

Section A

1.

(b) decreases with increase in V

Explanation:
The width of the depletion layer decreases with the increase in forward bias voltage.
2.

(d) The algebraic sum of changes in potential around any closed loop must be zero.

Explanation:
Kirchhoff's loop rule is based on the principle of conservation of energy. Since work done in transporting a charge in a closed loop is zero. The algebraic sum (since potential differences can be both positive and negative) of potential differences around any closed loop is always zero.
3.

(b) 5

Explanation:
Two plane mirrors placed asymmetrically at 70 degrees.
Number of images $\frac{360}{70} = 5$ (highest integral value)
4.

(c) spin motion of electrons

Explanation:
spin motion of electrons
5.

(c) $\frac{2\kappa_1 \kappa_2}{\kappa_1 + \kappa_2}$

Explanation:
For the original capacitor, $C = \frac{\epsilon_0 A}{d}$
The new arrangement is equivalent to a series combination of two capacitors, each with plate area A and separation $\frac{d}{2}$
The new capacitance C_1 is given by

$$\frac{1}{C_1} = \frac{1}{C} + \frac{1}{C'} = \frac{1}{\frac{\epsilon_0 A \kappa_1}{(\frac{d}{2})}} + \frac{1}{\frac{\epsilon_0 A \kappa_2}{(\frac{d}{2})}}$$

$$= \frac{d}{2\epsilon_0 A} \left(\frac{1}{\kappa_1} + \frac{1}{\kappa_2} \right)$$

or $C_1 = \frac{2\epsilon_0 A}{d} \left(\frac{\kappa_1 \kappa_2}{\kappa_1 + \kappa_2} \right)$

$$\therefore \frac{C_1}{C} = \frac{2\kappa_1 \kappa_2}{\kappa_1 + \kappa_2}$$
6.

(b) $\frac{\mu_0 q f}{2R}$

Explanation:
Current, $I = \frac{q}{T} = qf$
 $B = \frac{\mu_0 I}{2R} = \frac{\mu_0 q f}{2R}$

7.

(d) 30°

Explanation:

$$\varepsilon = -\frac{\phi_2 - \phi_1}{t}$$

$$125 \times 10^{-3} = -\frac{0 - 1 \times 0.5 \times 0.5 \times \cos(90^\circ - \theta)}{0.1}$$

$$125 \times 10^{-3} = 0.50 \times 0.50 \times \sin \theta$$

$$\sin \theta = \frac{125 \times 10^{-3}}{0.50 \times 0.50} = \frac{1}{2}$$

$$\theta = 30^\circ$$

8.

(b) $\mu \propto n$

Explanation:

$$L = n \cdot \frac{h}{2\pi} \text{ and } \mu = \frac{e}{2m} \cdot L$$

$$\therefore \mu = \frac{e}{2m} \cdot \frac{nh}{2\pi} \therefore \mu \propto n.$$

9.

(c) $\sin^{-1} \left(\frac{3}{4} \right)$

Explanation:

The condition for first minimum is

$$a \sin \theta = \lambda$$

$$\Rightarrow a \sin 30^\circ = \lambda$$

$$\Rightarrow a = 2\lambda$$

The condition for first secondary maximum is

$$a \sin \theta_1 = \frac{3\lambda}{2}$$

$$\Rightarrow \sin \theta_1 = \frac{3\lambda}{2a} = \frac{3\lambda}{2 \times 2\lambda} = \frac{3}{4}$$

$$\therefore \theta_1 = \sin^{-1} \left(\frac{3}{4} \right)$$

10. (a) directly proportional to the product of both charges.

Explanation:

The magnitude of the electric force F is directly proportional to the amount of an electric charge, q_1 , multiplied by the other, q_2 , and inversely proportional to the square of the distance 'r' between their centres.

11.

(b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junction

Explanation:

When p-n junction is forward biased, it opposes the potential barrier across junction. When p-n junction is reverse biased, it supports the potential barrier junction, resulting increase in potential barrier across the junction.

12.

(c) Total internal reflection

Explanation:

When light travelling in an optically dense medium hits a boundary at a steep angle, the light is completely reflected. This is called total internal reflection. This effect is used in optical fibres to confine light in the core.

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

Explanation:

Yes, because the metal will provide additional energy to the emitted photoelectron for light of higher frequency than that for lower frequency.

14.

(c) A is true but R is false.

Explanation:

A is true but R is false.

15.

(d) A is false but R is true.

Explanation:

When a light wave travels from rarer to denser medium, its speed decreases. But this reduction of speed does not imply the loss of energy carried by the light wave. So, the assertion is false.

Energy of wave is proportional to the frequency of the wave which remains same in every medium. Hence there is no loss of energy. So, the reason is true.

16.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

Explanation:

Assertion and reason both are correct statements but reason is not correct explanation for assertion.

Section B

17. The standard equation of magnetic field can be expressed as $B = B_0 \sin \omega t$.

We are given equation

$$B = 12 \times 10^{-8} \sin (120 \times 10^7 z - 3.60 \times 10^{15} t) \text{ T}$$

On comparing this equation with standard equation, we get

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

The average intensity of the beam is given by :-

$$I_{\text{av}} = \frac{1}{2} \frac{B_0^2}{\mu_0} \cdot c = \frac{1}{2} \times \frac{(12 \times 10^{-8})^2 \times 3 \times 10^8}{4\pi \times 10^{-7}} \\ = 1.71 \text{ W/m}^2$$

18. Torque of solenoid is given by

$$\tau = MB \sin \theta$$

$$= (NIA) B \sin \theta$$

$$= 1000 \times 2 \times 2 \times 10^{-4} \times 0.32 \times \frac{1}{2}$$

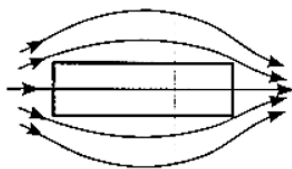
$$= 0.064 \text{ Nm}$$

OR

i. P is a paramagnetic bar. The lines of force get concentrated inside the material as shown in figure.



ii. Q is a diamagnetic bar. The lines of force get expelled from it as shown in figure.



19. Here, $\frac{n_p}{n_s} = 10$

R.M.S. primary voltage, $V_{\text{rms}} = 230 \text{ V}$

$$\text{Maximum primary voltage, } V_{m_p} = \sqrt{2} \times V_{\text{rms}} = \sqrt{2} \times 230 = 325.3 \text{ V}$$

$$\text{Maximum secondary voltage, } V_{m_s} = V_{m_p} \times \frac{n_s}{n_p} = 325.3 \times \frac{1}{10} = 32.53 \text{ V}$$

$$\text{Half wave rectified current, } I_{dc} = \frac{I_0}{\pi}$$

$$\text{Output dc voltage} = I_{dc} \times R_L$$

$$= \frac{I_0}{\pi} \times R_L = \frac{V_{m_s}}{\pi}$$

$$= \frac{32.53}{3.14} = 10.36 \text{ V}$$

20. Here, ground state energy, $E = -13.6 \text{ eV}$

$$\text{Kinetic energy, } E_k = \frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{2r}$$

$$\text{and Potential energy, } E_p = -\frac{1}{4\pi\epsilon_0} \frac{e^2}{r} [\because E_p = -2E_k]$$

$$\text{Total energy, } E = E_k + E_p$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{2r} - \frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{r}$$

$$E = -\frac{1}{2} \left(\frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{r} \right)$$

$$-13.6 = -\frac{1}{2} \left(\frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{r} \right)$$

$$\therefore \frac{1}{4\pi\epsilon_0} \frac{e^2}{r} = 27.2$$

$$\therefore E_k = \frac{1}{4\pi\epsilon_0} \frac{e^2}{2r} = \frac{27.2}{2} \text{ eV} = 13.6 \text{ eV}$$

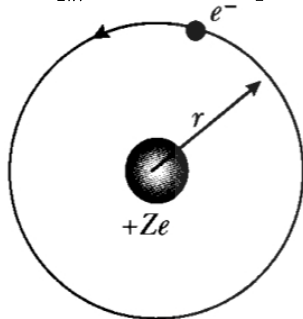
$$E_p = -\frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{r} = -27.2 \text{ eV}$$

21. a. If field lines were extremely confined between two ends of a straight solenoid, the flux through the cross section at each end would be non zero. But the flux of field B through any closed surface must always be zero, For a toroid this difficulty is absent.

b. No, there is no force on torque on an element due to the field produced by that element itself.

$$c. I = \frac{e}{T}, T = \frac{2\pi r}{v}$$

$$I = \frac{ev}{2\pi r}, \mu = I\pi r^2 = \frac{evr}{2}$$



Section C

22. a. Ohm's law state that keeping the physical conditions (temperature, pressure and material) constant, potential difference across the conductor is directly proportional to the current flowing through the two ends of the conductor.

$$V \propto I$$

$$\frac{V}{I} = \text{constant} = R \text{ (where } R \text{ is called as resistance)}$$

b. Resistance offered by a conductor is said to be 1ohm when a potential difference of 1 V is set up between the ends of the conductor and 1 A current flows through the ends of the conductor.

$$c. I = 0.5 \text{ A}$$

$$V = 2 \text{ V}$$

$$R = ?$$

$$R = \frac{V}{I} = \frac{2}{0.5} = 4\Omega$$

23. a. $\lambda = 200 \text{ nm}$, stopping potential = -2.5 V

$$\text{K.E.} = 2.5 \times 1.6 \times 10^{-19} \text{ J} = 4 \times 10^{-19} \text{ J}$$

$$E = h\nu = h\frac{c}{\lambda}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{200 \times 10^{-9}}$$

$$= 9.945 \times 10^{-19} \text{ J}$$

$$\text{Work function} = E - eV$$

$$= (9.945 \times 10^{-19} - 4 \times 10^{-19}) \text{ J}$$

$$= 5.595 \times 10^{-19} \text{ J}$$

b. Wavelength of red light = $6328 \text{ \AA}$

$$E = h\nu = h\frac{c}{\lambda}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{6328 \times 10^{-10}}$$

$$= 0.00314 \times 10^{-16} \text{ J}$$

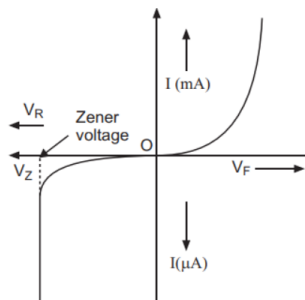
$$= 3.14 \times 10^{-19} \text{ J}$$

Energy of red light < work function of metal surface

∴ No emission of photoelectrons takes place.

24. **Zener diode:** A junction diode specially designed to operate only in the reverse breakdown region continuously (without getting damaged) is called a Zener diode.

I-V characteristics

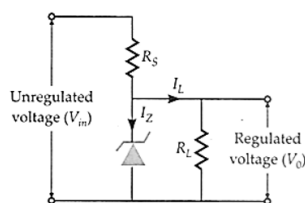


Zener diode as a Voltage Regulator

The Zener diode makes its use as a voltage regulator due to the following property:

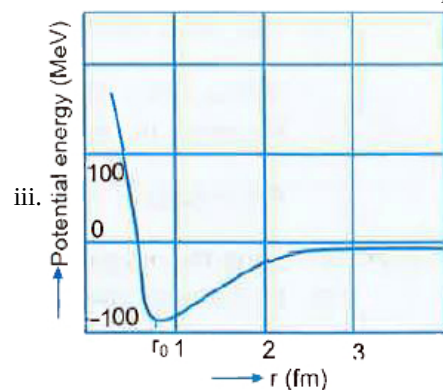
When a Zener diode is operated in the breakdown region, the voltage across it remains practically constant for a large change in the current.

A simple circuit of a voltage regulator using a Zener diode is shown in the figure. The Zener diode is connected across load such that it is reverse biased.



The series resistance R absorbs the output voltage fluctuations so as to maintain a constant voltage across the load. If the input dc voltage increases, the current through the R and Zener diode also increases. So, the voltage drop across R increases, without any change in the voltage across the Zener diode.

25. i. The density of nuclear matter is approximately $2.3 \times 10^{17} \text{ kgm}^{-3}$ which is tremendously larger than the density of ordinary material, say water, which is 10^3 kgm^{-3} . This is due to the fact that most of an atom is empty and its whole mass is concentrated at its nucleus. Ordinary material, consisting of atoms, has a large amount of empty space and consequently its density is small.
- ii. Coulombian force between two protons is repulsive. However, within a nucleus a number of protons and neutrons exist together within a very small space. So it is clear that nuclear force is not coulomb force but is an extremely short range force which is attractive in nature and is responsible for maintaining all the nucleons together.



26. **Bohr's quantization condition of angular momentum:** According to Bohr, the electron can revolve in certain discrete orbits called stationary orbits. The total angular momentum (L) of the revolving electron is an integral multiple of $\frac{h}{2\pi}$.

$$\text{Thus, angular momentum, } L = mvr = \frac{nh}{2\pi}$$

where $n = 1, 2, 3, \dots$

Brackett series is obtained when an electron jumps to fourth orbit ($n_1 = 4$) from any outer orbit ($n_2 = 5, 6, 7, \dots$) of the hydrogen atom.

The wavelength of a spectral line is given as

$$\frac{1}{\lambda} = RZ \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

where R is Rydberg's constant ($1.097 \times 10^7 \text{ m}^{-1}$) and Z is the atomic number ($Z = 1$ for hydrogen atom). For Brackett series, $n_1 = 4$ and $n_2 = 5, 6, 7 \dots$

Therefore,

$$\frac{1}{\lambda} = R \left(\frac{1}{4^2} - \frac{1}{n_2^2} \right)$$

For the shortest wavelength, $n_2 = \infty$. Therefore,

$$\frac{1}{\lambda} = R \left[\frac{1}{4^2} - \frac{1}{\infty^2} \right] = R \left(\frac{1}{4^2} - 0 \right)$$

$$\frac{1}{\lambda} = \frac{R}{16} = \frac{1.097 \times 10^7}{16}$$

$$\Rightarrow \lambda = \frac{16}{1.097 \times 10^7} = 14.585 \times 10^{-7}$$

or $\lambda = 1458.5 \text{ nm}$.

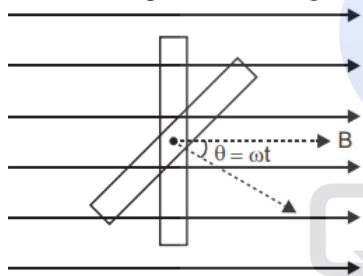
The shortest wavelength of the Brackett series is 1458.5 nm.

This wavelength belongs to infrared range of electromagnetic spectrum.

27. As n increases, deviation of light from straight direction increases thus the light spread out more and which result in decreasing intensity of bright fringes.

In interference pattern the fringes are of equal width (dark and bright) and are of equal intensity and in diffraction the central maxima is brightest and its width is wider twice as compare to the other maxima and intensity of bands goes on decreasing as we move away from the Centre.

28. i. Suppose initially the plane of coil is perpendicular to the magnetic field B. When coil rotates with angular speed ω , then after time t, the angle between magnetic field vector B and normal to plane of coil is



$$\theta = \omega t$$

$\therefore$ At this instant magnetic flux linked with the coil $\phi = BA \cos \omega t$. If coil contains, N-turns, then emf induced in the coil.

If coil contains, N-turns, then emf induced in the coil

$$\varepsilon = -N \frac{d\phi}{dt} = -N \frac{d}{dt} (BA \cos \omega t)$$

$$= +NBA\omega \sin \omega t$$

$\therefore$ For maximum value of emf ε ,

$$\sin \omega t = 1$$

$\therefore$ Maximum emf induced, $\varepsilon_{\max} = NBA\omega$

- ii. If R is resistance of coil, the current induced, $I = \frac{\varepsilon}{R}$

$\therefore$ Instantaneous power dissipated,

$$P = \varepsilon I = \varepsilon \left(\frac{\varepsilon}{R} \right) = \frac{\varepsilon^2}{R}$$

$$= \frac{N^2 B^2 A^2 \omega^2 \sin^2 \omega t}{R}$$

but, $(\sin^2 \omega t)_{av} = \frac{1}{2}$ (Average power dissipated in a complete cycle is obtained by taking average value of $\sin^2 \omega t$ over a complete cycle which is $\frac{1}{2}$)

$$\therefore \text{Average power dissipated } P_{av} = \frac{N^2 B^2 A^2 \omega^2}{2R}$$

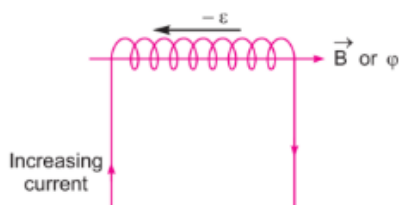
OR

Using formula, $|\varepsilon| = L \frac{dI}{dt}$

If $\frac{dI}{dt} = 1 \text{ A/s}$, then $L = |\varepsilon|$

Self inductance of the coil is equal to the magnitude of induced emf produced in the coil itself when the current varies at rate 1 A/s.

Expression for magnetic energy:



When a time varying current flows through the coil, back emf ($-\epsilon$) produces, which opposes the growth of the current flow. It means some work needs to be done against induced emf in establishing a current I . This work done will be stored as magnetic potential energy.

For the current I at any instant, the rate of work done is

$$\frac{dW}{dt} = (-\epsilon)I$$

Only for inductive effect of the coil $|\epsilon| = L \frac{dI}{dt}$

$$\therefore \frac{dW}{dt} = L \left(\frac{dI}{dt} \right) I \Rightarrow dW = LI dI$$

From work-energy theorem,

$$dU = LI dI$$

$$\therefore U = \int_0^I LI dI = \frac{1}{2} LI^2$$

Section D

29. Read the text carefully and answer the questions:

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ϵ will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

- (i) (d) $ML^{-1}T^{-2}$

Explanation:

$$\frac{1}{2} \epsilon_0 E^2 = \text{energy density} = \frac{\text{Energy}}{\text{Volume}}$$

$$\therefore \left[\frac{1}{2} \epsilon_0 E^2 \right] = \frac{ML^2 T^{-2}}{L^3} = [ML^{-1}T^{-2}]$$

- (ii) (c) $[\epsilon_0] = M^{-1}L^{-3}T^4A^2$

Explanation:

$$\text{As } \epsilon_0 = \frac{q_1 q_2}{4\pi F R^2} \text{ (from Coulomb's law)}$$

$$\epsilon_0 = \frac{C^2}{Nm^2} \frac{[AT]^2}{MLT^{-2}L^2} = M^{-1}L^{-3}T^4A^2$$

- (iii) (d) wavelength is halved and the frequency remains unchanged.

Explanation:

The frequency of the electromagnetic wave remains same when it passes from one medium to another.

$$\text{Refractive index of the medium, } n = \sqrt{\frac{\epsilon}{\epsilon_0}} = \sqrt{\frac{4}{1}} = 2$$

Wavelength of the electromagnetic wave in the medium,

$$\lambda_{\text{med}} = \frac{\lambda}{n} = \frac{\lambda}{2}$$

OR

- (b) β -rays

Explanation:

β -rays consists of electrons which are not electromagnetic in nature.

- (iv) (a) the speed of light $c = 3 \times 10^8 \text{ m s}^{-1}$ in free space

Explanation:

The velocity of electromagnetic waves in free space (vacuum) is equal to velocity of light in vacuum (i.e., $3 \times 10^8 \text{ m s}^{-1}$).

$$30. \text{ i. As, } qE = mg \Rightarrow q = \frac{1.08 \times 10^{-14} \times 9.8}{1.68 \times 10^5} = 6.4 \times 10^{-19} \text{ C}$$

The charge of this drop will be $6.4 \times 10^{-19} \text{ C}$.

ii. For the drop to be stationary,

Force on the drop due to electric field = Weight of the drop

$$qE = mg$$

$$q = \frac{mg}{E} = \frac{1.6 \times 10^{-6} \times 10}{100} = 1.6 \times 10^{-7} \text{ C}$$

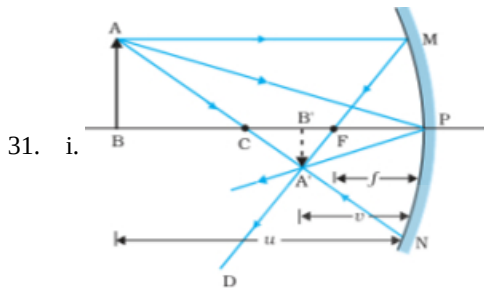
The number of electrons carried by the drop is

$$n = \frac{q}{e} = \frac{1.6 \times 10^{-7} \text{ C}}{1.6 \times 10^{-19} \text{ C}} = 10^{12}$$

iii. quantized

iv. Millikan's experiment confirmed that the charges are quantized, i.e., charges are small integer multiples of the base value which is a charge on the electron. The charges on the drops are found to be multiple of $4.8 \times 10^{-19} \text{ C}$. Hence, the quanta of charge are $4.8 \times 10^{-19} \text{ C}$.

Section E



From Fig. the two right-angled triangles $A'B'F$ and MPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP .) Therefore,

$$\frac{B'A'}{PM} = \frac{B'F}{FP}$$

or $\frac{B'A'}{BA} = \frac{B'F}{FP}$ ($\because PM = AB$) ... (i)

Since $\angle APB = \angle A'PB'$, the right angled triangles $A'B'P$ and ABP are also similar. Therefore,

$$\frac{B'A'}{BA} = \frac{B'P}{BP} \dots (ii)$$

Comparing equations (i) and (ii)

$$\frac{B'F}{FP} = \frac{B'P - FP}{FP} = \frac{B'P}{BP} \dots (iii)$$

$$B'P = -v, FP = -f, BP = -u;$$

$$\text{Using these in Eq. (iii) we get } \frac{1}{v} + \frac{1}{u} = \frac{1}{f} = \frac{2}{R}$$

ii. For lens: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$u = -5\text{m}; f = +1\text{m}$$

$$\frac{1}{v} - \frac{1}{-5} = \frac{1}{(+1)}$$

$$\Rightarrow v = \frac{5}{4} \text{ m} = 1.25\text{m}$$

hence, the position of the image formed is at 1.25m behind the lens.

$$m = \frac{I}{O} = \frac{v}{u} = \frac{(+\frac{5}{4})}{(-5)}$$

$$I = (-0.25) \times (1.8)$$

$$I = -0.45 \text{ m}$$

OR

Let I be the intensity of beam 1 incident on the first glass plate. Each plate reflects 25% of light incident on it and transmits 75%. Therefore,

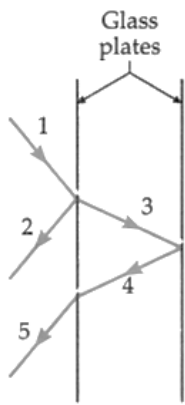
$$I_1 = I;$$

$$I_2 = \frac{25}{100} I = \frac{I}{4}$$

$$I_3 = \frac{75}{100} I = \frac{3}{4} I$$

$$I_4 = \frac{25}{100} I_3 = \frac{1}{4} \times \frac{3}{4} I = \frac{3}{16} I$$

$$I_5 = \frac{75}{100} I_4 = \frac{3}{4} \times \frac{3}{16} I = \frac{9}{64} I$$



∴ Amplitude ratio of beams 2 and 5 is

$$r = \sqrt{\frac{I_2}{I_5}} = \sqrt{\frac{I}{4} \times \frac{64}{9I}} = \frac{4}{3}$$

$$\frac{I_{\min}}{I_{\max}} = \left[\frac{r-1}{r+1} \right]^2 = \left[\frac{\frac{4}{3}-1}{\frac{4}{3}+1} \right]^2 = \frac{1}{49} = 1 : 49$$

32. a. During charging of the capacitor, work is done by the battery which is stored in the form of potential energy inside the capacitor.

Consider a capacitor which is to be charged by charge Q with the help of a battery. Let at any instant charge on the capacitor is q and the potential difference between the two plates of the capacitor is V .

We know that,

$$q = CV \Rightarrow V = q/C$$

Now small work done to charge the capacitor by small charge dq ,

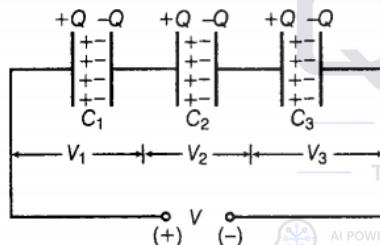
$$dW = Vdq = \frac{q}{C}dq$$

where, q = instantaneous charge, C = capacitance and V = voltage

∴ Total work done in storing charge from 0 to Q (total charge) is given by

$$\Rightarrow W = \int_0^Q \frac{q}{C} dq = \frac{Q^2}{2C}$$

- b. In a series combination of capacitors, the same charge lie on each capacitor for any value of capacitances.



Capacitors in series combination

Also, the net potential difference across the combination is equal to the algebraic sum of potential differences across each capacitor

$$\text{i.e. } V = V_1 + V_2 + V_3 \dots\dots\dots(i)$$

where V_1 , V_2 , V_3 and V are the potential differences across C_1 , C_2 , C_3 and equivalent capacitor, respectively.

$$\text{Again } q_1 = C_1 V_1 \Rightarrow V_1 = \frac{q_1}{C_1}$$

$$\text{Similarly, } V_2 = \frac{q}{C_2} \text{ and } V_3 = \frac{q}{C_3}$$

∴ Total potential difference [From Eq.(i)]

$$\Rightarrow V = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\Rightarrow \frac{V}{q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad \left[\frac{V}{q} = \frac{1}{C}, \text{ where } C \text{ is equivalent capacitance} \right]$$

OR

- i. Total energy stored in the two capacitors before they are connected,

$$u_i = \frac{1}{2} C_1 V_1^2 + \frac{1}{2} C_2 V_2^2$$

- ii. After the two capacitors are connected in parallel, the common potential is

$$V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{q_1 + q_2}{C_1 + C_2} = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

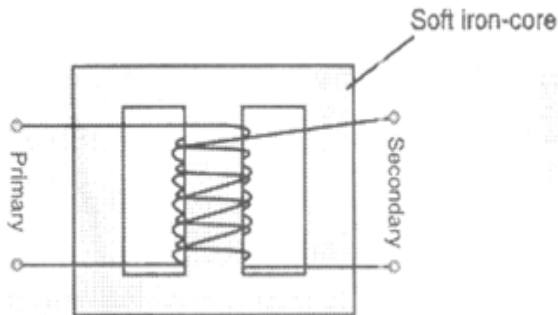
Total energy stored in the parallel combination,

$$U_f = \frac{1}{2}(C_1 + C_2)V^2 = \frac{1}{2}(C_1 + C_2) \left(\frac{C_1 V_1 + C_2 V_2}{C_1 + C_2} \right)^2$$

$$= \frac{1}{2} \frac{(C_1 V_1 + C_2 V_2)^2}{C_1 + C_2}$$

- iii. Clearly, $U_f < U_i$. Thus the total energy of the parallel combination is less than the sum of the energies stored in the two capacitors before they are connected. During sharing of charges, some energy is lost as heat due to the flow of charges in connecting wires.

33. i.



Working principle:

Step-down transformer is made up of two or more coil wound on the iron core of the transformer. It works on the principle of magnetic induction between the coils. Whenever current in one coil changes an emf gets induced in the neighboring coil (Principle of mutual induction)

Voltage across secondary

$$V_s = e_s = -N_s \frac{d\phi}{dt}$$

Voltage across primary

$$V_p = e_p = -N_p \frac{d\phi}{dt}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \text{ (here, } N_s > N_p \text{)}$$

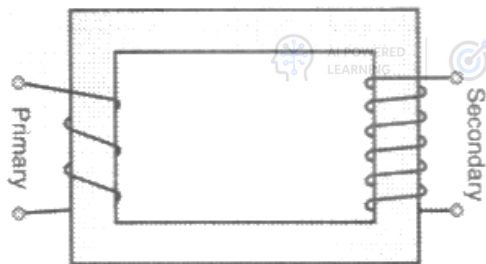
In an ideal transformer

Power Input - Power output

$$I_p V_p = I_s V_s$$

$$\therefore \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

ii.



$$\text{Input power, } P_i = I_i \times V_i = 15 \times 100 = 1500 \text{ W}$$

$$\text{Power output, } P_o = P_i \times \frac{90}{100} = 1350 \text{ W}$$

$$\Rightarrow I_o V = 1350 \text{ W}$$

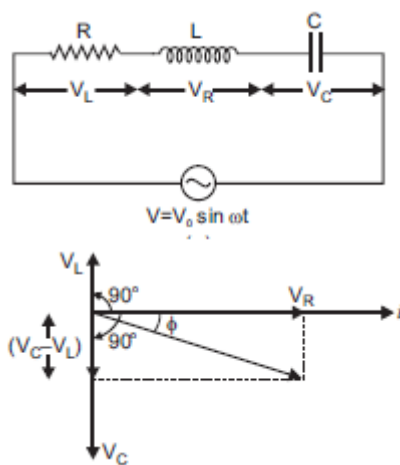
$$\text{Output voltage, } V_o = \frac{1350}{3} \text{ V} = 450 \text{ V}$$

OR

Suppose a resistance R, inductance L and capacitance C in series. An alternating source of voltage $V = V_o \sin \omega t$ is applied across it. Since all the components are connected in series, the current flowing through all is same.

Voltage across resistance R is V_R , voltage across inductance L is V_L and voltage across capacitance C is V_C .

V_R and $(V_C - V_L)$ are mutually perpendicular and the phase difference between them is 90° .



From the figure above, we have

$$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2} \dots\dots (i)$$

$$\text{and } V_R = Ri, V_C = X_C i \text{ and } V_L = V_L i \dots\dots (ii)$$

where $X_C = \frac{1}{\omega C}$ = capacitance reactance and $X_L = \omega L$ = inductive reactance

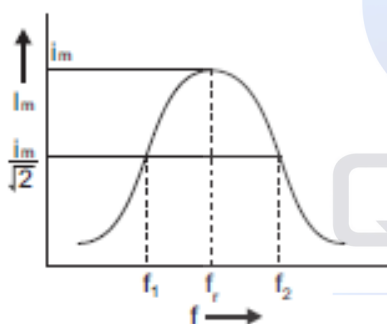
$$\therefore V = \sqrt{(Ri)^2 + (X_C i - X_L i)^2}$$

$$\therefore \text{Impedance of circuit, } Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$$

$$\text{i.e. } Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$$

The phase difference between current and voltage is given by,

$$\tan \phi = \frac{X_C - X_L}{R}$$



From the graph, we can see that with increase in frequency, current first increases and then decreases. At resonant frequency, current amplitude is maximum.



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