Q. No. 2 (i) **Safe To Stay Inside Automobile:** It is safe to stay inside an automobile during a light storm. The body of an automobile is made of a metal. Inside a metal, the electric field is zero as a result, the charge inside the metal will be zero.

$$E = 0 \Longrightarrow Q = 0$$

When a lightning from lightning storm strikes the car, it transfers charges to it. All these charges are distributed on the body of car (metal) whereas the inside of car remains totally free from the charge. Due to this, a person sitting inside the car is protected by a light storm. So, it is advised to stay inside a car during a light storm.

....

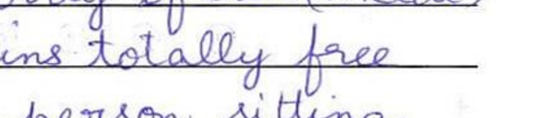
Q. No. 2 (ii) **Numerical:-**

Data: $q_1 = 5\times10^{-8}C$; $q_2 = -3\times10^{-8}C$; $d = 16\ cm = 0.16\ m$

Solution:

Let the point where the potential is zero is at distance x m from q_2, then its distance from q_1 is $0.16 - x$

Figure



According to given condition, $V_B = 0$

$\Rightarrow V_1 + V_2 = 0$

$V_1 = -V_2$

$\frac{kq_1}{r_1} = -\frac{kq_2}{r_2}$

$\frac{(5\times10^{-8})}{} = -\frac{(-3\times10^{-8})}{}$

$5x = 3(0.16 - x)$

$5x = 0.48 - 3x$

$8x = 0.48$

$\Rightarrow \mathbf{x = 0.06\ m} = 6\ cm$

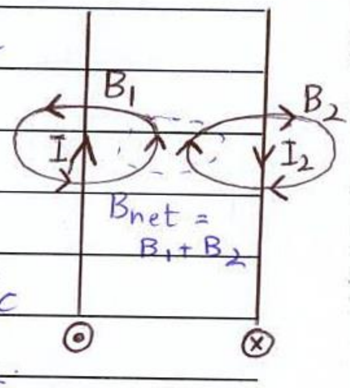
$\Rightarrow r_1 = 0.16 - x = 0.16 - 0.06 = 0.1\ m$

The relevant question should be answered only in the allotted space and inside the outer mark

Q. No. 2 (iii) Circuit with Varying Potential:

Q. No. 2 (iv)

Q. No. 2 (v) **Force Between Wires:** Two long straight wire carrying current in the opposite direction will **repel** each other. One of the wires will carry current out of the page so it produces magnetic field in anti-clockwise direction. The other wire carries current into the page having a magnetic field in clockwise direction. The net magnetic field between the wire adds up as $B_1 + B_2$. Whereas, the magnetic field outside the wires is weak. For this reason, the force will be directed from between centre of wire to outside. Hence, the wires repel each other.



Q. No. 2 (vi) **Numerical**

Data: $I_g = 5mA = 5 \times 10^{-3} A$; $R_g = 100\Omega$; $V = 20V$

Required: High resistance $R_h = ?$

Formula: $R_h = \frac{V}{I_g} - R_g$

Solution:

$$R_h = \frac{20}{5 \times 10^{-3}} - 100$$

$$= 4000 - 100$$

$$\boxed{R_h = 3900\Omega}$$

Result:

So, the 5mA, 100Ω galvanometer can be

Q. No. 2 (vii) **Increasing Power Level:** No, the power level can not be increased by an efficient step up transformer. ~~As~~ If the power is increased, law of conservation of energy would not remain valid. A step-up transformer can increase the voltage hence decreasing the current but the power always remain constant.

$$P = VI$$

According to the formula, the voltage and current variations keep the power constant between the primary and secondary coil. The voltage in secondary coil is increased by step-up transformer.

$$V_s > V_p \; ; \; I_s < I_p \; ; \; P = \text{constant}$$

Q. No. 2 (viii) **Proof of Second Postulate:** The second postulate of Bohr's atomic model states that the angular momentum of orbits is quantized and is an integral multiple of $h/2\pi$. $mvr = \frac{nh}{2\pi}$

This hypothesis of Bohr was proved later by **De-Brogile**. He said that electron while revolving around the nucleus in orbit can behave as a wave having wavelength 'λ'. These waves are considered standing waves.

$\lambda = \frac{h}{P}$ —① (∵ De-brogile hypothesis)

For standing waves;

$\lambda = \frac{2\pi r}{n}$ —②

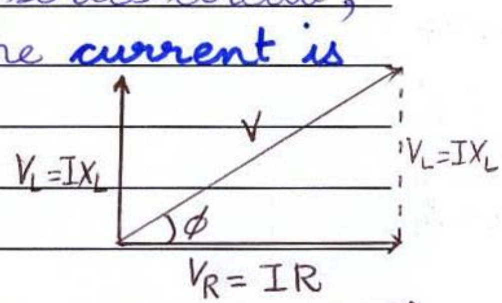
Comparing ① & ②.

$\frac{h}{P} = \frac{2\pi r}{n}$

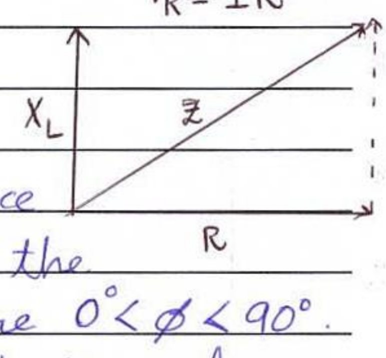
$\frac{nh}{2\pi} = Pr$

Q. No. 2 (ix)

Q. No. 2 (x) **RL Series Circuit;** In a RL series circuit, the **voltage is leading** whereas the **current is lagging**. The voltage of such a circuit is given by



$$V = \sqrt{V_L^2 + V_R^2}$$
$$V = \sqrt{(IX_L)^2 + (IR)^2}$$
$$V = \sqrt{I^2 (X_L^2 + R^2)}$$
$$V = I\sqrt{X_L^2 + R^2}$$



Where $Z = \sqrt{X_L^2 + R^2}$ is called the impedance of the circuit. The voltage is leading the current by a phase angle of ϕ where $0° < \phi < 90°$. Voltage leads the current A.C through inductor whereas

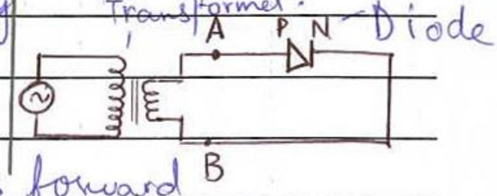
Q. No. 2 (xi)

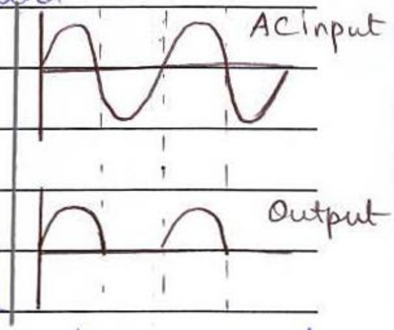
Q. No. 2 (xii)

Q. No. 2 (xiii) Magnetic Levitation Trains: The working principle of the magnetic levitation train is based on superconductors. The train remains suspended on the rail tracks thus virtually eliminating the friction between train tracks and train. The rail is made up of superconductor. The metal is placed at the bottom of the train. As the metal approaches superconductor, an **emf is induced** in the super conductor. This emf results in a current which opposes its cause. The opposition force provided by the superconductor balances the gravitational force acting on the train. Thus keeping it suspended in air. Such trains are able to acheive speeds upto **361 mph** due to no energy lost as friction.

Q. No. 2 (xiv) Transistor is called current amplification device because it is used to amplify current. It increases amplitude of current without changing original source of current through its configuration (Common Base, Common Emitter)

Q. No. 2 (xv) **PN Junction As Half Wave Rectifier:** A PN Junction diode acts as a half wave rectifies. It helps to convert AC to DC. During the first half of AC cycle, the potential at A becomes positive with respect to B. So diode becomes forward biased and allows the flow of current. During the negative cycle of AC, A point is at negative potential and B is at positive potential. So, diode becomes ~~forward~~ reverse biased and allows no flow of current. The whole potential of AC appears across the diode. In this way, PN junction rectifies half cycle of AC into DC





Q. No. 2 (xvi) **Relation between α & β;** The alpha factor of a transistor is denoted by 'α' whereas 'β' is the beta factor. Their formulae are;

$$\alpha = \frac{I_C}{I_E} \quad (1) \qquad \beta = \frac{I_C}{I_B} \quad (2)$$

Considering eq (2);

$$\beta = \frac{I_C}{I_B}$$

Dividing by I_E;

$$\beta = \frac{I_C/I_E}{I_B/I_E}$$

$$\beta = \frac{I_C/I_E}{I_E - I_C \ldots}$$

$$\beta = \frac{\alpha}{\frac{I_E}{I_E} - \frac{I_C}{I_E}} \quad (\because \text{From } (1))$$

$$\boxed{\beta = \frac{\alpha}{1-\alpha}}$$

($\because$ From (1))

This is the required relation between α and

Q. No. 2 (xvii) **Numerical**

Data: $\Delta t = 10^{-8} s$

Required: $\Delta E = ?$

Solution:

According to 2nd postulate of Heisenberg's uncertanity principle,

$$\Delta E \cdot \Delta t \approx h$$

So, $\Delta E = \frac{h}{\Delta t}$

Given uncertanity in time $= 10^{-8} s$.

$$\Rightarrow \Delta E = \frac{6.625 \times 10^{-34}}{10^{-8}}$$

$$\boxed{\Delta E = 6.625 \times 10^{-26} J}$$

Result:

So, the uncertanity in the energy during the time is $6.625 \times 10^{-26} J$.

Q. No. 2 (xviii) **Wavelength of Second Line:** The wavelength of ~~second line of~~ Paschen series is given by;

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$$

$\because R$ = Rydberg constant $= 1.09678 \times 10^7 m^{-1}$

For the second line, the electron emits a photon of certain wavelength by jumping from $n = 5$ to $n = 3$. So, wavelength of second line is;

$$\frac{1}{\lambda} = (1.09678 \times 10^7)\left(\frac{1}{3^2} - \frac{1}{5^2}\right)$$

$$\frac{1}{\lambda} = (1.09678 \times 10^7)(0.07111)$$

$$\frac{1}{\lambda} = 779932.4444 \ m^{-1}$$

$$\Rightarrow \boxed{\lambda = 1.282 \times 10^{-6} \ m}$$

Result

So, the wavelength of second line of Paschen series is **1.282×10^{-6} m**.

Q. No. 2 (xix) **Difficulty in Fusion:** In a fusion reaction, two small nuclei are combined together to form a large nuclei with a release of a large amount of energy. The first difficulty is to overcome the Coloumb's force that exists between the two atoms. To overcome this **Coloumb's force of repulsion**, a large amount of work has to be done. Secondly, for effective nuclear fusion, a very **high temperature** is required in the range of thousands of Kelvin. Such a high temperature is very difficult to acheive. Moreover, fusion reaction cannot be controlled when started which makes it dangerous. So, these factors make fusion reaction difficult to acheive.

Q. No. 2 (xx) **Energy Released:** The reaction of the beta-decay is given as follows;

$${}^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{0}_{-1}\beta + \bar{\nu}$$

First we calculate the mass defect by given data;

Δm = (Mass of Th) − (Mass of Pa + Mass of β)

$= 234.0436u - (234.0428u + 0.00055u)$

$= 234.0436u - 234.04335$

$\Delta m = 2.50 \times 10^{-4}\ u$

Now, the energy released can be calculated as;

$\Delta E = \Delta m \times 931.5\ \frac{MeV}{u}$ ($\because 1u = 931.5\ MeV$)

$= 2.50 \times 10^{-4} u \times 931.5\ MeV/u$

$\boxed{E = 0.2328\ MeV}$

Result

So, the energy released in the beta decay is 0.2328 MeV.

Q. No. 3 (Page 1/6) (c)

DATA

$n = 15 \frac{\text{turns}}{\text{cm}} = 15 \frac{\text{turns}}{10^{-2}\,\text{m}} = 1500$ turns/m

$A = 2\cdot0\ \text{cm}^2 = 2\cdot0 \times 10^{-4}\ \text{m}^2$

$I_1 = 2A$; $I_2 = 4A$; $\Delta I = I_2 - I_1 = 4 - 2 = 2A$

$t = 0\cdot1\ s$

REQUIRED

Induced emf $\mathcal{E} = ?$

SOLUTION

The magnetic field inside a solenoid is

$$B = \mu_o n I$$

$$B = 4\pi \times 10^{-7} \times 1500 \times 2$$

$$B = 3\cdot76 \times 10^{-3}\ T$$

Now, by Faraday's law of electromagnetic induction;

$$\mathcal{E} = N \frac{\Delta\phi}{\Delta t}$$

$$\mathcal{E} = \frac{N\ BA}{\Delta t} \qquad (\because \theta = 0^\circ \rightarrow \cos 0 = 90^\circ)$$

$$\mathcal{E} = \frac{1 \times 3\cdot76 \times 10^{-3} \times 2 \times 10^{-4}}{0\cdot1}$$

$$\mathcal{E} = \frac{7\cdot539 \times 10^{-7}}{0\cdot1}$$

$$\boxed{\mathcal{E} = 7\cdot539 \times 10^{-6}\ V}$$

RESULT

Q. No. 3 (Page 2/6) (b)

AMPERE'S LAW

Proposed By

Ampere's law was given by Andre Marie Peter Ampere in 1826.

Statement

"The sum of all length elements multiplied by the component of magnetic field parallel to it is proportional to the current carried by coil."

$$\Sigma B \cdot \Delta l = \mu_o I$$

MAGNETIC FIELD DUE TO CURRENT CARRYING SOLENOID

Definition

"A solenoid is a coil having many turns wound on a core."

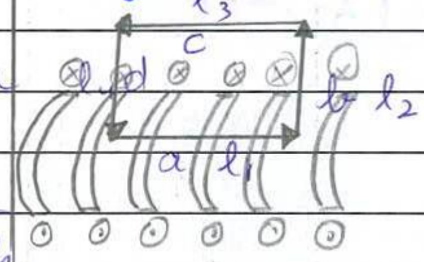
Explanation:

When current flows through the coil, a magnetic field is established in it parallel to axis. The magnetic field in the interior is strong, uniform and magnetic field lines are parallel to each other. While the field on the exterior is weak.

Ideal Solenoid

An ideal solenoid is approached when the a great volume.

Figure



Explanation 2

Consider a loop [struck out] with side a, b, c, d with length l_1, l_2, l_3 and l_4, l_3 lies outside solenoid while other length segments are inside solenoid. The solenoid is ideal.

Derivation

According to Ampere's law;

$$B \cdot l_1 + B \cdot l_2 + B \cdot l_3 + B \cdot l_4 = \mu_0 I$$

$$B \cdot l_1 \cos 0^\circ + Bl_2 \cos 90^\circ + Bl_3 \cos 180^\circ + Bl_4 \cos 270^\circ = 0$$

$$Bl_1 + 0 + 0 + 0 = \mu_0 I \quad (\because \cos 90^\circ = 0)$$

The expression '$Bl_3 \cos 180^\circ$' becomes zero because $B = 0$ in exterior due to ideal solenoid.

$$Bl_1 = \mu_0 I$$

For 'N' number of turns;

$$Bl = N \mu_0 I \quad (\because l_1 = l)$$

$$B = \frac{N}{l} \mu_0 I$$

$$\boxed{B = n \mu_0 I} \quad \text{—} (1)$$

$$n = \frac{\text{Number of turns}}{\text{Length of the coil}}$$

So eq (1) gives magnetic field through current carrying coil.

Q. No. 3 (Page 4/6) **(a)**

CAPACITOR

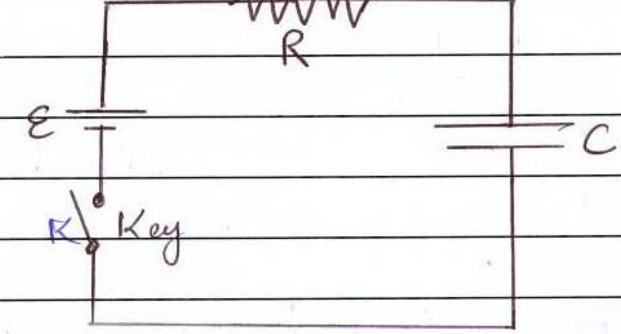
"A capacitor is a device that is used to store electric charges."

- The charges remain intact on the plates due to presence of electric field even after the voltage is removed hence they are stored.

DISCHARGING AND CHARGING

Circuit

Consider a circuit with battery of voltage $\mathcal{E}$, a key and a capacitor connected in the series with resistor R



A current flows through the circuit when the key is closed and vice versa.

Charging

To charge the capacitor, the key K is closed. As a result, a current starts flowing in the circuit due to potential applied by the battery. The charges start

Q. No. 3 (Page 5/6) the current keeps flowing. When the capacitor is fully charged, the current stops flowing. The maximum value stored by a capacitor is 63.2% of the maximum charge. It is given by formula:

$$q = q_0(1 - e^{-t/RC})$$ (∵ q_0 = Maximum value of charge)

Time Constant

"Time constant is defined as the time during which 63.2% of maximum value of charge is deposited on plates of capacitor."

Discharging

For discharging of the capacitor, the key K is opened. Now, the charges start getting discharged from the capacitor. 36.8% of the maximum value of charge is discharged from the capacitor. The equation for charge discharged by the capacitor is given by

$$q = q_0 e^{-t/RC}$$

Time Constant

"Time constant is defined as the time during which 36.8% of charge is discharged from capacitor."

It is given by $\tau = RC$

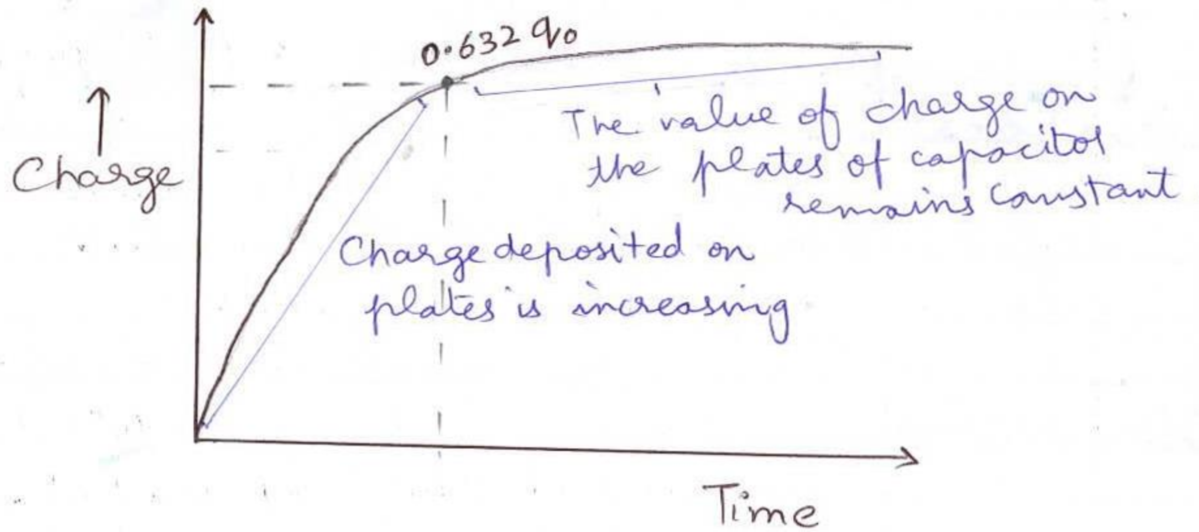
Applications

Discharging and charging of capacitor has many applications in CDI, Space for diagram/rough work

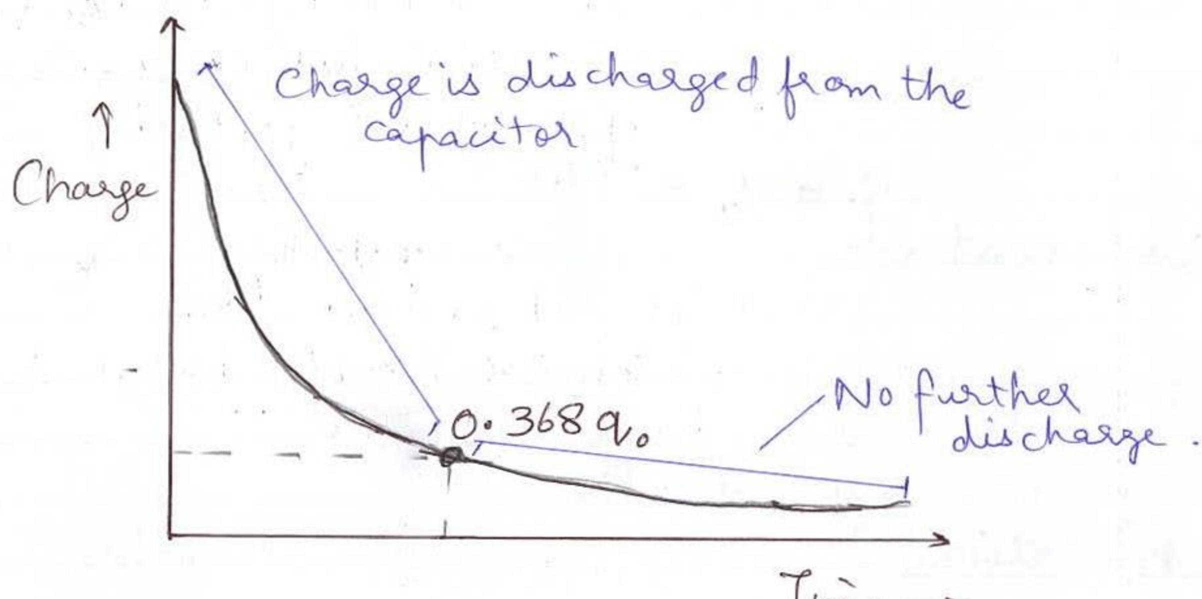
Q. No. 3 (Page 6/6)

GRAPHS

Charging



Discharging



Q. No. 4 (Page 1/6) (c)

DATA

$R_1 = 1\Omega$; $R_3 = 3\Omega$; $E_1 = 5V$

$R_2 = 2\Omega$; $E_2 = 10V$

REQUIRED

$I_1 = ?$ $I_2 = ?$

SOLUTION

There are two loops so the current is calculated as follows. The direction of current in both loops is clockwise direction.

Along Loop abefa

By Kirchoff's law;

$$+\mathcal{E}_1 - I_1R_1 - (I_1 - I_2)R_3 = 0$$

∵ I_1 : Current flowing in loop abefa.
I_2 : Current flowing in loop bcdeb.

Putting values;

$$5 - I_1(1) - (I_1 - I_2)3 = 0$$

$$5 - I_1 - 3I_1 + 3I_2 = 0$$

$$5 - 4I_1 + 3I_2 = 0 \quad \text{—(1)}$$

Along Loop bcdeb

$$-I_2R_2 - \mathcal{E}_2 - (I_2 - I_1)R_3 = 0$$

$$-I_2(2) - 10 - (I_2 - I_1)3 = 0$$

$$-2I_2 - 10 - 3I_2 + 3I_1 = 0$$

$$-10 + 3I_1 - 5I_2 = 0 \quad \text{—(2)}$$

Consider eq (1);

$$5 - 4I_1 + 3I_2 = 0$$

$$3I_2 = 4I_1 - 5$$

$$I_2 = \frac{4I_1 - 5}{} \quad \text{—(3)}$$

Q. No. 4 (Page 2/6) Put eq ③ in eq ②;

② ⇒ $-10 + 3I_1 - 5\left(\frac{4I_1 - 5}{3}\right) = 0$

$-10 + 3I_1 - \frac{5}{3}(4I_1 - 5) = 0$

$-10 + 3I_1 - \frac{20}{3}I_1 + \frac{25}{3} = 0$

$-5/3 - \frac{11}{3}I_1 = 0$

$-\frac{11}{3}I_1 = \frac{5}{3}$

$-11 I_1 = 5$

$I_1 = -\frac{5}{11} = -0.4545 A$

Put this value of I_1 in eq ③;

③ ⇒ $I_2 = \frac{4(-0.4545) - 5}{3}$

$= \frac{-6.1818}{3}$

$I_2 = -2.272 A$

The negative signs shows that the directions of current are assumed wrong.

Result

Current in loop abefa = $I_1 = -0.4545 A$

Current in loop bcdeb = $I_2 = -2.272 A$

The negative sign here shows that direction of current is clockwise although

Q. No. 4 (Page 3/6) (a)

IMPEDANCE

"The opposition offered to the flow of the current by the components of a circuit is called as impedance."

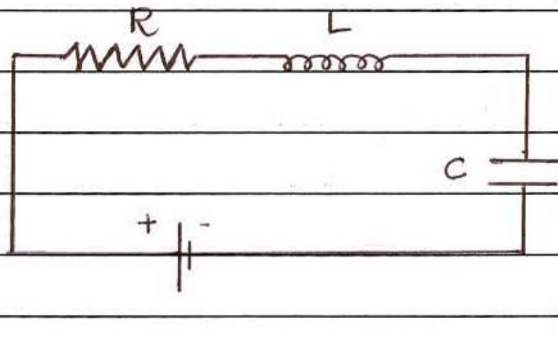
- It is denoted by 'Z'.

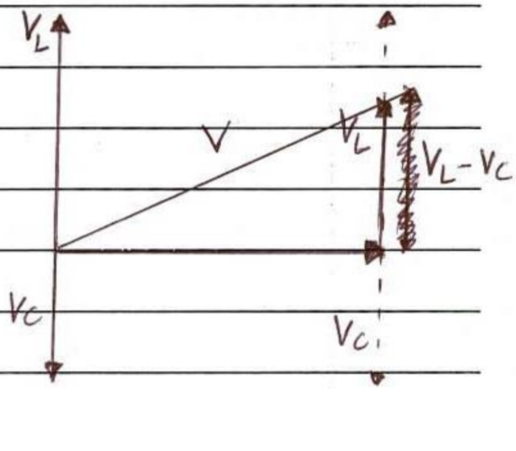
IMPEDANCE OF R.L.C SERIES CIRCUIT

Explanation

In RLC series circuit, resistor, capacitor and inductor are connected in series with each other. Since, the current remains same in series so current is taken as reference while drawing the phasor diagram. In resistor, the voltage and current both are in phase. In inductor, the voltage leads current by 90°. In capacitor, the current leads voltage by 90°.

Diagram





Q. No. 4 (Page 4/6) **Derivation:** In, R.L.C series circuit, the circuit can be either capacitive or reactive depending on values of V_L and V_C.

- If $V_L > V_C \longrightarrow$ circuit is inductive
- If $V_L < V_C \longrightarrow$ circuit is capacitive.

Here, we suppose that circuit is inductive.

So, $V = \sqrt{(V_R)^2 + (V_L - V_C)^2}$ $\quad (\because V^2 = (V_R)^2 + (V_L - V_C)^2)$

$= \sqrt{(IR)^2 + (IX_L - IX_C)^2}$

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

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

Let $X_L - X_C = X$

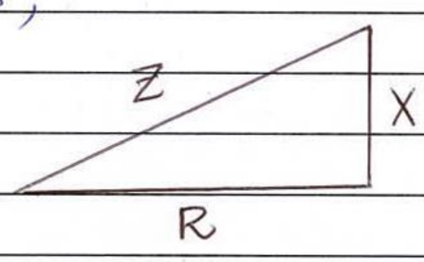
$V = I\sqrt{R^2 + X^2}$

$\because V = IZ$ so $Z = \sqrt{R^2 + X^2}$

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

Impedance Triangle

The impedance triangle of the circuit is as follows;



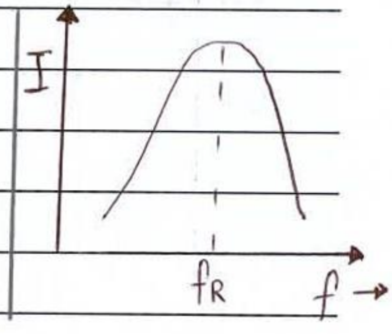
CONDITION OF RESONANCE

An R.L.C series circuit is said to be in resonance when $X_L = X_C$.

$X_L = X_C$

$2\pi f_r L = \frac{1}{2\pi f_r C}$

Q. No. 4 (Page 5/6) At resonance, the impedance is minimum at and current is maximum
($Z = R$)



X-RAYS

"X-rays are the strong electromagnetic radiations having wavelength in the range of 10^{-10} m (1A)."

Discovery: They were discovered by Rongeten in 1895

Production: X-rays are produced when high energy electrons strike the surface of high melting point metal (like tungsten etc.). These are of two types; characteristic and continuous.

CHARACTERISTIC X-RAYS

Production

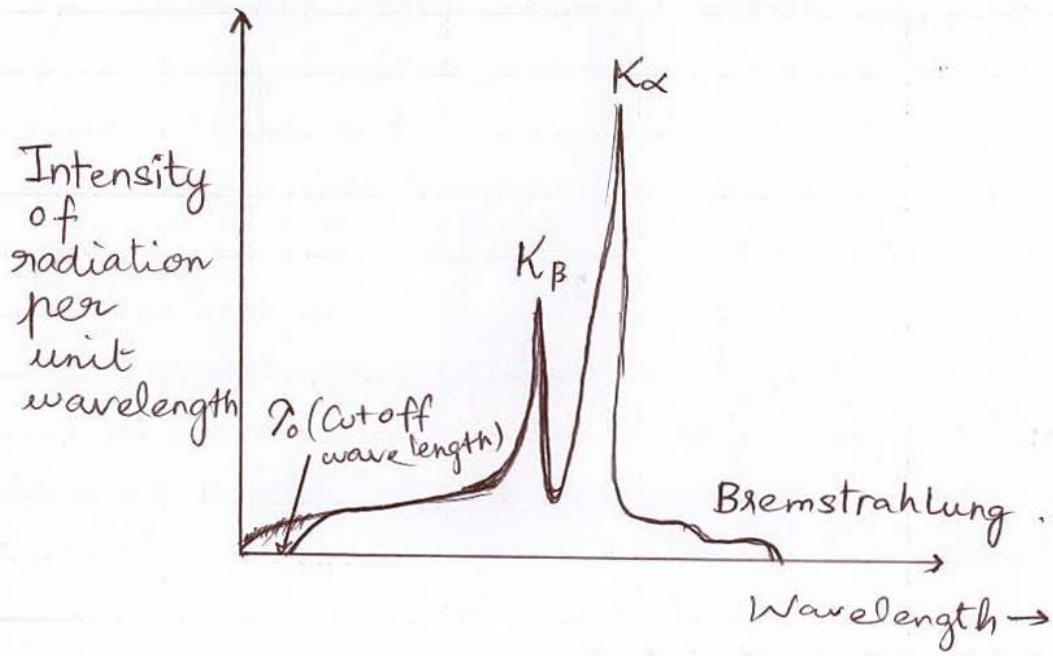
A metal like tungsten consists of a lot of atoms, hence, a lot of electron. When a high energy electron strikes the metal surface, it may knock off an electron in the orbit of an atom. As a result, a vacancy is created in the orbit. To fill this vacancy, an electron jumps from higher energy level to replace the electron. This results in the release of energy in the form of X-ray.

Types: If an electron is knocked off in K shell and an electron from L-shell fills its vacancy, it is called K_α X-ray. K_β X-ray is when electron jumps from M to K shell Similarly L_α, L_β X-rays are

Space for diagram/rough work

Q. No. 4 (Page 6/6)

Graph



Q. No. 5 (Page 1/6)

Q. No. 5 (Page 2/6)

Q. No. 5 (Page 3/6)

Q. No. 5 (Page 4/6)

Q. No. 5 (Page 5/6)

Space for Diagram/rough work

Q. No. 5 (Page 6/6)