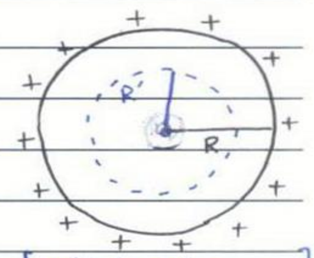
Q. No. 2 (i) → It is safe to stay inside an automobile during a light storm because charge resides on the surface of metallic surface

→ The metallic structure of the automobile along with insulation of interior doesn't let the charge enter.

→ As flux is given by:

$$\varphi = \frac{Q}{\varepsilon_o} \Rightarrow \vec{E}.\vec{A} = \frac{Q}{\varepsilon_o}$$



→ When $Q = 0$

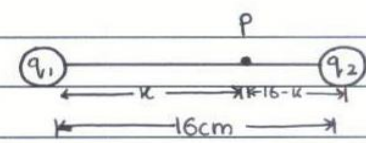
$\vec{E}.\vec{A} = 0$ where $\vec{A} \neq 0$

So $\boxed{\vec{E} = 0}$

[$R' < R$; R': gaussian surface]

→ This can be proved by considering a gaussian surface inside car where $\vec{E} = 0$ and thus we stay safe.

Q. No. 2 (ii) GIVEN DATA



$q_1 = 5 \times 10^{-8}\, C$, $q_2 = -3 \times 10^{-8}\, C$

$r = 16cm = 0.16\, m$

REQUIRED A point b/w q_1 and q_2 where $V = 0$, let P

SOLUTION let potential at P is:

$V_1 + V_2 = 0 \Rightarrow V_1 = -V_2$

As $V = \frac{kq}{r} \Rightarrow \frac{kq_1}{r_1} = -\frac{kq_2}{r_2}$

$\frac{q_1}{r_1} = -\frac{q_2}{r_2} \Rightarrow \frac{(5 \times 10^{-8} C)}{x} = -\frac{(-3 \times 10^{-8} C)}{0.16 - x}$

$5(0.16 - x) = 3x \Rightarrow 0.8 - 5x = 3x$

$0.8 = 8x \Rightarrow x = 0.1\, m$

$0.16 - x = 0.06\, m$

$V = 0$ at $0.1m$ from $5 \times 10^{-8} C$ charge, and $0.06m$ from $-3 \times 10^{-8} C$

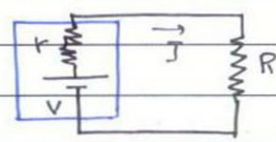
Q. No. 2 (iii)

Q. No. 2 (iv) "The power transferred to the load is maximum when the load resistance is equal to source resistance."

→ The condition for max power transfer is $R = r$ where R is load resistance and r is source resistance.

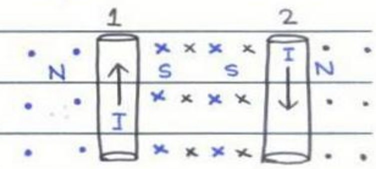
→ Power is: $P = \frac{\varepsilon^2}{4r}$

→ The power loss at load is maximum because of reduced value of resistance and large value of I.



Q. No. 2 (v) → Two straight wires placed parallel and carrying current in opposite direction **repel each other.**

→ The reason for this is **similar nature of magnetic field between them**



→ The wire 1 and 2 develop magnetic field around themselves and exert force on each other as:

$F_{12} = I L B_2 \sin\theta$, $F_{21} = I L B_1 \sin\theta$

→ The similar poles between them will add up the net effect of magnetic field

$B = B_1 + B_2$

thus causing repulsion.

....

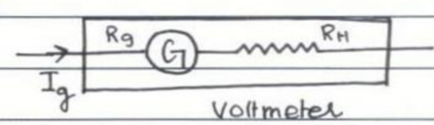
Q. No. 2 (vi) "Galvanometer is a device which detects small amount of current in the circuit."

→ For the conversion of galvanometer into a voltmeter, a high resistance R_h is connected in series with it.

→ The value of high resistance for 5mA I_g, 100 Ω R_g and V of 20 V can be found as:

$$R_H = \frac{V}{I_g} - R_g = \frac{20}{5 \times 10^{-3}} - 100$$

$$\boxed{R_H = 3900\,\Omega}$$



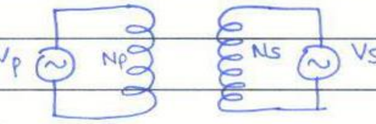
Q. No. 2 (vii) → An efficient transformer is the one whose input power is equal to the output power ~~los~~

$P_{in} = P_{out} \Rightarrow V_p I_p = V_s I_s$

→ An efficient stepup transformer cannot make $P_{out} > P_{inp}$ rather it prevents the losses that could result at the output.

→ It increases secondary voltage and reduces secondary current to keep the power output equivalent to input.

$N_s > N_p$, $V_s > V_p$, $I_s < I_p$



Q. No. 2 (viii) → The second postulate of Bohr's atomic model is:

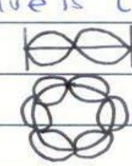
"Electron revolves only in those orbits for which the angular momentum is integral multiple of $\frac{nh}{2\pi}$"

$mvr = nh/2\pi$

→ Bohr stated that e^- cannot revolve in any arbitrary orbit but only revolves in that whose angular momentum is integral multiple on $\frac{nh}{2\pi}$ where $n = 1, 2, 3 \ldots$

→ The wavelength / length of a stationary wave is $l = n\lambda$

For e^- orbitting, it is $l = 2\pi r$



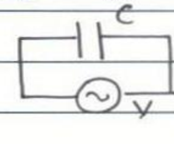
→ Equating: $n\lambda = 2\pi r \Rightarrow \lambda = 2\pi r / n$

→ By energy, wavelength is: $\lambda = h / mv$

→ Equating: $2\pi r / n = h / mv \Rightarrow$ $\boxed{mvr = nh / 2\pi}$

Q. No. 2 (ix) → Pure capacitive circuit doesn't dissipate power, i.e, power loss is zero.

→ In capacitive circuit, V and I are 90° out of phase.



→ Power is given by

$P = VI\cos\theta$

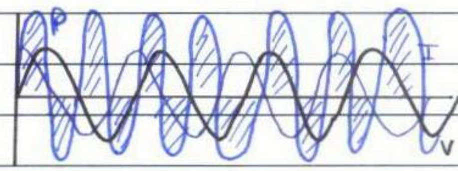
$= VI\cos 90°$

$= 0 \quad (\because \cos 90° = 0)$

→ The negative power is equal to positive power in one cycle thus average power loss is zero.

→ When V is max, I = 0 and V = 0 when I is max

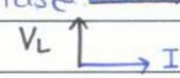
→ P is max when both are max



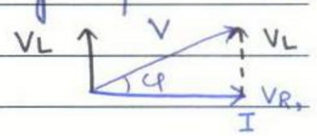
Q. No. 2 (x) → In RL series circuit, the **current lags behind the voltage by angle φ**

→ In resistive circuit, V and I are in phase

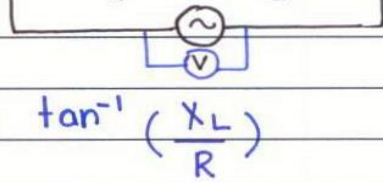
→ In inductive circuit, V leads I by 90°

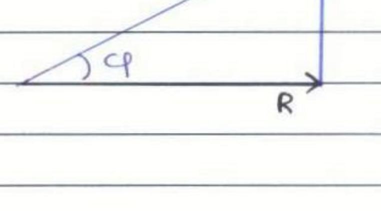


→ In RL circuit, the V leads I by φ where $0° < φ < 90°$



→ The phase angle can be found by impedance triangle.

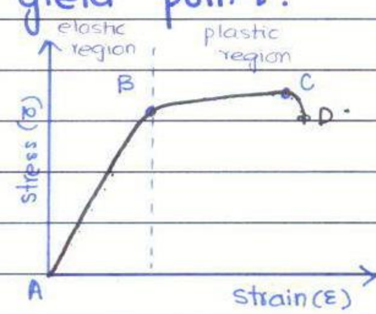




$$φ = \tan^{-1}\left(\frac{X_L}{R}\right)$$

Q. No. 2 (xi)

Q. No. 2 (xii) → Ductile material is the one which goes through **plastic deformation before breaking after reaching the elastic limit or yield point.**



→ The ductile material extends / elongates linearly in AB portion of curve (stress ∝ strain) until B.

→ After B, (yield point / elastic limit) it shows more strain for less stress, i.e, it has entered plastic region

→ In plastic region, it is deformed till UTS (ultimate tensile stress) and breaks at D by fracture stress (σ_f)

Q. No. 2 (xiii)

Q. No. 2 (xiv)

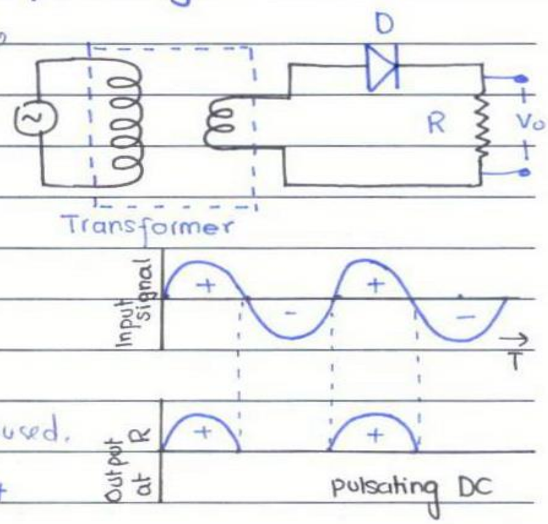
Q. No. 2 (xv) "In half wave rectification, diode conducts only one half of AC signal and produces pulsating DC."

→ In positive half cycle $(0 - T/2)$, diode is forward biased and produces output across R.

→ In negative cycle $(T/2 - T)$, diode is reverse biased and no V_o is obtained at R.

→ Step down transformer is used and for smoothening of pulsating DC, filter circuit is used.

→ $Frequency_{output} = Frequency_{input}$



Q. No. 2 (xvi) → α is amplification factor of common base configuration and is given by:

$$\alpha = \frac{I_C}{I_E} \quad \text{where} \quad I_E = I_B + I_C$$

$$\therefore \alpha = \frac{I_C}{I_B + I_C} \Rightarrow \alpha = \frac{I_C / I_B}{I_B/I_B + I_C/I_B}$$ ($\because$ dividing I_B in numerator and denominator)

$$\boxed{\alpha = \frac{\beta}{1 + \beta}} \quad \because \beta = \frac{I_C}{I_B}$$

→ β is amplificator factor / current gain of common emitter configuration and is given by:

$$\beta = \frac{I_C}{I_B} \Rightarrow \beta = \frac{I_C}{I_E - I_C} \quad \because I_E = I_B + I_C$$

$$\beta = \frac{I_C / I_E}{I_E/I_E - I_C/I_E}$$ ($\div I_E$ in numerator & denominator)

$$\boxed{\beta = \frac{\alpha}{1 - \alpha}} \quad \because \alpha = \frac{I_C}{I_E}$$

Q. No. 2 (xvii) GIVEN DATA

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

REQUIRED

$\Delta E = ?$

SOLUTION

$(\Delta E)(\Delta t) = h$

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

where h = Planck's constant = 6.63×10^{-34} Js

$$\Delta E = \frac{6.63 \times 10^{-34} \text{ Js}}{10^{-8} \text{ s}}$$

$$\boxed{\Delta E = 6.63 \times 10^{-26} \text{ J}}$$

Q. No. 2 (xviii) GIVEN

Second line of Poschen series;

$n = 3$, $p = 5$

REQUIRED

$\lambda = ?$

SOLUTION

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

$$\frac{1}{\lambda} = (1.09 \times 10^7 m^{-1}) \left(\frac{1}{3^2} - \frac{1}{5^2} \right)$$

$$\frac{1}{\lambda} = 1.09 \times 10^7 m^{-1} \times \frac{16}{225}$$

$$\frac{1}{\lambda} = 775111.11 \Rightarrow \lambda = \frac{1}{775111.11}$$

$\boxed{\lambda = 1290.13 \text{ nm}}$

Q. No. 2 (xix)

Q. No. 2 (xx)

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

$Q = \text{Energy of } (Th - Pa - \beta)$

→ Thorium:

$\Delta m = 234.0436u$

$E_{th} = (234.0436u)\left(931 \frac{MeV}{u}\right)$

$= 217894.5916 \text{ MeV}$

→ $^{234}_{91}Pa$:

$\Delta m = 234.0428u$

$E_{Pa} = (234.0428)(931)$

$= 217893.8468 MeV$

→ $^{0}_{-1}\beta$

$\Delta m = 0.00055u$

$E_{-1\beta} = (0.00055)(931) = 0.51205$

$Q = 217894.5916 - 217893.8468 - 0.51205$

$Q = 0.23275 \text{ MeV}$

$Q = 3.724 \times 10^{-14} J$

Q. No. 3 (Page 1/6) —(a)—

CHARGING OF CAPACITOR

→ When capacitor is connected to the voltage source, the current / charges start developing on its plates and reach the maximum value of q_0 (equilibrium charge)

→ For growth of charge, the already present ones cause repulsion thus time taken for charging increases.

→ The process of charging is fast in the beginning and slows down once q approaches max value.

→ The practical / non-ideal capacitor never charges to 100 % rather it follows exponential growth.

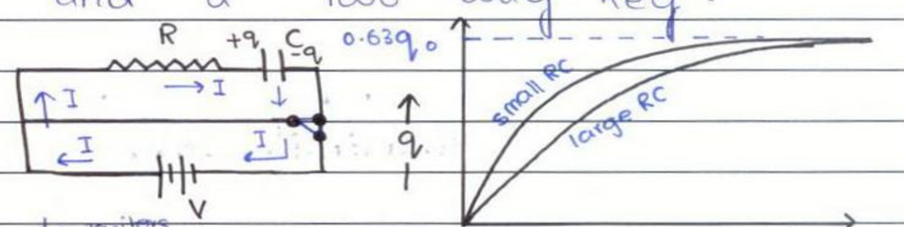
$$q = q_0 \left(1 - e^{-t/RC}\right)$$

where RC = time constant. (specific)

→ When time of charging (t) is one time constant, i.e, $t = RC$ then capacitor is 63% charged.

$$q = 63\%\ q_0$$

→ The circuit consists of capacitor and a resistor and a two way key.



→ Materials / capacitors with small RC get charged rapidly than those with large RC.

→ RC has dimensions of Time.

Q. No. 3 (Page 2/6) DISCHARGING OF CAPACITOR

→ When battery is disconneted, the capacitor discharges through resistor.

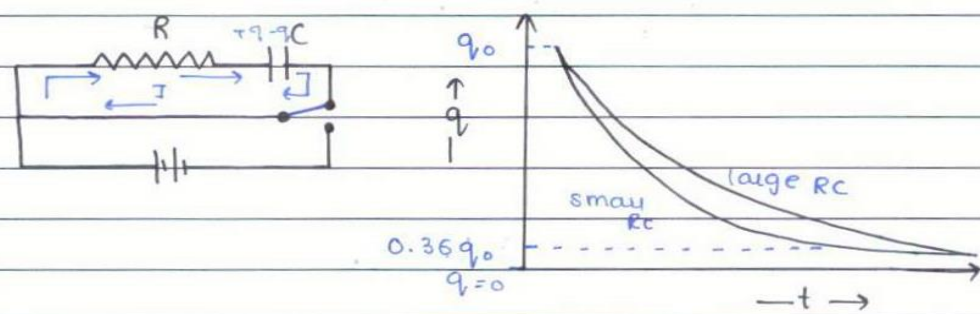
→ The charge falls to q = 0 following exponential law

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

→ In the beginning discharging is fast because the chardes flow rapidly on other plate to neutralize the charge but eventually face repulsion due to similar ~~opposite~~ chalges.

→ In one time constant, i.e $t = RC$, capacitor has 36 % charging / or has 36 % dischaged or has 36 % of equilibrium charge.

$$q = 36\% q_0$$



(b)

AMPERE'S LAW

"The sum of all length elements ΔB.l into which a closed loop has been divided equals μo times the total current"

Q. No. 3 (Page 3/6) FORMULA

→ By Ampere's law;

$$B . \Delta l = \mu_0 I$$

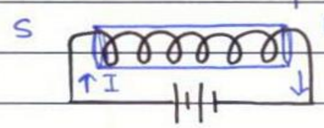
where in Amperian loop, $\Delta L = 2\pi r$

MAGNETIC FIELD DUE TO CURRENT CARRYING SOLENOID

→ A solenoid is a coil having several turns.

→ When current passes through it, it develops magnetic field around it like that of bar magnet.

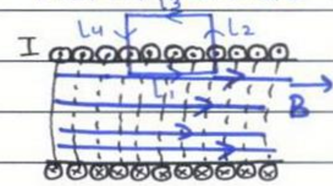
→ This $\vec{B}$ can be found by Ampere's law.



DERIVATION

→ Consider a solenoid carrying current and an amperian loop of square shape.

→ The magnetic field of solenoid resembles bar magnet, i.e, south to north inside the solenoid.



→ By Ampere's law:

$$\sum_{i=1}^{4} B . \Delta l_4 = \mu_0 I$$

$$B . \Delta l_1 + B . \Delta l_2 + B . \Delta l_3 + B . \Delta l_4 = \mu_0 I$$

$$B l_1 \cos 0° + B l \cos 90° + (0) \Delta l \cos 180° + B l_4 \cos 90° = \mu_0 I$$

→ $\cos 0° = 1$, $\cos 90° = 0$

$$B l_1 = \mu_0 I$$

→ l_1 is current for one loop. For N loops, Length is l

Q. No. 3 (Page 4/6)

$$Bl = N \mu_0 I$$

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

→ $\frac{N}{L} = n$ is the turns per unit length

$$\boxed{B = n \mu_0 I}$$

This is the expression of magnetic field inside a solenoid.

UNITS AND DIRECTION

It is measured in Tesla and direction is determined by Fleming's right hand rule. (curl fingers in $\vec{I}$ direction, thumb will point towards $\vec{B}$)

—— (C) ——

GIVEN

$n = \frac{15 \text{ turns}}{1 \text{cm}}$

$n = \frac{1500 \text{ turns}}{m}$

$Area = 2 \text{ cm}^2 = 2 (\times 10^{-2})^2 \text{ m}^2$

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

$I_1 = 2A$, $I_2 = 4A$

$\Delta I = 2A$

$t = 0.1s$

Q. No. 3 (Page 5/6)

REQUIRED

Induced emf $= \varepsilon$

SOLUTION

The self inductance of coil is:

$L = \mu_o n^2 l A$

$L = 4\pi \times 10^{-7} \times 1500 \times 1m \times 2 \times 10^{-4}$

$L = 3.77 \times 10^{-7}$ H

$\varepsilon = \dfrac{L \Delta I}{\Delta t}$

$= (3.77 \times 10^{-7}) \dfrac{(2)}{0.1}$

$\varepsilon = 7.54 \times 10^{-6}$ V

$\boxed{\varepsilon = 7.54 \mu V}$

Space for diagram/rough work

Q. No. 3 (Page 6/6)

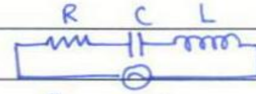
Q. No. 4 (Page 1/6) —— (a) ——

IMPEDENCE

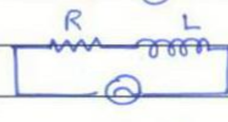
"The combined effect of all resistances and reactances of a circuit is called impedence."

→ It is a vector sum.

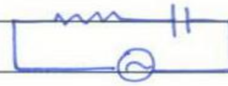
→ $\vec{Z} = \vec{R} + \vec{X_L} + \vec{X_C}$



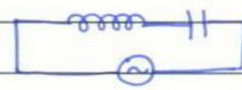
→ $\vec{Z} = \vec{R} + \vec{X_L}$



→ $\vec{Z} = \vec{R} + \vec{X_C}$

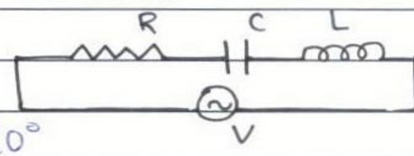


→ $\vec{Z} = \vec{X_L} + \vec{X_C}$



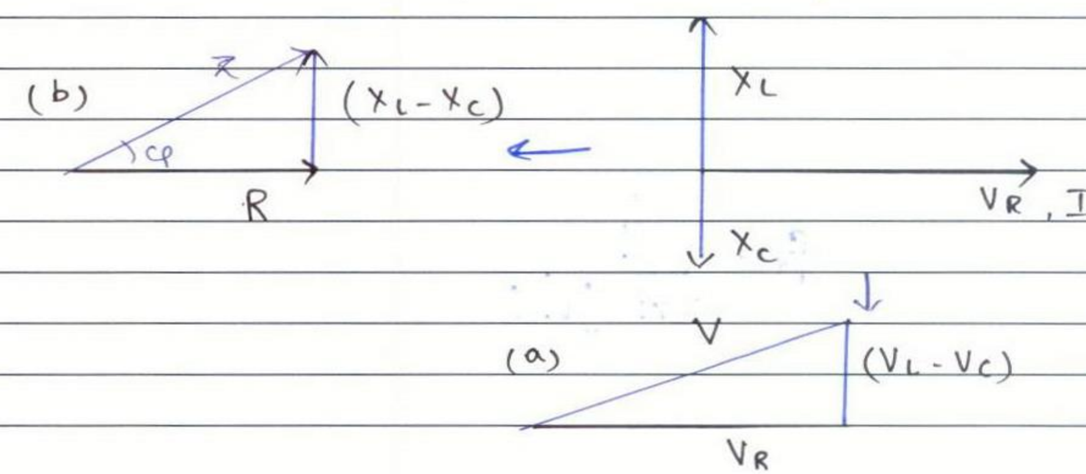
IMPEDENCE OF RLC SERIES

→ In RLC series AC circuit, V_R is in phase with I



→ V_L leads the I by 90° and V_C lags by 90°

→ The impedence is derived by:



Q. No. 4 (Page 2/6) → From (a) by pythagoras theorem

$$V^2 = V_R^2 + (V_L - V_C)^2$$

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

$$IZ = \sqrt{I^2R^2 + (IX_L - IX_C)^2}$$

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

RESONANCE

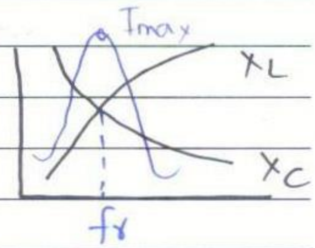
→ Resonance occurs when $X_L = X_C$

→ $Z = R$ i.e, resistive circuit

→ Power loss is max

→ I and V are in phase

→ $X_L = X_C$ in (A)



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

$$Z = R$$

→ For resonant frequency

$$X_L = X_C$$

$$2\pi f_r L = \frac{1}{2\pi f_r C} \Rightarrow f_r^2 = \frac{1}{4\pi^2 LC}$$

under root on both sides:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

(b)

X-RAYS

" Electromagnetic waves of wavelength 10^{-10} m are X-rays."

CHARACTERISTIC XRAY

→ When an e^- strikes the innermost shell, i.e K it knocks off the e^- from K shell.

→ e^- from L, M, N (higher shells) jump to fill the vacancy in K.

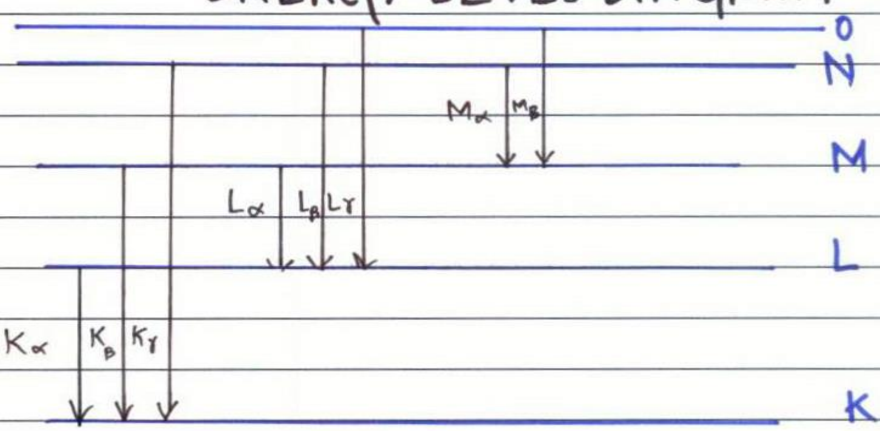
→ By doing so they emit X-ray photon whose energy is equal to energy difference of orbits

$$hf = E_p - E_n$$

→ The target atom should be heavy i.e tungsten.

→ It can be produced in x-ray tube.

ENERGY LEVEL DIAGRAM



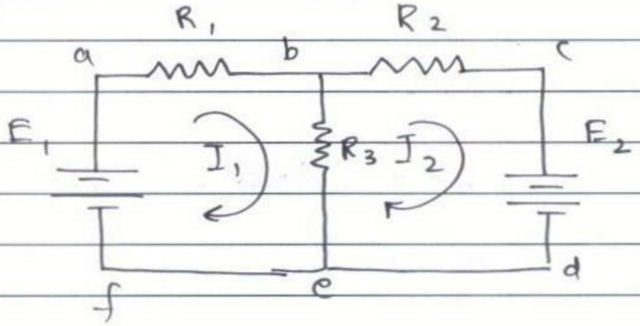
Energy, frequency: $K_\gamma > K_\beta > K_\alpha$

λ : $K_\gamma < K_\beta < K_\alpha$

→ Characteristic xrays are also called inner shell transition

Q. No. 4 (Page 4/6)

—— (C) ——



In loop abefa

$-I_1R_1 - (I_1 - I_2)R_3 + E_1 = 0$

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

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

$-4I_1 + 3I_2 = -5$ —(A)

In loop bcdeb

$-I_2R_2 - E_2 - (I_2 - I_1)R_3 = 0$

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

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

$3I_1 - 5I_2 = 10$ —(B)

(A) × 3 + (B) × 4

$-12I_1 + 9I_2 = -15$

$12I_1 - 20I_2 = 40$

$-11I_2 = 25$

$\boxed{I_2 = -2.27 \text{ A}}$

Q. No. 4 (Page 5/6)

(B) ⇒ $3I_1 - 5(-2.27) = 10$

$$\boxed{I_1 = -0.45\ A}$$

'−' sign shows current is anticlockwise

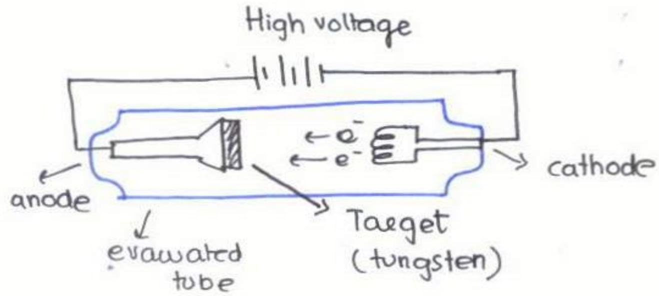
→ Current through $R_1 = I_1 = \underline{0.45\ A}$

Current through $R_2 = I_2 = \underline{2.27\ A}$

Current through $R_3 = I_2 - I_1 = \underline{1.82\ A}$

Q. No. 4 (Page 6/6)

(b) X-RAY TUBE



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)