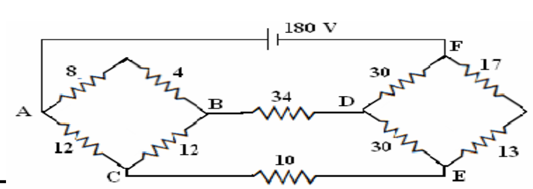
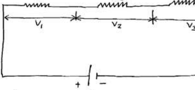
ALPHA COLLEGE OF ENGINEERING &TECHNOLOGY
DEPARTMENT OF ELECTRICAL ENGINEERING
ELEMENTS OF ELECTRICAL ENGINEERING (2110005)
B.E. – 1st YEAR CLASS: EE, CE, Civil, IT, EC (ALL)

1	Explain the following terms in detail ELCB, MCB and Fuse.
2	Explain the following Cleat Wiring, Conduit wiring, casing-caping wiring & batten wiring.
3	Explain Charging and Discharging of capacitors with voltage & current equations.
4	What is capacitor? List out different types of it.. Derive the expression for the equivalent capacitance of capacitors connected (i) in parallel (ii) in series
5	Define temperature co-efficient of resistance. How does the resistance of different materials vary with temperature? Prove that $\alpha_t = \alpha_0/(1+ \alpha_0 t)$
6	An inductive coil of resistance R and inductance L is connected in parallel with a capacitor of C. Derive an expression for resonant frequency and Q factor.
7	Explain power measure by two- watt meter method for 3 phase balanced load.
8	Compare Series and Parallel Resonance in AC Circuit.
9	Explain the following methods of charging a battery (i) Constant current method (ii) Constant voltage method. Also discuss electrical characteristics of batteries. Give connection diagram of a battery charging circuit with equations.
10	Draw the connection diagram of a tube light and explain its starting and working.
11	Explain following terms-Magnetic hysteresis,Magneto-motive force ,Reluctance,Permeability Magnetic Field Intensity,Electric Field Intensity,Electric Flux Density,Electric Potential,Potential gradient Permittivity,Coulombs Law,Ohms Law,KCL,KVL,Power factor,Lenz Law,B/H Curve
12	Give the comparison between electric and magnetic circuit.
13	State Faraday's laws of electromagnetic induction. What do you understand by statically induced e.m.f and dynamically induced e.m.f?
14	A 3-phase load consists of three similar inductive coils of resistances of 50 Ω and inductance 0.3 H. The supply is 415 V 50 Hz. Calculate:(i) the line current (ii)the power factor and the total power when the load is star connected
15	Explain construction of 3 phase cable in detail. & List the different types of illumination scheme and explain any one in detail.
16	Calculate the current flowing through the 10 resistor of circuit shown in fig. 
17	Derive the relation between phase and line values of voltages and currents in case of 3-phase (i) star (ii) delta connection.
18	Explain the method of transforming a star network of resistances into delta network and vice versa
19	Define (i) form factor (ii) peak factor. Obtain the rms value and average value of half wave rectified sinusoidal voltage wave.
20	Derive an expression for self inductance, mutual inductance. Also explain series and parallel connection of Inductance , coefficient of coupling

E.C. D.C. Circuits

Q:-1 Resistances in Series :-



→ When resistors are connected end to end, so that they form one path for the flow of current then resistors are said to be connected in series and such circuits are known as series circuits.

→ So;

Total Voltage (V) = Voltage drop across R_1 + Voltage drop across R_2 + Voltage drop across R_3.

$$\therefore \quad V = IR_1 + IR_2 + IR_3$$

$$\therefore \quad V = I(R_1 + R_2 + R_3)$$

$$\therefore \quad \frac{V}{I} = (R_1 + R_2 + R_3)$$

→ According to ohm's law; the ratio $\frac{V}{I}$ gives the total resistance of the whole circuits, say $\underline{R}$. is called the total (or) equivalent resistance of the three resistances.

$$\therefore \quad R = R_1 + R_2 + R_3 \quad \text{———} \quad (1)$$

$$\therefore \quad \boxed{R = \sum_{i=1}^{n} R_i}$$ (∴ If n^{th} Resistors are connected in series).

→ If we multiply the eq^n ① by current I^2;

$$\therefore \quad I^2R = I^2R_1 + I^2R_2 + I^2R_3$$

$$\therefore \quad \boxed{P = P_1 + P_2 + P_3} \quad \text{———} \quad (2)$$

→ therefore, the total power consumed in the series ckt is the sum of

→ IF a break occurs at any Point in the CKt, no Current will flow and the entire CKt becomes useless.

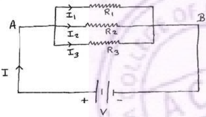
→ Since electrical devices have different Current ratings, they Cannot be Connected in Series for efficient Operation.

* Practical Applications :-

→ Connecting a regulator with the fan.

→ Fuses are used in Series with the equipment they Protect.

Q:-2 Resistances in Parallel :-



→ When a number of resistors are connected in Such a way that one end of each of them is Joined to a Common Point (A) and the other ends Joineds to another Common Point (B), then the resistors are said to be connected in Parallel and Such CKt are Known as Parallel CKt.

→ According in ohm's law :-

$\therefore$ I = Current in resistor R_1 + Current in resistor R_2 + Current in resistor R_3

$$\therefore I = I_1 + I_2 + I_3$$

$$\therefore I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$ ($\because$ Potential difference across each resistor is same)

$$\therefore I = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\overline{V} \quad R_1 \quad R_2 \quad R_3$$

$$\therefore \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \text{——— (1)}$$

$$\boxed{\therefore \frac{1}{R} = \sum_{i=1}^{n} \frac{1}{R_i}}$$ (∵ If n^{th} resistors are connected in Parallel).

$$\therefore G = G_1 + G_2 + G_3 \qquad \left(\because \frac{1}{R} = G\right)$$

→ multiplying the eq^n ① by V^2;

$$\frac{V^2}{R} = \frac{V^2}{R_1} + \frac{V^2}{R_2} + \frac{V^2}{R_3} \qquad \left[\because P = \frac{V^2}{R}\right]$$

$$\boxed{P = P_1 + P_2 + P_3} \text{ ——— (2)}$$

→ The total Power Consumed in a Parallel ckt is equal to the sum of Powers Consumed the individual resistances.

* Advantages of Parallel ckt :-

→ If a break occurs in any one of the branch ckt, it will have no effect on the other branch ckt.

* Practical Applications :

→ Parallel ckt are very common in use.
→ Various lamps and appliances in a house are Connected in Parallel.

Series ckt

1.) The Current Passing through all the elements Connected in Series is the Same.

i.e $I_1 = I_2 = I_3$

2.) There is only one Path for the flow of current.

i.e $I = \frac{V_1}{R_1} = \frac{V_2}{R_2} = \frac{V_3}{R_3} \cdots$

3) The total Potential difference applied across Series ckt is equal to the Sum of Voltage drops across all the elements connected in Series.

i.e $V = V_1 + V_2 + \cdots$

4.) The equivalent resistance is greater then the greatest resitance Connected in the series ckt.

Parallel ckt

1.) Potential difference across each element Connected in Parallel is the Same.

i.e $V_1 = V_2 = V_3$

2.) The Paths for flow of current are more then one.

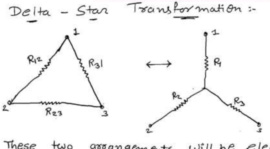
i.e $V = \frac{I_1}{G_1} = \frac{I_2}{G_2} = \frac{I_3}{G_3} \cdots$

3) The total Current flowing through the Parallel combination is equal to the Sum of all currents flowing through all the elements Connected in Parallel.

i.e $I = I_1 + I_2 + \cdots$

4.) The equivalent resistance is less than the least resistance connected in the Parallel ckt.

Q* Delta - Star Transformation :-



→ These two arrangements will be electrically equivalent if the resistance as measured between any Pair of terminals is the same in both the arrangements.

i.e :- $[R_{12}]_{\Delta}$

→ First consider delta connection :-

$$[R_{12}]_{\Delta} = \frac{R_{12} \times (R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}} \quad \text{----- (ii)}$$

→ Now consider star connection :-

$$[R_{12}]_{Y} = R_1 + R_2 \quad \text{----- (iii)}$$

→ By using eq^n (i); networks to be equivalent of each other,

$$[R_{12}]_{\Delta} = [R_{12}]_{Y}$$

$$\therefore \frac{R_{12} \times (R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}} = R_1 + R_2 \quad \text{----- (iv)}$$

→ Similarly, for terminals 2 and 3 and terminal 3 and 1 we get ;

$$R_2 + R_3 = \frac{R_{23} \times (R_{12} + R_{31})}{R_{12} + R_{23} + R_{31}} \quad \text{----- (v)}$$

$$R_3 + R_1 = \frac{R_{31} \times (R_{12} + R_{23})}{R_{12} + R_{23} + R_{31}} \quad \text{----- (vi)}$$

→ Now; Addition of eq^n (iv), (v) & (vi); we get,

$$2(R_1 + R_2 + R_3) = \frac{2(R_{12}R_{23} + R_{23}R_{31} + R_{31}R_{12})}{R_{12} + R_{23} + R_{31}}$$

$$R_1 + R_2 + R_3 = \frac{\ldots}{R_{12} + R_{23} + R_{31}} \quad \text{---- (vii)}$$

Now; Subtraction of eq^n (v) from eq^n (vii) gives :

$$\boxed{R_1 = \frac{R_{12} R_{31}}{R_{12} + R_{23} + R_{31}}} \quad \text{—— (A)}$$

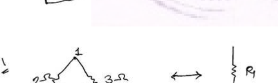
Now; Subtraction of eq^n (vi) from eq^n (vii) gives ,

$$\boxed{R_2 = \frac{R_{23} R_{12}}{R_{12} + R_{23} + R_{31}}} \quad \text{—— (B)}$$

Now; Subtraction of eq^n (iv) from eq^n (vii) gives ;

$$\boxed{R_3 = \frac{R_{31} R_{23}}{R_{12} + R_{23} + R_{31}}} \quad \text{—— (C)}$$

Ex:-



find R_1, R_2, R_3

$R_1 = \frac{2 \times 3}{2+4+3}$

$= 6 = \boxed{2}$

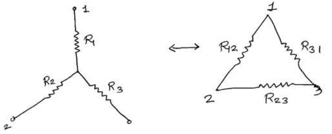
$R_2 = \frac{4 \times 2}{2+4+3}$

$= \boxed{\frac{8}{9}}$

$R_3 = \frac{3 \times 4}{2+4+3}$

$= \frac{12}{9} = \boxed{\frac{4}{3}}$

* Star - Delta :



→ Multiplying the eq^n A and B ; B & C ; C & A and adding them together, we get ;

$$R_1R_2 = \frac{R_{12}^2 R_{23} R_{31}}{(R_{12}+R_{23}+R_{31})^2} \quad R_2R_3 = \frac{R_{23}^2 R_{12} R_{31}}{(R_{12}+R_{23}+R_{31})^2} \quad R_3R_1 = \frac{R_{31}^2 R_{12} R_{23}}{(R_{12}+R_{23}+R_{31})^2}$$

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}^2 R_{23} R_{31} + R_{23}^2 R_{12} R_{31} + R_{31}^2 R_{12} R_{23}}{(R_{12}+R_{23}+R_{31})^2}$$

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12} R_{23} R_{31} \cancel{(R_{12}+R_{23}+R_{31})}}{(R_{12}+R_{23}+R_{31})^{\cancel{2}}}$$

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12} R_{23} R_{31}}{(R_{12}+R_{23}+R_{31})} \quad ----(i)$$

Now ; Division eq^n (i) by eq^n (A) ;

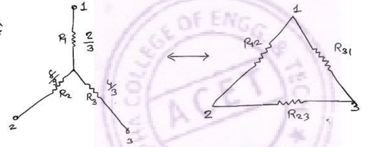
$$\therefore \boxed{R_2 + \frac{R_2R_3}{R_1} + R_3 = R_{23}} \quad ----(D)$$

$$\boxed{R_1 + R_3 + \frac{R_1 R_3}{R_2} = R_{31}} \quad \text{--- (E)}$$

Now; Division eqn (i) by eqn (c);

$$\boxed{\frac{R_1 R_2}{R_3} + R_2 + R_1 = R_{12}} \quad \text{--- (F)}$$

Ex 1



$$R_{12} = \frac{2}{3} + \frac{8}{9} + \frac{\frac{2}{3} \times \frac{8}{9}}{\frac{4}{3}}$$

$$= \frac{2}{3} + \frac{8}{9} + \frac{48}{108}$$

$$= \frac{2}{3} + \frac{8}{9} + \frac{4}{9}$$

$$= \frac{6+8+4}{9}$$

$$= \frac{18}{9}$$

$$\boxed{R_{12} = 2\,\Omega}$$

$$R_{23} = \frac{8}{9} + \frac{4}{3} + \frac{\frac{8}{9} \times \frac{4}{3}}{\frac{2}{3}}$$

$$= \frac{8}{9} + \frac{4}{3} + \frac{96}{54}$$

$$= \frac{8}{9} + \frac{4}{3} + \frac{16}{9}$$

$$= \frac{8+12+16}{9}$$

$$= \frac{36}{9}$$

$$\boxed{R_{23} = 4\,\Omega}$$

$$R_{31} = \frac{\;}{3} + \frac{\;}{3} + \frac{\;}{\frac{8}{9}}$$

$$= \frac{4}{3} + \frac{2}{3} + \frac{72}{72}$$

$$= \frac{4+2+3}{3}$$

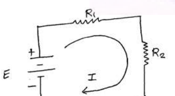
$$= \frac{9}{3}$$

$$\boxed{R_{31} = 3\,\Omega}$$

* Kirchhoff's Voltage law :-

→ At any instant of time, the algebraic sum of all branch Voltages around any closed loop (or Path) of a electric network is zero.

$$\boxed{\sum_{i=1}^{n} V_i = 0}$$



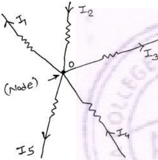
$$\rightarrow \boxed{E = IR_1 + IR_2 + IR_3}$$

→ Note :- In KVL ; you have to give one example on KVL in also theory ;

* Kirchhoff's Current Law

→ It states that the algebraic sum of all currents terminating at a Point (or a junction) is zero at any instant of time.

$$\boxed{\sum_{n=1}^{n} I_n = 0}$$



→ Applying KCL at node 0;

$\therefore (-i_1) + (i_2) + (-i_3) + (i_4) + (-i_5) = 0$

$$\boxed{\therefore \quad i_2 + i_4 = i_1 + i_3 + i_5}$$

∴ Sum of incoming currents = Sum of outgoing currents.

* MESH ANALYSIS :-

→ loop

→ Apply KVL;

→ $V = IR$ eq^n;

→ We get Current Value.

* NODAL ANALYSIS :-

→ NODE (Node) (More then two terminals are connected with each other)

→ Apply KCL;

→ $I = \frac{V}{R}$ eq^n.

→ We get Voltage Value.

* Examples :-

1> Series & Parallel Connection of Resistors.

2> KVL & KCL .

3> Mesh & Nodal

4> Star - Delta Connection of Resistors.

⇒ Resistance of almost all the materials changes with change in temperature

Suppose,

R_0 = Resistance at $0°c$.

R_t = Resistance at $t°c$

Change in Resistance $\Delta R = R_t - R_0$.

$$\Delta R \propto R_0 t$$

$$(R_t - R_0) \propto R_0 t$$

$$(R_t - R_0) = \alpha R_0 t$$

$$\alpha = \frac{R_t - R_0}{R_0 t}$$

Here α is known as temperature co-efficient of Resistance.

⇒ It is defined as change in Resistance per unit rise in temperature per original resistance.

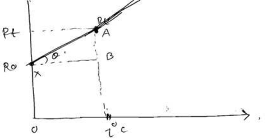
⇒ If α is tanken at $0°c$, then

$$\alpha_0 = \frac{R_t - R_0}{R_0 t}$$

$$\therefore R_t - R_0 = \alpha_0 R_0 t$$

$$\therefore R_t = R_0 + \alpha_0 R_0 t$$

$$\therefore \boxed{R_t = R_0 [1 + \alpha_0 t]}$$



$\Rightarrow$ ~~α~~ R_0 = Resistance at 0°c

R_t = Resistance at t°c

$$\alpha_0 = \frac{R_t - R_0}{R_0 t}$$

Here in the graph $R_t - R_0 = AB$.

$$\therefore \alpha_0 = \frac{AB}{R_0 t}$$

$$= \frac{AB}{R_0 (t-0)}$$

Here in the graph $t - 0 = XB$.

$$\therefore \alpha_0 = \frac{AB}{R_0 \cdot XB}$$

$$= \frac{AB/XB}{R_0}$$

$$\boxed{\tan\theta = \frac{AB}{XB}}$$

$$\boxed{\alpha_0 = \frac{\text{Slope of the graph R vs t}}{\text{Resistance at } 0^\circ c}}$$

$$\boxed{\alpha_t = \frac{\text{Slope of the graph R vs t}}{\text{Resistance at } t^\circ c}}$$

$$\boxed{R_t = R_0 [1 + \alpha_0 t]}$$

Suppose R_1 = Resistance at t_1°C.

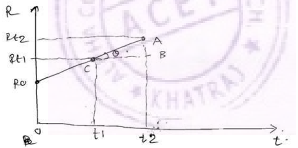
R_2 = Resistance at t_2°C

$\therefore \; R_2 = R_0 [1 + \alpha_0 t_2]$.

$R_1 = R_0 [1 + \alpha_0 t_1]$.

$$\therefore \frac{R_2}{R_1} = \frac{\cancel{R_0} [1 + \alpha_0 t_2]}{\cancel{R_0} [1 + \alpha_0 t_1]}$$

$$\boxed{\frac{R_2}{R_1} = \frac{1 + \alpha_0 t_2}{1 + \alpha_0 t_1}}.$$



Suppose R_{t_1} = Resistance at t_1°C

R_{t_2} = Resistance at t_2°C

$$\alpha_0 = \frac{\text{Slope of graph R vs t}}{\text{Resistance at } 0°C}$$

$$\alpha_{t_1} = \frac{\text{Slope of graph R vs t}}{\text{Resistance at } t_1°C}$$

Slope of graph R vs t = $\cancel{\alpha_{t0}}\ \alpha_{t_1} R_{t_1}$

$\Rightarrow$ In the graph $\tan\theta = \dfrac{AB}{BC}$

$AB = R_{t_2} - R_{t_1}$
$BC = t_2 - t_1$

$$\frac{AB}{BC} = \alpha_{t_1} R_{t_1}$$

$$\therefore \frac{R_{t_2} - R_{t_1}}{t_2 - t_1} = \alpha_{t_1} R_{t_1}$$

$$\therefore R_{t_2} - R_{t_1} = \alpha_{t_1} R_{t_1} (t_2 - t_1).$$

$$\therefore R_{t_2} = R_{t_1} + \alpha_{t_1} R_{t_1} (t_2 - t_1).$$

$$\therefore \boxed{R_{t_2} = R_{t_1} \left[1 + \alpha_{t_1} (t_2 - t_1)\right]}$$

$= \frac{1}{11} =$ Suppose a conductor has a Resistance of R_t at $t^\circ C$. Now, this conductor is cooled down to $0^\circ c$. The Resistance is R_0 at $0^\circ c$.

$t_1 = t, \quad t_2 = 0^\circ.$
$R_{t_1} = R_t, \quad R_{t_2} = R_0.$

$$R_0 = R_t \left[1 + \alpha_t (0 - t)\right].$$

$$\therefore R_0 = R_t \left[1 - t\,\alpha_t\right].$$

$$\therefore R_0 = R_t - R_t\,\alpha_t\,t.$$

$$\therefore \cancel{\alpha_{t0}}\ R_t \alpha_t t = R_t - R_0.$$

$$\therefore \cancel{R_t = -R_t \rightarrow} \boxed{\alpha_t = \frac{R_t - R_0}{R_t \cdot t}}$$

$$\boxed{R_t = R_0\left[1+\alpha_0 t\right]}$$

$$\alpha_t = \frac{R_0(1+\alpha_0 t) - R_0}{R_0(1+\alpha_0 t)\,t}$$

$$= \frac{\cancel{R_0}\left[1+\alpha_0 t - 1\right]}{\cancel{R_0}(1+\alpha_0 t)\,t}$$

$$= \frac{\alpha_0 \cancel{t}}{(1+\alpha_0 t)\cancel{t}}$$

$$\boxed{\alpha_t = \frac{\alpha_0}{1+\alpha_0 t}}$$

$$\alpha_{t1} = \frac{\alpha_0}{1+\alpha_0 t_1}, \quad \alpha_{t2} = \frac{\alpha_0}{1+\alpha_0 t_2}$$

$$\frac{1}{\alpha_{t1}} = \frac{1+\alpha_0 t_1}{\alpha_0}, \quad \frac{1}{\alpha_{t2}} = \frac{1+\alpha_0 t_2}{\alpha_0}.$$

$$\frac{1}{\alpha_{t2}} - \frac{1}{\alpha_{t1}} = \frac{1+\alpha_0 t_2}{\alpha_0} - \frac{1+\alpha_0 t_1}{\alpha_0}$$

$$= \frac{1+\alpha_0 t_2 - 1 - \alpha_0 t_1}{\alpha_0}$$

$$= \frac{\alpha_0(t_2 - t_1)}{\alpha_0} = t_2 - t_1$$

$$\therefore \boxed{\cancel{\alpha}\ \frac{1}{\alpha_{t2}} - \frac{1}{\alpha_{t1}} = t_2 - t_1}$$

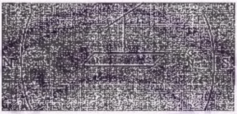
$$\frac{1}{\alpha t_2} = \frac{1}{\alpha t_1} + (t_2 - t_1)$$

$$\therefore \boxed{\alpha t_2 = \frac{1}{\frac{1}{\alpha t_1} + (t_2 - t_1)}}$$

Temperature Co-efficient of Resistance examples

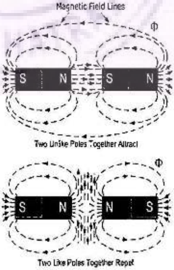
INTRODUCTION

- Magnet :
  - Any object that attracts iron and which when freely suspended points towards the poles of the earth is called magnet.
  - Any magnet will exist only as dipole.
  - When a magnet freely suspended the end which point towards the north pole of earth is called its north pole and which points towards earth's south pole is called magnet's south pole.



CONTI...

- Magnetism:
  - The power by which a magnet attracts certain substances is called magnetism.
- Magnetic material:
  - The substance or materials that are attracted by magnet is called magnetic material.

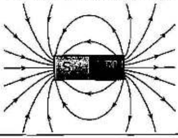


MAGNETIC QUANTITIES

- Magnetic field:
  - Whenever a magnet is placed near another magnet, it experiences a force.
  - The region around the magnet in which another magnet or magnetic material experience a force is called its magnetic field.
  - It is shown by hypothetical magnetic lines called magnetic flux lines.

CONTI...

- Magnetic flux :
  - The total number of magnetic lines of force passing through a surface in magnetic field is called the magnetic flux.
  - Unite of magnetic flux is Weber (Wb).
    - 1 Weber = 10^8 magnetic lines
      = 10^8 Maxwell
  - These lines of flux are purely imaginary.

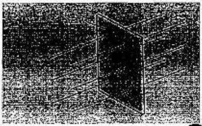


CONTI...

- Characteristics of flux lines :
  - They have no physical existence.
  - They form closed path
  - They never intersect each other.
  - Lines of magnetic flux (parallel lines) closer to each other and having same direction repel each other.
  - Lines of magnetic flux (parallel lines) closer to each other and having opposite direction attract each other.
  - They exert lateral pressure.
    - They emerge from the N-pole and enter into S-pole and are then continuous through the body of the magnet.

CONTI...

- Magnetic flux density :
  - It is defined as the magnetic flux per unit area of a surface at right angle to the magnetic field.
  - It is denoted by symbol B.
  - Unit : Wb/m^2
  - The recommended name for the unit in S.I. system is Tesla (T).
  - $1\ Wb/m^2 = 1$ Tesla (T)



Mathematically ,

$B = \frac{\Phi}{A}$ Wb/m^2 (Tesla)

where,

Φ = flux passing through the cross - section (Wb)

A = surface area of the cross section (m^2)

CONTI…

- Magneto motive force :
  - It is define as force required to produce magnetic flux.
  - The m.m.f. is given by the product of the current through the coil and the number of turns of the coil.
  - mmf(Fm) = NI
  - Where,

    N = number of turns on a coil

    I = current through the coil (A)
  - Unit :Ampere turn(AT)

CONTI…

- Magnetic field intensity (H) :
- It is defines as the m.m.f per unit length of the magnetic circuit. It is also known as magnetic field strength.
  - Mathematically,

$$\boxed{H = \frac{F}{l} = \frac{NI}{l}}$$

- Where,
  - I = current(A)
  - N= no. of turns
  - l =length of magnetic circuit
- Unit ampere-turn / meter (AT/m) or ampere / meter (A/m)

CONTI...

- Permeability:
- When the magnetomotive force is applied to ferromagnetic material, the flux produced is very large compared with that in air , vacuum or non-magnetic material.
- Thus magnetic material establish more magnetic flux than others under similar conditions.
- Permeability is the ability of a material to establish the magnetic flux. It is measure of ease with which the material can be magnetized.
- SI unit : Henry / meter (H/m)
- Symbol : μ (permeability of any material)

CONTI...

- The permeability of free space is written as μ_0. It is also called as magnetic space constant.
- $\mu_0 = 4\pi * 10^{-7}$ H/m
- When the permeability of any material is compared with that of air (μ_0), it shows the permeability of the material is how many times that of air and it is called its relative permeability (μ_r).

$$\mu_r = \frac{\text{absolute permeability}}{\text{permeability of air}}$$

$$\therefore \mu_r = \frac{\mu}{\mu_0}$$

CONTI…

- Reluctance :
- The property of a material that opposes the production of magnetic flux through it is called reluctance.

$$\text{Reluctance} = \frac{\text{mmf}}{\text{Flux}}$$

$$or \quad S = \frac{F}{\Phi}$$

- Where,

  S =reluctance of the magnetic circuit

  F = magnetomotive force (mmf)

  Φ = magnetic flux
- Unit : ampere turn /Wb (AT/Wb) or ampere/Wb (A/Wb)

CONTI…

- Now

$$S \propto \frac{F}{\Phi} \quad or \quad S = \frac{l}{\mu A}$$

$$= \frac{l}{\mu_0 \mu_r A}$$

- Where ,

  l = length of magnetic circuit

  A = area of cross section of magnetic path

CONTI…

- Reluctivity :

- Reluctivity or specific reluctance is defined as the reluctance offered by a magnetic circuit of a unit length and unit cross section.

$$\boxed{S = \frac{l}{\mu A}}$$

- When l = 1 and A =1 then ,

$$S = \frac{1}{\mu 1} = \frac{1}{\text{Absolute permeability}}$$

- Unit : meter/Henry

CONTI…

- Permeance :

- It is define as the reciprocal of the reluctance.
- Thus it is matter of ease with which the flux can be setup in the magnetic circuit.

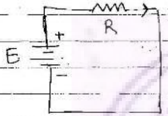
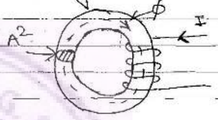
$$\boxed{\text{Permeance}(\lambda) = \frac{1}{\text{reluctance(S)}}}$$

- Unit : Weber / ampere (Wb/A) or Henry(H)

Magnetic ckt.

* Comparisson between Electric & Magnetic circuit. (V.A. Patel)

Similarities

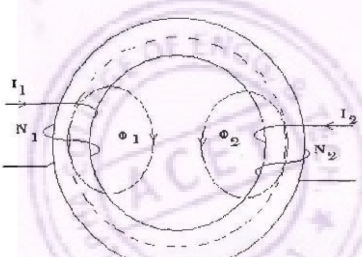
Electric ckt.	Magnetic ckt
	
- The closed path for electric current is called electric ckt.	- The closed path for magnetic flux is called magnetic ckt.
- Flow of Electrons through conductor is current & it flows in ckt.	- lines of force through a medium from N pole to S pole forms flux
- Unit : Amp	- Unit : Weber
- EMF :- It is driving force for current.	- MMF :- It is driving force for flux
- Unit = Volts	Unit :- Ampere-turn.
- current ~~Flux~~ = $\frac{e.m.f}{resistance}$	- Flux = $\frac{m.m.f}{reluctance}$
- Resistance opposes the flow of current.	- Reluctance opposes the flux
- Unit :- ohms(Ω)	- Unit AT/wb
- $R = \frac{\rho l}{a}\ \Omega$	- $S = \frac{l}{\mu_0\mu_r A}$ AT/wb
$R \propto l$ & $R \propto 1/a$	- $S \propto l$ & $S \propto \frac{1}{A}$

- Resistance depends upon nature of conductor material (ρ)	- Depends on the permeability of medium $\left(\frac{1}{\mu}\right)$
- Resistivity (ρ)	- Reluctivity ($1/\mu_0\mu_r$)
- Conductance = 1/resistance	- Permeance = 1/reluctance
- Conductivity (γ) = 1/Resistivity	- Permeability = 1/Reluctivity
- Current Density $\delta = \frac{I}{a}$ A/m^2	- Flux Density $B = \frac{\phi}{A}$ Wb/m^2
- Electric Field Intensity $E = V/d$ Volt/m	- Magnetic Field Intensity $H = \frac{NI}{l}$ AT/m
- The KCL & KVL are applicable to the ckt	- The Kirchhoff's flux & mmf laws are applicable

Dissimilarities

Electric ckt	Magnetic ckt.
- The Electric current actually flows in circuit.	- Magnetic flux does not actually flow in ckt.
- Energy is required to produce Current & to maintain it.	- Energy is required to produce flux but not for its maintenance
- Current does not pass through air.	- flux can pass through air.
- Resistance is almost Constant, it vary slightly due to change in temp.	- Reluctance depends on permeability, it vary to a great extent due to the variations in the flux density.
- There are many insulators for Electric ckt.	- There is no insulator for magnetic ckt

CO-EFFICIENT OF COUPLING



Let N_1 = no. of turns in coil 1

N_2 - no. of turns in coil 2

I_1 = current through coil 1

I_2 = current through coil 2

ϕ_1 = flux produced by I_1 in coil 1

ϕ_2 = flux produced by I_2 in coil 2.

L_1 = Self Inductance of coil 1

L_2 = Self Inductance of coil 2

M = Mutual Inductance between coils

$$\Rightarrow M = \frac{N_2 \phi_{12}}{I_1}$$

$$\Rightarrow \phi_{12} = K_1 \phi_1$$
$$\phi_{21} = K_2 \phi_2 \qquad (\because K = \text{Constant})$$

$$\therefore M_1 = \frac{N_2 K_1 \phi_1}{I_1} \qquad \text{for coil-1}$$

$$M_2 = \frac{N_1 K_2 \phi_2}{I_2} \qquad \text{for coil-2}$$

$$M \cdot M = \left(\frac{N_2 K_1 \phi_1}{I_1}\right)\left(\frac{N_1 K_2 \phi_2}{I_2}\right)$$

$$\Rightarrow M^2 = \frac{N_1 N_2 \; K_1 K_2 \; \phi_1 \phi_2}{I_1 I_2} = K_1 K_2 \frac{N_1 \phi_1}{I_1} \cdot \frac{N_2 \phi_2}{I_2}$$

$\frac{N_1 \phi_1}{I_1} = L_1$ (self induction of coil-1)

$$\therefore M^2 = K_1 K_2 \; L_1 L_2$$

$$\Rightarrow M = \sqrt{K_1 K_2 \; L_1 L_2}$$

assume $\sqrt{K_1 K_2} = K$ = co-officient of coupling

$$\Rightarrow \boxed{M = K \sqrt{L_1 L_2}}$$

$$\therefore K = \frac{M}{\sqrt{L_1 L_2}}$$

MAGNETIC HYSTERESIS LOOP:

Hysteresis

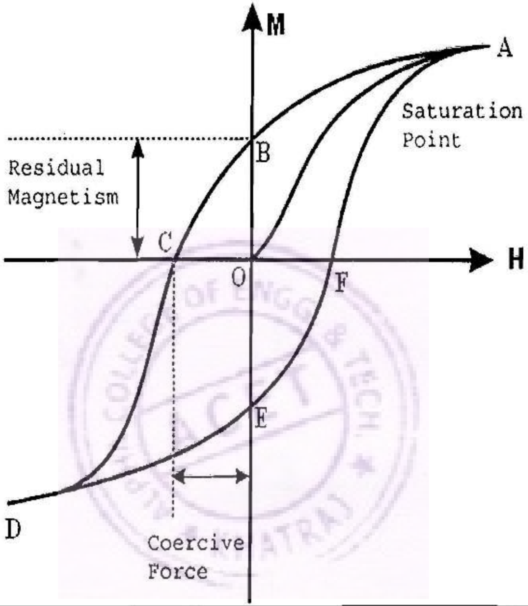
Hysteresis means "remaining" in Greek, an effect remains after its cause has disappeared. Hysteresis, a term coined by Sir James Alfred Ewing in 1881, a Scottish physicist and engineer (1855-1935), defined it as: When there are two physical quantities M and N such that cyclic variations of N cause cyclic variations of M, then if the changes of M lag behind those of N, we may say that there is hysteresis in the relation of M to N". The most notable example of hysteresis in physics is magnetism. Iron maintains some magnetization after it has been exposed to and removed from a magnetic field.

Magnetic Hysteresis

Consider a magnetic material being subjected to a cycle of magnetization. The graph intensity of magnetization (M) vs. magnetizing field (H) gives a closed curve called M-H loop. Consider the portion AB of the curve given below. The intensity of magnetization M does not become zero when the magnetizing field H is reduced to zero. Thus the intensity of magnetization M at every stage lags behind the applied field H. This property is called magnetic hysteresis. The M-H loop is called hysteresis loop. The shape and area of the loop are different for different materials.

Hysteresis Loop

An initially unmagnetized material is subjected to a cycle of magnetization. The values of intensity of magnetization M and the magnetizing field H are calculated at every stage and a closed loop is obtained on plotting a graph between M and H as shown in the figure. The point 'O' represents the initial unmagnetized condition of the material. As the applied field is increased, the magnetization increases to the saturation point 'A' along 'OA'. As the applied field is reduced, the loop follows the path 'AB'. 'OB' represents the intensity of magnetization remaining in the material when the applied field is reduced to zero. This is called the residual magnetism or remanence. The property of retaining some magnetism on removing the magnetic field is called retentivity. OC represents the magnetizing field to be applied in the opposite direction to remove residual magnetism. This is called coercive field and the property is called coercivity. When the field is further increased in the reverse direction the material reaches negative saturation point 'D'. When the field is increased in positive direction, the curve follows path 'DEF'.


M
A
Saturation Point
Residual Magnetism
B
C
O
H
F
E
D
Coercive Force

* Capacitors in Series connection

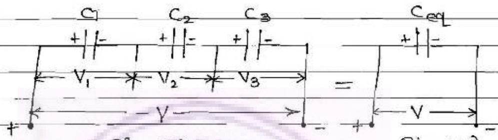


Fig (a) Fig (b)

- Consider three capacitors having capacitance C_1, C_2 and C_3 farads respectively, connected in series as shown in figure (a)

- The current passing through each capacitor is a same in a series connection.

- If a charging current I flows for a time t, the charge of each capacitor is

$$Q_1 = Q_2 = Q_3 = Q = I \cdot t$$

- If the potential difference across the three capacitors are V_1, V_2 and V_3 respectively, the total source voltage V must equal the sum of V_1, V_2 and V_3

$\therefore V = V_1 + V_2 + V_3$ —— (i)

Now

$\therefore V_1 = \frac{Q}{C_1}$

$\therefore V_2 = \frac{Q}{C_2}$

$\therefore V_3 = \frac{Q}{C_3}$

Substituting the values of V_1, V_2 and V_3, we get

$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$ —— (ii)

If a circuit is replaced by a single capacitor of capacitance C_{eq} as shown in fig. (b), such that it stores the same charge when connected to the same source V volt.

then $V = \frac{Q}{C_{eqn}}$ —— (iii)

Substitute eq. (iii) in eq. (ii)

$$\therefore \frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\therefore \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_2}$$

In general, for n capacitors in Series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$$

Thus,

When a number of capacitors are connected in Series, the reciprocal of the equivalent of the combination is equal to the arithmetic sum of the reciprocals of their individual capacitances.

for two capacitors in Series,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\therefore \boxed{C_{eq} = \frac{C_1 \cdot C_2}{C_1 + C_2}}$$

* Capacitors in parallel connection:-

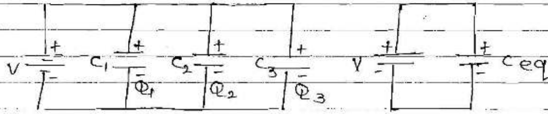


fig (i) fig (ii)

- fig (i) shows three capacitors connected in parallel across a supply voltage V.

- As in any parallel circuit, the voltage across each capacitor is the same and equal to the supply voltage

- When a potential difference of V volts is applied across the parallel combination, different charging current flows in each capacitor, hence Q_1, Q_2 and Q_3 respectively, depending upon their capacitances.

Total charge

$$Q = Q_1 + Q_2 + Q_3 \quad \text{--- (i)}$$

$\therefore\ Q_1 = C_1 V$

$\therefore\ Q_2 = C_2 V$

$\therefore\ Q_3 = C_3 V$

Substituting these value in eq. (i)

$$Q = C_1 V + C_2 V + C_3 V \quad \text{--- (ii)}$$

If the three capacitors in fig (i) are replaced by a single capacitor of capacitance C_{eq} then

$$\therefore\ Q = C_{eq} \cdot V \quad \text{--- (iii)}$$

Combining eq (ii) & (iii)

$$C_{eq} \cdot V = C_1 V + C_2 V + C_3 V$$

$$= V \left[C_1 + C_2 + C_3 \right]$$

$$\boxed{C_{eq} = C_1 + C_2 + C_3}$$

In general, for n capacitors in parallel

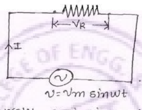
$$\boxed{C_{eq} = C_1 + C_2 + C_3 + \ldots\ldots + C_n}$$

Q:- Prove Analytically that the PowerFactor of purely resistive ckt is unity

Ans :- Pure resistor has no Inductance or negligible inductive Reactance compared to resistance

∴ Practically Pure resistor is not available, but normal Frequency, its Inductive resistance is negligible compared to Resistance

Ch-4 . EEE



Purely Resistive circuit

∴ consider An A.C circuit having Pure Resistance 'R' which connected across AC sinusoidal voltage $v = V_m \sin\omega t$

∴ Applying the ohm's Law
The instanteneous value of current is

$$i = \frac{V}{R} = \frac{V_m \sin\omega t}{R} = \frac{V_m}{R} \sin\omega t \quad -(I)$$

∴ This eqn is comparing the standard current equation

$$i = I_m \sin(\omega t + \phi) \quad -(ii)$$

comparing both equation

$$\frac{V_m}{R} \sin\omega t = I_m \sin(\omega t + \phi)$$

Here $\phi = 0$ that means no-phase Angle between voltage & current

$V_m \sin\omega t = I_m \sin(\omega t + \phi)$

$$\therefore \frac{V_m}{R} \sin\cancel{\omega t} = I_m \sin\cancel{\omega t}$$

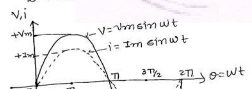
$$\boxed{\therefore I_m = \frac{V_m}{R}}$$

$\therefore$ When we apply sinusoidal voltage $\underline{V = V_m \sin\omega t}$ to purely Resistive circuit & instanteneous value of current is $i = I_m \sin\omega t$

When $\theta = 0$	$V = 0$	$i = 0$
$\theta = \frac{\pi}{2}$	$V = V_m$	$i = I_m$
$\theta = \pi$	$V = 0$	$i = 0$
$\theta = \frac{3\pi}{2}$	$V = -V_m$	$i = -I_m$
$\theta = 2\pi$	$V = 0$	$i = 0$

$\therefore$ We can say that both the quantity voltage & current will attain its maximum value as well as negative value at the same time

$\therefore$ So phase angle difference between voltage & current is zero.



phasor diagram

Wave Form of Pure Resistive circuit

* Power : In case of AC circuit, both the quantity voltage and current are varying in nature

$\therefore$ so power is not constant but it is the product of instanteneous value of voltage & current

$\therefore$ The instanteneous power is given by.

$$P = v \times i$$
$$= V_m \sin\omega t \times I_m \sin\omega t$$
$$= V_m I_m \sin^2\omega t$$
$$= V_m I_m \left(\frac{1-\cos 2\omega t}{2}\right)$$
$$= \frac{V_m I_m}{2}\left[1-\cos 2\omega t\right]$$

$$P = \frac{V_m I_m}{2} - \frac{V_m I_m}{2}\cos 2\omega t$$

The power component has two component

i) A constant component $\frac{V_m I_m}{2}$

ii) A.C component "$\frac{V_m I_m}{2}\cos 2\omega t$"

This component has twice the supply frequency

suppose $V_1 = \frac{V_m I_m}{2}\cos 2\omega t$

$$v_1 = \frac{V_m I_m}{2}\cos 2\theta \quad (\theta = \omega t)$$

when

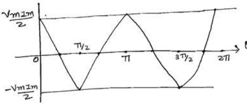
$\theta = 0$ $\quad V_1 = \frac{V_m I_m}{2}\cos 2(0) = \frac{V_m I_m}{2}$

$\theta = \frac{\pi}{2}$ $\quad V_1 = \frac{V_m I_m}{2}\cos 2\left(\frac{\pi}{2}\right) = -\frac{V_m I_m}{2}$

$\theta = \pi$ $\quad V_1 = \frac{V_m I_m}{2}\cos(2\pi) = \frac{V_m I_m}{2}$

$\theta = \frac{3\pi}{2}$ $\quad V_1 = \frac{V_m I_m}{2}\cos 2(3\pi/2) = -\frac{V_m I_m}{2}$

∴ The voltage waveform is



wave Form From For $V_1 = \frac{I_m V_m}{2} \cos 2\theta$

∴ The average value of $V_1 = \frac{V_m I_m}{2}$ over the whole cycle is zero

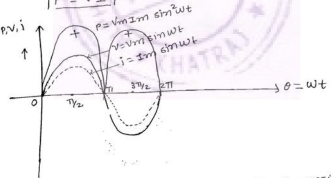
∴ so the average power is the First component only

$$P = \frac{V_m I_m}{2}$$

$$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$

$$= V_{rms} \times I_{rms}$$

$$\boxed{P = VI}$$



Wave Form For v, i, P For pure resistive circuit

☆ other way to Find out Average power $P = ?$ For one cycle

$$= \frac{1}{2\pi} \int_0^{2\pi} P \, d\theta = \frac{1}{2\pi} \int_0^{2\pi} v \times i \, d\theta$$

$$\therefore \frac{1}{2\pi} \int_0 V_m I_m \sin^2\theta \, d\theta$$

$$\therefore \frac{V_m I_m}{2\pi} \int_0^{2\pi} \left(\frac{1-\cos 2\theta}{2}\right) d\theta$$

$$\therefore \frac{V_m I_m}{4\pi} \int_0^{2\pi} (1-\cos 2\theta)\, d\theta$$

$$\therefore \frac{V_m I_m}{4\pi} \left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}$$

$$\therefore \frac{V_m I_m}{4\pi} \left[2\pi - \sin\frac{2\pi}{2} - 0 + \sin\frac{2(0)}{2}\right]$$

$$\therefore \frac{V_m I_m}{4\pi} [2\pi - 0 - 0 + 0]$$

$$\therefore \frac{V_m I_m}{4\pi} [2\pi]$$

$$\therefore \frac{V_m I_m}{2}$$

$$\therefore \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$

$$\therefore V_{rms} \times I_{rms}$$

$$\boxed{P = VI}$$

Power Factor

→ In a purely resistive circuit V and I are both in phase with each other

→ so Phase Angle between V and I is zero

$$\text{Power Factor} = \cos\phi$$
$$= \cos(0)$$
$$= 1$$
$$= \text{unity}$$

Thus power factor of a purely resistive circuit is "unity".

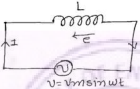
circuit lags behind its voltage by 90°

* Prove that average power consumption in pure inductor is zero when AC voltage is Applied (3)

Ans A Pure inductor is without resistor or negligible resistance +1

→ practically Pure inductor is not available in Market, always inductor has Pure inductor

→ Pure inductor connected across the intanteneous supply voltage $v = v_m \sin\omega t$



→ IF we are Applying voltage $v = v_m \sin\omega t$ Pure inductive circuit, self emf Induced across inductor and its value is given by

$$e = -L\frac{di}{dt}$$

where $\frac{di}{dt}$ = rate of change of current with respect to time

L = self inductance of coil

e = self induced emf

According to Lenz's Law, the voltage is produced across the inductor is due to Applied voltage so it will oppose the supplied voltage

$$v = -e$$

$$\therefore v_m \sin\omega t = -\left[-L\frac{di}{dt}\right]$$

$$\therefore v_m \sin\omega t = L\,di/dt$$

$$\therefore \frac{v_m}{L}\sin\omega t\, dt = di$$

$$\therefore di = \frac{v_m}{L}\sin\omega t\, dt$$

$$\int di = \int \frac{V_m}{L} \sin\omega t \, dt$$

$$i = \frac{V_m}{L}\left[-\frac{\cos\omega t}{\omega}\right]$$

$$= -\frac{V_m}{\omega L}[\cos\omega t]$$

$$= -\frac{V_m}{\omega L} \sin(\pi/2 - \omega t)$$

$$= -\frac{V_m}{\omega L}\left[\sin\left(-(\omega t - \pi/2)\right)\right] \quad (\because \sin(-\theta) = -\sin\theta)$$

$$i = \frac{V_m}{\omega L}\left[\sin(\omega t - \pi/2)\right]$$

Here ωL = inductive Reactance of the coil

It is denoted by X_L

$$X_L = \omega L$$

$$i = \frac{V_m}{X_L}\left[\sin(\omega t - \pi/2)\right]$$

When $\theta = \pi$

$$i = \frac{V_m}{X_L} \sin(\pi - \pi/2)$$

$$i = \frac{V_m}{X_L}(1)$$

$$i = I_m = \frac{V_m}{X_L} \quad [\text{maximum current produced}]$$

$\therefore$ when we apply AC sinusoidal voltage $V = V_m \sin\theta$ to purely inductive circuit

The current following through in this circuit is

$$i = I_m \sin(\omega t - \pi/2) \quad [\theta = \omega t]$$

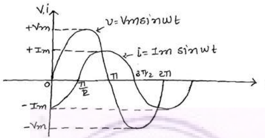
or $i = I_m \sin[\theta - \pi/2]$

$\therefore$ comparing above eqn with $i = I_m \sin(\theta \pm \phi)$

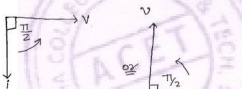
$$\phi = -\pi/2$$

∴ So the phase relationship between voltage & current is $\pi/2$ but it is (-ve)

∴ It Indicates that current 'i' lags the voltage v by Angle $\pi/2$ radian or $90°$



∴ Wave Form of v & i



Fig(i) Fig(ii)

Phase relationship between voltage & current.

Fig (i) = Indicate that current 'i' lags that voltage $\frac{\pi}{2}$

or Fig(ii) = voltage v leads the current 'i' by $\pi/2$ radian.

Remember $v = V_m \sin \omega t$ [For Pure Inductive ckt]

$i = I_m \sin(\omega t - \pi/2)$

☆ Power :- The Power in any AC circuit ~~is given by~~

$$
\begin{aligned}
p &= v \times i \\
&= V_m \sin \omega t \times I_m \sin(\omega t - \pi/2) \\
&= V_m I_m \sin \omega t \, (-\cos \omega t) \\
&= -V_m I_m \sin \omega t \cos \omega t \\
&= -V_m I_m \left[\frac{2 \times \sin \omega t \cos \omega t}{2} \right]
\end{aligned}
$$

$= -V_m I_m$ [...]

$-\frac{V_m I_m}{2} \sin 2\theta$

When $\theta = 0 \qquad P = 0$

$\theta = \frac{\pi}{4} \qquad P = -\frac{V_m I_m}{2} \sin 2(\frac{\pi}{4}) = -\frac{V_m I_m}{2}$

$\theta = \frac{\pi}{2} \qquad P = -\frac{V_m I_m}{2} \sin 2(\pi/2) = 0$

$\theta = \frac{3\pi}{4} \qquad P = -\frac{V_m I_m}{2} \sin 2(\frac{3\pi}{4}) = \frac{V_m I_m}{2}$

$\theta = \pi \qquad P = -\frac{V_m I_m}{2} \sin 2\pi = 0$

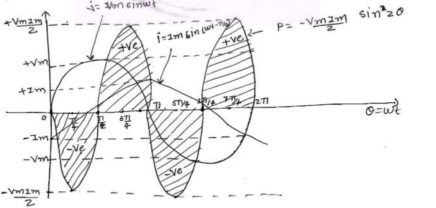
$\theta = \frac{5\pi}{4} \qquad P = -\frac{V_m I_m}{2} \sin 2(\frac{5\pi}{4}) = -\frac{V_m I_m}{2}$

$\theta = \frac{3\pi}{2} \qquad P = -\frac{V_m I_m}{2} \sin 2(3\pi/2) = 0$

$\theta = \frac{7\pi}{4} \qquad P = -\frac{V_m I_m}{2} \sin 2(7\pi/4) = \frac{V_m I_m}{2}$

$\theta = 2\pi \qquad P = -\frac{V_m I_m}{2} \sin 2(2\pi) = 0$

∴ The corresponding waveform for instanteous power for the above value



∴ If we found average power for the ... is zero

$$P = \frac{1}{2\pi}\int_0^{2\pi} p \, d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi} v \times i \, d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\theta \;\; I_m \sin(\theta - \pi/2) \, d\theta$$

$$= \frac{1}{2\pi} V_m I_m \int_0^{2\pi} \sin\theta \; (-\cos\theta) \, d\theta$$

$$= -\frac{V_m I_m}{2\pi}\int_0^{2\pi} \sin\theta \cos\theta \, d\theta$$

$$= -\frac{V_m I_m}{2\pi}\int_0^{2\pi} \frac{2\sin\theta\cos\theta}{2} \, d\theta$$

$$= -\frac{V_m I_m}{4\pi}\int_0^{2\pi} \sin 2\theta \, d\theta$$

$$= -\frac{V_m I_m}{4\pi}\left[-\frac{\cos 2\theta}{2}\right]_0^{2\pi}$$

$$= \frac{V_m I_m}{8\pi}\left[\cos 2\pi - \cos 0\right]$$

$$= \frac{V_m I_m}{8\pi}[1-1]$$

$$= \frac{V_m I_m}{8\pi}[0]$$

$$\boxed{P = 0}$$

∴ So, In pure inductive circuit Average Power is zero.

☆ Power Factor :- The phase relationship between voltage & current in purely inductive circuit is

$v = V_m \sin\omega t$ | compare with $i = I_m \sin(\omega t - \phi)$

$\phi = -\pi/_{...}$

Que : Prove that the current in purely capacitive circuit leads its voltage by 90°

OR

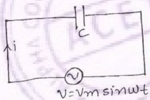
Que : Derive an expression for the instantaneous current in a purely capacitive circuit when a sinusoidal voltage given by $e = E_m \sin \omega t$ is applied to the circuit.

Ans If capacitor is connected across AC-Voltage it will start to charge upto Applied voltage

→ If capacitor is fully charged, meaning that if we measure the voltage across capacitor it is equal to the Applied voltage

→ when capacitor is fully charged, no current will flow through capacitor, it will work as an open circuit.

→



Purely capacitive circuit

→ when the capacitor is connected across A.C voltage source,

→ the capacitor is charged and discharged during alternate quartered cycle

$$V = V_m \sin \omega t$$

∴ The charge devlope across capacitor plate is given by

$$q = CV$$

where q = charge on capacitor plate at any instant

V = Applied voltage

C = capacitance of capacitor in Faraday of change of charge

∴ so current in this circuit

$$i = \frac{dq}{dt}$$

$$= \frac{d}{dt}(C \cdot V)$$

$$= \frac{d}{dt}(C \cdot V_m \sin\omega t)$$

$$= C \cdot V_m \frac{d}{dt} \sin\omega t$$

$$= C V_m (\cos\omega t)\, \omega$$

$$= \omega \cdot C\, V_m \cos\omega t$$

$$= \frac{V_m}{1/\omega C} \cos\omega t \qquad \left(\because X_C = \frac{1}{\omega C}\right)$$

capacitive Reactance

$$= \frac{V_m}{X_C} \cos\omega t$$

$$i = \frac{V_m}{X_C} \sin\left(\omega t + \frac{\pi}{2}\right)$$

when $\omega t = 0$ current flowing through the capacitor is maximum

$$i = I_m = \frac{V_m}{X_C}$$

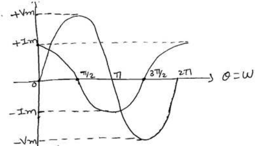
$$i = I_m \sin(\omega t + \pi/2)$$

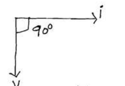
Remember: In purely capacitive circuit

$$v = V_m \sin\omega t$$

$$i = I_m \sin(\omega t + \pi/2)$$

From the above eqn, the current flowing purely capacitive circuit leads the voltage by 90° or π radian.





Phasor diagram

wave Form For voltage & current

$\therefore$ current i Leads the ~~current~~ voltage 'V' by 90°

☆ Power :. The Power in AC circuit given by

$$P = V \times i$$
$$= V_m \sin \omega t \times I_m \sin(\omega t + \pi/2)$$
$$= V_m I_m \sin \omega t \cos \omega t$$
$$= V_m I_m \left[\frac{2 \sin \omega t \cos \omega t}{2} \right]$$
$$= \frac{V_m I_m}{2} [\sin 2\omega t]$$
$$= \frac{V_m I_m}{2} [\sin 2\theta] \qquad [\omega t = \theta]$$

when

$\theta = 0 \quad = \frac{V_m I_m}{2} \sin 2(0) \Rightarrow P = 0$

$\theta = \frac{\pi}{4} \quad = \frac{V_m I_m}{2} \sin 2(\pi/4) \Rightarrow P = \frac{V_m I_m}{2}$

$\theta = \frac{\pi}{2} \quad = \frac{V_m I_m}{2} \sin 2(\pi/2) \Rightarrow P = 0$

$\theta = \frac{3\pi}{4} \quad = \frac{V_m I_m}{2} \sin 2(3\pi/4) \Rightarrow -\frac{V_m I_m}{2}$

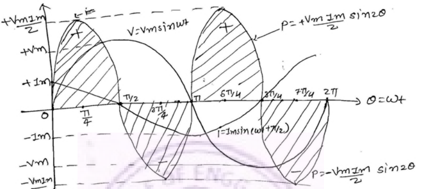
$\theta = \pi \quad = \frac{V_m I_m}{2} \sin 2(\pi) \Rightarrow P = 0$

$\theta = 5\pi/4 \quad = \frac{V_m I_m}{2} \sin 2(5\pi/4) \Rightarrow P = \frac{V_m I_m}{2}$

$\theta = \frac{3\pi}{2} \quad = \frac{V_m I_m}{2} \sin 2(\frac{3\pi}{2}) \Rightarrow P = 0$

$\theta = \frac{7\pi}{4} \quad = \frac{V_m I_m}{2} \sin 2\left(\frac{7\pi}{4}\right) \Rightarrow P = -\frac{V_m I_m}{2}$

$\theta = 2\pi \quad = \frac{V_m I_m}{2} \sin 2(2\pi) \Rightarrow P = 0$



Wave Form For power, voltage & current in purely capacitive circuit

∴ IF we Found the average power For the whole circuit is zero.

$$P = \frac{1}{2\pi} \int_0^{2\pi} p \, d\theta$$

$$= \frac{1}{2\pi} \int_0^{2\pi} v \times i \, d\theta$$

$$= \frac{1}{2\pi} \int_0^{2\pi} V_m \sin\theta \; I_m \sin(\theta + \pi/2) \, d\theta$$

$$= \frac{1}{2\pi} \times V_m I_m \int_0^{2\pi} \sin\theta \cos\theta \, d\theta$$

$$= \frac{V_m I_m}{2\pi} \int_0^{2\pi} 2 \times \frac{\sin\theta \cos\theta}{2} \, d\theta$$

$$= \frac{V_m I_m}{4\pi} \int_0^{2\pi} \sin 2\theta \, d\theta$$

$$= \frac{V_m I_m}{4\pi} \left[-\frac{\cos 2\theta}{2} \right]_0^{2\pi}$$

$$= \frac{-V_m I_m}{8\pi} \left[\cos 2\pi - \cos 0\right]$$

$$= \frac{-V_m I_m}{8\pi} [1-1]$$

$$= \frac{-V_m I_m}{8\pi} [0]$$

$$\boxed{P = 0}$$

∴ Average power consumed by purely capacitive circuit is zero

★ Power Factor :

The phase relationship between voltage & current in purely capacitive circuit

$$v = V_m \sin \omega t$$

$$i = I_m \sin(\omega t + \pi/2)$$

$$\phi = \pi/2$$

$$\text{Power Factor} = \cos\phi$$
$$= \cos \pi/2$$
$$= 0$$
$$= \text{leading.}$$

so power factor in pure capacitive circuit is zero

here current leads the voltage.

because ϕ is positive

∴ power factor is also called as zero leading.

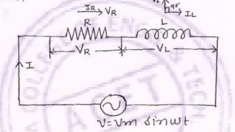
QUE: Draw the phasor diagram in R-L-circuit. T4
Draw the impedance triangle and power triangle

OR Derive the equation of current & power in RL circuit supplied with sinusoidal alternating voltage. Draw necessary vector diagram

OR Impedance, voltage and power triangle in RL-circuit with AC supply.

OR Discuss how the inductance of a chock coil can be measured using rheostate, a voltmeter and Ammeter

Ans - Let us consider a circuit in which a pure Resistance of R ohms and a purely inductive coil of Inductance L henries are connected in series.



Let

$V = V_m \sin\omega t$ be the applied voltage
I = r.m.s value of the Resultant current
$V_R = IR$ = potential difference across R
$V_L = IX_L$ = potential difference across L
f = Frequency of Applied voltage (Hz)

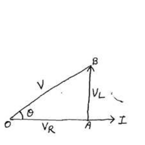
∴ The phasor diagram, the magnitude of the Applied voltage is given by

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

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

$$= I\sqrt{R^2 + X_L^2}$$

$$\boxed{I = \frac{V}{\sqrt{R^2 + X_L^2}}}$$



∴ The term $\sqrt{R^2+X_L^2}$ is usually called the impedance of the circuit and denoted by Z.

$$\boxed{Z=\sqrt{R^2+X_L^2}}$$

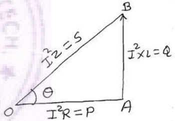
∴ In the phasor diagram of R-L circuit is multiplied with I, the same becomes a power triangle

$$\therefore OA = I^2R$$
$$= I(IR) \qquad [I=\frac{V}{Z}]$$
$$= \frac{V}{Z}[IR]$$
$$= VI(R/Z) \qquad (\therefore \cos\phi = R/Z)$$
$$= VI\cos\phi$$

OA = Represent the active power.
It is denoted by P

$$\boxed{P=VI\cos\phi}$$

$$AB = I^2X_L$$
$$= I(IX_L)$$
$$= \frac{V}{Z}(IX_L)$$
$$= VI\left(\frac{X_L}{Z}\right)$$
$$= VI\sin\phi$$



Power triangle

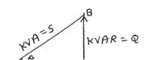
Thus AB Re-represent active power
It is denoted by Q

$$\boxed{Q=VI\sin\phi}$$

$$\therefore OB = I^2Z =$$
$$= I(IZ) \qquad (I=V/Z)$$
$$= VI$$

Thus OB Re-present the Apperent power

$$\boxed{S=VI}$$



circuit

⇒ Here phasor diagram drawn for an Inductive circuit.

From phasor diagram

$$OB^2 = OA^2 + AB^2$$

$$OB = \sqrt{(OA)^2 + (AB)^2}$$

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

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

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

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

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

→ This opposition offered to the flow of alternating current by an R-L-C series circuit is called Impedance of the circuit

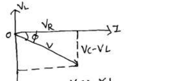
From phasor diagram.

$$\cos\phi = \frac{V_R}{V}$$

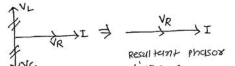
$$= \frac{IR}{IZ}$$

$$\cos\phi = \frac{R}{Z}$$

$$\boxed{\cos\phi = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}}$$



$X_L = X_C$



Apperent power

+2

Ans. The average a power is called the active power

→ Also the power consumed by resistance is called the active power

→ The unit of active power is watt.

$$\text{Active Power (P)} = VI\cos\phi$$

→ **Re-active Power**

→ It is a product of Voltage and reactive component of the current

→ The reactive component of the power is $I\sin\phi$

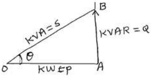
$$\therefore \text{Reactive power } Q = VI\sin\phi$$

→ The unit of Reactive power is (VAR) (Volt-Ampere-Reactive)

→ **Apperant power**

→ It is the product of RMS value of Voltage & current

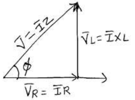
→ Apperent power $S = VI$



→ Power triangle

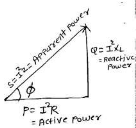
→ If multiplied all the vectors of phasor diagram by current vector I

→ The phasor diagram is converted into Phasor tri-angle



(phasor diagram)

$\Rightarrow$



(power triangle)

$\therefore$ From power triangle

$$P = VI\cos\phi \qquad I = \frac{V}{Z},\ V = IZ$$
$$= VI\, R/Z$$
$$= I\cdot\cancel{Z}\ I(R/\cancel{Z})$$
$$\boxed{P = I^2R} = \text{Active power}$$

$$\therefore\ Q = VI\sin\phi \qquad X_L = Z\sin\phi$$
$$= (I\cancel{Z})\,I\left(\frac{X_L}{\cancel{Z}}\right)$$
$$\boxed{Q = I^2X_L\ (VAR)}$$
= Reactive power

$$\therefore\ S = VI$$
$$= IZ\cdot I$$
$$\boxed{S = I^2Z\ (VA)}$$
= Apperent power

☆ Explain the term Power-Factor

→ It is defined as the Ratio of Resistence of the circuit to the Impedance of the circuit

$$\text{Power Factor} = \frac{\text{Resistence}}{\text{Impedance}} = R/Z$$

$\therefore$ with Reference phasor diagram

$$\cos\phi = \frac{\bar{V}_R}{\bar{V}} = \frac{R}{Z} = \frac{R}{\sqrt{R^2+X_L^2}}$$

with Reference power triangle

$$\cos\phi = \frac{\text{Active Power}}{\text{Apperent Power}} = P/S$$

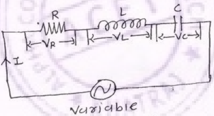
Que: Explain the phenomena of electrical in R-L-C series circuit connected to variable frequency supply. Draw relant vector diagram & define Q factor of the circuit.

OR Explain with the aid of a phasor diagram the phenomenon of resonance in a circuit containing an inductor, capacitor, and a resistor in series

OR: Define the term (i) reactance (ii) Inductive Reactance and (iii) capacitive Reactance and explain how it depend on frequency in AC circuit.

OR: Discuss resonance in R-L-C series circuit. Explain how PF, XL and R vary with frequency

Ans: Let us consider R-L-C series circuit



→ The circuit is connected variable frequency A.C. source

→ Now if the frequency is increased, the value of Resistance is not increased because the Resistance is not depend on frequency

→ Inductive Reactance $X_L = 2\pi F L$, if the frequency is increased, the value of X_L is increased

→ The capacitive reactance $X_C = \frac{1}{2\pi FC}$, IF the Frequency is increased, the value of X_C is decreased.

→ IF we varying the Frequency of AC source X_L can be made equal to the X_C at some Frequency

→ when in RL-C circuit $X_L = X_C$, This Phenomenon is known as series Resonance.

→ we will Find out the Resonance Frequency is

$$X_L = X_C$$

$$2\pi FL = \frac{1}{2\pi FC}$$

$$F^2 = \frac{1}{(2\pi)^2 LC}$$

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

→ The Resonance Frequency notation is F_r

$$\boxed{F_r = \frac{1}{2\pi\sqrt{LC}}}$$

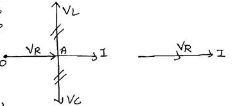
→ Thus in RLC series circuit the Frequency at which the value of Inductive reactance (X_L) becomes equal to capacitive (X_C) is called the resonance Frequency.

→ At Resonance condition Vector diagram is

→ $OA = V_R$ = Resistance voltage drop
$AB = V_L$ = Inductive voltage drop
$AC = V_C$ = capacitive voltage drop

And $V_L = V_C$ cancel the effect of eachother

→ The Resonance vector diagram is shown in Fig (b)



→ Series Resonance $X_L = X_C$

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

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

$$Z = \sqrt{R^2 + 0^2}$$

$$Z = \sqrt{R^2}$$

$$\boxed{Z = R}$$

→ At Resonance condition the value of Impedance is equal to the value of Resistance.

→ Suppose the capacitive Reactance is higher than Inductive Reactance

$X_C > X_L$ condition

→ The net Reactance of R-L-C circuit is capacitive

→ That means the after the Resonance condition Inductive Reactance is higher the capacitive Reactance.

$\therefore X_L > X_C$

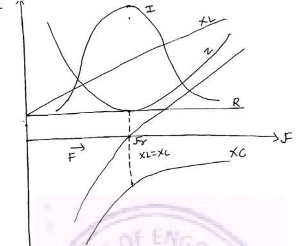
→ The net Reactance ~~is~~ of R-L-C circuit is Inductive

→ The Resonance condition The current is maximum $I = \frac{V}{R}$ $\boxed{Z = R}$

→ If we are Increasing the value of Frequency Resistance value is contant, Inductive Reactance is increased and capacitive Reactance is decrease.

→ The Resistance R is not depend on frequency so Resistance curve is horizontal line

→ The Inductive Reactance 'X_L' is depend on Frequency If Increase The Frequency, Increase the value



Resonance curve

- The capacitive ~~Reactance~~ Reactance 'XC' also depend on Frequency, but here Increase the value of Frequency decrease the value of capacitive Reactance $\boxed{X_C \propto \frac{1}{F}}$
- The Impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$, IF the Freq^n is Low at that time Impedance value is high
- Then after Increase the value of ~~Imped~~ Freq^n decreasing the value of Impedance
- At the Resonance condition $(X_L = X_C)$, Impedance value is equal to Resistance value $(R = Z)$
- Then after Further increasing the value of Frequency Incresing the value of Impedance gradually.
- The Low Frequency Impedance is at that time current is minimum $(I = V/Z)$
- Then after Increase the value of Frequency decrease the value of ~~Imdu~~ Impedance 'Z'

→ At Resonance condition $R=Z$, at that time

∴ $I = V/R$ maximum value of current.

→ then after further increasing the value of frequency increasing the value of Impedance and decreasing the value of current.

☆ Q-Factor of series R-L-C circuit

→ series circuit $Q = \frac{W_r L}{R}$

Q = Quality - Factor

→ $F_r = \frac{1}{2\pi\sqrt{LC}}$, $2\pi F_r = \frac{1}{\sqrt{LC}}$

→ $W_r = \frac{1}{\sqrt{LC}}$

$Q = \frac{W_r L}{R}$ put the value of W_r

$= \frac{1}{\sqrt{LC}} \times \frac{L}{R}$

$= \frac{1}{\cancel{\sqrt{L}}\sqrt{C}} \times \frac{\cancel{\sqrt{L}} \times \sqrt{L}}{R}$

$$\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

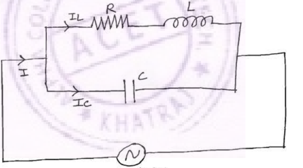
Que: Explain the phenomena of Parallel Resonance

OR : What is dynamic impedance ? Drive an expression for the same.

OR An individual coil of resistance R and inductance L is connected in parallel with capacitor C. Derive the expressions for resonant frequency and Q-Factor.

OR Explain the phenomena in AC Parallel circuit. Derive mathematically expression of Resonance Frequency. sketch the graphical representation of parallel resonance.

Ans In Fig the circuit consisting of an inductive coil in parallel with capacitor



Varible Frequency source.

→ For parallel circuit, the Applied voltage is taken as reference Phasor.

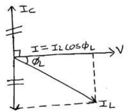
→ The current drawn by an inductive coil Lags the Applied voltage by an angle 'ϕ_L'

→ It can be resolved into two components.

The active component = $I_L \cos\phi_L$

and Re-active component = $I_L \sin\phi_L$

→ The current I_C ...
Applied voltage by 90°



Phasor diagram.

- → Here we see that current I_C and component $I_L \sin\phi_L$ both are in opposite direction
- → The value of current I_C and I_L it is ~~deper~~ depend on Inductive capacitance X_C and Inductive Reactance X_L
- → And this two term $X_L = 2\pi f L$ and $X_C = \frac{1}{2\pi f C}$ both are depend on Frequency.
- → If we Increase the value of Frequency the value of X_L is Increase and the value of X_C is decrease.
- → In between the Frequency occur current I_C and $I_L \sin\phi_L$ value both are equal
- → when the value of current I_C & $I_L \sin\phi_L$ both are equal this condition is known as Parallel Resonance
- → At Resonance condition $I_C = I_L \sin\phi_L$ both are opposite direction
- → The Impedance curve is

$I_L \sin\phi_L = I_C$

$I_L = \frac{V}{Z}$, $\sin\phi_L = \frac{X_L}{Z}$, $I_C = \frac{V}{X_C}$

Put this value in eqn

$$\therefore I_C = I_L \sin\phi_L$$

$$\therefore \frac{V}{X_C} = \frac{V}{Z} \times \frac{X_L}{Z}$$

$$\therefore \frac{1}{X_C} = \frac{X_L}{Z^2}$$

$$\therefore Z^2 = X_L X_C$$

$$\therefore Z^2 = \omega L \times \frac{1}{\omega C}$$

$$\therefore Z^2 = \frac{L}{C}$$

$$\boxed{\therefore Z = \sqrt{L/C}}$$

In parallelogram method

Impedance triangle

$$\therefore Z^2 = R^2 + X_L^2$$

$$\therefore \frac{L}{C} = R^2 + (2\pi F_r L)^2$$

$$\therefore (2\pi F_r L)^2 = L/C - R^2$$

$$\therefore (2\pi F_r)^2 L^2 = \frac{L}{C} - R^2$$

$$\therefore (2\pi F_r)^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

$$\therefore 2\pi F_r = \sqrt{\frac{1}{LC} - R^2/L^2}$$

$$\boxed{\therefore F_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$$

→ we see that at Resonance condition component I_C & $I_L \sin\phi_L$ both are cancel each other

→ so the Result is voltage & current both are in phase

$$I = I_L \cos\phi_L$$

$$= \frac{V}{Z} \cdot \frac{R}{Z}$$

$$= \frac{VR}{Z^2}$$

$$= \frac{VR}{L/C} \quad (\because Z^2 = L/C)$$

$$I = \frac{VR}{L/C} = \frac{V}{\frac{L}{CR}}$$

$$\boxed{I = \frac{V}{L/CR}}$$

$I = I_L \cos\phi_L \longrightarrow V$

vector diagram Resonance condition

→ At Parallel Resonance condition Impedance $Z = L/CR$ is maximum,

→ so at Resonance condition current is minimum

→ But Voltage & current both are in phase so Power Factor is 'unity'

* Q-Factor of Parallel circuit

→ In Resonance condition Impedance is high so supply current 'I' is minimum

→ but LC circulating current is high. so at Parallel Resonance current magnification occure in this circuit.

→ This current magnification of this circuit is known as Q-Factor

$$\therefore Q = \frac{I_C}{I}, \quad I_C = \frac{V}{X_C}, \quad I = \frac{V}{L/CR}$$

$$\therefore Q = \frac{\frac{V}{X_C}}{\frac{V}{L/CR}}$$

$$\therefore Q = \frac{\cancel{V}}{X_C} \times \frac{L}{\cancel{V}CR}$$

$$\therefore Q = \frac{L}{X_C \cdot CR} = \frac{L}{\frac{1}{WC} \cdot CR} = \frac{W\cancel{C}L}{\cancel{C}R}$$

$$\boxed{\therefore Q = \frac{WL}{R}}$$

$$Q = \tan\phi$$

$$Q = \frac{WL}{R} = \frac{2\pi F_r L}{R} = \tan\phi$$

$\therefore \phi$ = coil Power Factor Angle

Resonance

Q8. compare the series and parallel resonance of R-L-C series and R-L-C parallel circuit.

Ans

Sr No	Item Description	Series circuit	Parallel circuit
1.	Resonance Frequency f_r	$\frac{1}{2\pi\sqrt{LC}}$	$\frac{1}{2\pi}\sqrt{\frac{1}{LC}-\frac{R^2}{L^2}}$
2.	Impedance at Resonance	minimum	maximum.
3.	Effective impedance at Resonance	R	$\frac{L}{CR}$
4.	current at Resonance	maximum $\left(=\frac{V}{R}\right)$	minimum $\left(=\frac{V}{L/CR}\right)$
5.	Power Factor at Resonance	unity	unity
6.	It magnifies	Voltage	current.
7.	magnification at Resonance	$\frac{W_r L}{R}$	$\frac{W_r L}{R}$
8.	Application	Q-meter	Radio tunig

Rectangular to Polar Conversion

Mathamatics

Complex number

$Z = x + iy$

$\downarrow$ convert into polar

$r \angle \theta$

$r = \sqrt{x^2 + y^2}$

$\theta = \tan^{-1} \frac{y}{x}$

ex. $Z = 1 + i$

$r = \sqrt{2}$

$\theta = 45^\circ$

How to use calculator

Press Pol (

↓

Enter x [No]

↓

Press ,

↓

Enter y [No.]

↓

Presss)

↓

Press = will give you $\boxed{r}$ ← Ans1

↓

Press Alpha

↓

Press tan

↓

Press = → Give you $\boxed{\theta}$ ← Ans2

Polar to Rectangular

Mathamatics	Cackulator
$r \angle \theta$	Press shift
$\downarrow$ Convert into rectangular	$\downarrow$ Press Pol
$x + iy$	$\downarrow$ Enter r
	$\downarrow$ Press ,
$x = r \cos\theta$	$\downarrow$ Enter θ
$y = r \sin\theta$	$\downarrow$ Press =
$r = 5$	$\downarrow$ will give you x that is redd part
$\theta = 53.13$	
$x = 3$	$\downarrow$ Press Alpha
$y = 4$	$\downarrow$ Press tan
$3 + 4i$	$\downarrow$ Press =
	$\downarrow$ will give you y that is Imaginary part

. . . in star connected Load.

OR Derive the relationsheep between phase and Line values of voltages and currents in case of 3-phase star connection

OR write down the line value and phase value relationship of voltage and currents in 3-ϕ star connected systems.

Ans Voltage and current relationship in star connected system.

→ star connection system is 3-phase, 4-wire balanced system

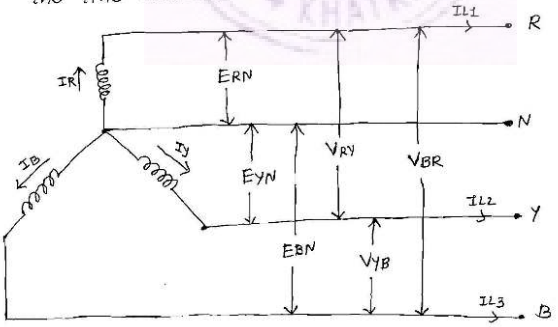
→ The voltage across each winding is called phase voltage

→ They are denoted by ERN, EYN, EBN and voltage between any two lines is called line voltage.

→ They are represented by VRY, VYB, and VBR respectively

→ similarly currents flowing flowing in each winding is known as phase current

→ And current flowing in each line is called the line current



$\therefore I_R = I_Y = I_B = I_{ph}$

$I_{L1} = I_{L2} = I_{L3} = I_L$

$E_{RN} = E_{YN} = E_{BN} = E_{ph}$

$V_{RY} = V_{YB} = V_{BR} = V_L$

→ Relationship between line current and phase current

$I_R = I_{L1} \rightarrow I_{ph} = I_L$

$I_Y = I_{L2} \rightarrow I_{ph} = I_L$

$I_B = I_{L3} \rightarrow I_{ph} = I_L$

In star connection

Line current = phase current

→ because the Line current and phase current both are in series

$$\boxed{I_L = I_{ph}}$$

Relation between line Voltage and phase Voltage

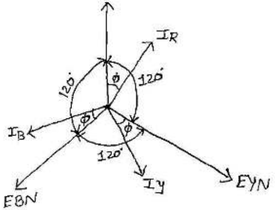
→ In star connection balanced Load system There are two phase windings between each Pair of line terminals.

→ since similarly ends of these two windings are connected together

→ The Voltage across them oppose each other and their instanteneous values will have opposite polarities.

→ Therefor the r.m.s value of Line voltage between any two lines will be obtained by the vector difference of the two phase Voltages.

→ The Phasor diagram of the phase Voltage (emf) and current in a star connected system shown in Fig



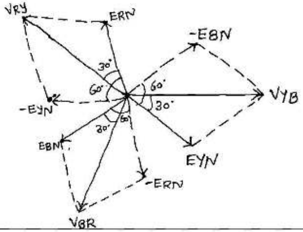
→ Line voltage between terminal R and y

$$V_{RY} = E_{RN} + E_{NY}$$
$$= E_{RN} + (-E_{YN}) \quad (\because E_{NY} = -E_{NY})$$
$$= E_{RN} - E_{YN}$$
$$= \text{Phasor difference}$$

→ Similarly

$$V_{YB} = E_{YN} - E_{BN}$$
$$\text{and } V_{BR} = E_{BN} - E_{RN}$$

→ Hence it is clear that in a star connected system the line voltage is obtained as the vector difference of the two corresponding phase voltages.



and its magnitude is given by the diagonal of the parallelogram

→ since sides of the parallelogram are of equal length and angle between two phase phase voltages is 60°

The line voltage is given by

$$V_{RY} = E_{RN} - E_{YN}$$

$$= 2V_{ph} \cos\frac{60^\circ}{2}$$

$$= 2V_{ph}\cos 30^\circ$$

$$= \cancel{2}V_{ph} \times \frac{\sqrt{3}}{\cancel{2}}$$

$$\boxed{V_{RY} = \sqrt{3}\,V_{ph}}$$

Similarly $V_{YB} = V_{BR} = \sqrt{3}\,V_{ph}$

$$V_{RY} = V_{YB} = V_{BR} = V_L$$

$$\boxed{V_L = \sqrt{3}\,V_{ph}}$$

in delta connected Load.

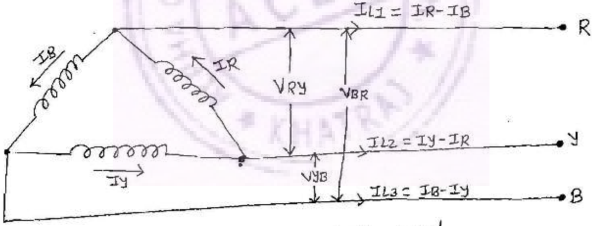
OR Established relationship between line and phase voltages and currents in balanced delta connection Draw complete phasor diagram of voltages and currents.

Ans. In delta connection, the three coil windings are connected together

→ such that the Finishing end of one coil is connected to the starting end of the other coil and so on.

→ In other words, the three windings are connected in series to form a closed path.

→ There is no neutral wire and so it is called as 3-phase, 3-wire system.



Delta connected Load

→ This is the 3-phase- 3-wire delta connected system

→ The voltage (emf) across each winding is called The phase voltage.

→ They are denoted by E_R, E_Y, and E_B

→ And voltage between any two lines is called the line voltage.

→ There are denoted by V_{RY}, V_{YB} and V_{BR} respectively

Known as phase currents

→ They are denoted by I_R, I_Y and I_B

→ And currents Flowing in the lines are called line currents denoted by I_{L1}, I_{L2} and I_{L3}

Since the system is balanced.

$$I_R = I_Y = I_B = I_{ph}$$
$$I_{L1} = I_{L2} = I_{L3} = I_L$$
$$E_R = E_Y = E_B = E_{ph}$$
$$V_{RY} = V_{YB} = V_{BR} = V_L$$

☆ Relationship between line voltage and phase voltage

It is clear that

$$E_R = V_{RY} \rightarrow E_{ph} = V_L$$
$$E_Y = V_{YB} \rightarrow E_{ph} = V_L$$
$$E_B = V_{BR} \rightarrow E_{ph} = V_L$$

→ In delta connection

Line voltage = phase voltage

$$\boxed{V_L = V_{ph}}$$

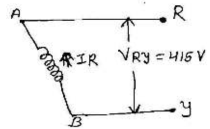
only Remember Do not write in Exam

→ because the voltage of single winding is Applied two votages like R and Y

→ see in that Fig The starting of winding 'A' connected R phase similarly end of this winding 'B' connected 'y' phase

→ so total voltage across single winding is 415V

→ Thats Reason we are write



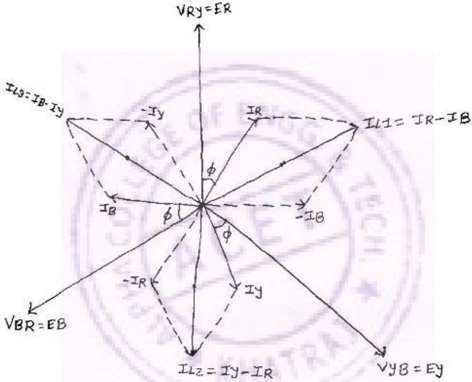
only For Remember not write in Exam.

$$\boxed{V_L = V_{ph}}$$

→ current passing through I_{L1} is divided into two parts 'I_R' and 'I_B'

→ so the current flowing in each line is the vector difference of the two phase currents.

→ current in line 1, $I_{L1} = I_R - I_B$
current in line 2, $I_{L2} = I_Y - I_R$
current in line 3, $I_{L3} = I_B - I_Y$



Vector diagram

→ current in line -1 can be found the vector difference of the two corresponding phase current

→ For example, I_{L1} can be obtained by adding I_R and I_B reversed and its value is given by the diagonal of the parallelogram

→ since the sides of parallelogram are equal in magnitude and angle between them is 60°

→ The Resultant current or the line current is given as

$I_{L1} = I_R - I_B$ [vector difference]

$= 2 \times I_{ph} \times \frac{\cos 60^\circ}{2}$

$= 2 \times I_{ph} \times \cos 30^\circ$

$= \cancel{2}\, I_{ph}\, \sqrt{3}/\cancel{2}$

$= \sqrt{3}\, I_{ph}$

$$\boxed{I_{L1} = \sqrt{3}\, I_{ph}}$$

Thus in delta connection

Line current = $\sqrt{3}$ x phase current

$$\boxed{I_{L1} = \sqrt{3}\, I_{ph}}$$

two wattmeters

OR How can we measure the power with help of two-watt meter method in three phase system with star connected load?

OR show that the power input to the three-phase circuit can be measured by two wattmeters connected properly in the circuit

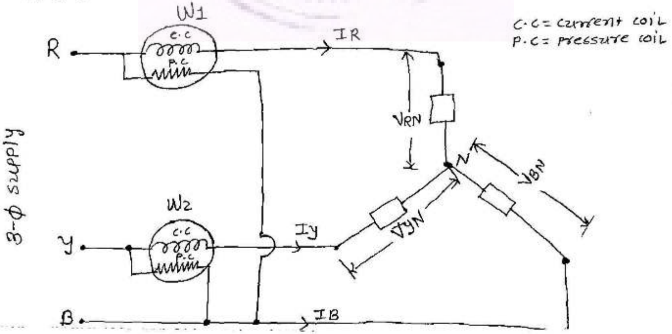
OR A balanced three phase supply is given to a star connected load. Give proof of two-wattmeter method for this system. state demerits of this method.

OR Explain the method of measuring 3-ϕ power by two wattmeters.

OR prove that the sum of reading of two-wattmeter connected to measure power in 3-ϕ AC circuit gives total power consumed by the circuit.

Ans This is the most common method for the measurement of Power in 3-ϕ system.

→ In this method two wattmeters connected as shown in Fig below



in series and the Potential coil (P.C) are connected between these lines and Third line in which the current coil is not connected.

→ It can be proved that the sum of instanteneous values of power indicated by these wattmeters equals the total power absorbed by the 3-ϕ Load.

→ 3-phase star connected balanced load with two wattmeters connected in the circuit to measure total power input to the Load.

→ Let I_R, I_Y, and I_B be the rms value of currents flowing in the lines

→ And V_{RN}, V_{YN} and V_{BN} be the r.m.s value of phase voltage of the Load.

→ Total power absorbed by the 3-ϕ Load is

$$W = W_1 + W_2$$

→ so, First we are find out the value of W_1 wattmeter

∴ First wattmeter Reading = Voltage across pressure coil × current coil current × the Angle between voltage & current (cosine Angle)

$$\therefore W_1 = V_{RB} I_R \cos(V_{RB} \wedge I_R)$$

→ V_{RY} is Found by adding V_{RN} and V_{YN} reversed and its magnitude given by diagonal of the Parallelogram.

$$V_{RB} = V_{RN} + V_{NB}$$

$$= V_{RN} + (-V_{BN})$$

$$= V_{RN} - V_{BN}$$

→ Phase difference between I_R and $V_{RB} = (30-\phi)$

→ Therefore, the Reading of wattmeter

$$W_1 = V_{RB}\, I_R \cos(30-\phi) \quad \text{--- (i)}$$

Similarly

$$W_2 = V_{YB}\, I_Y \cos(V_{YB} \wedge I_Y)$$

$$V_{YB} = V_{YN} + V_{NB}$$
$$= V_{YN} + (-V_{BN})$$
$$= V_{YN} - V_{BN}$$

→ Phase difference between I_Y and $V_{YB} = (30+\phi)$

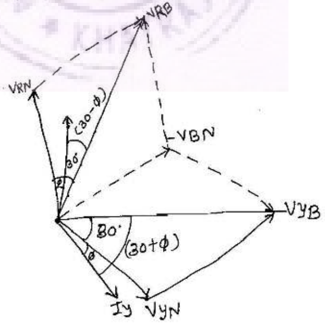
Therefore, the Reading of wattmeter

$$W_2 = V_{YB}\, I_Y \cos(30+\phi) \quad \text{--- (ii)}$$

→ since the load Assumed is balanced

$$I_R = I_Y = I_B = I_L$$
$$V_{RY} = V_{YB} = V_{BR} = V_L$$

→ Vector diagram of two-wattmeter method.



Vector diagram

$$\therefore W_1 = V_L I_L \cos(30-\phi) \quad -(i)$$

$$\therefore W_2 = V_L I_L \cos(30+\phi) \quad -(ii)$$

→ Adding these, we get

$$W_1+W_2 = V_L I_L \cos(30-\phi) + V_L I_L \cos(30+\phi)$$

$$= V_L I_L [\cos(30+\phi) + \cos(30-\phi)]$$

$$= V_L I_L [\cos 30 \cos\phi - \cancel{\sin 30 \sin\phi} + \cos 30 \cos\phi + \cancel{\sin 30 \sin\phi}]$$

$$= V_L I_L [2 \times \cos 30 \cos\phi]$$

$$= V_L I_L [\cancel{2} \times \sqrt{3}/\cancel{2} \cos\phi]$$

$$\boxed{W = \sqrt{3} V_L I_L \cos\phi}$$

→ Hence, the sum of the readings of two wattmeter is equal to the total power drawn by 3-ϕ balanced load.

For 3-ϕ power measurement by two wattmeter method as power factor takes the value of unity, 0.5, between 0.5 & 0 and 0.

Ans Effect of power factor on wattmeter readings:

→ The equations for $W_1 = V_L I_L \cos(30-\phi)$ &
$W_2 = V_L I_L \cos(30+\phi)$

Lagging power factor has been assumed

→ From equations W_1 and W_2 it is also clear that the readings of W_1 and W_2 depend not only on the load but also on the power factor of the load.

Case-1 Power factor unity

When the power factor is unity at that time purely inductive load.

$$\cos\phi = 1, \quad \phi = \cos^{-1}(1)$$
$$\phi = 0$$

$$\therefore W_1 = V_L I_L \cos(30^\circ - 0)$$
$$= V_L I_L \cos 30^\circ$$

$$\therefore W_2 = V_L I_L \cos(30^\circ + 0)$$
$$= V_L I_L \cos 30^\circ$$

→ Thus, both wattmeters indicate equal and positive readings.

$\cos\phi = 0.5 \qquad \phi = \cos^{-1}(0.5)$

$\phi = 60°$

$\therefore W1 = V_L I_L \cos(30 - 60°)$
$= V_L I_L \cos(-30°)$
$= V_L I_L \cos 30°$

$\therefore W2 = V_L I_L \cos(30° + 60°)$
$= V_L I_L \cos(90°)$
$= V_L I_L (0)$
$= 0$

→ Hence, power is measured by W1 alone as other wattmeter (W2) shows zero reading.

<u>case-3</u> <u>Power Factor between unity and 0.5</u>

→ when the power factor is unity 7 > 0.5 at that time we are assume that phase Angle is between 0° to 60°

→ suppose here phase Angle 40°, so wattmeter Reading is

$\therefore W1 = V_L I_L \cos(30 - 40°)$
$= V_L I_L \cos(-10°)$
$= V_L I_L \cos 10°$

$\therefore W2 = V_L I_L \cos(30° + 40°)$
$= V_L I_L \cos 70°$

→ The wattmeter both Reading are Positive but no-equal.

$\cos\phi = 0$, $\phi = \cos^{-1}(0)$

$\phi = 90^\circ$

$\therefore W_1 = V_L I_L \cos(30^\circ - 90^\circ)$

$= V_L I_L \cos(-60^\circ)$

$= V_L I_L \cos 60^\circ$ or $V_L I_L \sin 30^\circ$

$\therefore W_2 = V_L I_L \cos(30 + 90^\circ)$

$= V_L I_L \cos(120^\circ)$

$= V_L I_L \cos(90^\circ + 30^\circ)$

$= V_L I_L (-\sin 30^\circ)$

$= -V_L I_L \sin 30^\circ$

→ Hence the two readings are equal but opposite in sign

$\boxed{W_1 = -W_2}$

Case-5 when the power factor between 0.5 and 0

→ when the power factor is $0.5 > \cos\phi > 0$ at that time we are assume that phase angle is between 60° to 90°

→ suppose here phase angle is 80°

$\therefore W_1 = V_L I_L \cos(30^\circ - 80^\circ)$

$= V_L I_L \cos 50^\circ$

$\therefore W_2 = V_L I_L \cos(30^\circ + 80^\circ)$

$= V_L I_L \cos 110^\circ$

$= V_L I_L \cos(90^\circ + 20^\circ)$

$= V_L I_L (-\sin 20^\circ)$

$= -V_L I_L \sin 20^\circ$

→ Hence both wattmeter indicate un-equal reading and un-equal sign.

with Power Factor

Phase Angle ϕ	0°	60°	between 60° to 90°	90°
Power Factor	1	0.5	Less than 0.5	0
Reading of wattmeter W_1	+Ve	+Ve	+Ve	+Ve
Reading of wattmeter W_2	+Ve $W_1 = W_2$	0	−Ve	−Ve $W_2 = W_1$

OR

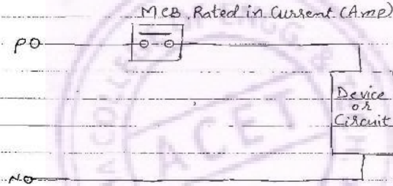
Power Factor $\cos\phi$	wattmeter Reading
$\cos\phi = 1$	equal & positive
$0.5 < \cos\phi < 1$	un-equal & positive
$\cos\phi = 0.5$	one wattmeter Indication is zero
$0 < \cos\phi < 0.5$	un-equal & one wattmeter negative Indication
$\cos\phi = 0$	equal & one wattmeter negative Indication.

* MCB :- Miniature Circuit Breaker

- It is a one type of protecting device which protects electrical circuit or electrical equipments against overcurrent

- It can use as a switch in normal condition and it works as a fuse in case of overload or shortcircuit condition.

-

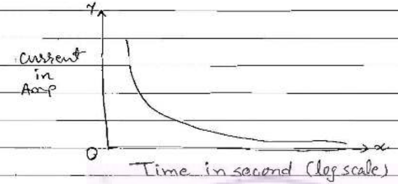


- It consists thermal relay inside it and current carrying contacts made copper or silver alloy.

- The relay (tripping mechanism) and contacts are assembled in moulded case.

- Operating time of fuse is 0.02 to 0.05 sec whereas MCB takes 0.1 to 0.3 sec to operate for same rating but MCB has an advantage ~~to~~ that by toggaling its ~~contact; it~~ switch possition; it back to normal condition.

(1)



- MCB does not show wear & tear with time. It does not requires maintainance or repair.

- MCB's are used in residences, offices, shops, complexes, industries.

- Available rating of MCB ← 230 V or 440 V, upto 100A.

- Differance of fuse & MCB.

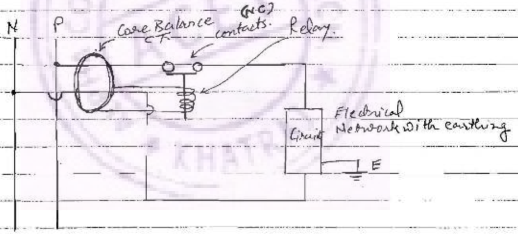
(2)

* ELCB :- Earth Leackage Circuit Breaker.

- It is a one type of electrical protection device which protects operator against electric shock and electrical installation.

- Generally it is placed at mains (incoming point of power) of consumer; so it provides protection to total electrical wiring and connected equipments.

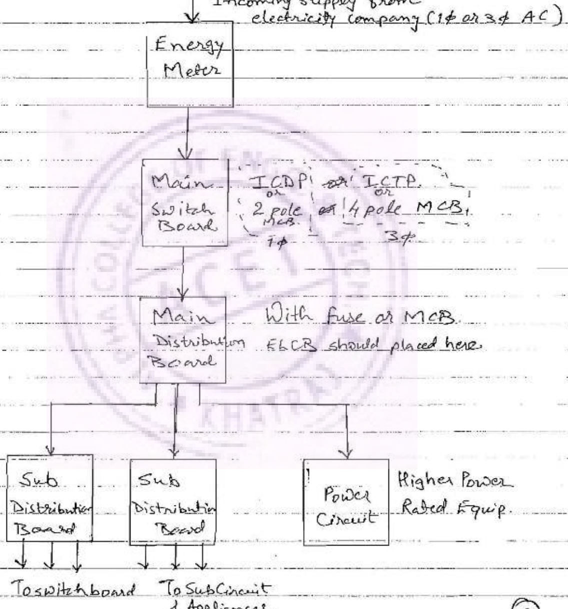
- ELCB is a current operated device, it is also known as Residual Current Circuit Breaker (RCCB).



- In ELCB Core Balance Current Transformer (CBCT) is provided which detects any leackage of current in a circuit
- If any leackage of current detect by CBCT it energize relay and by actuating it circuit trips.
- In some case CT is provided in only earthwire.
- Generally ELCB is rated in mA. Available range of ELCB is 05 mA to 50 mA.

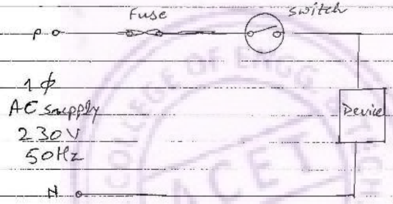
* Wiring ✓

a) Position of major equipments in domestic wiring



b) Wiring of domestic installation.

- In India for domestic installation, 1 ϕ AC supply of 230V, 50Hz is provided.
- Lighting circuit rated upto 5 Amp where as power circuit rated upto 15 Amp.



- Stair case wiring

- Godown Wiring

(5)

BATTERY

A battery is a combination of two or more cells connected in series, parallel or series-parallel grouping.
It is a device which can store energy and supply the same as electrical energy.

Lead- Acid Battery

Lead acid battery is a secondary cell.
During the charging process, electrical energy is supplied to the battery which is stored as chemical energy.
During the discharging process chemical energy is converted into electrical energy which is supplied to the load.

It consists of the following parts:

1. Positive plate or anode which is made of lead peroxide (PbO2) and is chocolate brown in colour.
2. Negative plate or cathode which is made of lead and is grey in colour.
3. Electrolyte-dilute sulphuric acid(H2SO4)

- ## Discharging process

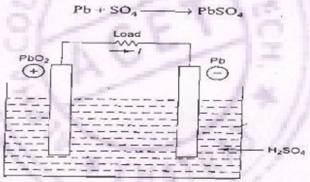


Fig. 6.6 *Discharging process*

At anode: $PbO_2 + H_2SO_4 + H_2 \rightarrow PbSO_4 + 2H_2O$

When the charged battery is connected to a load, the current starts flowing from positive terminal to the negative terminal of the battery.
Due to this current, the sulphuric acid(H2SO4) decomposes into positive hydrogen ions(H+) and negative sulphate ions (SO_4^-).
The hydrogen ions (H+) move towards the anode and react with lead peroxide (PbO2) and sulphuric acid (H2SO4) to form lead sulphate (PbSO4) and water (H2O).

During discharging process:

1. A layer of PbSO4 is formed on both the plates which is whitish in colour.
2. The specific gravity of the electrolyte decreases due to formation of water.
3. The voltage of the cell falls down.
4. The chemical energy is converted into electrical energy which is supplied to the load.

- ## Charging Process:

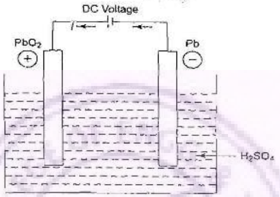


Fig. 6.7 *Charging process*

When a DC voltage higher than battery voltage is applied across the battery ,the current starts flowing from positive terminal to the negative terminal inside the battery.
Due to this current, the sulphuric acid(H2SO4) decomposes into hydrogen ions (H^+) and sulphate ions (SO_4^-).
The sulphate ions(SO_4^-)move toward the anode and react with lead sulphate(PbSO4) and water (H2O) to form lead oxide (Pbo2) and sulphuric acid(H2SO4).

At anode: $PbSO_4 + 2H_2O + SO_4 \rightarrow PbO_2 + 2H_2SO_4$

The hydrogen ions (H+) move towards the cathode and react with lead sulphate (PbSO4) to form lead (Pb) and sulphuric acid (H2SO4).

At cathode: $PbSO_4 + H_2 \rightarrow Pb + H_2SO_4$

During charging process:

1. The positive plate changes to lead peroxide (PbO_2) which is chocolate brown in colour.
2. The negative plate changes to lead which is grey in colour.
3. The specific gravity of the electrolyte increases due to formation of sulphuric acid.
4. The voltage of the cell increases.
5. The electrical energy is converted into chemical energy which is stored in the battery.

CONSTRUCTION OF CABLES

Such insulated conductors are called cables.

It is externally protected against mechanical injury, moisture entry & chemical reaction.

The conductor is usually aluminium or copper while insulation is mostly PVC.

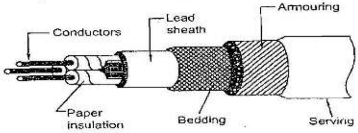


Fig.- 15.1 Construction of a cable

1. Cores or Conductors

It consists of one central core or a number of cores(two, three or four) of tinned stranded copper or aluminium conductors.

It used in stranded form to provide flexibility.

2. Insulation

To bear voltage stress insulation is required between conductor and earth and between two conductors.

Various types of insulating materials are used such as- paper, rubber, pvc etc.

3. Metallic Sheath

The insulation is covered by lead sheath or aluminium sheath.

It restricts moisture to reach insulation.

4. Bedding

It is a layer of paper tape compounded with fibrous material

The purpose of bedding is to protect the metallic sheath from corrosion and from mechanical injury due to armouring.

5. Armouring

It provide protection to cable from mechanical injury.

It is made of steel wire or steel tape and placed above bedding.

6. Serving

Serving is the last layer above the armouring which is made of fibrous material like jute cloth which protects armouring from atmospheric condition.

FLUROSENT TUBE

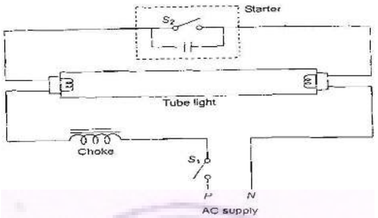


Fig. 8.4 *Wiring Diagram of a Fluorescent tube*

1. Chock provide high impulse voltage for starting(4 to 5 times the normal voltage).
2. Initially S2 is closed.
3. When S1 is closed,current flows through the chock coil,tube & starter.
4. When current flows through the starter,it gets heated & bend thus opening its contacts.
5. This high voltage ionize the argon gas in the tube between two electrodes.
6. The generated heat vapourizes the mercury & current start flowing between two electrodes.

4.[2] Purpose of Earthing :-

(1) Safety for Human life / Building / Equipments

* To save human life from danger of electrical shock or deth by blowing a fuse.

* To protect building, machinery & appliances under fault condition

* To ensure that all exposed conductive part do not reach a dangerous potential.

* To provide safe path to short circuit currents.

* To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.

(2) Over Voltage Protection :-

* Lightning, line surges can cause dangerous high voltage to the electrical distribution system. Earthing provide an alternative path around the electrical system to minimize damage in the system.

Q:- What is Earthing ? Explain requirement for any Electrical Equipment.

Or.

Disuss any one method of Earthing ?.

Or.

State and Explain plate and Pipe Earthing with neat diagram.

Or

What is the need of Earthing ? Explain the different method of Earthing.

[Dec-08, June-09, June-10, June-11, Jan-13]

→ What is Earthing ?

Def:- In Electricity Supply System, an Earthing or grounding is circuitry which connects part of the Electric circuit with the ground, thus defining the electric potential of the conductors relative to the Earth's conductive surface.

4.[2] Purpose of Earthing :-

(1) Safety for Human life/ Building/ Equipments

* To save human life from danger of electrical shock or deth by blowing a fuse.

* To protect building, machinery & appliances under fault condition

* To ensure that all exposed conductive Part do not reach a dangerous Potential.

* To provide safe path to short circuit currents.

* To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or Excessive Voltage on the appliances or Equipment

(2) Over Voltage Protection :-

* Lightning, line surges can cause dangerous high voltage to the Electrical distribution system. Earthing Provide an alternative Path around the electrical system to minimize damage in the system.

* Voltage stabilization :-

* There are many source Electricity. it ~~was~~ Earth ~~was~~ is the most omnipresent conductive surface. and so it was adopted in the very beginnings of Electrical distribution systems as a nearly universal standard for all Electrical system.

Types :-

* Plate Earthing.
* Pipe Earthing.

1) Plate Earthing :-

* In Plate Earthing, Earth wire is connected to copper (G.I) plate.

* First, the selected plate is placed vertically inside the ground at a depth of 1.5 m and is embedded in alternate layers of coal and salt to a thickness of 15 cm.

* The Earth wire is drawn through G.I pipe and is prefectly bolted to the Earth plate

4(4).

* One thing ; nuts and bolts must be coppez far copper plate and must be galvanized iron for G.I plate.

* A cement masonry chamber is built with a cast iron cover for easy regular maintenance.

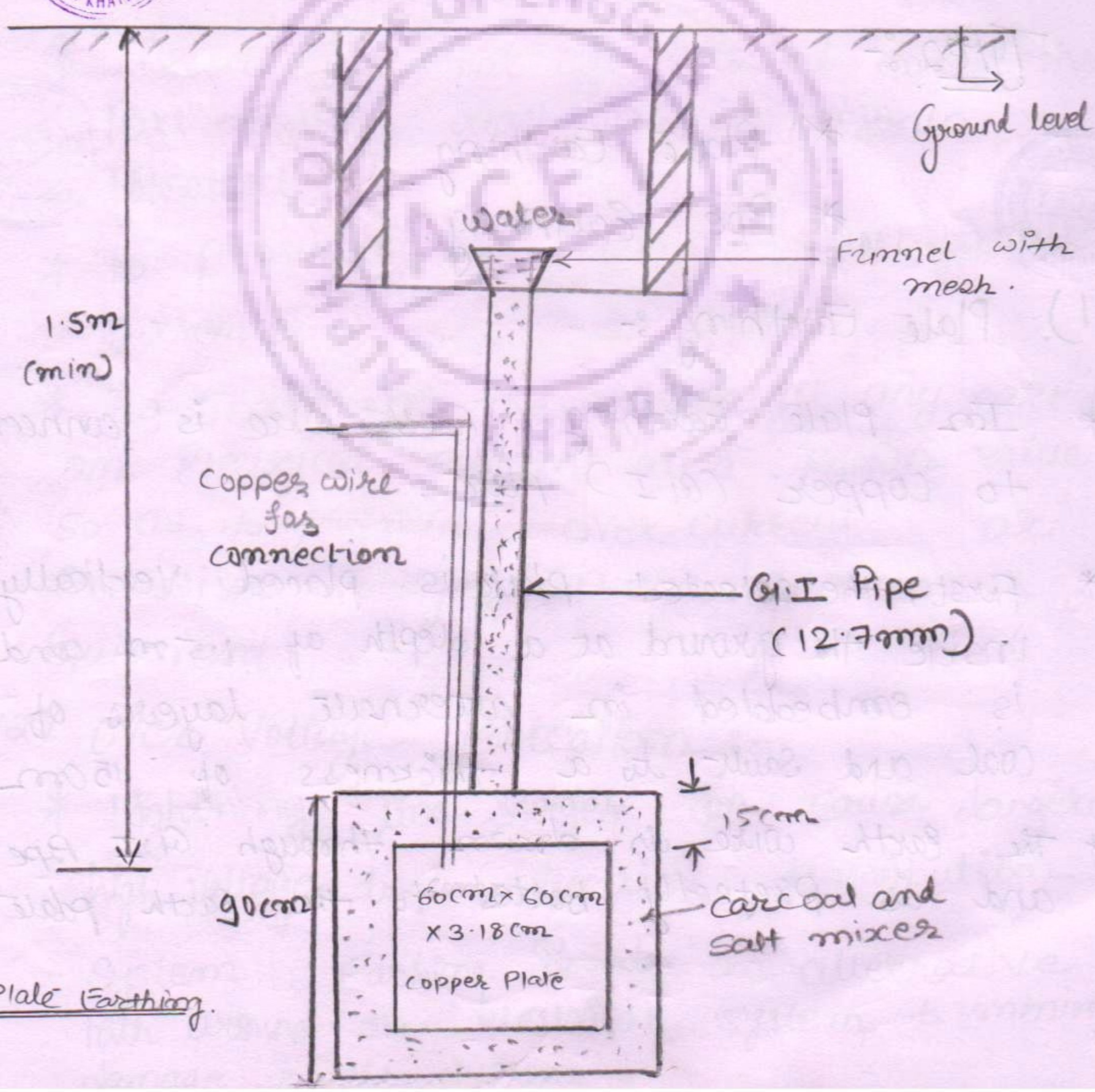
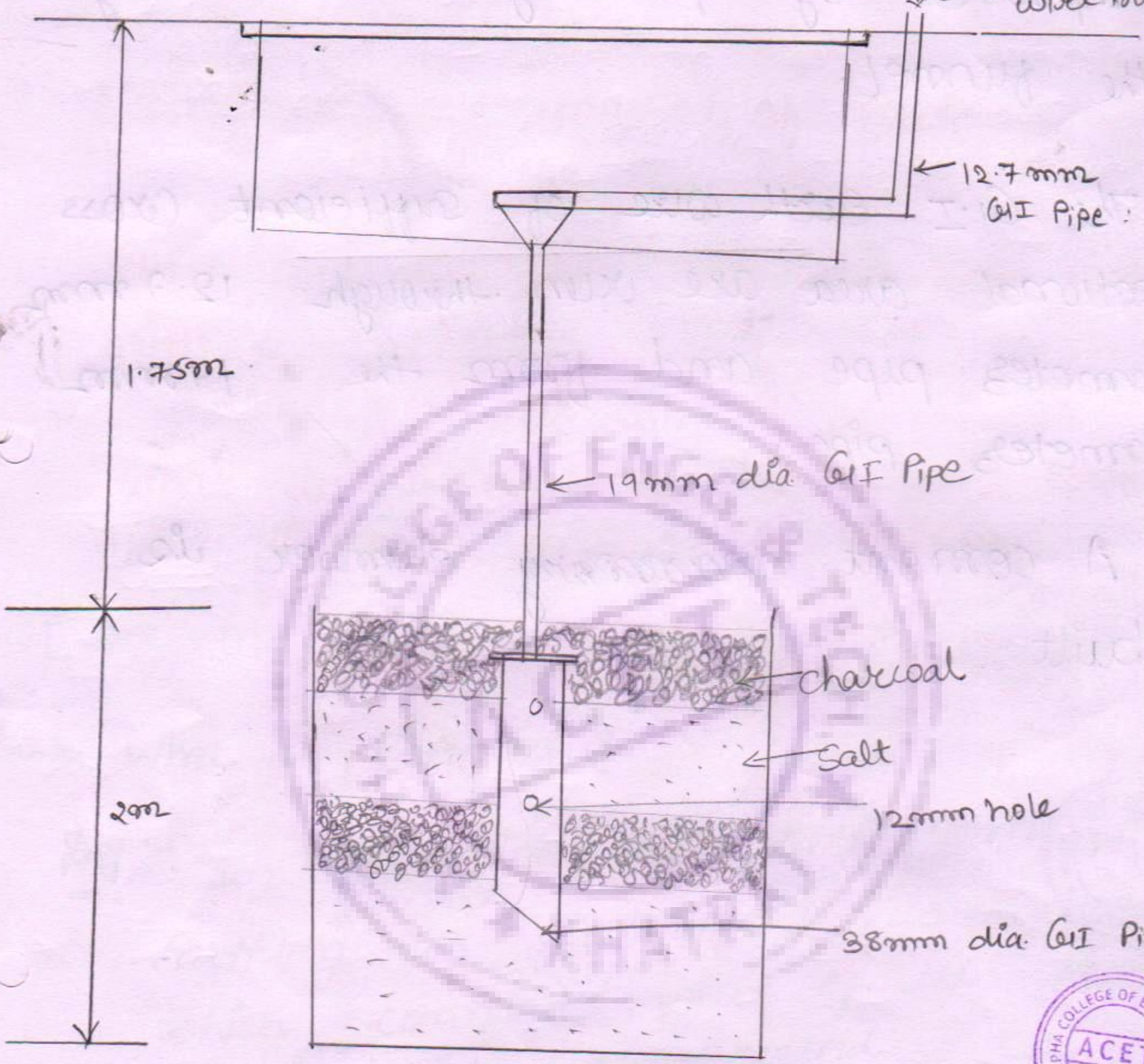


Plate Earthing.

Pipe Earthing :-



* First, the pipe is placed at a depth of 1.75m in permenently wet ground and the are (15cms) surrounding the GI pipe is filled with an alternate layers of charcoal & salt to increase effective area of the Earth and to reduce the Earth resi. respectively.

4.(6).

↳ Efficiency of the Earthing system is impooved by powring water through the funnel.

↳ The G.I Earth wire of sufficient cross sectional area are run through 12.7 mm diameter pipe and from the 19mm diameter pipe.

↳ A cement ~~masonary~~ chamber is built

Types of wiring :-

There are various methods of installing a wiring system.

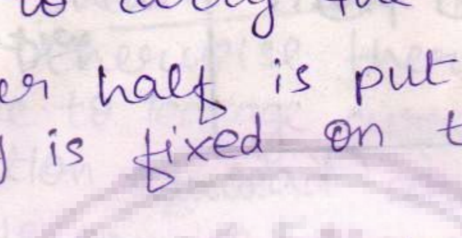
① Cleat wiring :

-> This wiring system consists of two halves of porcelain cleats one of the halve is grooved to carry the VIR conductor.

-> The other half is put over it & entire assembly is fixed on the walls using screws.

-> cleat wiring system is mostly used for temporary wiring & is having low installation cost.

-> Drawback of this system is that there is not protection provided against atmospheric condition therefore maintenance cost is high.



② wooden casing caping wiring :-

-> This type of wiring is used for domestic applications.

-> It consists of rectangular wooden blocks mode from season teak wood.

-> These blocks consists of grooves in which PVC or VIR wires are laid.

-> wooden casings are fixed to walls /ceilings with the help of wooden plugs.

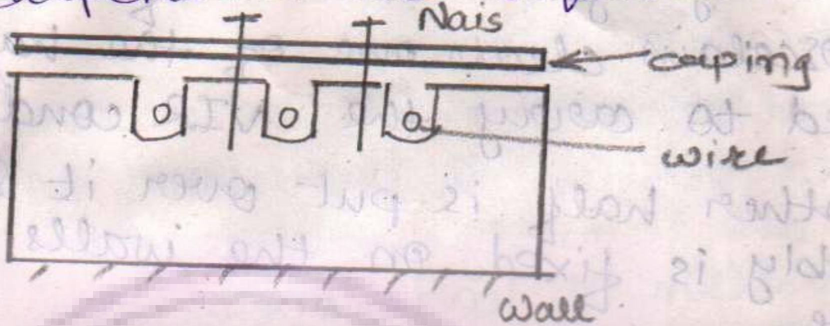
-> Casing is covered with varnished clipping with the help of screws.

-> This type of wiring has comparatively weather.

→ But this wiring system suffers from following drawbacks:-

i) There is a danger of fire hazards as casings is inflammable.

ii) Installation cost is large as skilled carpenters are required.



③ Tough rubber sheathed wiring:-

→ In this case, TRS or PVC insulated wire are used.

→ Wiring is carried out on wooden batten & wires are fixed to wooden batten with the help of clips.

→ wooden battens are fixed to wall with the help of wooden plug.

→ Main advantage of this type of wiring is its low cost. Therefore ~~are~~ very much suitable for domestic wiring.

→ Drawback is - it is suitable only for dry conditions also cannot be used for locations exposed to sun.

(4) Metal sheathed wiring:
→ In this type of wiring VIR or PVC insulated & sheathed with lead or lead alloy cable is used.
→ Out sheath of lead or lead alloy provides the protection of to the cable against mechanical injury.
→ But lead sheath must be necessarily earthed otherwise there will be electrolytic action due to leakage current which causes deterioration of lead cover.
→ This cable can be run on wooden batten and fixed by means of metal clips.
→ Metal sheathed wiring is very much suitable for places exposed to sun, rain and dampness.
→ Main drawback is its initial high cost.

(5) Conduit wiring
→ In this system of wiring, VIR or PVC insulated wires are run in metallic tubes or PVC pipes called as conduit.
→ Conduit is mounted on the wall or ceiling with the help of clips screwed to wooden plug.
→ This system of wiring has following advantages:-

i) It gives very good protection from mechanical injury.

ii) It also provides protection against fire due to short circuit.

iii) It also provides protection against moisture etc.

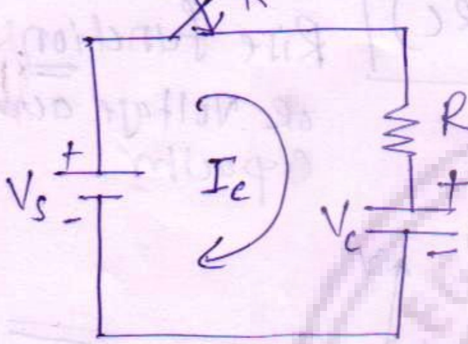
iv) It gives very good appearance since it can be concealed in the wall.

Q ⇒ Rise and decay of voltage in capacitor.

OR

Charging and discharging of RC Series ckt. (capacitor)

<u>Ans:-</u> Charging of Capacitor (Rise function):-



applying KVL in RC-Series ckt

$$V_s = I_c R + V_c \quad -(1)$$

$$\therefore I_c = C\frac{dV_c}{dt} \quad --(2)$$

Put the value of (2) in (1)

$$V_s = C\frac{dV_c}{dt}R + V_c$$

$$V_s - V_c = RC\frac{dV_c}{dt}$$

$$\frac{dV_c}{V_s - V_c} = \frac{dt}{RC}$$

Integrate both side

$$\int_0^{V_c}\frac{dV_c}{V_s - V_c} = \int_0^t \frac{dt}{RC} \Rightarrow -\log_e(V_s - V_c) + K = \frac{t}{RC} \quad -(3)$$

find the value of K using initial condition

at $t=0$, $V_c = 0$

then $-\log_e(V_s) + K = 0 \Rightarrow \quad K = \log_e V_s \quad -(4)$

Put the value of (4) in (3)

$$-\log_e (V_s - V_c) + \log_e V_s = \frac{t}{RC}$$

$$-[\log_e (V_s - V_c) - \log_e V_s] = \frac{t}{RC}$$

$$\log_e \frac{V_s - V_c}{V_s} = -t/RC$$

$$\Rightarrow \frac{V_s - V_c}{V_s} = e^{-t/RC}$$

$$\Rightarrow \boxed{V_c = V_s (1 - e^{-t/RC})}$$ Rise function or Voltage across capacitor

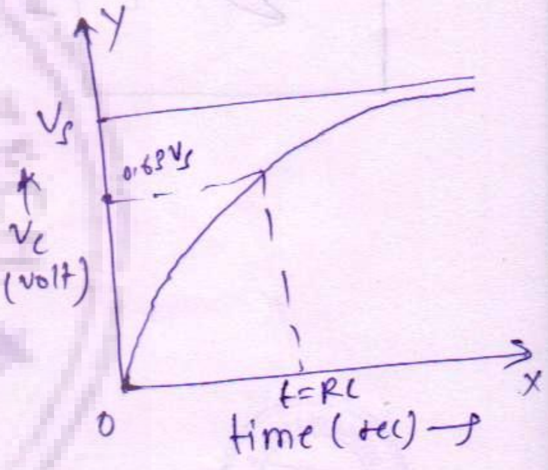
Plot the graph V_c v/s time

if $t = 0$, $V_c = V_s(1 - e^{-0/RC}) = 0$

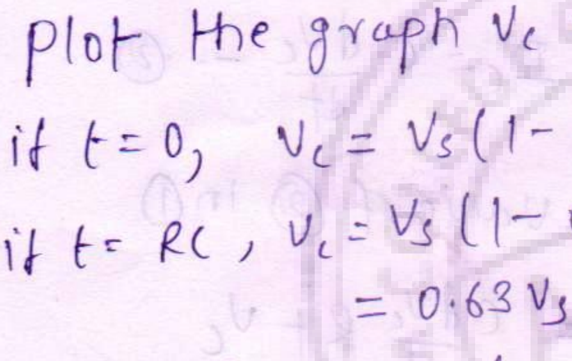
if $t = RC$, $V_c = V_s(1 - e^{-1}) = V_s(1 - 0.367)$

$= 0.63\, V_s$

If $t = 2RC$, $V_c = V_s(1 - e^{-2})$



$\Rightarrow$ Discharging of Capacitor (Decaying function):-



If DPST switch 'K' connect to switch 'A' than ckt behave as a charging ckt

$$V_c = V_s(1 - e^{-t/RC}) \quad \text{—(1)}$$

If DPST switch 'K' connect with switch 'B' than ckt behave as a discharging ckt.

$\rightarrow$ Applying KVL in discharging ckt

$$V_c + I_c R = 0 \quad \text{—(2)}$$

$$\because I_c = C \frac{dV_c}{dt} \quad \text{—(3)}$$

Put the value of ③ in ②

$$V_c + C\frac{dV_c}{dt}R = 0$$

$$RC\frac{dV_c}{dt} = -V_c$$

$$\frac{dV_c}{V_c} = -\frac{dt}{RC}$$

Integrate both side

$$\int_0^{V_c}\frac{dV_c}{V_c} = -\int_0^t \frac{dt}{RC}$$

$$\log_e V_c + K = -\frac{t}{RC} \quad \text{—— ④}$$

find the value of K using initial Condition

$$t=0, \quad V_c = V_s$$

$$\log_e V_s + K = 0 \Rightarrow K = -\log_e V_s \quad \text{—⑤}$$

Put the value of ⑤ in ④

$$\log_e V_c - \log_e V_s = -t/RC$$

$$\log_e \frac{V_c}{V_s} = -t/RC$$

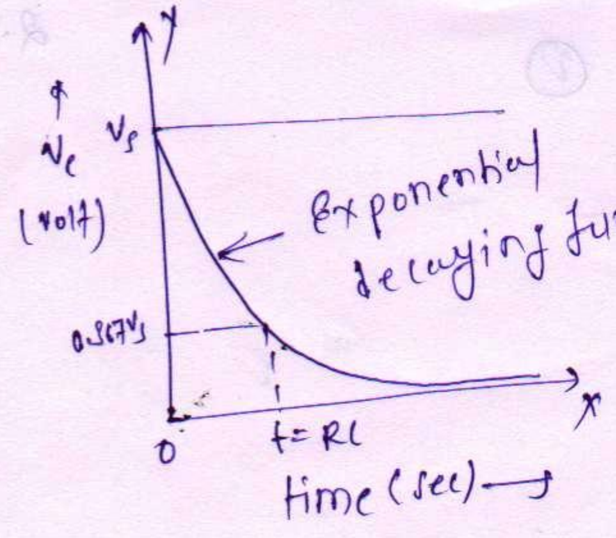
$$\frac{V_c}{V_s} = e^{-t/RC}$$

$$\boxed{V_c = V_s e^{-t/RC}}$$ decaying function

Plot the graph V_c v/s time(sec)

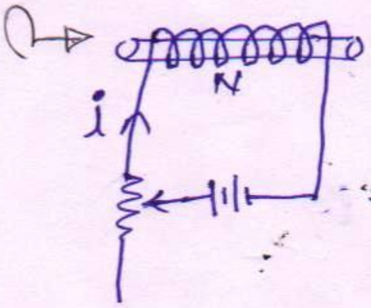
If $t=0$, $\quad V_c = V_s e^{-0/RC} = V_s$

If $t=RC$, $\quad V_c = V_s e^{-RC/RC} = V_s e^{-1} = 0.367 V_s$



<u>time constant</u> :- $\boxed{t = RC = \lambda}$ "time constant is a time taken by rise function to achieve 63% of its final value."

* Energy Stored in Magnetic field
Or
Energy Stored in Inductor.



→ N turns coil wound on iron bar.
→ Now current in the circuit increasing gradually.
→ Current in the ckt increases from '0' to a finite value of 'i' amp in a finite time 'dt', there will be a self induced emf in the coil.

→ Let Induced emf is given by.

$$\therefore e = L \cdot \frac{di}{dt}$$, where i = instantaneous value of current

→ To overcome the opposition provided by the Self Induced emf, some energy is required.

→ The energy consumed in time 'dt'.

$$\therefore dW = e \cdot i \cdot dt$$

now $e = L \cdot \frac{di}{dt}$

$$\therefore dW = \left(L \cdot \frac{di}{\cancel{dt}}\right) \cdot i \cdot \cancel{dt}$$

$$\boxed{\therefore dW = L \cdot i \cdot di} \quad \text{—— (i)}$$

Power
$P = V \cdot I \cos\phi$, $\cos\phi = $ p.f. for resistive load p.f. $= 1$ $\therefore \cos\phi = 1$

$\therefore P = V \cdot I$
or $V = $ e.m.f $= e$.

$\therefore P = e \cdot i$

→ now energy consumed in time t.
W = Power × time.
$W = P \times t$
$W = e \cdot i \times t$

$$\boxed{\therefore dW = ei \cdot dt}$$

→ total work done to enable final current I to flow will be.

$$\int_0^W dW = L \cdot \int_0^I i\, di$$

$$\therefore W = L\left[\frac{i^2}{2}\right]_0^I$$

$$\boxed{\therefore W = \frac{1}{2} L I^2 \text{ Joule}}$$

Thus the energy stored in the inductor $= \frac{1}{2} L I^2$ Joule.

ALPHA COLLEGE OF ENGINEERING &TECHNOLOGY, KHATRAJ
ELECTRICAL DEPARTMENT

ELEMENTS OF ELECTRICAL ENGINEERING
IMPORTANT TOPICS ASKED IN GTU EXAMS

Sr No	Topic	Papers 12	Avg Marks
1	ELCB MCB	11	6
2	ELECTRICAL WIRING	11	5
3	MAGNETIC CKT EXAMPLES	10	7
4	RISE AND DECAY OF VOLTAGE IN CAPACITOR	9	7
5	SERIES PARALLEL CONNECTION OF CAPACITOR	9	7
6	TEMPRATURE CO EFF OF RESISTOR	9	6
7	RLC SERIES CIRCUIT POWER & POWER FACTOR EXAMPLES	9	7
8	TWO WATT METER THEORY	9	7
9	STAR DELTA CONVERSION	8	6
10	ELECT & MAGN CKT DIFFERENCE	8	5
11	KCL KVL	7	5
12	LIGHTING SCHEME DESIGN	7	6
13	3 PH STAR DELTA EXAMPLES	7	6
14	FARADAY'S LAW OF EM INDUCTION	7	5
15	BATTERY CHARGING & DISCHARGING	6	5
16	WHISTON BRIDGE EXAMPLE	6	6
17	AC VECTOR EXAMPLES (R-P & P-R)	6	6
18	EARTHING SYSTEM	5	5
19	AC FUNDAMENTALS DEFINATIONS	5	6
20	AC FUNDAMENTAL EXMPL (R-L-C SERIES)	5	6
21	COEFFICIENT OF COUPLING IN MAG CKT	5	5
22	HYSTERISIS LOOP	5	4
23	FLORESCENT TUBELIGHT	4	6
24	ELECTRO MAGNETICS DEFINATIONS	4	4
25	R-L-C SERIES RESONANCE AND Q FACTOR	4	7
26	BATTERY CONST WORKNIG	3	5
27	CABLE	3	5
28	CAPACITOR EXAMPLES	3	7
29	EM INDUCTION EXAMPLE	3	7
30	PURE INDUCTOR V & I RELATION AND AVG POWER	3	6
31	SELF AND MUTUAL INDUCED EMF	3	5