therefore \quad \frac{12}{8} = \frac{6}{R_2}$

$\Rightarrow \quad R_2 = \frac{6\times 8}{12} = 4\Omega$

$\therefore \quad \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$

23. Given that

Initial kinetic energy of photoelectrons is given by = K_1

Final kinetic energy of photoelectrons is given by $K_2 = 2K_1$

Wavelength of light changes from λ_1 to λ_2

Let the threshold frequency is ν_0 and work function is ϕ_0

Now, we know that:-

$\frac{\mathrm{hc}}{\lambda} = \phi_0 + \mathrm{KE}$

$\frac{\mathrm{hc}}{\lambda_1} = \phi_0 + K_1$ ...(i)

$\frac{\mathrm{hc}}{\lambda_2} = \phi_0 + K_2$ ...(ii)

$K_2 = 2K_1$

$\frac{\mathrm{hc}}{\lambda_2} = \phi_0 + 2K_1$ ...(iii)

$\frac{2\mathrm{hc}}{\lambda_1} = 2\phi_0 + 2K_1$ (eq (i) $\times$ 2)

$\frac{2\mathrm{hc}}{\lambda_1} - \frac{\mathrm{hc}}{\lambda_2} = \phi_0$

$\Rightarrow \phi_0 = \text{hc}\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

We know

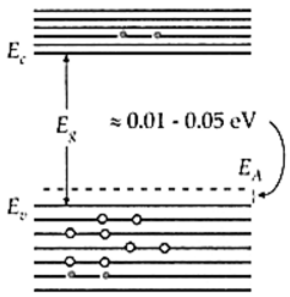
work function is given by $\phi_0 = \frac{\text{hc}}{\lambda_0}$

$\frac{\text{hc}}{\lambda_0} = \text{hc}\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

$\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}$

$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

24. For energy band diagram,



The expression for the conductivity of a p-type semiconductor: A p-type semiconductor has holes as the majority charge carriers.

$\therefore$ I = I_h = $en_h A v_h$

Also R = $\rho \frac{l}{A}$

$\therefore$ V = RI = $\rho \frac{l}{A} \cdot en_h A v_h$

E = $\frac{V}{l} = \rho e n_h v_h = \rho e n_h \cdot \mu_h E$ $\left[\because \mu_h = \frac{v_h}{E}\right]$

$\therefore$ Conductivity, $\rho = \frac{1}{\rho} = en_h \mu_h$

25. Nuclear fission is a process of splitting of a heavier nucleus into two lighter nuclei. It generally occurs in elements of high atomic mass.

Nuclear fusion is a process of a combination of two light nuclei to form heavier nuclei. It generally occurs in elements of low atomic mass. This process releases a tremendous amount of energy because some mass is converted into energy.

In both processes, the total mass of the products is slightly less than the mass of the original nuclei. This difference in mass is converted to energy.

In the given problem, mass defect is

Δm = 2.014102 + 3.016049 - 4.002603 - 1.008665

Δm = 0.018883 u

Energy released, ΔE = Δmc^2

ΔE = 0.018883 $\times$ 931.5 = 17.589 MeV

26. Total energy of the electron in hydrogen atom is –13.6 eV = –13.6 $\times$ 1.6 $\times$ 10^{-19} J = –2.2 $\times 10^{-18}$ J.

Thus from Eq., we have

$-\frac{e^2}{8\pi\varepsilon_0 r}$ = E

This gives the orbital radius

$r = -\frac{e^2}{8\pi\varepsilon_0 E} = -\frac{\left(9\times10^9 \text{Nm}^2/\text{C}^2\right)\left(1.6\times10^{-19}\text{C}\right)^2}{(2)\left(-2.2\times10^{-18}\text{J}\right)}$

= 5.3 $\times$ 10^{-11} m

The velocity of the revolving electron can be computed from Eq. with m = 9.1 $\times$ 10^{-31} kg,

$\frac{1}{2}mv^2 = \frac{e^2}{4\pi\epsilon_0 r^2}$ thus velocity of electron is given by :-

$v = \frac{e}{\sqrt{4\pi\varepsilon_0 m r^2}} = 2.2 \times 10^6 \text{m/s}$

27. angular width of central maxima of a single slit diffraction is given as $2\theta = \frac{2\lambda}{a}$

a. As λ increases (orange light has greater wave length) diffraction angle 2θ will also increase.

b. Increasing or decreasing closeness of screen and slit does not affect angular width.

c. If a (slit width) decreases, 2θ will increase as $2\theta \propto \frac{1}{a}$

28. i. In the one revolution, change of area,

$dA = \pi l^2$

$\therefore$ Change of magnetic flux in one revolution of the rod,

$d\phi_B = \vec{B} \cdot d\vec{A} = BdA\cos 0^\circ = B\pi l^2$

(Given, magnetic field intensity, $\vec{B}$ is parallel to change in area, $d\vec{A}$)

If period of revolution is T,

a. Induced emf (e) = {tex}\frac {d\phi}{dt} = \frac {Bπl^2}{T} = Bπl^2 \nu{/tex} ($\because \nu = \frac{1}{T}$)

b. Induced current in the rod,

$I = \frac{e}{R} = \frac{\pi\nu B l^2}{R}$

(Given R = resistance of the rod)

ii. Magnitude of force acting on the rod,

$|\vec{F}| = |I(\vec{l} \times \vec{B})| = BIlsin90^0 = \frac{\pi\nu B^2 l^3}{R}$

The external force required to rotate the rod opposes the Lorentz force acting on the rod, i.e external force acts in the direction opposite to the Lorentz force.

iii. Power required to rotate the rod,

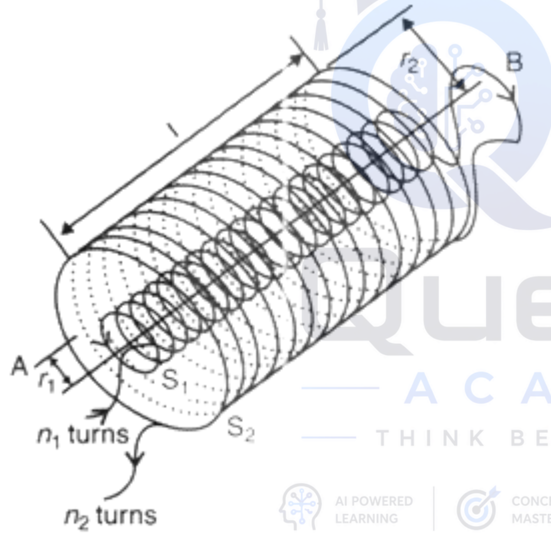
$P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi\nu B^2 l^3 v}{R}$

OR

i. Self-Inductance is the property by which an opposing induced emf is produced in a coil due to a change in current, or magnetic flux, linked with the coil.

The S.I. unit of self-inductance is Henry (H).

ii. In this question, a long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.



Let a current l_2 flow in the secondary coil

$\therefore$ $B_2 = \frac{\mu_0 N_2 i_2}{l}$

$\therefore$ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

= $M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_2}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

Section D

29. **Read the text carefully and answer the questions:**

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(i) **(d)** $\vec{E} \times \vec{B}$

Explanation:

Electromagnetic waves propagate in the direction of $\vec{E} \times \vec{B}$.

(ii) **(b)** photon

Explanation:

Photon is the fundamental particle in an electromagnetic wave.

(iii) **(a)** polarisation

Explanation:

Polarisation establishes the wave nature of electromagnetic waves.

OR

(d) frequency

Explanation:

Frequency ν remains unchanged when a wave propagates from one medium to another. Both wavelength and velocity get changed.

(iv) **(b)** in phase and perpendicular to each other

Explanation:

The electric and magnetic fields of an electromagnetic wave are in phase and perpendicular to each other.

30. i. There are two plates A and B having surface charge densities, $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on B, respectively. According to Gauss' theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$E_I = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$

ii. The electric field in region III is also zero.

$E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$

iii. In region II or between the plates, the electric field.

$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$

$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0\times10^{-22}}{8.85\times10^{-12}}$

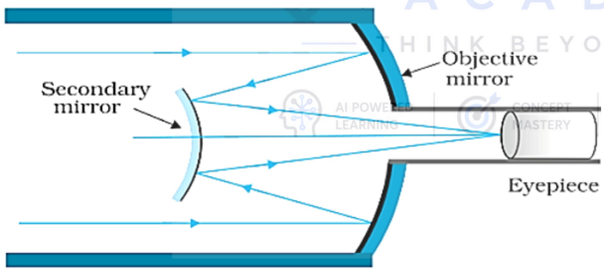
$E = 1.9 \times 10^{-10}$ NC^{-1}

iv. Since electric field due to an infinite-plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge. So, for the given distances, the ratio of E will be 1 : 1.

v. In order to estimate the electric field due to a thin finite plane metal plate, we take a cylindrical cross-sectional area A and length 2r as the Gaussian surface.

Section E

31. a.



It consists for large concave (primary) paraboidal mirror having in its central part a hole. There is a small convex (secondary) mirror near the focus of concave mirror. Eye pieces if placed near the hole of the concave mirror.

The parallel rays from distance object are reflected by the large concave mirror. These rays fall on the convex mirror which reflects these rays outside the hole. The final magnified image in formed.

b. For eyepiece.

$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

or $\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{40} - \frac{1}{10}$

$u_e = \frac{40}{3}$ cm

Magnification produced by eye pieces is

$m_e = \frac{v_e}{|u_e|} = \frac{40}{\frac{40}{3}} = 3$

Diameter of the image formed by the objective is

d = $\frac{6}{3}$ = 2 cm

If D be the diameter of the SUN then the angle subtended by it on the objective will be

$\alpha = \frac{D}{1.5 \times 10^{11}} \text{rad}$

Angle subtended by the image at the objective

= angle subtended by the SUN

$\therefore \alpha = \frac{\text{size of image}}{f_o} = \frac{2}{200} = \frac{1}{100} \text{rad}$.

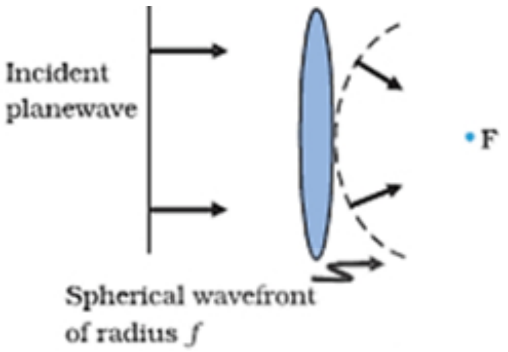
$\therefore \frac{D}{1.5 \times 10^{11}} = \frac{1}{100}$

or

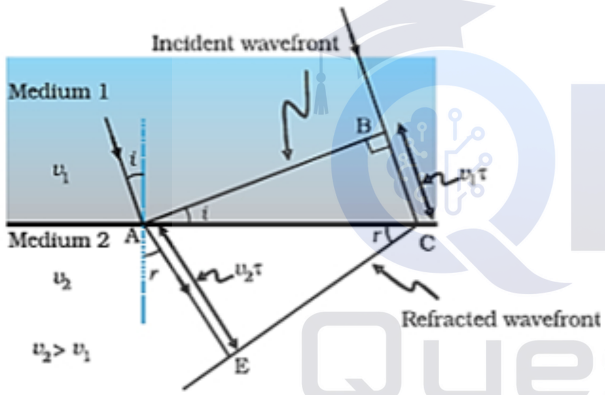
D = 1.5 $\times$ 10^9 m

OR

a.



b.



In right triangle ABC

$\sin i = \frac{BC}{AC}$

In $\triangle AEC$ $\sin r = \frac{AE}{AC}$

$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 \tau}{v_2 \tau} = \frac{v_1}{v_2} = \mu$

c. Speed of yellow light inside the glass slab

$v = \frac{c}{\mu}$

$= \frac{3 \times 10^8}{1.5}$ m/s

$= 2 \times 10^8$ m/s

Wavelength of yellow light inside the glass slab

$\lambda' = \frac{\lambda}{\mu}$

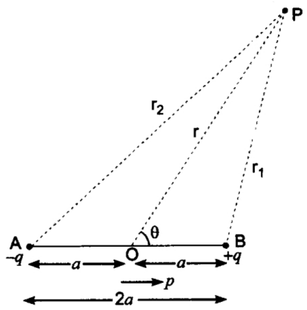
$= \frac{590}{1.5}$ nm

= 393.33 nm

32. Consider an electric dipole having charges -q and +q at separation '2a'. The dipole moment of dipole is $\vec{p} = q(\overrightarrow{2\,a})$, directed from -q to +q.

The electric potential due to dipole is the algebraic sum of potentials due to charges +q to -q

If r_1 and r_2 are distances of any point P from charge +q to -q respectively as shown in the figure, then the potential due to electric dipole at point P, is



$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$ ...(i)

If (r, θ) are polar coordinates of point P with respect to mid-point O of dipole, then

By geometry,

$r_1^2 = r^2 + a^2 - 2ar\cos\theta$ ...(ii)

and, $r_2^2 = r^2 + a^2 - 2ar\cos\theta$ ...(iii)

From (ii), $r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$

If r >> a i e.,$\frac{a}{r}$ <<1, then it is sufficient to retain terms only upto first order in $\left(\frac{a}{r}\right)$.

$\therefore r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r}\right] \Rightarrow r_1 = r\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(iv)

Similarly from (iii), ${r_2}^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right] \Rightarrow r_2 = r\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(v)

From (iv) and (v), $\frac{1}{r_1} = \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$ and, $\frac{1}{r_2} = \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$

Using binomial theorem and retaining terms upto first order in $\left(\frac{a}{r}\right)$ only, we have

$\frac{1}{r_1} = \frac{1}{r}\left[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r}\right] = \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$ ...(vi)

and, $\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$ ...(vii)

Substituting these values in (i), we get

$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) - \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)\right]$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[1 + \frac{a}{r}\cos\theta - 1 + \frac{a}{r}\cos\theta\right]$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[\frac{2a}{r}\cos\theta\right] = \frac{1}{4\pi\varepsilon_0}\frac{(q\cdot 2a)\cos\theta}{r^2}$

or, $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$ ...(viii)

But, $p\cos\theta = \vec{p}\cdot\hat{r}$ where, $\hat{r}$ is unit vector along position vector $\vec{OP} = \vec{r}$.

Electric potential due to an electric dipole is

$V = \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$ (for r >> a) $= \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\vec{r}}{r^3}$ ...(ix)

Contrasting features: The electric potential due to a dipole depends on distance r and also on the angle between position vector $\vec{r}$ and dipole moment $\vec{p}$. The electrostatic potential at large distances falls off, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$ which is the characteristic of potential due to a single charge.

Special Cases:

i. When point P lies on the axis of dipole, then θ = 0°

$\therefore$ cos θ = cos 0 = 1

$\therefore V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

ii. When point P lies on the equatorial plane of the dipole, then

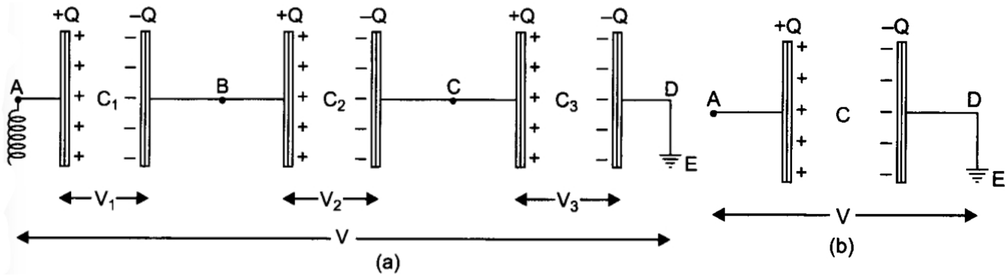
$\therefore$ cos θ = cos 90° = 0

$\therefore$ V = 0

It may be noted that the electric potential at any point on the equitorial line of a dipole is zero.

OR

i. In fig. (a) three capacitors of capacitances C_1, C_2, C_3 are connected in series between points A and D.



In series first plate of each capacitor has charge +Q and second plate of each capacitor has charge -Q i.e., charge on each capacitor is Q.

Let the potential differences across the capacitors C_1, C_2, C_3 be V_1, V_2, V_3 respectively. As the second plate of first capacitor C_1 and first plate of second capacitor C_2 are connected together, their potentials are equal. Let this common potential be V_B. Similarly the common potential of second plate of C_2 and first plate of C_3 is V_C. The second plate of capacitor C_3 is connected to earth, therefore its potential $V_D = 0$. As charge flows from higher potential to lower potential, therefore $V_A > V_B > V_C > V_D$.

For the first capacitor, $V_1 = V_A - V_B = \frac{Q}{C_1}$ ...(i)

For the second capacitor, $V_2 = V_B - V_C = \frac{Q}{C_2}$ ...(ii)

For the third capacitor, $V_3 = V_C - V_D = \frac{Q}{C_3}$ ...(iii)

Adding (i), (ii) and (iii), we get

$V_1 + V_2 + V_3 = V_A - V_D = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ ...(iv)

If V be the potential difference between A and D, then

$V_A - V_D = V$

$\therefore$ From (iv), we get

$V = (V_1 + V_2 + V_3) = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ ...(v)

If in place of all the three capacitors, only one capacitor is placed between A and D such that on giving it charge Q, the potential difference between its plates become V, then it will be called **equivalent capacitor**. If its capacitance is C, then

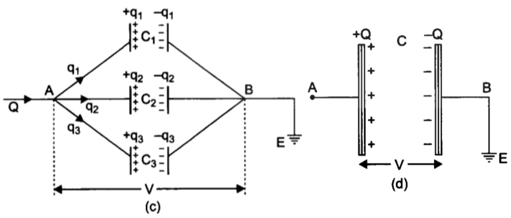
$V = \frac{Q}{C}$ ...(vi)

Comparing (v) and (vi), we get

$\frac{Q}{C} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ or $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ ...(vii)

Thus in series arrangement, "The reciprocal of equivalent capacitance is equal to the sum of the reciprocals of the individual capacitors."

ii. **Parallel Arrangement:** In fig. (c) three capacitors of capacitance C_1, C_2, C_3 are connected in parallel.



In parallel the potential difference across each capacitor is same V (say). Clearly the potential difference between plates of each capacitor

$V_A - V_B = V$ (say)

The charge Q given to capacitors is divided on capacitors C_1, C_2, C_3.

Let q_1, q_2, q_3 be the charges on capacitors C_1, C_2, C_3 respectively.

Then $Q = q_1 + q_2 + q_3$ ...(I)

and $q_1 = C_1V, q_2 = C_2V, q_3 = C_3V$

Substituting these values in (i), we get

$Q = C_1V + C_2V + C_3V$ or $Q = (C_1 + C_2 + C_3)V$ ...(ii)

If, in place of all the three capacitors, only one capacitor of capacitance C be connected between A and B; such that on giving it charge Q the potential difference between its plates be V, then it will be called equivalent capacitor. If C be the capacitance of equivalent capacitor, then

Q = CV ...(iii)

Comparing equations (ii) and (iii), we get

$CV = (C_1 + C_2 + C_3)V$ or $C = (C_1 + C_2 + C_3)$

Important Note: It may be noted carefully that the formula for the total capacitance in series and parallel combination of capacitors is the reverse of corresponding formula for combination of resistors in current electricity.

33. i. The figure shows the variation of resistance and reactance versus angular frequency, thus the Curve B corresponds to inductive reactance and curve C corresponds to resistance.

ii. At resonance,

$X_L = X_C$

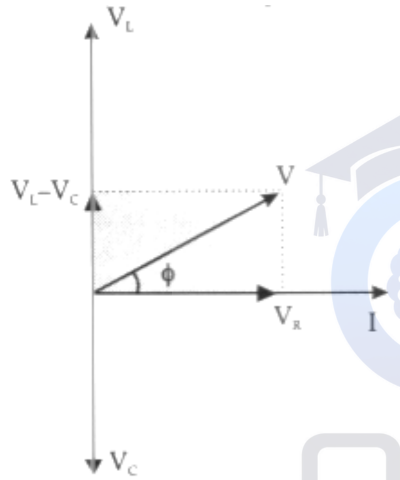
Therefore, impedance is given as:

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

Z = R

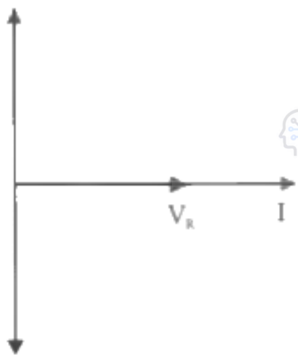
Thus, a series LCR circuit at resonance behaves as a purely resistive circuit.

Fr $X_L > X_C$, $V_L > V_C$. Therefore a phasor diagram is:



Here, ϕ is phase difference.

For $X_L = X_C$, $V_L = V_C$. Therefore phasor diagram is:

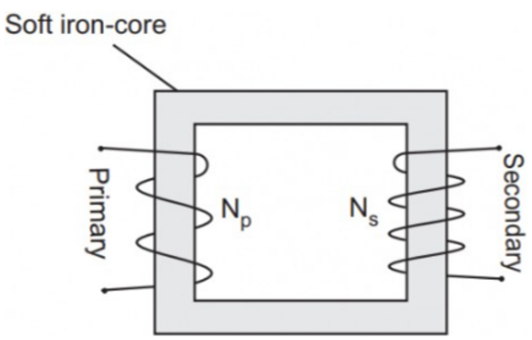


iii. A Series resonance LCR circuit is called an acceptor circuit.

They are widely used in the tuning mechanism of a radio or a TV.

OR

i.



The working principle of transformer is mutual induction.

When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it.

Causes of energy losses

a. **Copper Losses (I^2R Losses):**
Explanation: These losses occur due to the resistance of the wire in the coils. When current flows through the wire, some energy is dissipated as heat due to the resistance.
Mitigation: Using thicker wires with lower resistance and cooling mechanisms can help reduce these losses.

b. **Core Losses (Iron Losses):**
Explanation: Core losses include hysteresis loss and eddy current loss. Hysteresis loss occurs due to the lagging of magnetic domains behind the changing magnetic field. Eddy current loss is caused by circulating currents induced within the core material due to the changing magnetic field.
Mitigation: Using laminated silicon steel cores reduces eddy currents, and using materials with low hysteresis loss minimizes core losses.

c. **Leakage Flux:**
Explanation: Not all magnetic flux produced by the primary coil links with the secondary coil. Some flux "leaks" and does not contribute to energy transfer between coils, leading to inefficiency.
Mitigation: Improving core design and using better core materials can help reduce leakage flux.

ii. A step-up transformer does not violate the conservation of energy. It increases voltage by decreasing current proportionally. The power input (low voltage, high current) equals the power output (high voltage, low current), ensuring energy conservation. The transformer merely transfers energy, with losses typically due to inefficiencies.

iii. 1. $\frac{V_s}{V_P} = \frac{N_s}{N_P}$

$V_s = \frac{N_s}{N_P} \times V_P = \frac{3000}{200} \times 90$

$V_s = 1350 \text{ V}$

2. $\frac{I_P}{I_s} = \frac{N_s}{N_P}$

$I_P = \frac{3000}{200} \times 2 = 30 \text{ A}$