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Module - 1

* Current :- Flow of charge.
* Intensity of current :- Rate of flow of charge.
(strength)

$I = Q/t$; $A = C/s$; unit : Ampere (A)

* The flow of 1C of charge in 1s is known as 1A.

$(1A = 1C/1s)$

* Electric potential :- Capacity of charge to do work.

$V = W/Q$; $V = J/C$; unit :- volts (V).

* When 1C of charge posses an energy of 1J, then the body has an electric potential of 1V.

* Potential difference :- Force which causes the electric current flow in a closed circuit.

$V_{ba} = V_b - V_a$.

* Electromotive Force :- Pressure or force which causes an electric current to flow.

unit : volt (V).

* Power :- The rate of doing work.

$P = VI$; $P = V^2/R$; $P = I^2R$; unit : watts or hp or kilowatts.

1 horse power = 746 watts.

* Energy :- Capacity to do work.

unit : J or kwh.

kwh = power in kw × time in hr.

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- Resistance :- Property of a substance to oppose the flow of electric current.
  Unit's ohm (Ω)
- When 1A current flowing through a conductor produces a heat at the rate of 1 J/s, then a conductor is said to have 1 Ω resistance.

Q1) Consider a resistance which is connected to a 12V supply having resistance 2 Ω, the what will be the charge produced in Coulombs for 10 sec?

Ans) $V = 12V$; $R = 2\Omega$

$V = IR$

$12 = I \times 2$

$I = 6A$

$Q = ?$; $t = 10s$; $I = 6A$

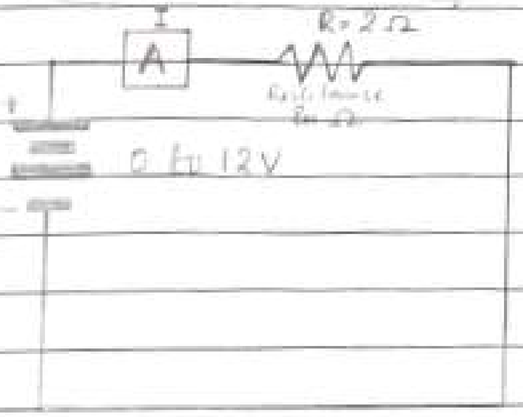
$Q = It$

$= 10 \times 6$

$= \underline{\underline{60C}}$

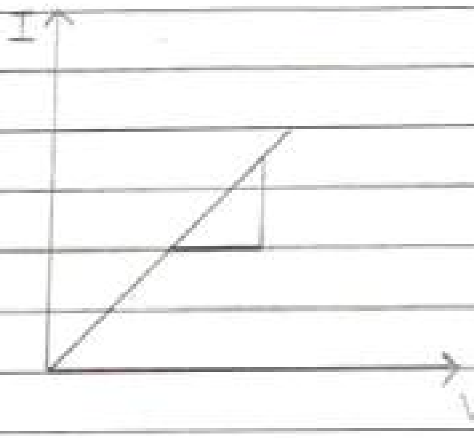
- Ohm's Law : At a constant temperature, the ratio of potential difference (V) between any 2 points on a conductor to the current (I) flowing between them, is constant.
- V/I = constant
  $= R$

- Volt - Ampere Characteristics (VI characteristics)



V	R	I = V/R
0	2	0
4	2	2
10	2	5
12	2	6.

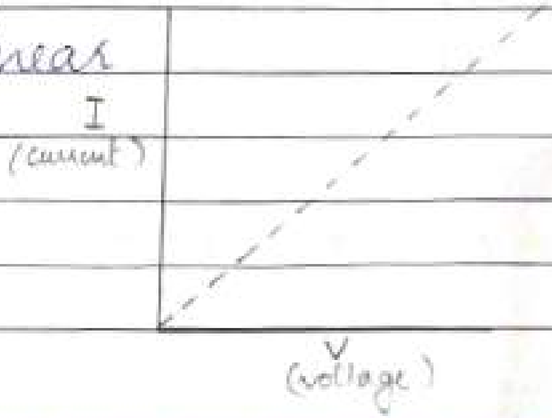
Slope = y/x
= I/V
= $1/R$



- Conductance ($1/R$)
- VI characteristics of R: Shows how much current a resistor allows.

* Linear Resistance

- Resistance doesn't vary with the flow of current through it.
- The current through it, will always be proportional to the voltage applied across it.
- VI characteristic is linear
- eg: Rheostat, potentiometer



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Non Linear Resistance

- Resistance varies with the flow of current through it.
- Non Linear VI characteristics.

eg: Tungsten filament, Thermistor.

* Laws of Resistance

- The resistance offered by a conductor depends on the following factors:

•) varies directly as its length, l
•) varies inversely as cross sectional area, A
•) depends on the nature of material
•) also depends on the temperature of the conductor.

- For const temp

$$R \propto \frac{l}{A}$$

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

•) ρ is the specific resistance or resistivity
•) when $l = 1m$, $A = 1m^2$ then $R = \rho$
•) ρ is the resistance between the opposite faces of 1m cube of that material.

* Conductor & Conductivity

- Reciprocal of resistance (conductance)
- Conductance is defined as the potential for a substance to conduct electricity.

$$G = \frac{1}{R}$$
$$= \frac{A}{\rho l}$$
$$= \sigma \frac{A}{l}$$

- unit of σ : $ohm^{-1} m^{-1}$ or mho/m
- unit of G : mho or $\mho$

* Inductor

- Inductance (L): property to oppose the change in flux.
- Conductor is twisted like a coil - basic inductor
- unit : Henry (H).

* Current through an Inductor.

- According to Faraday's Law

$$v = L \frac{di}{dt}$$
$$di = \frac{v}{L} dt$$
$$\int_0^t di = \frac{1}{L} \int_0^t v dt$$

$$i(t) - i(0) = \frac{1}{L}\int_0^t v\,dt$$

$$i(t) = \frac{1}{L}\int_0^t v\,dt.$$

- $i(0)$ is the initial current.
- Current through the inductor dependant upon the integral of the voltage of its terminals and initial current in the coil.

* Energy Stored in an Inductor

Power,

$$P = vi \qquad \text{(inductor → instantaneous power)}$$

$$= L\frac{di}{dt}.i \qquad v = L\frac{di}{dt} \text{ (Faraday's Law)}$$

Energy,

$$E = \int_0^t P.dt$$

$$= \int_0^t L\frac{di}{dt}.i \times dt.$$

$$= L\int_0^t i\,di$$

changing limits,

At $t = 0$; $i = 0$

$t = t$; $i = I$, DC current

$$E = L\int_0^t i\,di$$

$$= \frac{1}{2}L\left[i^2\right]_0^t$$

$$= \frac{1}{2} L(I^2 - 0)$$

$$E = \frac{1}{2} L I^2$$

- If current through the inductor is constant, induced voltage = 0.
  (Inductor acts as a short circuit)

- Small change in zero time will give infinite voltage. This is practically impossible. So impulsive change in inductor current is not possible.

- A pure inductor cannot dissipate energy. Hence it is known as non-dissipative passive element.

Q1) Show that, $P = I^2R = V^2/R$ using Ohm's law.

Ans) $V = IR$ — (1)

$P = VI$ — (2)

~~From~~ (1) Sub (1) in (2)

$$P = (IR)I$$

$$= I^2R \quad -(3)$$

multiplying & dividing the 3rd eqn by R

$$P = I^2R \times \frac{R}{R}$$

$$= \frac{(IR)^2}{R} = \frac{V^2}{R}$$

Hence proved

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Q2) Calculate the resistance of 100m length of a wire having a uniform cross-sectional area of $0.1\ mm^2$. If the wire is made of manganin having a resistivity of $50 \times 10^{-8}\ \Omega m$. If the wire is drawn out to three times its original length, by how many times would you expect its resistance to be increased?

Ans) $l_1 = 100m$

$A_1 = 0.1\ mm^2$

$= 1 \times 10^{-7}\ m^2$

$\rho = 50 \times 10^{-8}\ \Omega m$

$$R_1 = \frac{\rho l_1}{A_1} \quad -(1)$$

$$= \frac{50 \times 10^{-8} \times 100}{1 \times 10^{-7}}$$

$$= 50 \times 10^{-8} \times 10^{9}$$

$$= \underline{\underline{500\ \Omega}}$$

$$R_2 = \frac{\rho l_2}{A_2} \quad -(2)$$

∴ as the length is increased by 3 times, area decreases by 3 times.

$l_2 = 3l_1 \quad -(3)$

$A_2 = \frac{A_1}{3} \quad -(4)$

∴ Sub (3) & (4) in (2)

$$R_2 = \frac{\rho \times 3l_1 \times 3}{A_1} = \frac{9 \rho l_1}{A_1}$$

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According to eqn (1)

$R_2 = 9R_1$

* Capacitor (C)

- Capacitor consist of 2 conducting surface separated by a layer of insulating medium called dielectric

- Capacitor stores electrical energy in dielectric.

- Capacitance

- Ability to store electricity
- unit - Farad, F

$$C = \frac{Q}{V}$$

- One farad is amount of capacitance when 1C charge stored with 1V across the plate.

- Voltage Across Capacitor

$$C = \frac{Q}{V} \text{ or } C = \frac{q}{v}$$

$$i = C\frac{dv}{dt} \qquad \left\{ i = \frac{dq}{dt} \right\}$$

$$dv = \frac{1}{C} i\,dt$$

$$\int_0^t dv = \frac{1}{C}\int_0^t i\,dt$$

$$v(t) - v(0) = \frac{1}{C}\int_0^t i\,dt \qquad \left\{ v(0) \text{ is considered } 0 \right.$$

$$v(t) = \frac{1}{C}\int_0^t i\,dt + v(0)$$

- Energy stored in capacitor

$$P = VI = vi = vC\frac{dv}{dt} \qquad \left\{ i = C\frac{dv}{dt} \right\}$$

Energy, $W = \int_0^t p\,dt$

$$= \int_0^t vC\frac{dv}{dt}\,dt$$

$$= C\int_0^t v\,dv = C\left[\frac{v^2}{2}\right]_0^t$$

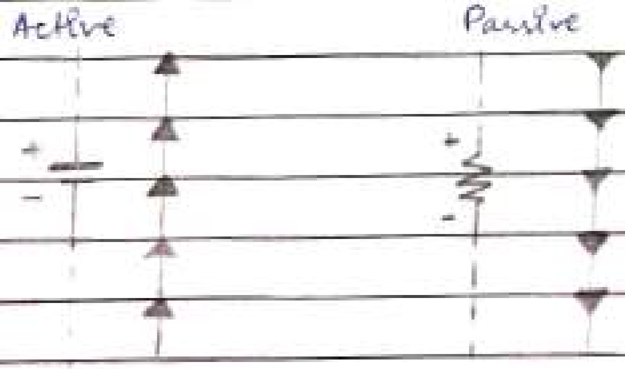
$$W = \frac{1}{2}CV^2$$

- Current in the capacitor is zero when voltage is constant.
- In a fixed capacitor, voltage cannot change abruptly
- Capacitor can store finite amount of energy even if the current through it is zero.
- Pure capacitor never dissipate energy - non-

dissipative passive element.

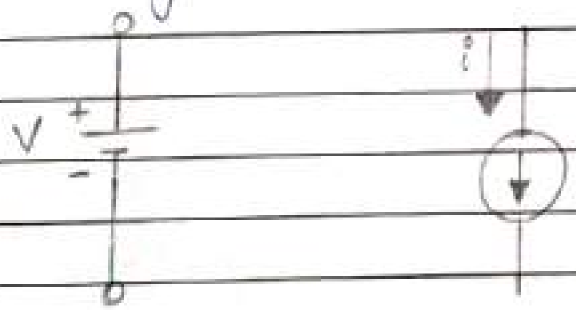
Active and passive sign convention

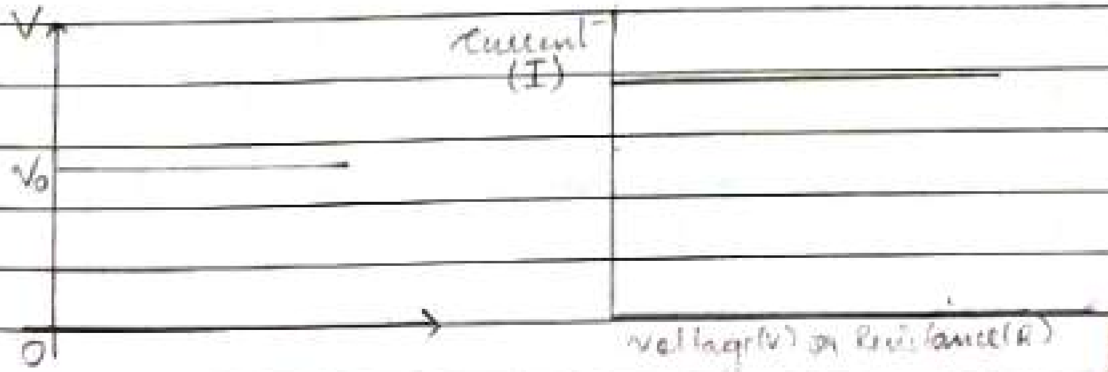
- Active sign convention is used for the devices which deliver energy to the circuit
  eg: battery
- Passive sign convention is commonly used for resistors.



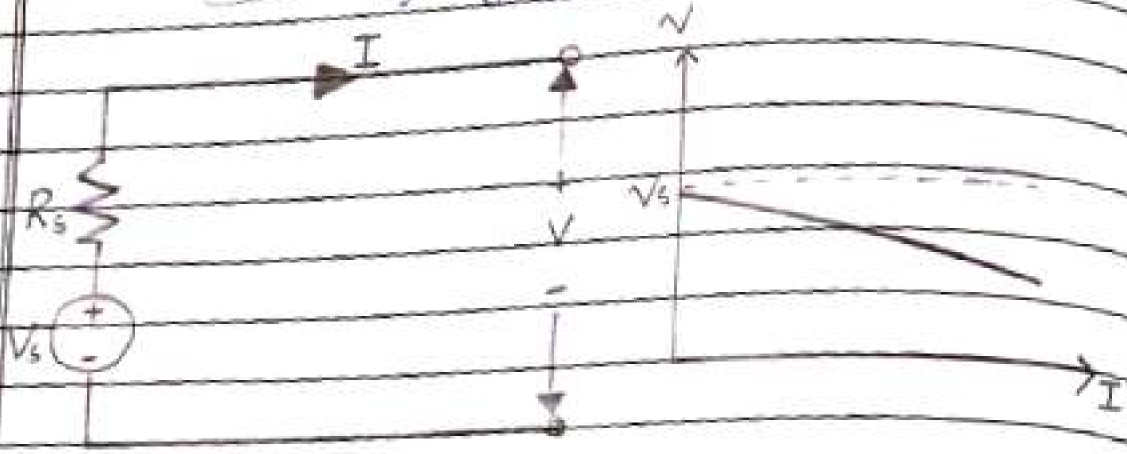
* Energy Sources

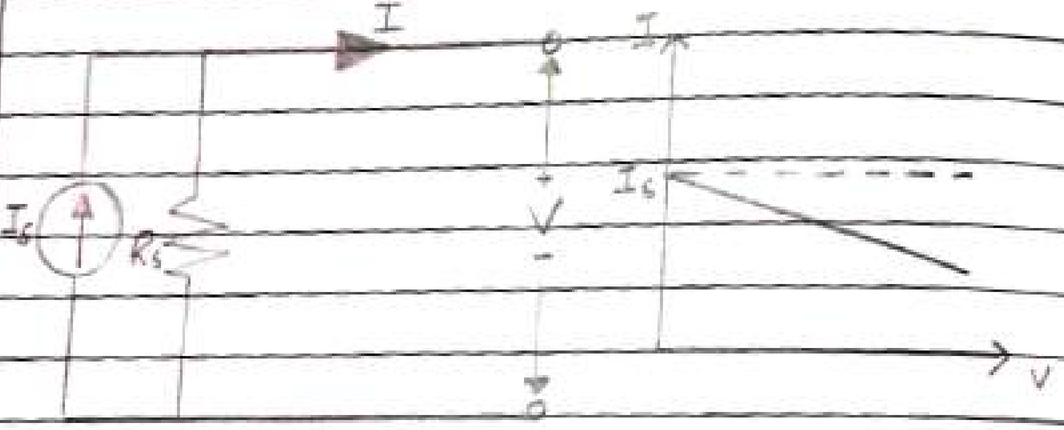
- Ideal voltage and Ideal current source



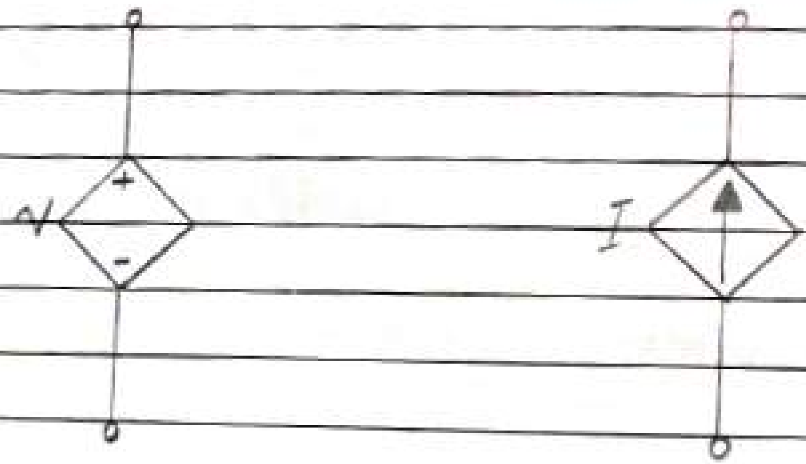


* Practical Energy Sources





* Dependant Sources



(a) Dependent voltage source (b) Dependent current source

- Voltage controlled by voltage source.
- Voltage controlled by current source.

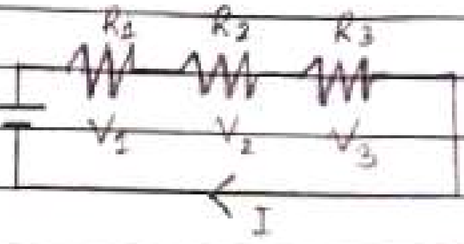
- Current controlled by voltage source.
- Current controlled by current source.

* Series Circuit

$V = IR_s$

But $V = V_1 + V_2 + V_3$

$\therefore IR_s = IR_1 + IR_2 + IR_3$



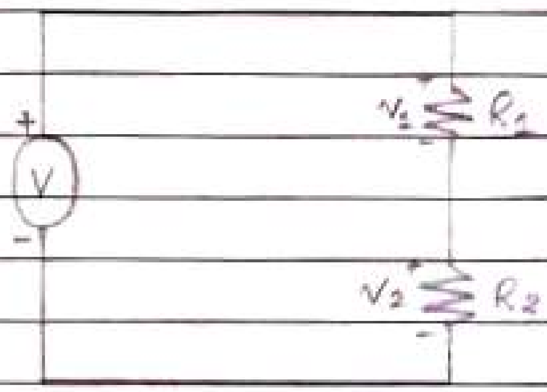
i.e. $IR_s = I(R_1 + R_2 + R_3)$

$$R_s = R_1 + R_2 + R_3$$

* Voltage Divider Rule

$R = R_1 + R_2$ — (1)

$I = \frac{V}{R}$ — (2)



$V_1 = IR_1$

$V_1 = \frac{V}{R} R_1$ from (2)

$V_1 = \frac{R_1 V}{R}$

$= \frac{R_1}{R_1 + R_2} V$ from (1)

* Parallel Circuit

Total current = $I_1 + I_2 + I_3$

$I = \frac{V}{R}$

$\frac{V}{R_p} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$ $\{V_1 = V_2 = V_3 = V\}$

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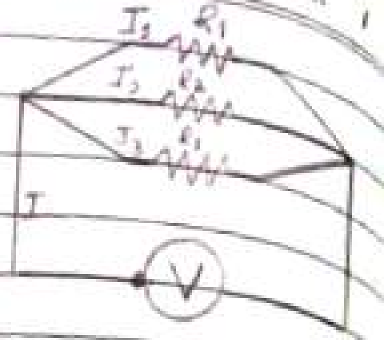
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

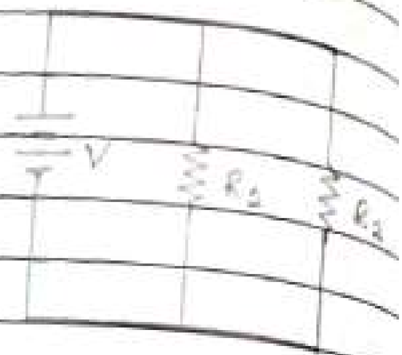


$$G = \frac{1}{R}$$

$$\therefore \quad G_p = G_1 + G_2 + G_3$$

- Two Resistors in Parallel

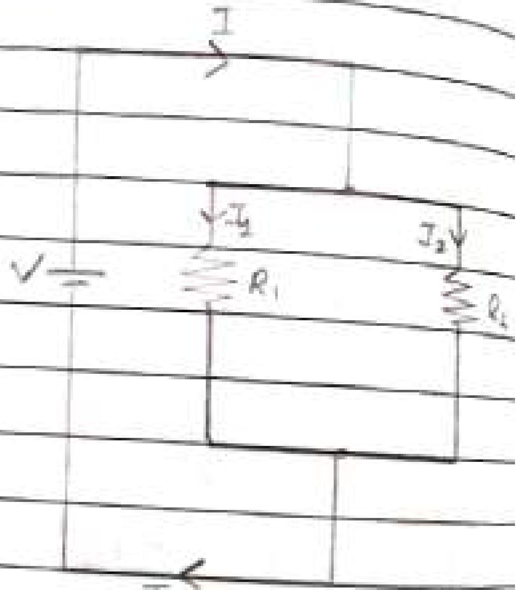
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$



$$R = \frac{R_1 R_2}{R_1 + R_2}$$

- Current division Rule

$V = IR \qquad R = \dfrac{R_1 R_2}{R_1 + R_2}$

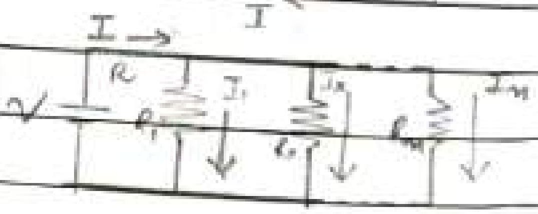


$$I_1 = \frac{V}{R_1} = \frac{IR}{R_1}$$

$$= I \times \frac{\cancel{R_1} R_2}{\cancel{R_1}(R_1 + R_2)}$$

$$= \frac{R_2 I}{R_1 + R_2}$$

$$I_2 = \frac{V}{R_2}$$



$$= \frac{R_1 I}{R_1 + R_2}$$

$\therefore \quad I_x = V/R_x$ $\qquad \{V = IR\}$

$$I_x = \frac{I}{R_x} R$$

51) The resistivity of a ferric-chromium-aluminium alloy is $51\times10^{-8}\,\Omega m$. A sheet of the material is 15cm long, 6 cm, wide and 0.014 cm thick. Determine resistance between

a) opposite ends and b) opposite sides.

Ans) a) $l = 15\,cm$

$\frac{15}{100} = 0.15\,m$

$A = \frac{6}{100} \times \frac{0.014}{100} = 6\times14\times10^{-7}\,m^2$

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

$= 51\times10^{-8} \times \frac{0.15}{\frac{6}{100}\times\frac{0.014}{100}}$

$= 51\times10^{-8} \times \frac{15\times10000}{6\times100\times0.014}$

$= \frac{51\times\cancel{15}^{5}\times10^{-8}\times10^{3}\times10^{2}}{2\cancel{6}\times14}$

$= \underline{9.1\times10^{-3}\,\Omega}$

b) $l =$

$A = \frac{15\times6}{10000}$

$= 15\times6\times10^{-4}\,m^2$

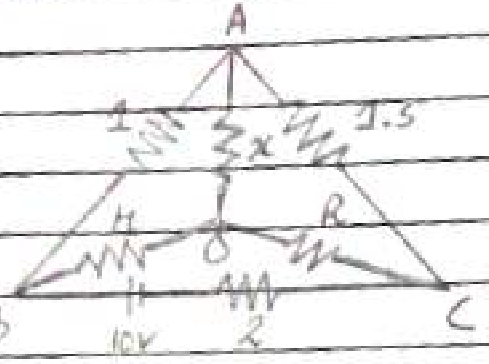
$R = \frac{\rho l}{A}$

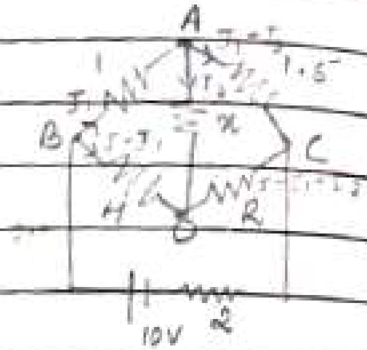
$= 51\times10^{-8} \times \frac{0.014}{15\times6\times10^{-4}}$

$= 51\times10^{-8} \times \frac{14\times10^{4}}{15\times6\times1000}$

$= \frac{51\times14}{15\times6} \times \frac{10^{-8}\times10^{4}}{1000} = 7.9\times10^{-9}\,\Omega = \underline{79.3\times10^{-10}\,\Omega}$

Q2) Determine the value of R and current through it. if current through branch AO is zero.





$I_3 = 0$

$I - I_1 = 5 - I_1$

Ans)

$R_1 = 1\,\Omega$

$R_2 = 1.5\,\Omega$

$R_3 = 4\,\Omega$

$R_4 = R = ?$

$V = 10V$

$R = 2\,\Omega$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$\frac{1}{1.5} = \frac{4}{R_4}$$

$$R_4 = 4 \times 1.5$$

$$= \underline{\underline{6\,\Omega}}$$

$R_{BC} = ?$

$$\frac{1}{R_{BC}} = \frac{1}{2.5} + \frac{1}{10}$$

$$= \frac{10 + 2.5}{25}$$

$$R_{BC} = \frac{25}{12.5} = \frac{250}{125} = 2\,\Omega$$

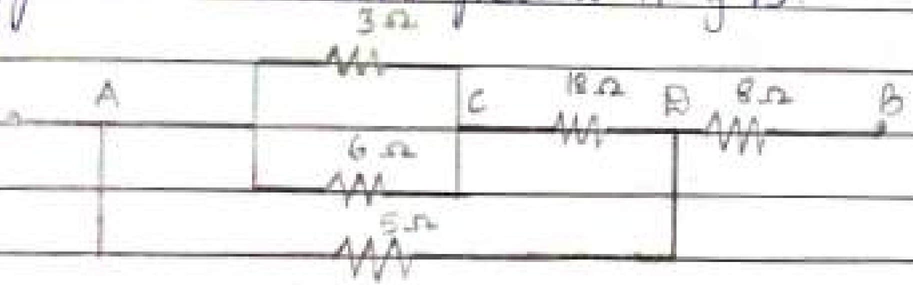
total resistance = 2+2 = 4 Ω

total current = $\frac{V}{R_{total}}$

$= \frac{10}{4} = 2.5 A$

$I_2 = \frac{2.5 \times 2.5}{12.5} = 0.5 A$

Q3) Calculate the effective resistance of the following combination of resistance and the voltage drop across each resistance when a P.D of 60V is applied between points A & B.



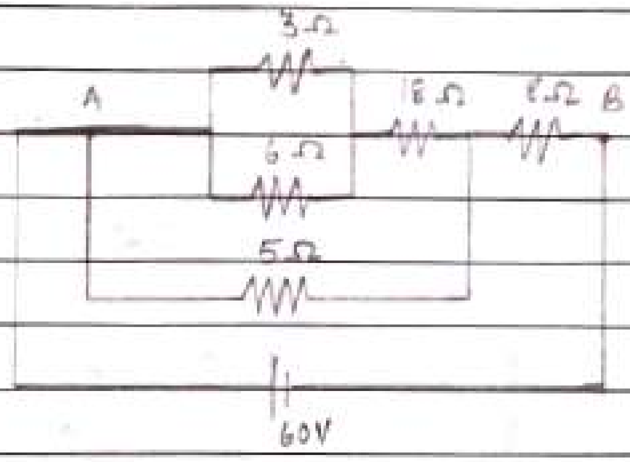
Ans) $R_1 = 3 \Omega$

$R_2 = 6 \Omega$

$R_3 = 18 \Omega$

$R_4 = 5 \Omega$

$R_5 = 8 \Omega$



$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{3} + \frac{1}{6}$$

$$= \frac{2}{6} + \frac{1}{6} = \frac{\cancel{3}\,1}{\cancel{6}\,2}$$

$R_P = 2 \Omega$

$R_S = R_P + R_3$

$= 2 + 18 = 20 \Omega$

$$\frac{1}{R_p} = \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{20} + \frac{1}{5}$$

$$= \frac{1}{20} + \frac{4}{20}$$

$$= \frac{5}{20}$$

$R_p = 4\,\Omega$

$R_s = R_p + R_5$

$= 4 + 8$

$= 12\,\Omega$

total effective resistance $= 12\,\Omega$

Voltage across AB is 60V

$V = IR$

$60V = I \times 12$

$I = \frac{60}{12} = 5A$

current across $5\,\Omega$ resistor

$$I_x = \frac{I \times R_2}{(R_1 + R_2)}$$

$$= \frac{5 \times 20}{25}$$

$= 4A$

Current across $20\,\Omega$ resistors (R_1, R_2 & R_3)

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$$I_y = \frac{5 \times 5}{25}$$ $\left\{ I_x = \frac{I \times R}{R_x} \right\}$

$= \underline{\underline{1A}}$

∴ voltage ~~acros~~ across ~~3 & 6~~ 3Ω & 6Ω resistors

$V = IR$

$V = 1A \times 2\Omega$ $(R_p = 2\Omega)$

$= \underline{\underline{2V}}$

∴ voltage across 5Ω resistor.

$V = IR$

$V = 4 \times 5$

$= \underline{\underline{20V}}$

∴ voltage across 18Ω resistor

$V = IR$

$= 1 \times 18$

$= \underline{\underline{18V}}$

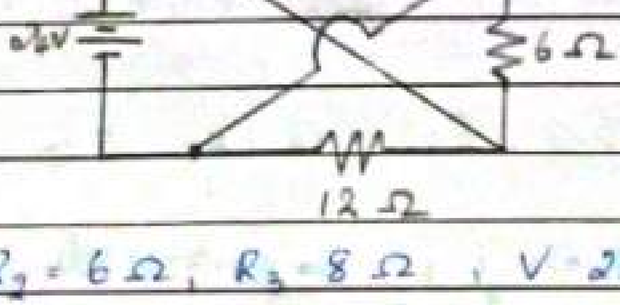
∴ voltage across 8Ω resistor

$V = IR$

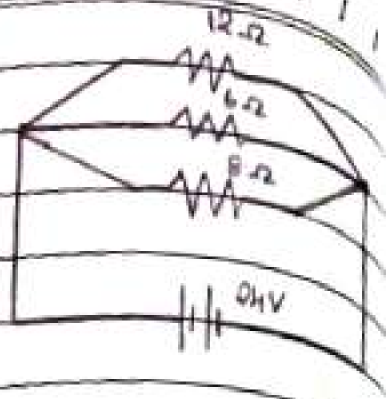
$= 5 \times 8$ $\{I = 4 + 1 = 5A\}$

$= \underline{\underline{40V}}$

Q4) Compute total circuit resistance and battery current



Ans) $R_1 = 12\Omega$, $R_2 = 6\Omega$, $R_3 = 8\Omega$, $V = 24V$.



$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{12} + \frac{1}{6} + \frac{1}{8}$$

$$= \frac{2+4+3}{24}$$

$$= \frac{9}{24}$$

$$R_P = \frac{24}{9} = \frac{8}{3}\ \Omega$$

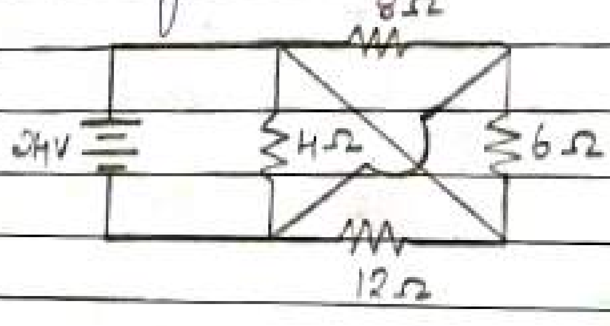
$$V = IR$$

$$24 = I \times \frac{8}{3}$$

$$\cancel{24 \times 8 \times I} \qquad I = 24 \times \frac{3}{8}$$

$$\cancel{I = 64A} \qquad = 9A$$

Q5) Calculate battery current and equivalent resistance of the network.



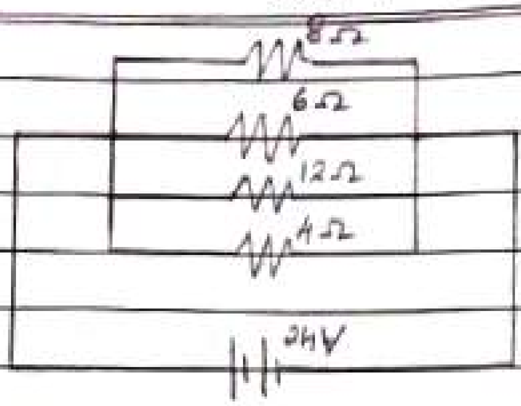
Ans) $R_1 = 8\Omega$, $R_2 = 6\Omega$, $R_3 = 12\Omega$, $R_4 = 4\Omega$, $V = 24V$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{6} + \frac{1}{12} + \frac{1}{4}$$

$$= \frac{3+4+2+6}{24}$$

$$= \frac{15}{24}$$



$$R_p = \frac{\cancel{24}^{8}}{\cancel{15}_{5}} = \frac{8}{5}\ \Omega$$

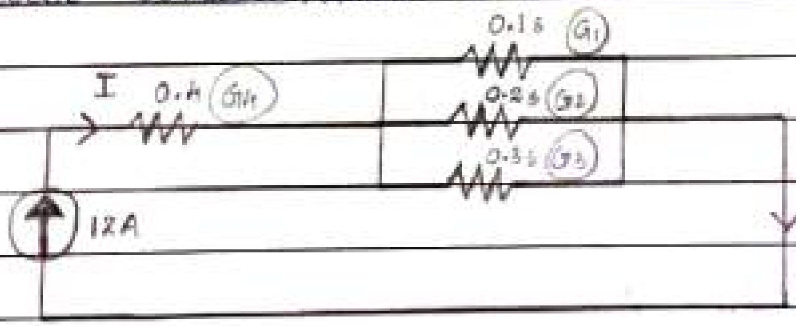
$$V = IR$$

$$24 = I \times \frac{8}{5}$$

$$I = \cancel{24}^{3} \times \frac{5}{\cancel{8}}$$

$$= \underline{\underline{15A}}$$

9b) Calculate the values of different currents for the circuit shown in the figure, what is the total circuit conductance? and resistance?



Ans) $R = \frac{1}{G}$

$$G_p = G_1 + G_2 + G_3$$

$$= 0.1 + 0.2 + 0.3$$

$$= \underline{\underline{0.6S}}$$

$$\frac{1}{G_T} = \frac{1}{G_p} + \frac{1}{G_4}$$

$$= \frac{1}{0.6} + \frac{1}{0.4}$$

$$= \frac{4+6}{24}$$

$$\frac{1}{G_s} = \frac{10}{24}$$

$$G_s = \frac{24}{10} = \underline{\underline{2.4\ S}}$$

$$R = \frac{\cancel{10}^{5}}{\cancel{24}\,12} = \underline{\underline{\frac{5}{12}\ \Omega}}$$

$$I_x = \frac{I \times G_x}{G}$$

$$I_1 = \frac{I \times G_1}{G}$$

$$\cancel{= \frac{12 \times 0.1 \times 10^{5}}{24\,2}}$$

$$= \frac{12 \times 0.1}{0.6}$$

$$= \frac{12}{6} = \underline{\underline{2A}}$$

$$I_2 = \frac{I \times G_2}{G}$$

$$= \frac{12 \times 0.2}{0.6}$$

$$= \cancel{12}^{2} \times \frac{2}{\cancel{6}}$$

$$= \underline{\underline{4A}}$$

$$I_3 = \frac{I \times G_3}{G}$$

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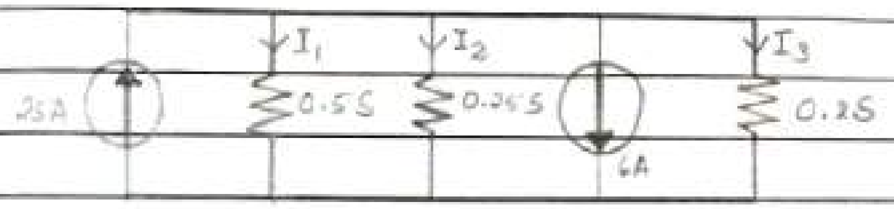
$= \frac{12 \times 0.3}{0.6}$

$= \frac{12 \times 3}{6}$

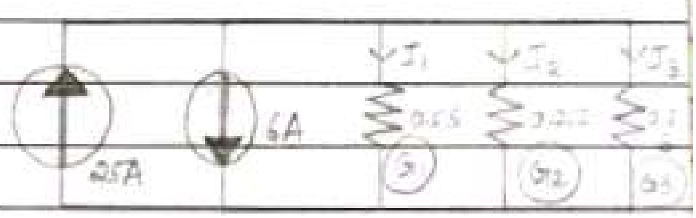
$= \underline{6A}$

Q1) Compute the values of 3 branch currents for the circuit shown. What is the p.d b/w points A & B.



Ans) $I = 25 - 6$

$= \underline{19A}$



$I_1 = \frac{I \times G_1}{G}$ — ①

$G = ?$

$G_p = G_1 + G_2 + G_3$

$= 0.5 + 0.25 + 0.2$

$= \underline{0.95S}$

$I_1 = 19 \times \frac{0.5}{0.95}$

$= \frac{\cancel{19} \times \cancel{50}^{10}}{\cancel{95}_{\cancel{19}}}$

$= \underline{10A}$

$I_2 = \frac{I \times G_2}{G}$

$= 19 \times \frac{0.25}{0.95}$

$19 \times \frac{25^{5}}{95_{19}}$

$= \underline{5A}$

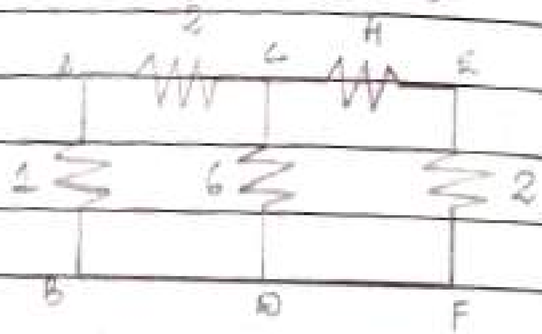
$I_3 = I \times \frac{G_3}{G}$

$= 19 \times \frac{0.2}{0.95}$

$= 19 \times \frac{20^{4}}{95_{19}}$

$= \underline{4A}$

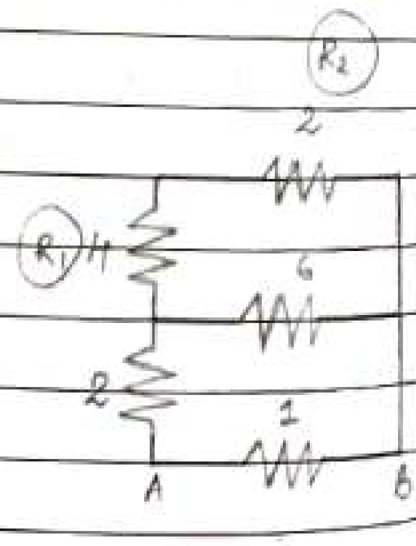
Q8) Find the equivalent resistance of the circuit shown:



(i) B/w A & B
(ii) B/w C & D
(iii) B/w E & F
(iv) B/w A & F
(v) B/w A & C.

the number represents resistances in Ω.

Ans) (i) B/w A & B.



$R_s = R_1 + R_2$
$= 4 + 2$
$= \underline{6\Omega}$

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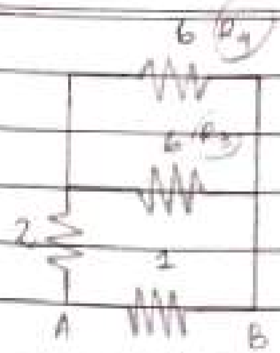
$1/R_p = 1/R_3 + 1/R_4$

$= 1/6 + 1/6$

$= 2/6$

$R_p = 3\,\Omega$



$R_s = R_5 + R_6$

$= 2 + 3$

$= 5\,\Omega$

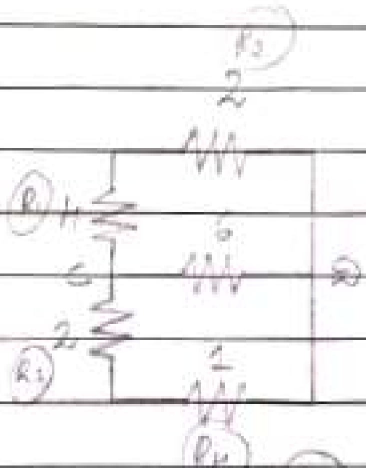
$1/R_p = 1/R_s + 1/1$

$= \frac{1}{5} + \frac{1}{1}$

$= \frac{6}{5}$

$R_p = 5/6\,\Omega$

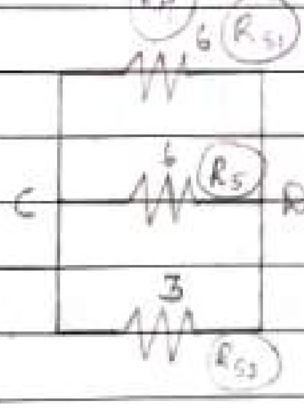
(iii) B/w C & D



$R_{s_1} = R_1 + R_2$

$= 4 + 2$

$= 6\,\Omega$



$R_{s_2} = R_3 + R_4$

$= 2 + 1$

$= 3\,\Omega$

$1/R_p = 1/R_{s_1} + 1/R_5 + 1/R_{s_2}$

$= 1/6 + 1/6 + 1/3$

$= 2/6 + 1/3$

$= 4/6$

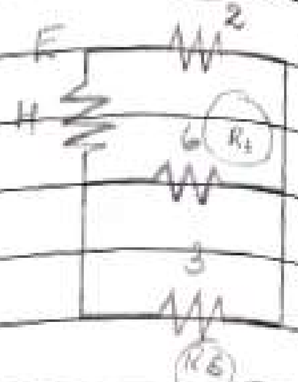
$R_p = \frac{6}{4} = \frac{3}{2}\,\Omega$

(iii) B/W E & F

$R_s = R_1 + R_2$

$= 2 + 1$

$= 3\ \Omega$



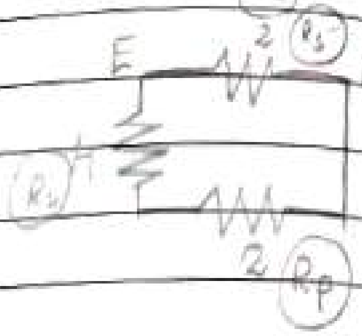
$1/R_P = 1/R_s + 1/R_3$

$= 1/3 + 1/6$

$= \frac{2+1}{6}$

$= \frac{3}{6}$

$R_P = 2\ \Omega$



$R_{S_1} = R_P + R_4$

$= 2 + 4$

$= 6\ \Omega$

$1/R_{P_1} = 1/R_{S_1} + 1/R_5$

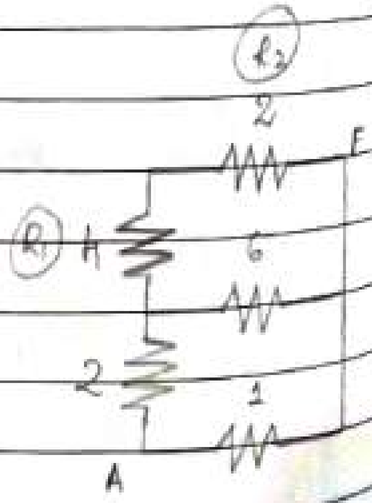
$= 1/6 + 1/2$

$= 1/6 + 3/2$

$= \frac{4}{6}$

$R_{P_1} = \frac{6}{4}\ \Omega = \frac{3}{2}\ \Omega$

(iv) B/W A & F

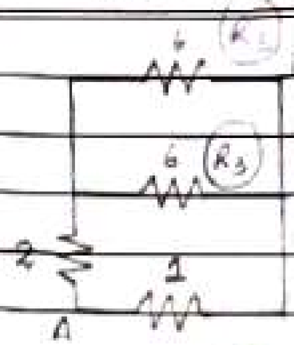


$R_s = R_1 + R_2$

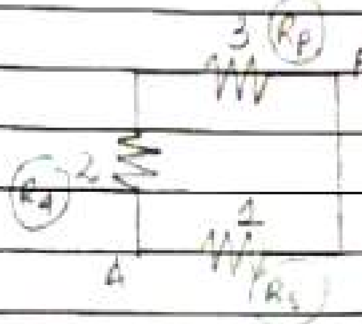
$= 4 + 2$

$= 6\ \Omega$

$$1/R_P = 1/R_5 + 1/R_3$$
$$= 1/6 + 1/6$$
$$= 2/6 = 1/3$$
$$R_P = \underline{\underline{3\Omega}}$$



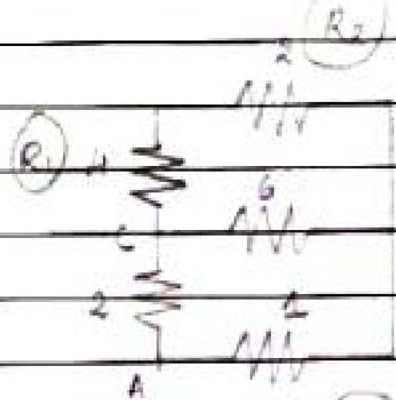
$$R_{S_1} = R_P + R_4$$
$$= 3 + 2$$
$$= \underline{\underline{5\Omega}}$$



$$1/R_{P_1} = 1/R_{S_1} + 1/R_5$$
$$= 1/5 + 1/1$$
$$= \frac{6}{5}$$

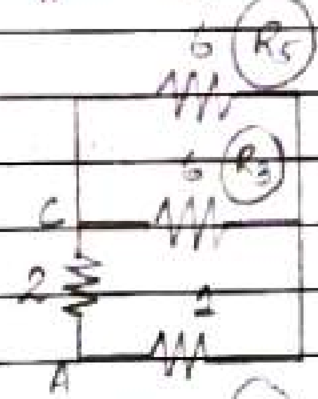
$$R_{P_1} = \underline{\underline{\frac{5}{6}\Omega}}.$$

(V) B/w A & C

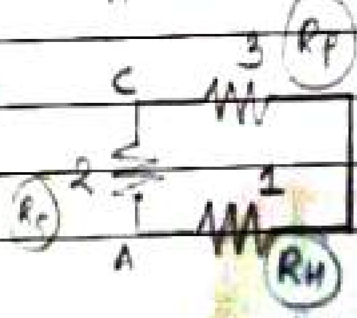


$$R = R_1 + R_2$$
$$= 4 + 2$$
$$= \underline{\underline{6\Omega}}$$

$$1/R_p = 1/R_5 + 1/R_3$$
$$= 1/6 + 1/6$$
$$= 2/6$$
$$R_p = \underline{\underline{3\Omega}}$$



$$R_{S_1} = R_p + R_4$$
$$= 3 + 1$$
$$= \underline{\underline{4\Omega}}$$



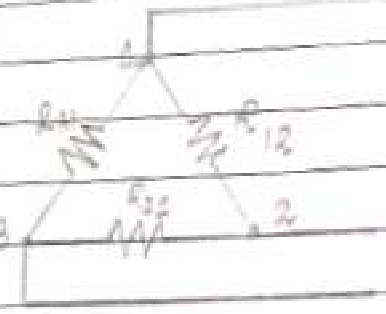
$$\frac{1}{R_{p_1}} = \frac{1}{R_{s_1}} + \frac{1}{R_s}$$

$$= \frac{1}{4} + \frac{1}{2}$$

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

$$R_{p_1} = \frac{4}{3}\ \Omega$$

* Delta - Star Transformation

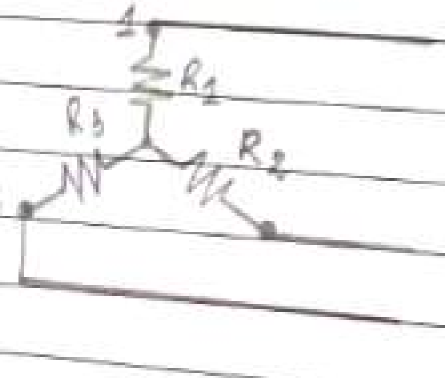


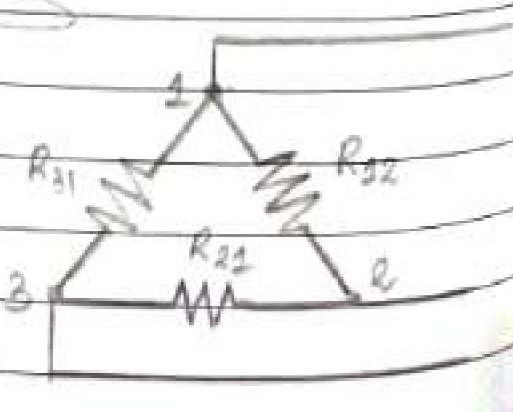
$$R_1 = \frac{R_{12} R_{31}}{R_{12} + R_{23} + R_{31}}$$

$$R_2 = \frac{R_{12} R_{23}}{R_{12} + R_{23} + R_{31}}$$

$$R_3 = \frac{R_{31} R_{23}}{R_{12} + R_{23} + R_{31}}$$

* Star - Delta Transformation





$$R_{12} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

$$= \frac{R_1R_2}{R_3} + R_2 + R_1$$

$$R_{23} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

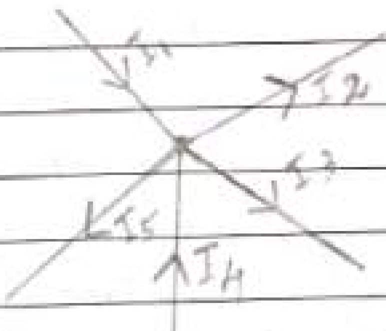
$$= R_2 + \frac{R_2R_3}{R_1} + R_3$$

$$R_{31} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

$$= R_1 + R_3 + \frac{R_3R_1}{R_2}$$

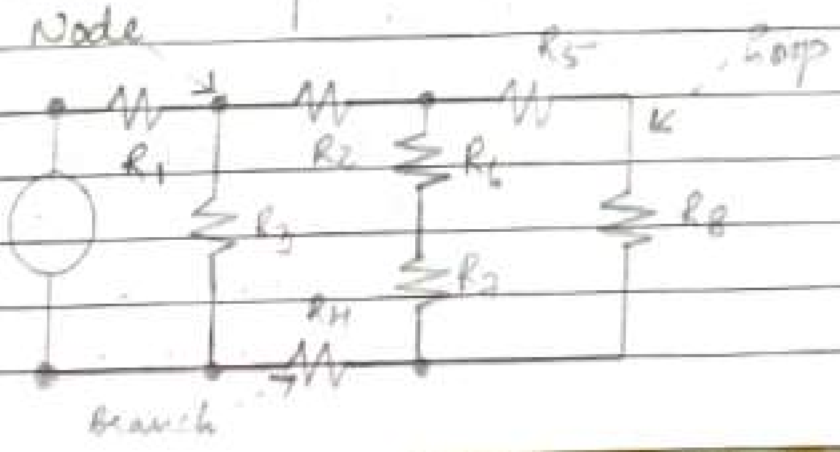
Kirchhoff's Point Law or Current Law (KCL)

- In any electrical network, the algebraic sum of the currents meeting at a point (or junction) is zero.
- Incoming currents - Outgoing currents.



$$I_1 - I_2 - I_3 + I_4 - I_5 = 0$$

$$I_1 + I_4 = I_2 + I_3 + I_5$$



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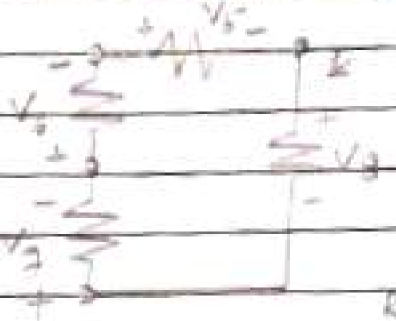
Kirchhoff's Mesh Law or Voltage Law (KVL)

- The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.fs in that path is zero.

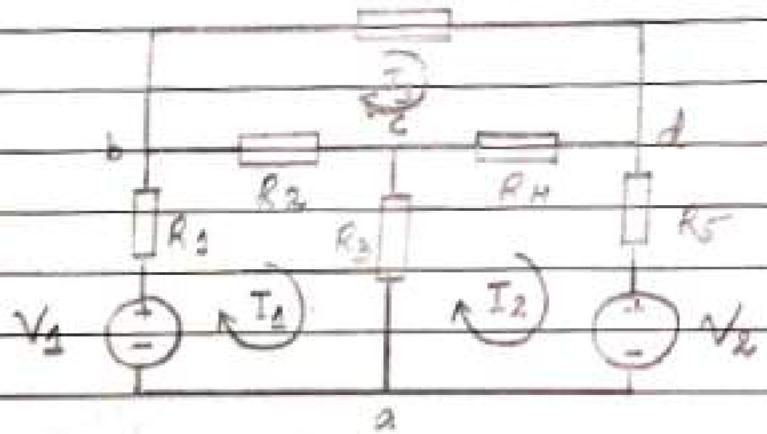
- $\Sigma IR + \Sigma e.m.f = 0$

Loop.



$V_5 + V_6 + V_7 + V_8 = 0$

Q1)



Ans)

Consider loop/mesh abca.

$$-I_1R_1 - (I_1 - I_3)\cdot R_2 - (I_1 - I_2)\cdot R_3 + V_1 = 0.$$

$$-I_1R_1 - I_1R_2 + I_3R_2 - I_1R_3 + R_3I_2 + V_1 = 0$$

$$I_1(R_1 + R_2 + R_3) - I_2R_3 - I_3R_2 = V_1 \quad \text{—(1)}$$

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Consider acda

$$-(I_2-I_1)R_3-(I_2-I_3)(R_4)-I_2R_5-V_2=0$$
$$I_1R_3-I_2(R_3+R_4+R_5)+R_4I_3=V_2 \quad -②$$

Consider bdcb

$$-R_2(I_3-I_1)-R_6(I_3)-R_4(I_3-I_2)=0$$
$$R_2I_1+R_4I_2-I_3(R_2+R_4+R_6)=0 \quad -③$$

$$I_1(R_1+R_2+R_3)-I_2R_3-I_3R_2=V_1 \quad -①$$
$$I_1R_3-I_2(R_3+R_4+R_5)+R_4I_3=V_2 \quad -②$$
$$I_1R_2+I_2R_4-I_3(R_2+R_4+R_6)=0 \quad -③$$

Matrix form:

$$\begin{bmatrix} (R_1+R_2+R_3) & -R_3 & -R_2 \\ -R_3 & (R_3+R_4+R_5) & -R_4 \\ -R_2 & -R_4 & (R_2+R_4+R_6) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ 0 \end{bmatrix}$$

* Cramer's Rule

$$ax+by=c$$
$$dx+ey=f$$

1) Write the two equations in the matrix form as

$$\begin{bmatrix} a & b \\ d & e \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} c \\ f \end{bmatrix}$$

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2) The common determinant is given as

$$\Delta = \begin{vmatrix} a & b \\ d & e \end{vmatrix}$$
$$ae - bd$$

3) For finding the determinant for x, replace the coefficients of x in the original matrix by the constants so that we get determinant Δ_1 given by

$$\Delta_1 = \begin{vmatrix} c & b \\ f & e \end{vmatrix}$$
$$= ce - bf.$$

4) For finding the determinant for y, replace coefficients of y by the constants so that we get.

$$\Delta_2 = \begin{vmatrix} a & c \\ d & f \end{vmatrix}$$
$$= af - cd.$$

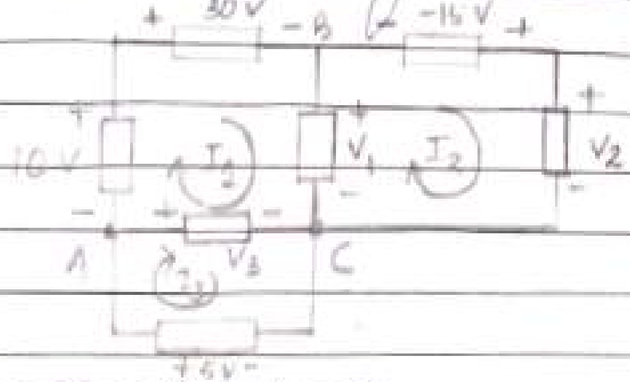
5) Apply Cramer's rule to get the value of x and y.

$$x = \frac{\Delta_1}{\Delta} = \frac{ce - bf}{ae - bd}$$

$$y = \frac{\Delta_2}{\Delta} = \frac{af - cd}{ae - bd}$$

(||ly for 3 variables).

S1) Applying Kirchoff's laws to different loops, find the values of V_1 and V_2.



Ans) $10 - 30 - V_1 + V_3 = 0$

$V_1 - V_3 = -20$ — (1)

$V_1 + 15 - V_2 = 0$

$V_1 - V_2 = -15$ — (2)

$-V_3 + 5 = 0$

$V_3 = 5$ — (3)

Sub (3) in (1)

$V_1 = -20 + V_3$

$= -20 + 5$

$= -15\ V$

Sub $V_1 = -15V$ in (2)

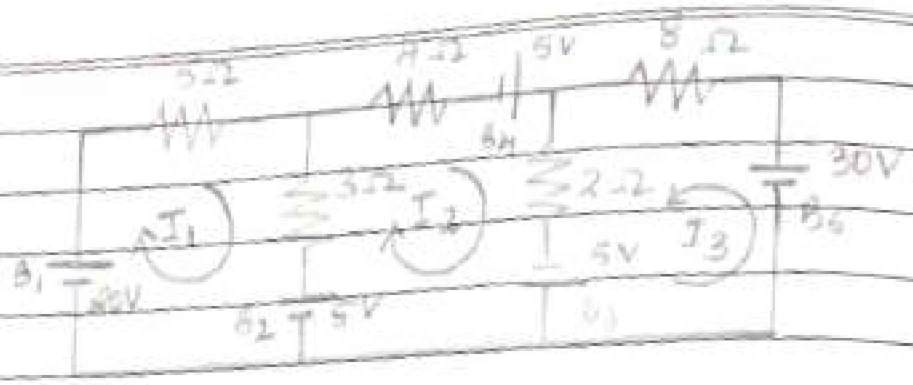
$V_1 = \mp 15 + V_2$

$V_2 = +15 - 15$

$= 0\ V$

$\therefore\ V_1 = -15\ V$ & $V_2 = 0$

S2) Determine the current supplied by each battery in the circuit shown in the fig.



Ans) Considering the 1^{st} loop

$$20 - 5I_1 - 3(I_1 - I_2) - 5 = 0$$
$$15 = 5I_1 + 3I_1 - 3I_2$$
$$8I_1 - 3I_2 = 15 \quad - (1)$$

Considering the 2^{nd} loop

$$5 - 3(I_2 - I_1) - 4I_2 + 5 - 2(I_2 + I_3) + 5 = 0$$

$$15 - 3I_2 + 3I_1 - 4I_2 - 2I_2 - 2I_3 = 0$$

$$3I_1 - 9I_2 - 2I_3 = -15 \quad - (2)$$

Considering the 3^{rd} loop

$$30 - 8I_3 - 2(I_2 + I_3) + 5 = 0$$
$$-8I_3 - 2I_2 - 2I_3 + 35 = 0$$
$$2I_2 + 10I_3 = 35 \quad - (3)$$

$$8I_1 - 3I_2 = 15$$
$$3I_1 - 9I_2 - 2I_3 = -15$$
$$2I_2 + 10I_3 = 35$$

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$$\begin{bmatrix} 8 & -3 & 0 \\ 3 & -9 & -2 \\ 0 & 2 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 15 \\ -15 \\ 35 \end{bmatrix}$$

$$\Delta = 8(-90+4) - (-3)(30)$$
$$= 8 \times -86 + 90$$
$$= -688 + 90$$
$$= \underline{\underline{-598}}$$

For finding I_1

$\Delta_1 = ?$

$$\begin{bmatrix} 15 & -3 & 0 \\ -15 & -9 & -2 \\ 35 & 2 & 10 \end{bmatrix} \begin{bmatrix} \cancel{I_1} \\ \cancel{I_2} \\ \cancel{I_3} \end{bmatrix}$$

$$\Delta_1 = 15(-90+4) - (-3)(-150+70)$$
$$= -1290 - 240$$
$$= \underline{\underline{-1530}}$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{-1530}{-598}$$
$$= \frac{1530}{598}$$
$$= \underline{\underline{2.55A}}.$$

For finding I_2

$$\begin{bmatrix} 8 & 15 & 0 \\ 3 & -15 & -2 \\ 0 & 35 & 10 \end{bmatrix}$$

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$\Delta_2 = 8(-260+70) - 15(30)$

$= -640 - 450$

$= -1090$

$I_2 = \frac{\Delta_2}{\Delta}$

$= \frac{-1090}{-598}$

$= 1.82A$

for finding I_3

$$\begin{vmatrix} 8 & -3 & 15 \\ 3 & -9 & -15 \\ 0 & 2 & 35 \end{vmatrix}$$

$\Delta_3 = 8(-9(35)+30) - (-3)((35)3) + 15(6)$

$= -2280 + 315 + 90$

$= -2280 + 405$

$= -1875$

$I_3 = \frac{\Delta_3}{\Delta}$

$= \frac{-1875}{-598}$

$= 3.13A$.

Current flowing through $B_1 = I_1 = 2.55A$
Current flowing through $B_2 = I_1 - I_2 = 0.73A$
Current flowing through $B_3 = I_2 + I_3 = 4.95A$
Current flowing through $B_4 = I_2 = 1.82A$

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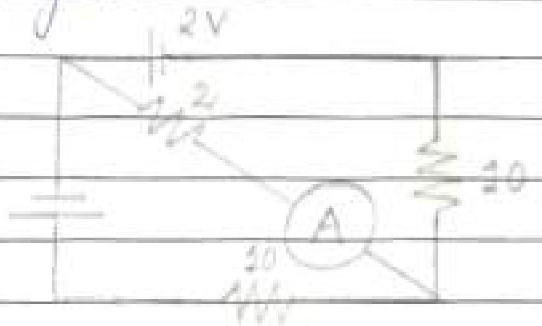
Current flowing through R_2 = I_2 = 3.13 A

H.W

Q1) Find the ammeter current in the fig using loop analysis:



Ans)
$$4 - 10I_1 - 2(I_1 - I_2) = 0$$
$$4 - 10I_1 - 2I_1 + 2I_2 = 0$$
$$-12I_1 + 2I_2 = -4$$
$$6I_1 - I_2 = +2 \quad - (1)$$

$$2 - 2(I_2 - I_1) - 10I_2 = 0$$
$$2 - 2I_2 + 2I_1 - 10I_2 = 0$$
$$2I_1 - 12I_2 = -2$$
$$I_1 - 6I_2 = -1 \quad - (2)$$

$$\begin{bmatrix} 6 & -1 \\ 1 & -6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} +2 \\ -1 \end{bmatrix}$$

$$\Delta = -36 + 1$$
$$= -35$$

For calculating I_1

$$\begin{vmatrix} 2 & -1 \\ -1 & -6 \end{vmatrix}$$

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$\Delta_1 = -12 - 1$

$= -13$

$I_1 = \frac{\Delta_1}{\Delta}$

$= \frac{-13}{-35} = \frac{13}{35} A$

For calculating I_2

$\begin{vmatrix} 6 & 2 \\ 1 & -1 \end{vmatrix}$

$\Delta_2 = -6 - 2$

$= -8$

$I_2 = \frac{\Delta_2}{\Delta}$

$= \frac{-8}{-35}$

$= \frac{8}{35} A$

$\therefore$ the current through ammeter $= I_1 - I_2$

$= \frac{13}{35} - \frac{8}{35}$

$= \frac{5}{35}$

$= \frac{1}{7} A$

2) Using ...

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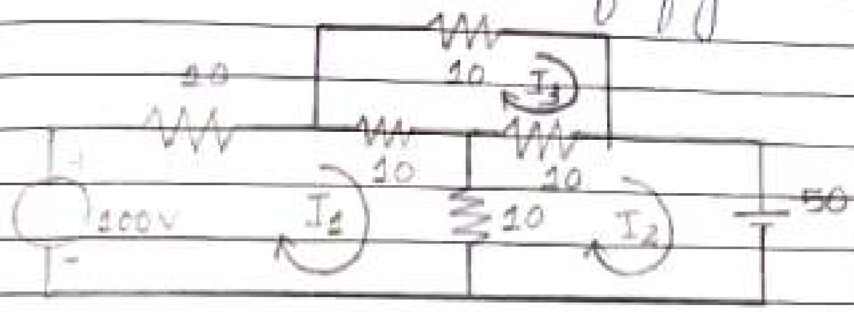
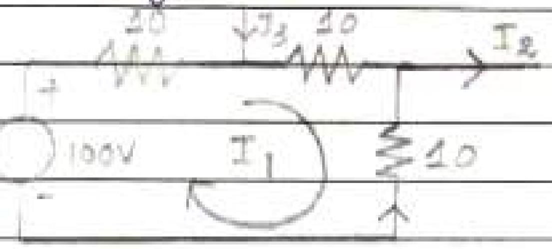
53) Apply loop current method to find loop currents I_1, I_2 & I_3 in the circuit of fig 2.



Ans) Considering loop 1



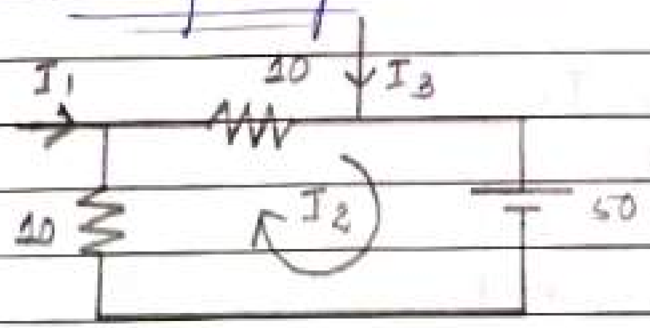
$$100 - 10(I_1) - 10(I_1 - I_3) - 10(I_1 - I_2) = 0$$

$$100 - 10I_1 - 10I_1 + 10I_3 - 10I_1 + 10I_2 = 0$$

$$30I_1 - 10I_2 - 10I_3 = 100$$

$$3I_1 - I_2 - I_3 = 10 \quad — (1)$$

Considering loop 2



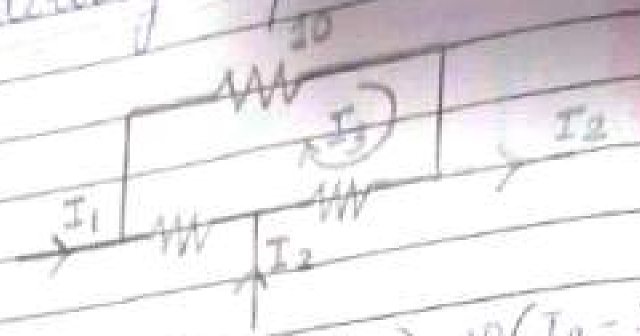
$$-50 - 10(I_2 - I_1) - 10(I_2 - I_3) = 0$$

$$-50 - 10I_2 + 10I_1 - 10I_2 + 10I_3 = 0$$

$$10I_1 - 20I_2 + 10I_3 = 50$$

$$I_1 - 2I_2 + I_3 = 5 \quad — (2)$$

Considering loop 3



$$10(I_3) - 10(I_3 - I_2) - 10(I_3 - I_1) = 0$$

$$-10(I_3) - 10(I_3 - I_2) - 10I_3 + 10I_1 = 0$$

$$-10I_3 - 10I_3 + 10I_2 - 10I_3 + 10I_1 = 0$$

$$10I_1 + 10I_2 - 30I_3 = 0$$

$$I_1 + I_2 - 3I_3 = 0 \quad -(3)$$

Matrix representation

$$\begin{bmatrix} 3 & -1 & -1 \\ 1 & -2 & 1 \\ 1 & 1 & -3 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 5 \\ 0 \end{bmatrix}$$

$$\Delta = 3(6-1) - (-1)(-3-1) + (-1)(1+2)$$

$$= 15 - 4 - 3$$

$$= 15 - 7$$

$$= \underline{\underline{8}}$$

For finding I_1

$$\begin{vmatrix} 10 & -1 & -1 \\ 5 & -2 & 1 \\ 0 & 1 & -3 \end{vmatrix}$$

$$\Delta_1 = 10(+6-1) - (-1)(-15) + (-1)(5)$$

$$= 50 - 15 - 5$$

$$= 50 - 20 = \underline{\underline{30}}$$

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$I_1 = \frac{\Delta_1}{\Delta}$

$= \frac{30}{8}$

$= \underline{3.75\,A}$

For finding I_2

$$\begin{vmatrix} 3 & 10 & -1 \\ 1 & 5 & 1 \\ 1 & 0 & -3 \end{vmatrix}$$

$\Delta_2 = 3(-15) - (10)(-3-1) + (-1)(-5)$

$= -45 + 40 + 5$

$= \underline{0}$

$I_2 = \frac{\Delta_2}{\Delta}$

$= \frac{0}{8} = \underline{0A}$

For finding I_3

$$\begin{vmatrix} 3 & -1 & 10 \\ 1 & -2 & 5 \\ 1 & 1 & 0 \end{vmatrix}$$

$\Delta_3 = 3(-5) - (-1)(-5) + 10(1+3)$

$= -15 - 5 + 40$

$= \underline{20}$

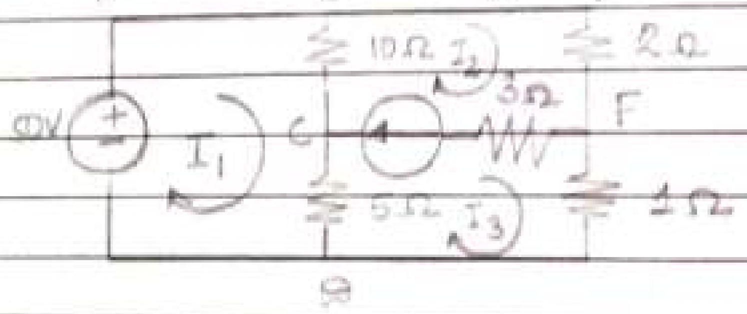
$I_3 = \frac{\Delta_3}{\Delta} = \frac{10}{8} = \underline{1.25\,A}$

∴ $I_1 = 3.25\,A$
$I_2 = 0\,A$
$I_3 = 1.25\,A$

Mesh Analysis

- Identify the loops / meshes.
- Assign a current variable to each mesh/loop using a consistent direction (clockwise or anticlockwise).
- Write Kirchhoff's voltage law equations around each mesh.
- Solve the resulting system of equations for all mesh currents.
- Solve for other elements currents and voltages you want using Ohm's law.

Q4) Determine the current in the 5 Ω resistor in the network given in fig:



Ans) Considering loop abda

$$50 - 10(I_1 - I_2) - 5(I_1 - I_3) = 0$$

$$50 - 10I_1 + 10I_2 - 5I_1 + 5I_3 = 0$$

$$10I_1 + 5I_1 - 10I_2 - 5I_2 = 50$$

$$15I_1 - 10I_2 - 5I_3 = 50$$

$$3I_1 - 2I_2 - I_3 = 10 \quad -(1)$$

Considering loop bcfdcb

$$\cancel{-2(I_2) - 3(I_2 - I_3) - 10(I_2 - I_1) = 0}$$

$$-2(I_2) - 1(I_3) - 5(I_3 - I_1) - 10(I_2 - I_1) = 0$$

$$-2I_2 - I_3 - 5I_3 + 5I_1 - 10I_2 + 10I_1 = 0$$

$$15I_1 - 12I_2 - 6I_3 = 0$$

$$5I_1 - 4I_2 - 2I_3 = 0 \quad -(2)$$

$$I_2 - I_3 = 2A. \quad -(3)$$

$$\begin{bmatrix} 3 & -2 & -1 \\ 5 & -4 & -2 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ 2 \end{bmatrix}$$

$$\begin{aligned} \Delta &= 3(4+2) - (-2)(-5) + (-1)(5) \\ &= 18 - 10 - 5 \\ &= 18 - 15 \\ &= 3 \end{aligned}$$

Considering I_1

$$\begin{vmatrix} 10 & -2 & -1 \\ 0 & -4 & -2 \\ 2 & 1 & -1 \end{vmatrix}$$

$$\begin{aligned} \Delta_1 &= 10(4+2) - (-2)(4) + (-1)(+8) \\ &= 60 + 8 - 8 \\ &= 60 \end{aligned}$$

$$I_1 = \frac{\Delta_1}{\Delta}$$

$$= \frac{60}{3}$$

$$= \underline{20A}$$

Considering I_2

$$\begin{vmatrix} 3 & 10 & -1 \\ 5 & 0 & -2 \\ 0 & 2 & -1 \end{vmatrix}$$

$$\Delta_2 = 3(4) - (10)(-5) + (-1)(10)$$

$$= 12 + 50 - 10$$

$$= 12 + 40$$

$$= 52$$

$$I_2 = \frac{\Delta_2}{\Delta}$$

$$= \frac{52}{3} = \underline{\underline{17.33A}}$$

Considering I_3

$$\begin{vmatrix} 3 & -2 & 10 \\ 5 & -4 & 0 \\ 0 & 1 & 2 \end{vmatrix}$$

$$\Delta_3 = 3(-8) - (-2)(10) + 10(5)$$

$$= -24 + 20 + 50$$

$$= 70 - 24$$

$$= 46$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{46}{3} = \underline{\underline{15.33A}}$$

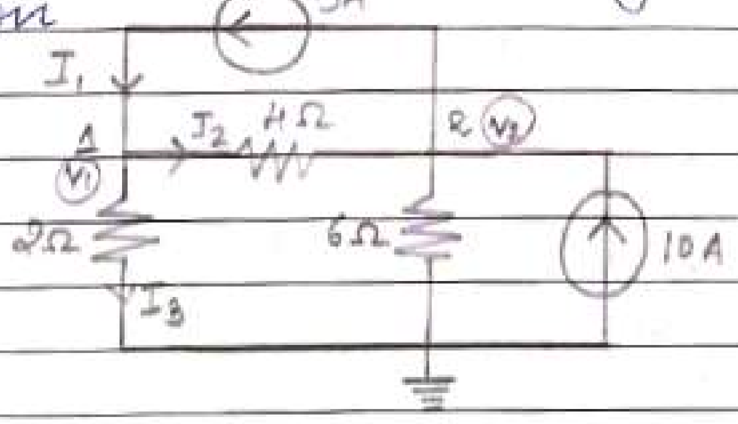
Current through 5Ω resistor $= I_2 - I_1$
$= 15.33 - 20$
$= -4.67A$

Node Analysis

Steps to determine node voltage:

- Select a node as the reference node. Assign voltages $v_1, v_2, \ldots, v_{n-1}$ to the remaining $n-1$ nodes. The voltages are referenced with respect to the reference node.
- Apply KCL to each of the $n-1$ nonreference nodes. Use Ohm's law to express the branch current in terms of node voltages.
- Solve the resulting simultaneous equations to obtain the unknown node voltages.

Q1) Calculate the node voltages in the circuit shown



Ans) Consider node 1

$$I_1 = I_2 + I_3$$

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$$5 = \frac{V_1 - V_2}{4} + \frac{V_1}{2}$$

$$5 = \frac{V_1 - V_2 + 2V_1}{4}$$

$$20 = 3V_1 - V_2 \quad \text{—} (1)$$

Consider node 2

$$5 - 10 + \frac{V_2 - V_1}{4} + \frac{V_2}{6} = 0$$

$$-5 + \frac{6V_2 - 6V_1 + 4V_2}{24} = 0$$

$$10V_2 - 6V_1 = 120$$

$$5V_2 - 3V_1 = 60 \quad \text{—} (2)$$

Using Cramer's rule

$$\begin{bmatrix} 3 & -1 \\ -3 & 5 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 60 \end{bmatrix}$$

$$\Delta = 15 - 3 = 12$$

Finding V_1

$$\begin{vmatrix} 20 & -1 \\ 60 & 5 \end{vmatrix}$$

$$\Delta_1 = 100 + 60$$

$$= 160$$

$$V_1 = \frac{\Delta_1}{\Delta}$$

$$= \frac{\cancel{160}^{40}}{\cancel{12}_{3}} = \frac{40}{3} V$$

2
2H
12D

Finding V_2

$$\begin{vmatrix} 3 & 20 \\ -3 & 60 \end{vmatrix}$$

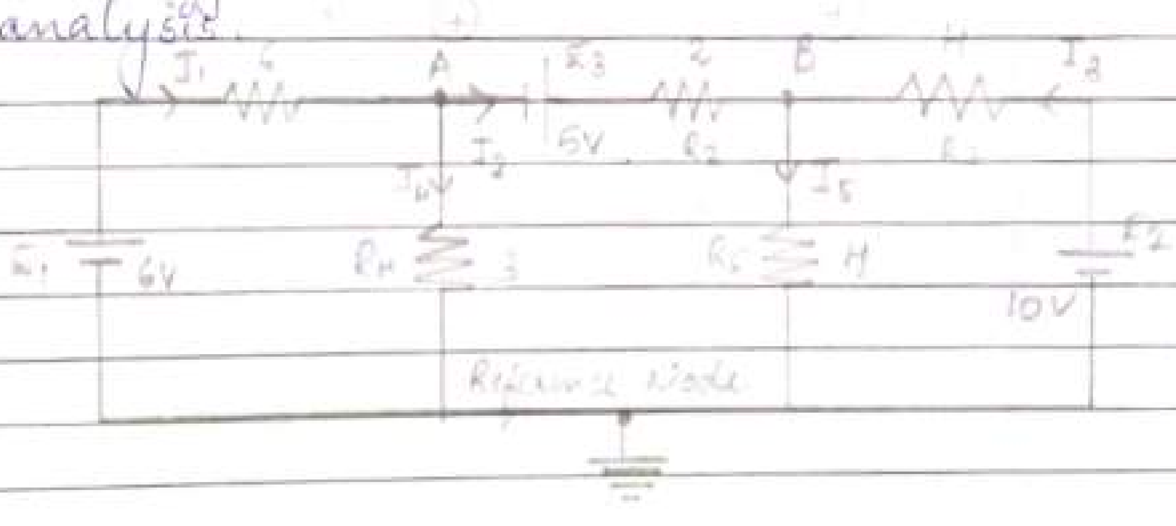
$\Delta_2 = 180 + 60$
$= 240$

$V_2 = \frac{\Delta_2}{\Delta}$

$= \frac{240}{12} = \underline{\underline{20\,V}}$

Q2) Find the branch current in the circuit of fig by using

1) Nodal analysis and
2) loop analysis.



Ans) 1) Consider node 1 $(V_1 > V_2)$

$I_1 + I_2 + I_4 = 0$

$\frac{V_A - 6}{6} + \frac{V_A + 5 - V_B}{2} + \frac{V_A - 0}{3} = 0$

$V_A - 6 + 3V_A + 15 - 3V_B + 2V_A = 0$

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$$6V_A - 3V_B + 9 = 0$$

$$2V_A - V_B + 3 = 0$$

$$V_B - 2V_A = 3 \quad -(1)$$

Considering node 2 $(V_2 > V_1)$

$$\frac{V_B - 5 - V_A}{2} + \frac{V_B}{4} + \frac{V_B - 10}{4} = 0$$

$$2V_B - 10 - 2V_A + V_B + V_B - 10 = 0$$

$$4V_B - 2V_A = 20$$

$$2V_B - V_A = 10 \quad -(2)$$

Using Cramer's rule

$$\begin{bmatrix} -2 & 1 \\ -1 & 2 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 3 \\ 10 \end{bmatrix}$$

$$\Delta = -4 + 1$$
$$= -3$$

Considering V_A

$$\begin{bmatrix} 3 & 1 \\ 10 & 2 \end{bmatrix}$$

$$\Delta_1 = 6 - 10$$
$$= -4$$

$$V_A = \frac{\Delta_1}{\Delta} = \frac{-4}{-3} = \frac{4}{3} V$$

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Considering V_B

$$\begin{vmatrix} -2 & 3 \\ -1 & 10 \end{vmatrix}$$

$$\Delta_2 = -20 + 3$$
$$= -17$$

$$V_B = \frac{\Delta_2}{\Delta}$$

$$= \frac{-17}{-3} = \underline{\frac{17}{3} V}$$

$I_1 = ?$

$$I_1 = \frac{-V_A + 6}{6}$$

$$= \frac{\frac{-4}{3} + 6}{6}$$

$$= \frac{-4 + 18}{18}$$

$$= \underline{\frac{+14}{18} A} = \underline{\underline{\frac{7}{9}}} A$$

$I_2 = ?$

$$I_2 = \frac{V_A - V_B + 5}{2}$$

$$= \frac{\frac{4}{3} - \frac{17}{3} + 5}{2}$$

$$= \frac{4 - 17 + 15}{6} = \frac{2}{6} = \frac{1}{3} A$$

$I_3 = ?$

$$I_3 = \frac{-V_B + 10}{4}$$

$$= \frac{\frac{-17}{3} + 10}{4}$$

$$= \frac{-17 + 30}{12}$$

$$= \underline{\frac{+13}{12} A}$$

$I_4 = ?$

$$I_4 = \frac{V_A}{3}$$

$$= \underline{\frac{4}{9} A}$$

$I_5 = ?$

$$I_5 = \frac{V_B}{4}$$

$$= \frac{17}{3 \times 4}$$

$$= \underline{\frac{17}{12} A}$$

Using loop current method:

Consider loop 1.

$$-6I_1 \cancel{- 3I_4 + 6 = 0} \quad -6I_1 - 3(I_1 - I_2) + 6 = 0$$

$-6I_1 - 3I_1 + 3I_2 + 6 = 0$

$9I_1 - 3I_2 = 6$

$3I_1 - I_2 = 2 \quad - (1)$

Considering loop 2

$5 + (-2I_2) - 4(I_2 - I_3) - 3(I_2 - I_1) = 0$

$5 - 2I_2 - 4I_2 + 4I_3 - 3I_2 + 3I_1 = 0$

$5 + 3I_1 - 9I_2 + 4I_3 = 0$

$3I_1 - 9I_2 + 4I_3 = -5 \quad - (2)$

Considering loop 3

$-4I_3 - 10 - 4(I_3 - I_2) = 0$

$-4I_3 - 10 - 4I_3 + 4I_2 = 0$

$-8I_3 + 4I_2 - 10 = 0$

$\cancel{-4I_3 + 8I_2 = +10}$

$-8I_3 + 4I_2 = 10$

$-4I_3 + 2I_2 = 5 \quad - (3)$

From (1)

$3I_1 - I_2 = 2$

$I_2 = 3I_1 - 2 \quad - (4)$

From (3)

$2I_2 - 4I_3 = 5$

$4I_3 = 2I_2 - 5$

$I_3 = \dfrac{2I_2 - 5}{4} \quad - (5)$

Sub (4) & (5) in (2)

$$3I_1 - 9(3I_1 - 2) + 4\left(\frac{2I_2 - 5}{4}\right) = -5$$

$$3I_1 - 27I_1 + 18 + 2I_2 - 5 = -5$$

$$3I_1 - 27I_1 + 18 + 2\times(3I_1 - 2) - 5 = -5$$

$$3I_1 - 27I_1 + 6I_1 + 18 - 4 - 5 = -5$$

$$\cancel{-18I_1 + 19 = 0} \qquad -18I_1 + 14 = 0$$

$$\cancel{18I_1 = 19} \qquad 18I_1 = 14$$

$$\cancel{I_1 = \frac{1}{2}A} \qquad I_1 = \frac{14}{18} = \frac{7}{9}A$$

from (4)

$$I_2 = 3I_1 - 2$$

$$= 3\times\frac{7}{9} - 2 = \frac{21-18}{9} = \frac{1}{3}A$$

from (5)

$$I_3 = \frac{2I_2 - 5}{4}$$

$$= \frac{2\times\frac{1}{3} - 5}{4} = \frac{2-15}{12} = \frac{-13}{12}A$$

$$I_4 = I_1 - I_2$$

$$= \frac{7}{9} - \frac{1}{3} = \frac{4}{9} = \frac{2}{3}A$$

$$I_5 = I_2 - I_3$$

$$= \frac{1}{3} + \frac{13}{12}$$

$$= \frac{4+13}{12}$$

$$= \frac{17}{12}A$$

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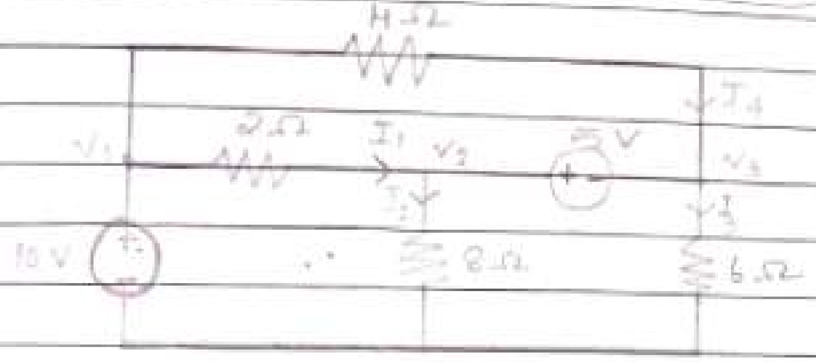
Nodal Analysis or Super node method

Q1)



Find V_1, V_2 & V_3

Ans) Considering node 1

$$V_1 = 10\,V \quad -①$$

Considering node 2

$$\frac{V_2}{8} + \frac{(V_2 - V_1)}{2} = 0 \quad -②$$

Considering node 3

$$\frac{V_3}{6} + \frac{V_3 - V_1}{4} = 0 \quad -③$$

Adding from ③ & ④

$$\frac{V_2}{8} + \frac{(V_2 - V_1)}{2} + \frac{V_3}{6} + \frac{(V_3 - V_1)}{4} = 0 \quad -④$$

$$6V_2 + 24V_2 - 2\cancel{4}V_1 + 8V_3 + 12V_3 - 12\cancel{V_1} = 0$$

$$-36V_1 + 30V_2 + 20V_3 = 0$$

$$36V_1 - 30V_2 - 20V_3 = 0$$

$$360 = 30V_2 + 20V_3$$

$$3V_2 + 2V_3 = 36 \quad - (5)$$

Considering the equation between V_2 & V_3

$$V_2 - V_3 = 5 \quad - (6)$$

$$\begin{bmatrix} 3 & 2 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 36 \\ 5 \end{bmatrix}$$

$$\Delta = -3 - 2$$
$$= -5$$

Finding V_1

$$\begin{bmatrix} 36 & 2 \\ 5 & -1 \end{bmatrix}$$

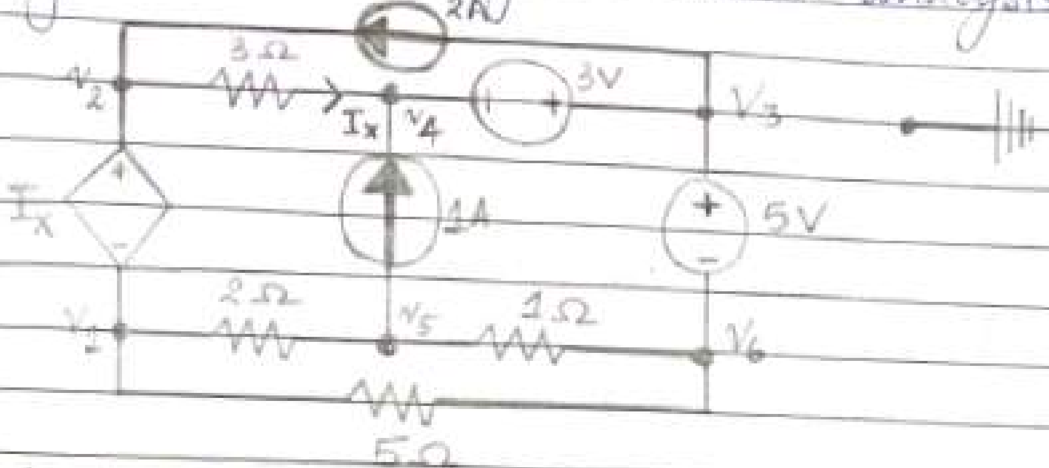
$$\Delta_1 = -36 - 10$$
$$= -46$$
$$V_1 = \frac{\Delta_1}{\Delta} = \frac{-46}{-5}$$
$$= \frac{46}{5} V$$

Finding V_2

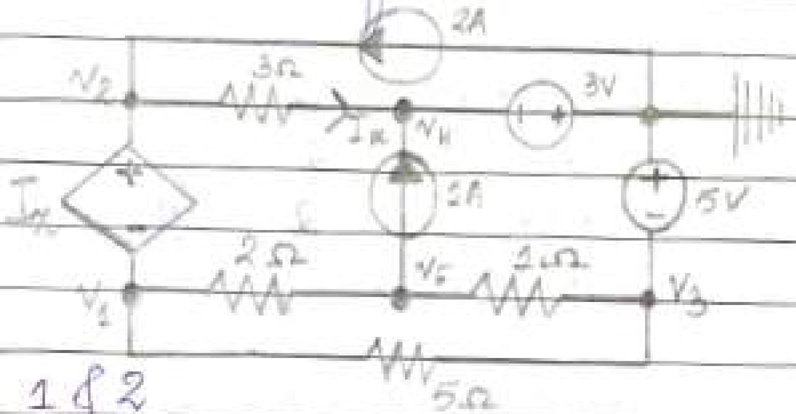
$$\begin{bmatrix} 3 & 36 \\ 1 & 5 \end{bmatrix}$$

$$\Delta_2 = 15 - 36$$
$$= -21$$
$$V_2 = \frac{\Delta_2}{\Delta} = \frac{-21}{-5} = \frac{21}{5} V$$

5.2) Determine the power of each source after solving the circuit by the nodal analysis.



Ans) Let v_3 be the reference node.



Node 1 & 2

We cannot apply KCL to this node directly due to the presence of voltage source in the branch shown.

$\therefore$ consider 1 & 2 as supernode

$$\frac{v_1 - v_5}{2} + \frac{v_1 - v_3}{5} + \frac{v_2 - v_4}{3} - 2 = 0$$

$$\frac{3v_1 - 3v_5 + 2v_2 - 2v_4}{6} + \frac{v_1 - v_3}{5} - 2 = 0$$

$$15v_1 - 15v_5 + 10v_2 - 10v_4 + 6v_1 - 6v_3 - 60 = 0$$

$$21v_1 + 10v_2 - 6v_3 - 10v_4 - 15v_5 = 60 \quad -(1)$$

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Considering the node 3

$$v_3 = -5V \quad - (2)$$

Considering the node 4

$$v_4 = -3V \quad - (3)$$

Considering node 5

$$\frac{v_5 - V_1}{2} + \frac{v_5 - V_3}{1} + 1 = 0$$

$$v_5 - V_1 + 2V_5 - 2V_3 = -2$$

$$-V_1 - 2V_3 + 3V_5 = -2$$

$$v_1 + 2V_3 - 3V_5 = 2$$

Sub v_3 in eqn.

$$v_1 + 2(-5) - 3V_5 = 2$$

$$v_1 - 10 - 3V_5 = 2$$

$$V_1 - 3V_5 = 12 \quad - (4)$$

Considering the supernode.

$I_x \Rightarrow v_2 - V_1 = 0$

$I_x \Rightarrow \frac{v_2 - V_4}{3} = 0$

$$v_2 - V_1 = \frac{v_2 - V_4}{3}$$

$$3V_2 - 3V_1 = v_2 - V_4$$

$$2V_2 - 3V_1 + V_4 = 0$$

$$3V_1 - 2V_2 - V_4 = 0$$

$$3V_1 - 2V_2 = -3 \quad - (5)$$

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From eqn (1)

$21V_1 + 10V_2 + 30 + 30 - 15V_5 = 60$

$21V_1 + 10V_2 - 15V_5 = 0$ — (6)

Sub (4) & (5) in (6)

$21V_1 + \cancel{10}^{5}\left(\frac{3V_1+3}{\cancel{2}}\right) - \cancel{15}^{5}\left(\frac{V_1-12}{\cancel{3}}\right) = 0$

$21V_1 + 15V_1 + 15 - 5V_1 + 60 = 0$

$31V_1 + 75 = 0$

$V_1 = \frac{-75}{31}$

$= -2.41V$

Sub $V_1 = -2.41$ in (5)

$3(-2.41) - 2V_2 = -3$

$2V_2 = 3(-2.41) + 3$

$V_2 = (-7.23 + 3)/2$

$= -4.23V/2 = -2.115V$

Sub $V_1 = -2.41$ in (4)

$V_1 - 3V_5 = 12$

$3V_5 = -2.41 - 12$

$V_5 = \frac{-2.41-12}{3}$

$= \frac{-14.41}{3} = -4.803V$

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$V_1 = -2.41V$

$V_2 = -2.115V$

$V_3 = -5V$
$V_4 = -3V$
$V_5 = -4.803V$

$P_{2A} = ?$

$V_{2A} = -V_2$
$= -(-2.115) = 2.115V$

$P_{2A} = I_{2A} V_{2A}$
$= 2 \times -V_2$
$= 2 \times 2.115$
$= 4.230W$

$P_{1A} = ?$

$V_{1A} = (V_5 - V_4)$
$= (-4.803 + 3)$
$= -1.803V$

$P_{1A} = I_{1A} \times V_{1A}$
$= 1 \times -1.803$
$= -1.803W$

$P_{5V} = ?$

$I_{5V} = I_{1\Omega} + I_{3\Omega}$
$= V_3 - V_5 + \frac{V_3 - V_1}{5}$

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$$= \frac{5V_3 - 5V_5 + V_3 - V_1}{5}$$

$$= \frac{6V_3 - 5V_5 - V_1}{5}$$

$$= \frac{6(-5) - 5(-4.803) - (-2.41)}{5}$$

$$= \frac{-30 + 24.015 + 2.41}{5}$$

$$= \frac{\cancel{-10.985}}{5} \quad -\frac{3.575}{5} A$$

$$P_{5V} = V_{5V} \times I_{5V}$$

$$= 5 \times -\frac{3.575}{5}$$

$$= -3.575 W$$

$$P_{3V} = ?$$

$$I_{3V} = I_{3\Omega} - 1A$$

$$= \frac{V_4 - V_2}{3} - 1$$

$$= \frac{V_4 - V_2 - 3}{3}$$

$$= \frac{-3 + 2.115 - 3}{3}$$

$$= \frac{\cancel{6}+2.115}{3} A$$

$$P_{3V} = V_{3V} I_{3V}$$

$$= \cancel{3} \times \frac{2.115 - 6}{\cancel{3}}$$

$$= -3.885 W$$

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$P_x = V_x I_x$

$V_x = V_2 - V_1$
$= -2.115 + 2.41$
$= -0.295\,V$

$I_x = I_{2A} + I$
$= 2 + (V_2 - V_1)$
$= 2 + (-0.295)$
$= 1.705\,A$

$P_x = V_x I_x$
$= 0.295 \times 1.705$
$= 0.502\,W$

Module-2
Elementary Concept of Magnetic Materials

* A magnetic is a material or object that produces a magnetic field.

eg: Iron, steel, nickel, cobalt

* Classified into 3:

- Diamagnetic material
- Paramagnetic material
- Ferromagnetic material

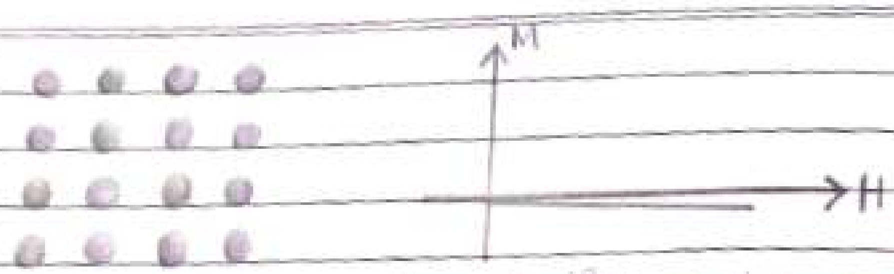
* Diamagnetic materials

- Diamagnetic substances are composed of atoms which have no net magnetic moments.

- i.e. all the orbital shells are filled and there are no unpaired electrons.

- when exposed to a field, a negative magnetization is produced and thus the susceptibility is negative.

- Susceptibility: measure of how much a material will become magnetized in an applied magnetic field.



Magnetization and magnetic field intensity.

★ **Paramagnetic materials**

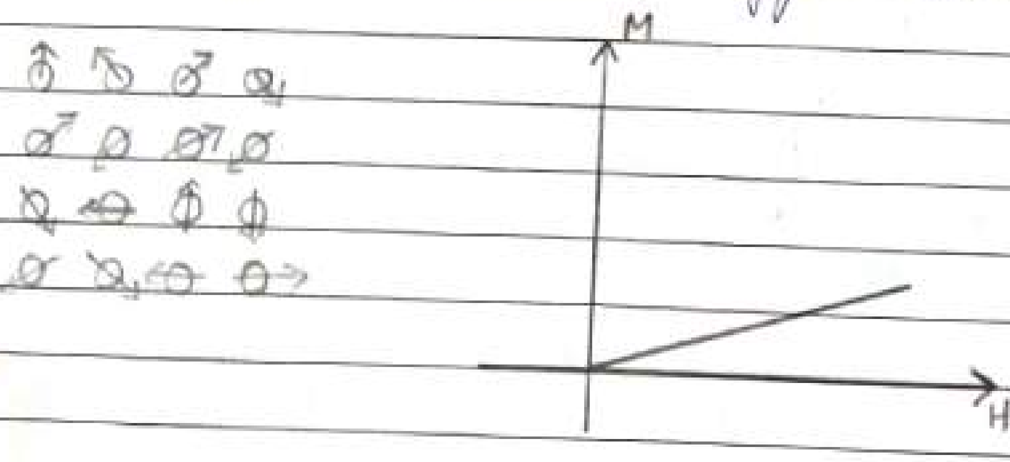
Some of the atoms or ions in the materials have a net magnetic mom-ent due to unpaired electrons.

When placed in a magnetic field, magnetic field within the material gets enhanced.

When placed in a non uniform MF, it tends to move from low to high field region.

Have permanent dipole moment.

eg: Aluminium, Sodium, Copper choride.



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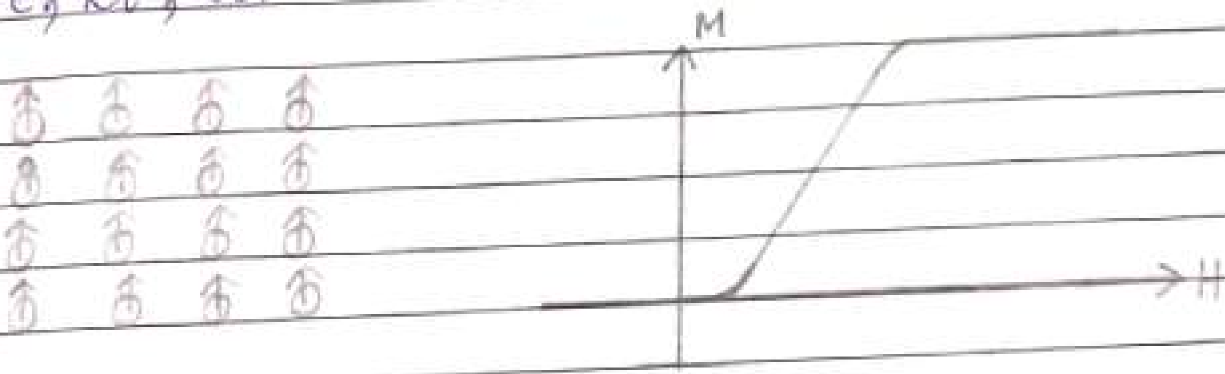
* Ferromagnetic Materials

- Gets magnetized even by weak magnetic field.

- Ferromagnetic materials exhibit parallel alignment of moments resulting in large net magnetization even in the absence of a magnetic field.

eg: Fe, Ni, Co.



Classification of magnets

* Permanent magnet

- Retain magnetism even after removing the external magnetic field.

- An retain their magnetism and magnetic properties for a longer time. Strongly magnetized hard materials make up permanent magnets.

- Hardened steel and alloy of steel can be transformed into ~~paramagnets~~ permanent

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magnets - Artificial Magnets.

- A permanent magnet does not require a continuous supply of electrical energy to maintain its magnetic field.

★ electromagnet

- Magnetization is done by passing electric current in a coil surrounding the material is called electromagnet.

- Strength of electromagnet varies according to the flow of electric current into it.

- An electromagnetic magnet only displays magnetic properties when an electric current is applied to it.

- An electromagnet's magnetic field can be rapidly manipulated over a wide range by controlling the amount of electric current supplied to the electromagnet.

★ Magnetic Induction

- Phenomenon of changing magnetic substance to magnet.

- Two properties :

i) Attraction

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ii) Repulsion

- Magnet has 2 end-poles
i) North pole
ii) South pole.

- Magnetic field

Space around a magnet where magnetic effect can be detected.

- Magnetic flux

- Represents total number of magnetic lines of force in a magnetic field.

- Denoted by ϕ

- Unit : Weber (Wb)

- Magnetic Flux Density

- Flux passing per a unit area.
- B
- Wb/m^2 or Tesla (T)
- $B = \phi/A$

- Permeability / Absolute Permeability

- Ability of a material to pass/ conduct magnetic flux.

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- $\mu_0 = 4\pi \times 10^{-7}$ H/m

→ Relative permeability

- Permeability with resp to free space
- μ_r
- $\mu_r = \mu/\mu_0$
- Relative permeability of air is 1.

★ Magnetic Field Intensity

- Force experienced in a unit north pole placed at that point.
- H
- N/Wb
- $B = \mu H$ $(\mu = \mu_0 \mu_r)$

★ Magneto motive force (mmf)

- Magnetic pressure that sets up magnetic flux in a magnetic circuit.

- Mmf = no of turns ~~in~~ of coil × current in it
- Unit AT (ampere turns).

★ Reluctance

- Opposition offered to magnetic lines of force in a magnetic circuit.

- S
- AT/Wb

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- $l/\mu A$
  - l - length of magnetic path
  - A - cross sectional area.

- Permeance
- Reciprocal of reluctance
- Wb/AT

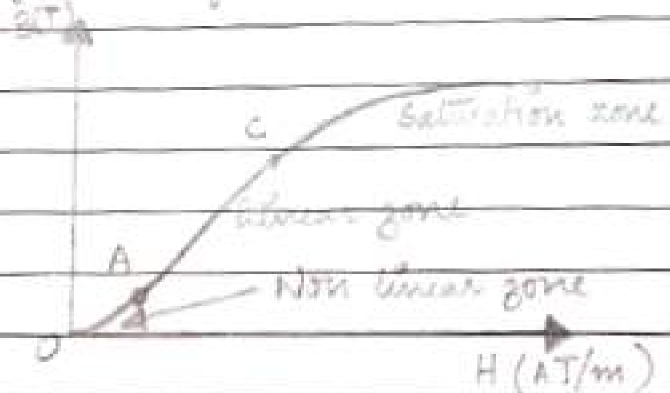
* Electric and Magnetic Circuit - comparison

Electric Circuit	Magnetic Circuit
Path traced by the current is known as electric current.	Path traced by the magnetic flux is called as magnetic circuit.
EMF is the driving force in the electric circuit. The unit is volts.	MMF is the driving force in the magnetic circuit. The unit is ampere turns.
There is a current I in the electric circuit which is measured in amperes.	There is a flux ϕ in the magnetic circuit which is measured in weber.
The flow of electrons decides the current in conductor.	The number of magnetic lines of force decides the flux.
Resistance (R) oppose the flow of the current. The unit is Ohm.	Reluctance (S) is opposed by magnetic path to the flux. The unit is Aturn/wb
$R = \rho l/A$ Directly proportional to l. Inversely proportional to A. Depends on nature of material.	$S = l/\mu_0\mu_r A$ $S = l/$ Directly proportional to l. Inversely proportional to $\mu = \mu_0\mu_r$. Inversely proportional to A

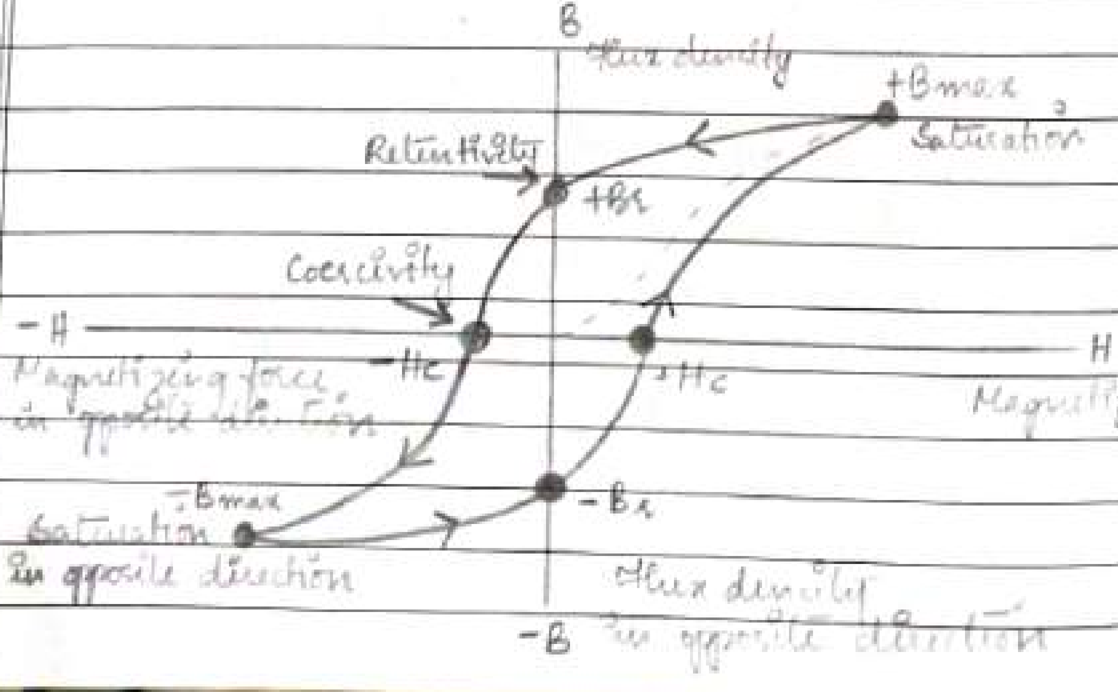
• The current I = MMF/Resistance	The flux = MMF / Reluctance
• The current density	The flux density
• Kirchhoff current law & voltage law is applicable to the electric circuit.	Kirchhoff mmf law & flux law is applicable to the magnetic flux.

★ Magnetization Curve (BH Curve)

• Graph between magnetic flux density (B) and magnetic force (H).



★ Magnetic Hysterisis



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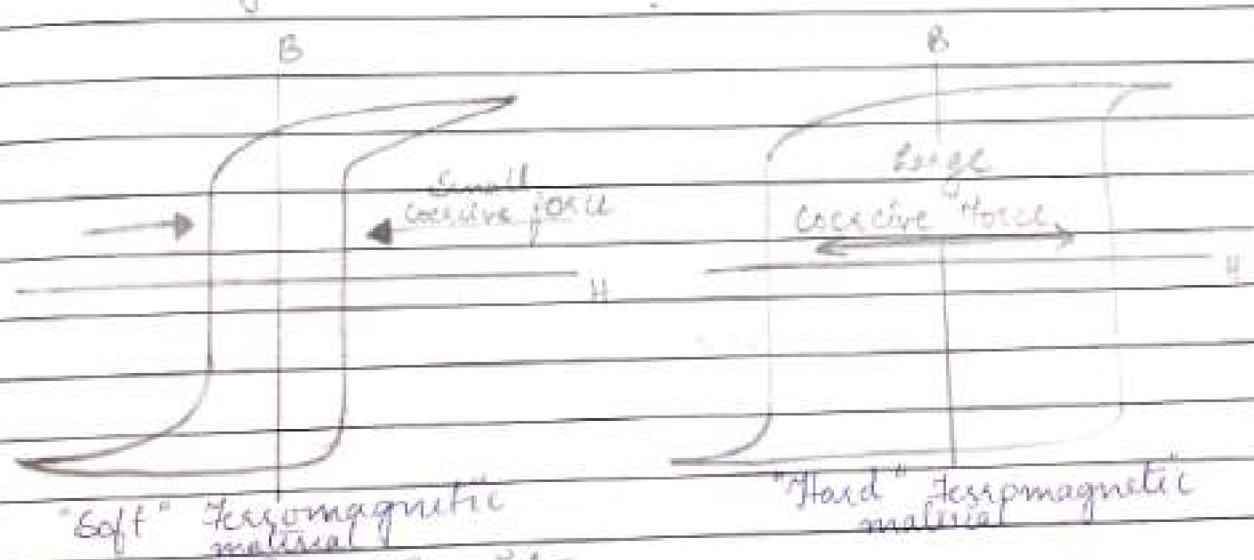
- Retentivity

It is defined as the degree to which a magnetic material gains its magnetism after magnetizing force (H) is reduced to zero.

- Coercivity

The amount of reverse driving field required to demagnetize it is called its coercivity.



★ Magnetic Circuit

Closed path followed by magnetic lines of force.

- $S = \frac{l}{\mu_0 \mu_r A} = \frac{l}{\mu A}$

- l is the length in 'm'.
- μ_0 is the permeability of vacuum, equal to $4\pi \times 10^{-7} \frac{\text{henry}}{\text{metre}}$

- μ_r is the relative permeability of the material
- μ is the permeability of the material ($\mu = \mu_0 \mu_r$)
- A is the cross-sectional area of the circuit in square meters.

- Composite magnetic circuit

- $S = \frac{l_1}{\mu_0 \mu_{r_1} A_1} + \frac{l_2}{\mu_0 \mu_{r_2} A_2} + \frac{l_g}{\mu_0 \mu_{rg} A_g}$

total MMF = flux × reluctance (S)

$$= \phi \times \left[\frac{l_1}{\mu_0 \mu_{r_1} A_1} + \frac{l_2}{\mu_0 \mu_{r_2} A_2} + \frac{l_g}{\mu_0 A_g} \right] \quad \left\{ \begin{matrix} \mu_{rg} = 1 \\ (\text{air}) \end{matrix} \right\}$$

Magnetic flux density,

$$B = \frac{\phi}{A}$$

$$\therefore \text{total MMF} = \frac{B_1 l_1}{\mu_0 \mu_{r_1}} + \frac{B_2 l_2}{\mu_0 \mu_{r_2}} + \frac{B_g l_g}{\mu_0}$$

6) An iron ring having cross-sectional area of 400 mm^2 and mean circumference of 500 mm carries a coil of 250 turns wound uniformly around it. Calculate
a) Reluctance of the ring.
b) Current required to produce a flux of 800 μWb in the ring.
Relative permeability of iron is 400.

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a) 1) $S = \frac{l}{\mu_0 \mu_r A}$

$l = 500 \times 10^{-3} m$

$A = 400 \times 10^{-6} m^2$

$n = 250$

$\mu_r = 400$

$\mu_0 = 4\pi \times 10^{-7}$

$$S = \frac{500 \times 10^{-3}}{4\pi \times 10^{-7} \times 400 \times 400 \times 10^{-6}}$$

$$= \frac{500 \times 10^{-3} \times 10^{7} \times 10^{6}}{16 \times 4 \times 10^{4} \times \pi}$$

$$= \frac{500}{64\pi} \times \frac{10^{10}}{10^{4}}$$

$$= \frac{500 \times 10^{6}}{64\pi}$$

$$S = 2.48 \times 10^{6} \ AT/wb$$

b) $I = ?$

$\phi = 1000 \mu wb = 1000 \times 10^{-6} wb$

$mmf = \phi \times S$

$NI = \phi \times S$

$$I = \frac{\phi \times S}{N}$$

$$= \frac{\cancel{1000}^{4} \times 10^{-6} \times 2.48 \times 10^{6}}{\cancel{250}}$$

$$= 4 \times 2.48$$

$$= 9.92 A$$

52) A mild steel ring has a mean circumference of 500mm and a uniform cross-sectional

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area of 300 mm^2. Calculate the mmf required to produce a flux of 500 μwb? Assume $\mu_r = 1200$.

Ans) $l = 500\ mm$

$= 500 \times 10^{-3}\ m$

$A = 300\ mm^2$

$= 300 \times 10^{-6}\ m$

$\mu_r = 1200$

$\mu_o = 4\pi \times 10^{-7}$

$$S = \frac{l}{\mu_o \mu_r A}$$

$$= \frac{500 \times 10^{-3}}{4\pi \times 10^{-7} \times 1200 \times 300 \times 10^{-6}}$$

$$= \frac{500 \times 10^{-3} \times 10^{7} \times 10^{6}}{144 \times \pi \times 10^{4}}$$

$$= \frac{500}{144\pi} 10^{6}$$

$$= 1.10 \times 10^{6}\ AT/wb$$

$mmf = \phi \times S$

$= 500 \times 10^{-6} \times 1.1 \times 10^{6}$

$= 550\ AT$

23) An iron ring of mean length 60 cm has an air gap of 2mm and a winding of 300 turns. If the relative permeability of iron used in the ring is 400 when a ~~circuit~~ current of 1.5 A flows through it, find

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the flux density ?

Ans) $l = 60cm$
$= 60 \times 10^{-2} m$
$l_g = 2mm$
$= 2 \times 10^{-3} m$
$n = 300$
$\mu_r = 400$
$I = 1.5 A$
$B = ?$

$mmf = Hl$
$mmf_1 = H_1 l_1$
$B = \mu H$
$H = \frac{B}{\mu_0 \mu_r}$

$\therefore \quad mmf_1 = \frac{B}{\mu_0 \mu_r} \times l_1$

$mmf_2 = \frac{B l_2}{\mu_0 \mu_r} \quad \{\mu_r = 1 \text{ air}\}$

$= \frac{B l_2}{\mu_0}$

total $mmf = mmf_1 + mmf_2$

$N \times I = \frac{B l_1}{\mu_0 \mu_r} + \frac{B l_2}{\mu_0}$

$300 \times 1.5 = \frac{B}{\mu_0} \left\{ \frac{l_1}{\mu_r} + l_2 \right\}$

$300 \times 1.5 \times \mu_0 = B \left\{ \frac{60 \times 10^{-2}}{400} + 2 \times 10^{-3} \right\}$

$450 \times 4\pi \times 10^{-7} = B \left\{ \frac{60 \times 10^{-2} + 8 \times 10^{-1}}{400} \right\}$

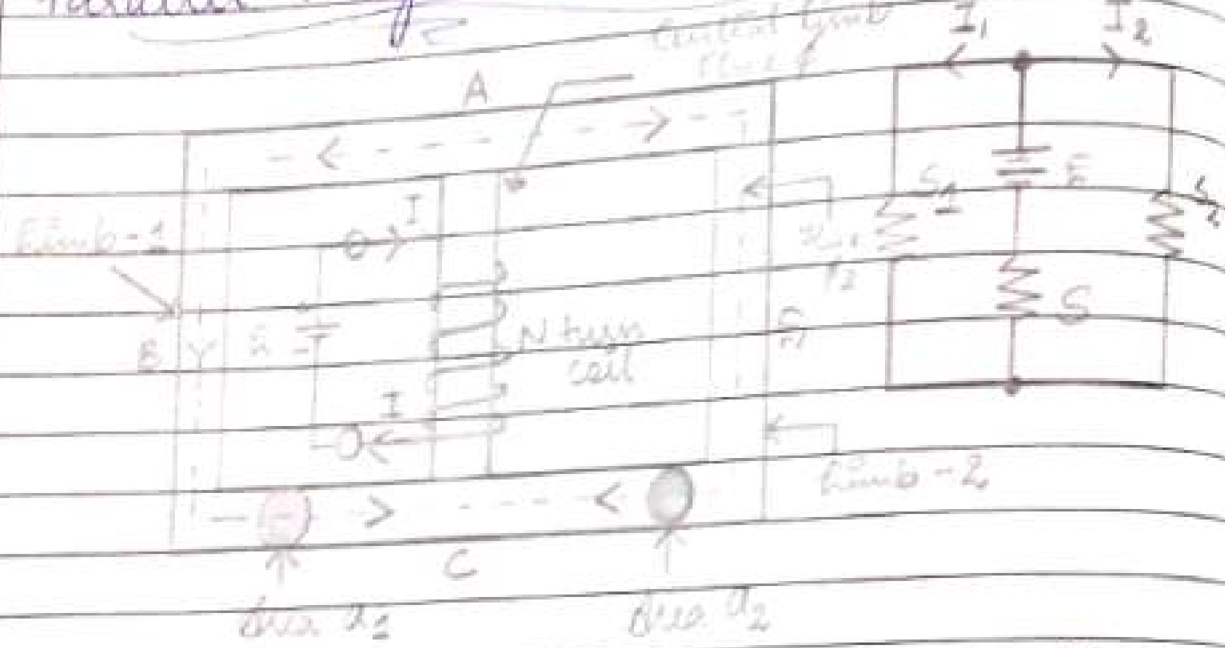
$\frac{450 \times 400 \times 4\pi \times 10^{-7}}{60 \times 10^{-2} + 8 \times 10^{-1}} = B$

$$B = \frac{2260800 \times 10^{-7}}{1.4}$$

$$= 1614857.143 \times 10^{-7}$$

$$= 0.1615 \text{ T}$$

* Parallel Magnetic circuit



The total m.m.f produced by the coil of N turns is,

Total mmf = $N \times I$ (AT)

Total m.m.f can also be expressed as,

total m.m.f = Total reluctance * Total flux

m.m.f for path ABCA : F = MMF of path ABC + MMF of path AC

Thus total MMF = MMF of central limb + MMF of limb - 1 or 2

$$\therefore S \times \phi = NI = \phi_c S_c + |\phi_1 S_1 \text{ or } \phi_2 S_2|$$

The reluctances S_1, S_2, and S_c are given by

$$S_1 = \frac{l_1}{\mu a_1}, \quad S_2 = \frac{l_2}{\mu a_2}, \quad S_c = \frac{l_c}{\mu a_c}$$

Assuming the cross sectional area of the three limbs to be same i.e

$$a_1 = a_2 = a_c = a.$$

the expression for S_1, S_2, S_c gets modi-fied as

$$S_1 = \frac{l_1}{\mu a}, \quad S_2 = \frac{l_2}{\mu a}, \quad S_c = \frac{l_c}{\mu a}$$

Substituting these values in equations

Total MMF,

$$F = \phi_1 \times \frac{l_1}{\mu a} + \phi_c \times \frac{l_c}{\mu a}$$

$$\therefore F = \frac{B_1 l_1}{\mu} + \frac{B_c l_c}{\mu}$$

$$= \frac{B_1 l_1 + B_c l_c}{\mu}$$

and $F = \frac{B_2 l_2}{\mu} + \frac{B_c l_c}{\mu}$

$$= \frac{B_2 l_2 + B_c l_c}{\mu}$$

But $(B/\mu) = H$

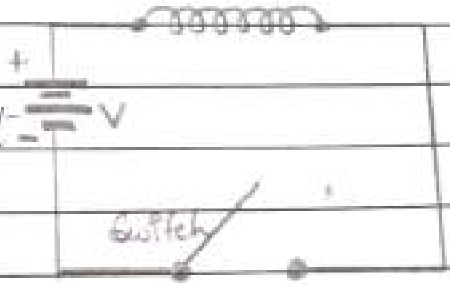
$\therefore$ For loop ABCA, MMF(F) $= H_1 l_1 + H_c l_c$

and for loop ADCA, MMF(F) $= H_2 l_2 + H_c l_c$

* Energy stored in a magnetic field

$e = L\,di/dt$

$V = iR + L\,di/dt$



• Multiplying through out by $i.dt$

$$Vi\,dt = i^2 R\,dt + Li\,di$$

• Energy absorbed by the magnetic field during time dt

$$= Li\,di \text{ Joules}$$

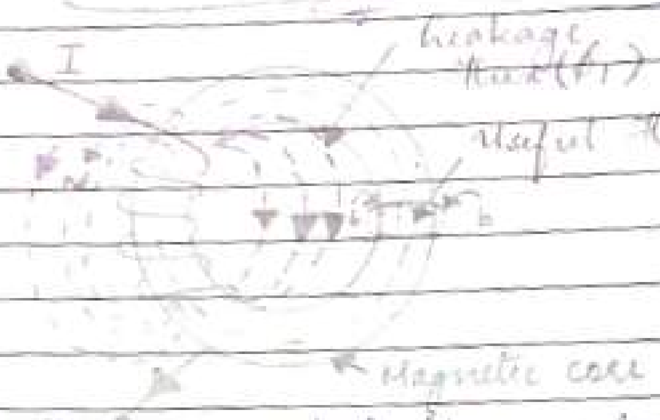
• Total energy $= \int_0^I Li.\,di$

$$= L\int_0^I i\,di$$

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

$$= \frac{1}{2}LI^2$$

- Leakage and fringing in magnetic circuit



- Total flux = useful flux + leakage flux

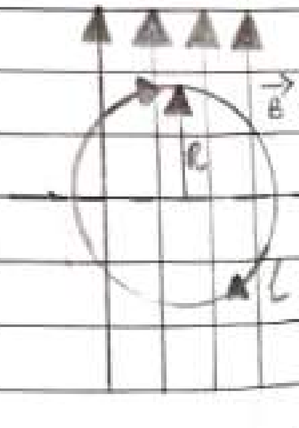
- Leakage factor

$$\lambda = \frac{\text{total flux}}{\text{useful flux}}$$

* Force experienced by a current carrying conductor in a magnetic field

- F = Bil (newton) ; F = Bil sinθ

B -> ~~flux~~ flux density
i -> current through the conductor (A)
l -> conductor length



Q1) A circular iron ring having cross sectional area of 20 cm² and length 30 cm in iron has an airgap of 2 mm made by saw cut.

Relative permeability of iron is 900. The ring is wound with a coil of 2500 turns and current in the coil is 3A. Determine air gap flux. Given leakage coefficients is 1.1.

Ans) $A = 20 cm^2$

$= 20 \times 10^{-4} m$

$l = 30 cm$

$= 30 \times 10^{-2} m$

$l_A = 2 mm$

$= 2 \times 10^{-3} m$

$\mu_r = 900$

$n = 2500$

$I = 3A$

$\lambda = 1.1$

$$\lambda = \frac{\text{total flux}}{\text{useful flux}}$$

$$1.1 = \frac{\phi_{total}}{\phi_g}$$

$$\phi_g = \frac{\phi_{total}}{1.1}$$

$$NI = \phi_{total} \times S_{total}$$

$$S_{total} = S_I + S_A$$

$$= \frac{l_I}{\mu_0 \mu_r A} + \frac{l_A}{\mu_0 A}$$

$$= \frac{30 \times 10^{-2} + 2 \times 10^{-3} \times 900}{4\pi \times 10^{-7} \times 900 \times 20 \times 10^{-4}}$$

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$= \frac{30 \times 10^{-2}}{4 \times 9 \times 2 \times 3.14 \times 10^{-11}} + \frac{18 \times 10^{-1}}{}$

$= \frac{0.30 + 1.8}{22608 \times 10^{-11}}$

$S = \frac{2.1 \times 10^{-11}}{22608}$

$\cancel{S = 9.288 \times 10^{-11} \times 10^{-5}}$

$\phi_{total} = \frac{NI}{S_{total}}$

$= \frac{2500 \times 3}{9.288 \times 10^{-16}} = \frac{2500 \times 3 \times 22608 \times 10^{-11}}{2.1}$

$= \frac{2500 \times 3 \times 10^{+16}}{9.288} = 8074285711.4 \times 10^{-11}$

$\phi_g = \frac{\phi_{total}}{1.1}$

$= \frac{8074285711.4 \times 10^{-11}}{1.1}$

$= 7340259744 \times 10^{-16}$

$\phi_g = 7.340 \times 10^{-3}$ Wb

* Induced e.m.f

- Two types:

- Dynamically induced e.m.f
- Statically induced e.m.f

* Dynamically Induced emF

- By moving a conductor in a uniform magnetic field and e.m.f produced in this way is known as dynamically induced e.m.f.
- Area swept by conductor = $l\,dx$
- Flux cut by the conductor = flux density × area

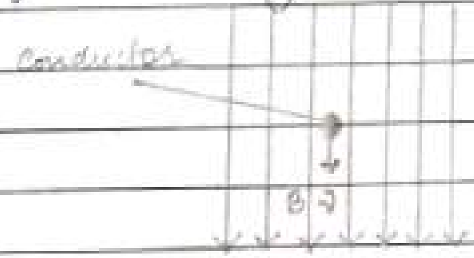
$$= B \cdot l \cdot dx \text{ (Weber)}$$

- According to Faraday's law

e = rate of change of flux linkage

$$= Bl\frac{dx}{dt}$$

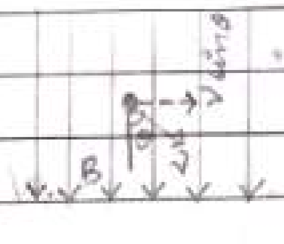
$$= Blv \text{ (volt)}$$



where $v = \frac{dx}{dt}$ -> velocity.

- Dynamically induced e.m.f = Blv (volt)

$e = Blv\sin\theta$ (volt)



★ Statically Induced e.m.f

- By changing the magnetic flux

eg: transformer.

- Magnitude and direction can be changed

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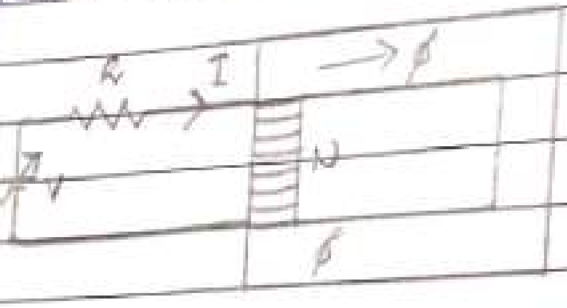
- Two types :

i) Self induced e.m.f

ii) Mutually induced e.m.f

* Self induced emf

- Self induced e.m.f is the e.m.f induced in the coil due to the change of its own flux linked with it.



- The property of coil, which opposes a change of current or flux through it, is called its self inductance, L.

* Self inductance of the coil

- $e = -N\frac{d\phi}{dt}$ — ①

$N\phi \propto I$

$= -\frac{d(N\phi)}{dt}$

$e = -\frac{dI}{dt} \times L$ — ② {L is the self inductance}

- Unit of inductance — Henry

$L = -\frac{e}{dI/dt}$

$$1 \text{ henry} = \frac{1 \text{ volt}}{1 \text{ ampere/second}}$$

- 1 henry is the amount of inductance of a coil in which rate of change of current of one ampere induces an e.m.f of one volt.

- Comparing eqns ① and ②

$$N\frac{d\phi}{dt} = -L\frac{dI}{dt}$$

Integrating

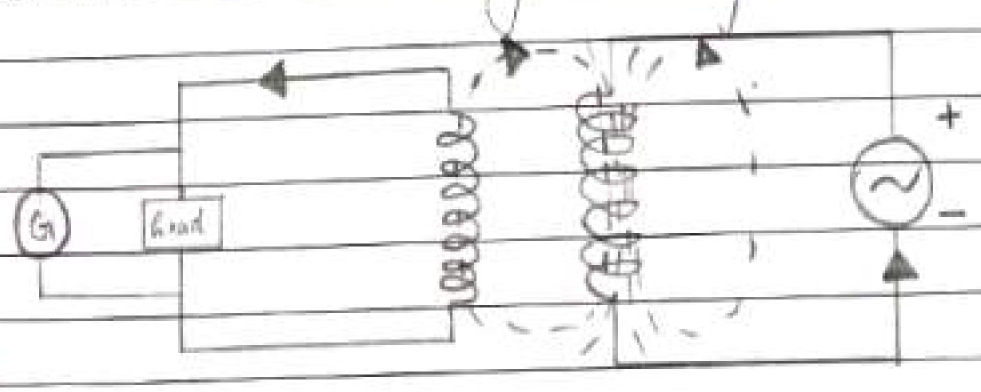
$$N\phi = LI$$

$$L = \frac{N\phi}{I}$$

- Self inductance of the coil is the flux linkage per ampere.

* Mutually induced e.m.f

- Mutual induction : Generation of induced emf in a circuit by changing the current in the neighbouring circuits



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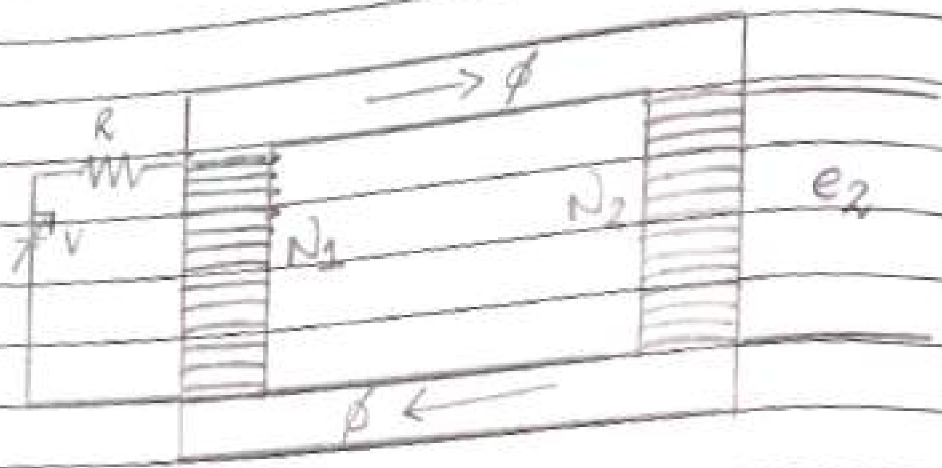

$$e_2 = -N_2 \frac{d\phi}{dt} \quad -①$$

{-ve, it is opposing the cause producing it

But $\frac{d\phi}{dt} \propto \frac{dI_1}{dt}$

$$e_2 \propto -\frac{dI_1}{dt}$$

$$e_2 = -M\frac{dI_1}{dt} \quad - ②$$

Equating ① and ②

$$N_2 \frac{d\phi}{dt} = M \frac{dI_1}{dt}$$

integrating,

$$N_2 \phi = MI_1$$

$$M = \frac{N_2 \phi}{I_1}$$

Similarly,

$$M = \frac{N_1 \phi}{I_2}$$

* Coefficient of coupling

* $\phi_2 = k_1 \phi_1$

$$M = \frac{N_2 \phi_2}{I_1} = \frac{N_2 k_1 \phi_1}{I_1} \quad -①$$

ϕ_2 produced in second coil.

$$M = \frac{N_1 \phi_1}{I_2} = \frac{N_1 k_2 \phi_2}{I_2} \quad -②$$

Multiplying ① & ②

$$M^2 = \frac{N_2 k_1 \phi_1 \times N_1 k_2 \phi_2}{I_1 \times I_2}$$

$$M^2 = k_1 k_2 L_1 L_2$$

$\{k = \sqrt{k_1 k_2}\}$

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

{K is called coefficient of coupling.}

* Self Inductance of a solenoid

$l \rightarrow$ length of the solenoid
$N \rightarrow$ number of turns
$I \rightarrow$ currents through the solenoid
$A \rightarrow$ Area of cross-section of the solenoid
$L \rightarrow$ Self inductance of the solenoid.

$$\text{Flux}(\phi) = \frac{\text{MMF}}{\text{Reluctance}}$$

$$\phi = \frac{N_2 I}{l / \mu_0 \mu_r A} \quad -①$$

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But $L = \frac{N\phi}{I}$

$\phi = \frac{LI}{N}$ — (2)

Comparing equations (1) and (2)

$$\frac{LI}{N} = \frac{NI}{l/A(\mu_0\mu_r)}$$

$$L = \frac{N^2 A(\mu_0\mu_r)}{l}$$

But reluctance $(S) = \frac{l}{A(\mu_0\mu_r)}$

$$\therefore L = \frac{N^2}{S}$$

Q) Derive the expression for effective inductance when 2 coils are connected in

1) Series
2) parallel

Ans) (i) Consider induced emf across each conductor

a) aiding

$V = L' \frac{dI}{dt}$ — (1)

$V_1 = L_1 \frac{dI}{dt} + M \frac{dI}{dt}$ — (2)

$V_2 = L_2 \frac{dI}{dt} + M \frac{dI}{dt}$ — (3)

total voltage $= V_1 + V_2$

$$② + ③ = L_1 \frac{dI}{dt} + M \frac{dI}{dt} + L_2 \frac{dI}{dt} + M \frac{dI}{dt}$$

$$V = (L_1 + L_2 + 2M) \frac{dI}{dt}$$

$\therefore$ from ①

$$L' = L_1 + L_2 + 2M$$

Effective inductance when 2 coils are connected in series.

b) opposing.

$$V = L'' \frac{dI}{dt} \quad -①$$

$$V_1 = L_1 \frac{dI}{dt} - M \frac{dI}{dt} \quad -②$$

$$V_2 = L_2 \frac{dI}{dt} - M \frac{dI}{dt} \quad -③$$

$$② + ③ = L_1 \frac{dI}{dt} + L_2 \frac{dI}{dt} - 2M \frac{dI}{dt}$$

$$= (L_1 + L_2 - 2M) \frac{dI}{dt}$$

$\therefore$ from ①

$$L'' = L_1 + L_2 - 2M$$

Effective inductance when 2 coils are connected in series.

ii) Parallel connection

$$V = L_1 \frac{dI_1}{dt} + M \frac{dI_2}{dt} \quad -(1)$$

$$V = L_2 \frac{dI_2}{dt} + M \frac{dI_1}{dt} \quad -(2)$$

from (1)

$$\frac{V - M \frac{dI_2}{dt}}{L_1} = \frac{dI_1}{dt} \quad -(3)$$

Sub (3) in (2)

$$V = L_2 \frac{dI_2}{dt} + M \left(\frac{V - M \frac{dI_2}{dt}}{L_1} \right)$$

$$V = \frac{L_1 L_2 \frac{dI_2}{dt} + MV - M^2 \frac{dI_2}{dt}}{L_1}$$

$$VL_1 - MV = (L_1 L_2 - M^2) \frac{dI_2}{dt}$$

$$\frac{dI_2}{dt} = \frac{V(L_1 - M)}{L_1 L_2 - M^2} \quad -(4)$$

Sub (4) in (3)

$$\frac{dI_1}{dt} = \frac{V - M \times \frac{V(L_1 - M)}{L_1 L_2 - M^2}}{L_1}$$

$$= \frac{V(L_1 L_2 - M^2) - MVL_1 + M^2 V}{L_1 (L_1 L_2 - M^2)}$$

$$= \frac{VL_1 L_2 - \cancel{VM^2} - MVL_1 + \cancel{M^2 V}}{L_1 (L_1 L_2 - M^2)}$$

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$$= \frac{V \cancel{L_1} (L_2 - M)}{\cancel{L_1}(L_1 L_2 - M^2)}$$

$$\frac{dI_1}{dt} = \frac{V(L_2 - M)}{L_1 L_2 - M^2}$$

$$\therefore \frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt}$$

$$= \frac{V(L_2 - M)}{L_1 L_2 - M^2} + \frac{V(L_1 - M)}{L_1 L_2 - M^2}$$

$$\frac{dI}{dt} = \frac{V(L_1 + L_2 - 2M)}{L_1 L_2 - M^2}$$

$$V = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M} \frac{dI}{dt}$$

$$V = L_p \frac{dI}{dt}$$

$$L_p = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$$

Effective inductance when 2 coils are connected in parallel.

Q) Two coupled coils connected in series have an equivalent inductance of 0.725H when aiding and 0.425 H when opposing. Find self and mutual inductance when K = 0.42.

Ans) $L' = 0.725H$; $L'' = 0.425\,H$

$K = 0.42$

$\frac{M}{\sqrt{h_1 h_2}} = 0.42$

$0.725 = h_1 + h_2 + 2M \quad -①$

$0.425 = h_1 + h_2 - 2M \quad -②$

①+②

$0.575 = h_1 + h_2 \quad - ③$

②-①

$0.03 = 2M$

$M = 0.075$

∴ sub $M = 0.075$ and ③ in K

$0.42 = \frac{0.075}{\sqrt{(0.575 - h_2) h_2}}$

$h_2^2 - 0.575 h_2 + 0.03188 = 0$

$D = b^2 - 4ac = \sqrt{(-0.575)^2 + 4(1)(0.03188)}$

$= \sqrt{0.203055} = 0.4506$

$h_2 = \frac{-b \pm D}{2a}$

$h_2 = \frac{-(-0.575) + 0.4506}{2}$; $h_2 = \frac{0.575 - 0.4506}{2}$

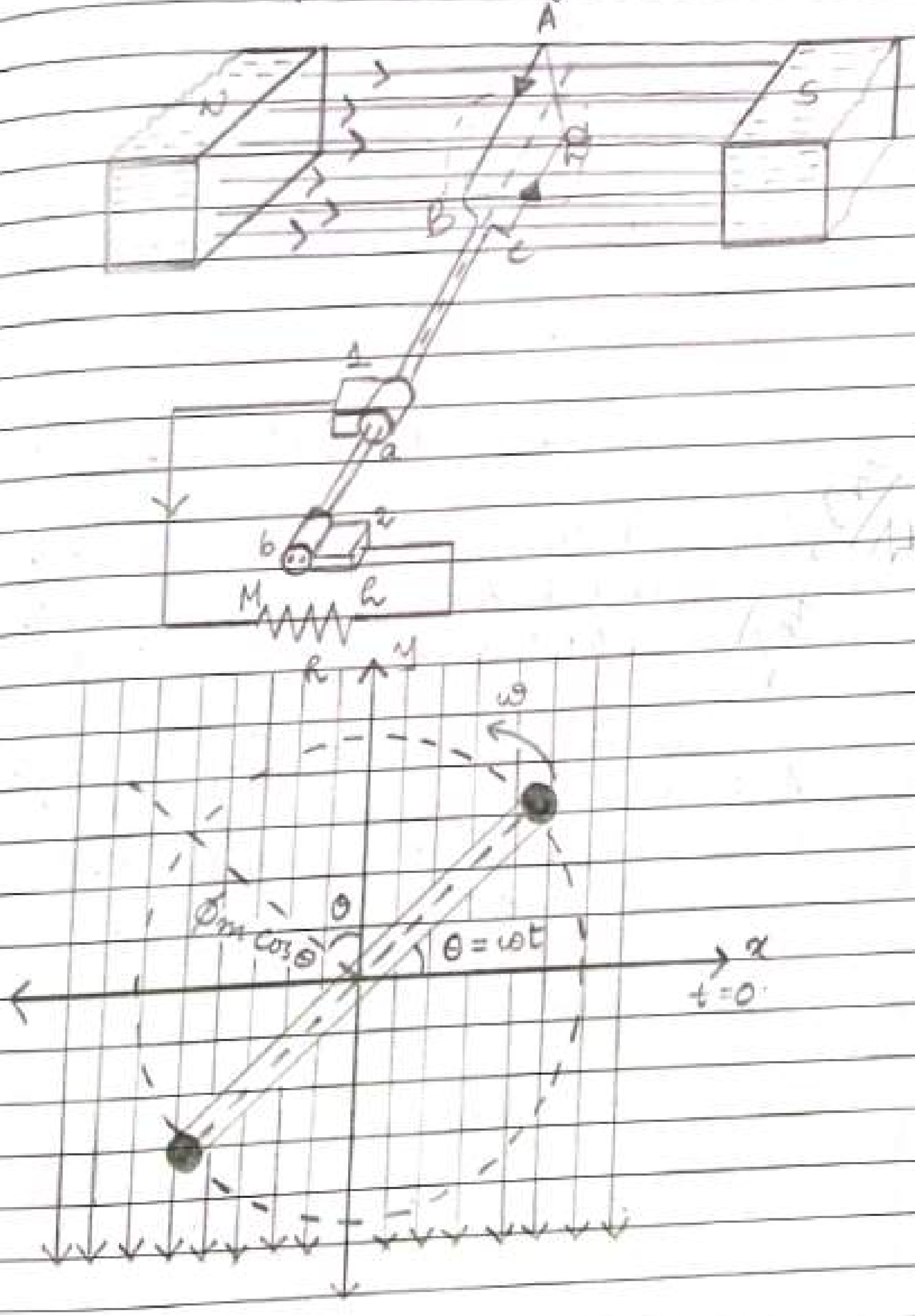
∴ when $h_2 = 0.5126$; $h_1 = 0.0624$

and when $h_2 = 0.0624$; $h_1 = 0.5126$

$M = 0.075$

Alternating e.m.f

Production of alternating emf



$$\theta = \omega t \quad -①$$

$$\phi = \phi_m \cos\omega t$$

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$$N\phi = N\phi_m \cos\theta \quad \{\text{from } ①\}$$

$$e = -\frac{d(N\phi)}{dt}$$

$$= -\frac{d(N\phi_m \cos\theta)}{dt}$$

$$= -N\frac{d(\phi_m \cos\theta)}{dt}$$

$$= -N\phi_m \omega(-\sin\omega t) \text{ volt}$$

$$= N\omega\phi_m \sin\omega t$$

$$e = \omega N\phi_m \sin\theta \text{ volt} \quad — ②$$

$$E_m = \omega N\phi_m$$

$$= \omega N B_m A$$

$$= 2\pi f N B_m A \text{ volt} \quad — ③ \quad \left\{\begin{array}{l}\omega = 2\pi f \\ \phi_m = B_m A\end{array}\right\}$$

B_m : maximum flux density in Wb/m^2
A : area of the coil in m^2
f : frequency of rotation of the coil in (rev/second.)

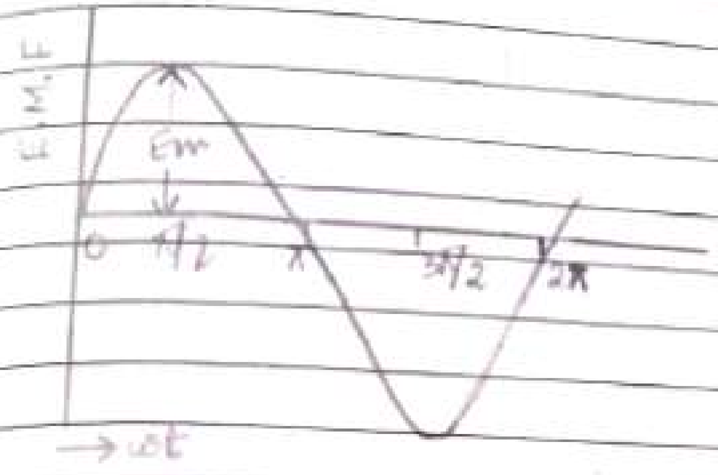
$\therefore$ from ② & ③

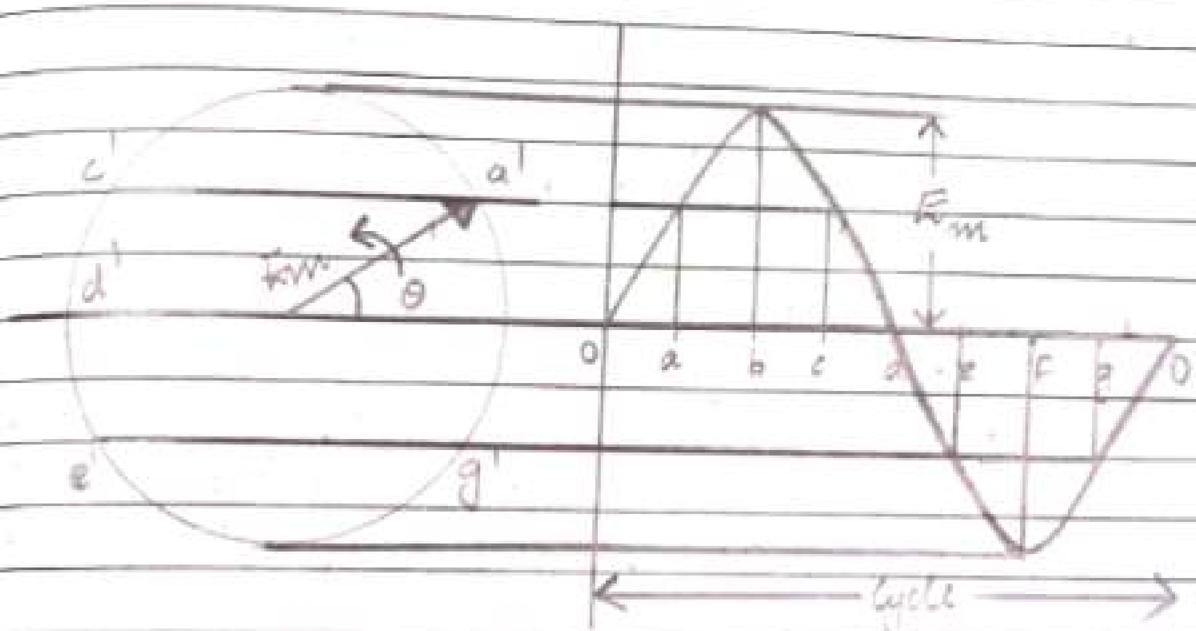
$$e = E_m \sin\theta$$

$$e = E_m \sin\omega t \quad \{\text{from } ①\}$$

Ily,

$$i = I_m \sin\omega t \quad \left\{I_m = \frac{E_m}{R}\right\}$$





- Cycle

- One complete set of positive and nega-
-tive values of alternating quantity is known as cycle.

- One complete cycle is said to spread over 360° or 2π

- Time period

The time taken by an alternating

quantity to complete one cycle is called its time period. (T)

eg: 50 Hz alternating current has a time period of $\frac{1}{50}$ seconds.

- Frequency

- The number of cycles/second is known as frequency.
- unit hertz. ; $f = \frac{1}{T}$

* Amplitude

The maximum value, positive or negative, of an alternating quantity is known as amplitude.

* Instantaneous value

It is the value at a particular instant.

* Average value

It is the arithmetic mean of the ordinates at equal interval over a half cycle of a wave.

2 Methods :

1) Mid ordinate method : Graphical method
2) Analytical method.

Mid - ordinate method

Analytical method

avg $= \frac{\text{Area}}{\pi} = \frac{\int_0^{\pi} i \, d\omega t}{\pi}$ $\quad i = I_m \sin \omega t$

RMS Value (Root mean square value)

RMS Value : That value of DC current which when flows through a given conductor produces same amount of heat as that produced by the alternating current passing through the same conductor for the same time.

$$i = I_m \sin \omega t$$

$$I_{rms} = \sqrt{\frac{\int_0^{\pi} i^2 dt}{\pi}}$$

RMS value of sinewave $= \frac{I_m}{\sqrt{2}}$

Average value of sine wave = $\frac{2 I_m}{\pi}$

* **Form Factor**

Form factor = $\frac{\text{RMS value}}{\text{Avg value}}$

* **Peak factor**

Peak factor = $\frac{\text{Max. value}}{\text{RMS value}}$

- Form factor of sine wave = $\frac{I_m/\sqrt{2}}{2I_m/\pi}$

$$= \frac{\pi}{2\sqrt{2}}$$

$$= 1.11$$

- Peak factor of sine wave = $\frac{I_m}{I_m/\sqrt{2}}$

$$= \frac{1}{\sqrt{2}}$$

Module : 3

Phasors

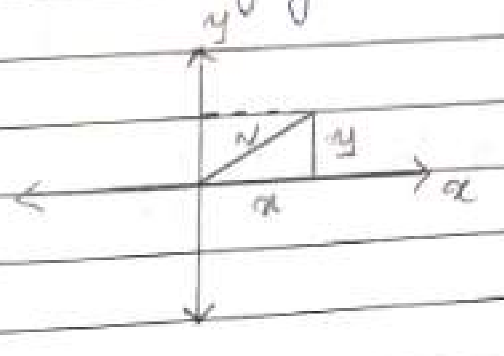
4 types of phasors are:

1) Rectangular form
2) Trigonometric form
3) Exponential form
4) Polar form

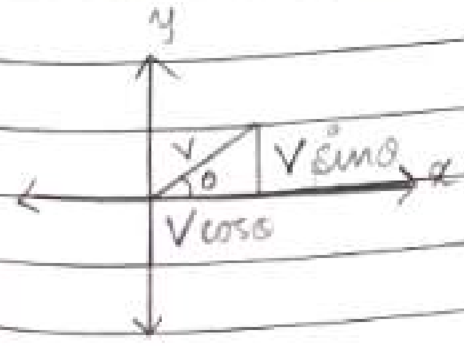
$j = \sqrt{-1}$, J is an operator it is used to express the 90° operation in counter clo-ckwise direction.

Rectangular Form

$v = x + jy$ $\quad\{j = i = \sqrt{-1}\}$



Trigonometric form



$v = V(\cos\theta + j\sin\theta) =$

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- Exponential Form ($e^{j\theta}$)

$$e^{j\theta} = \cos\theta + j\sin\theta$$
$$e^{-j\theta} = \cos\theta - j\sin\theta$$

$$v = Ve^{-j\theta}$$

- Polar Form

$$v = V\angle\theta$$ {$\angle\theta$ - angle θ}

- Addition & Subtraction

(most suitable for rectangular form)

$$V_1 = x_1 + jy_1$$
$$V_2 = x_2 + jy_2$$

$$V_1 + V_2 = (x_1 + x_2) + j(y_1 + y_2)$$

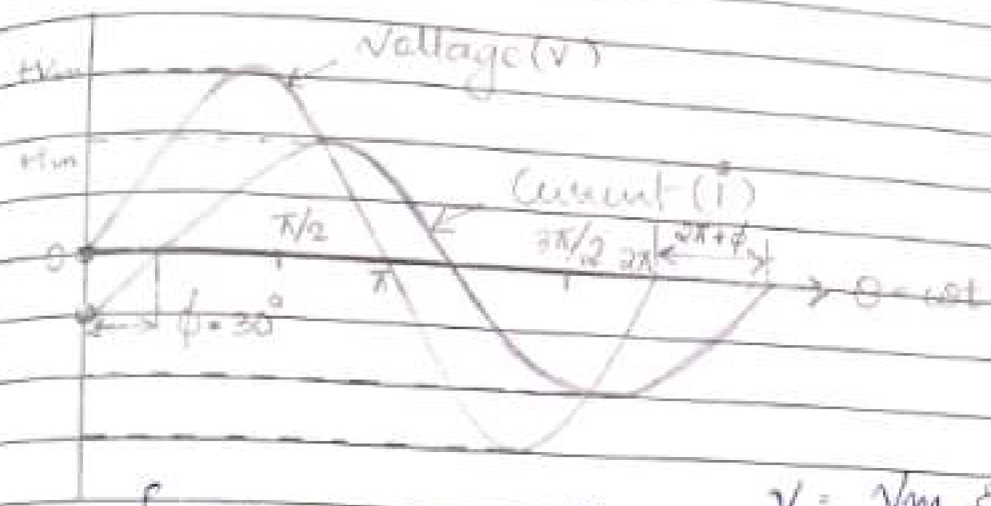
$$V_1 - V_2 = (x_1 - x_2) + j(y_1 - y_2)$$

- Multiplication and division (polar form)

$$V_1 = V_1\angle\theta_1$$
$$V_2 = V_2\angle\theta_2$$

$$V_1 \cdot V_2 = V_1 V_2 \angle\theta_1 + \theta_2$$

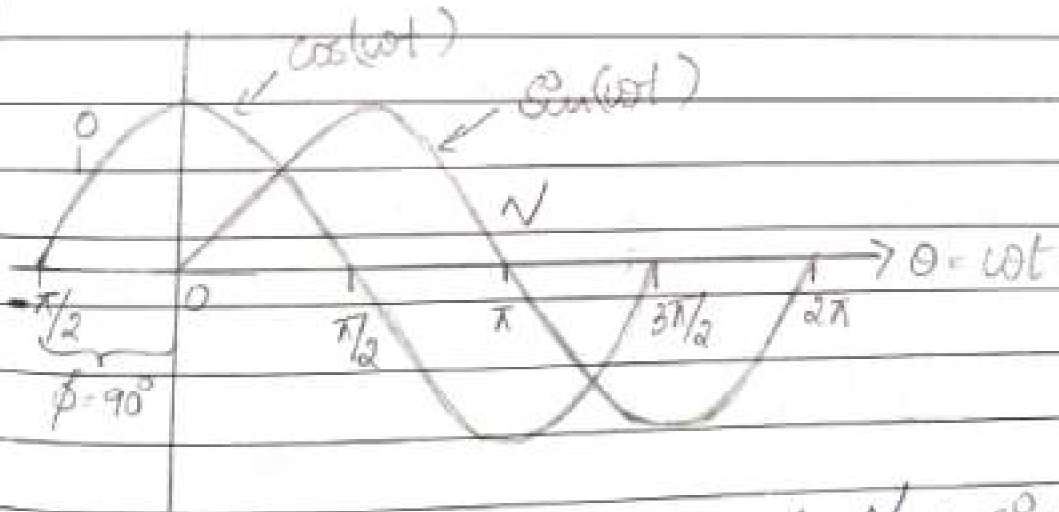
$$\frac{V_1}{V_2} = \frac{V_1}{V_2}\angle\theta_1 - \theta_2$$



{out of phase}

$v = V_m \sin(\omega t)$
reference wave

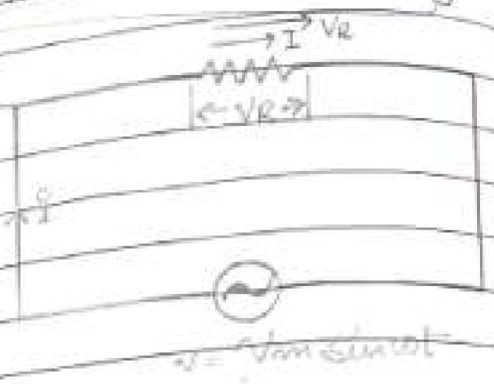
$i = I_m(\omega t - \phi)$
lagging by ϕ degree



$v = V_m \sin(\omega t)$
reference wave

$i = I_m \sin(\omega t + \phi)$
leading wave
leading by ϕ degree

AC circuit with resistance only



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

$v = iR$

$V_m \sin(\omega t) = iR$

$i = \dfrac{V_m \sin(\omega t)}{R}$

$\therefore \; I_m = \dfrac{V_m}{R}$

$(i = I_m \sin(\omega t))$

Instantaneous power,

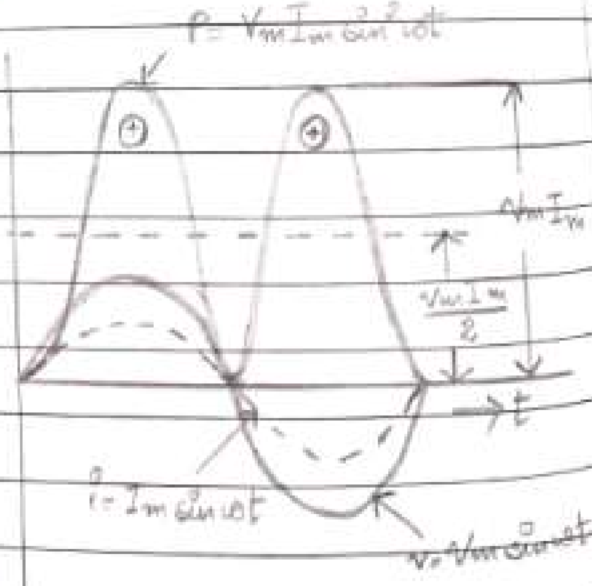
$p = vi$
$= V_m I_m \sin^2\omega t$
$= \dfrac{V_m I_m}{2}(1 - \cos 2\omega t)$
$= \dfrac{V_m I_m}{2} - \dfrac{V_m I_m}{2}\cos(2\omega t)$

Power consist of a constant part:

$\Rightarrow \dfrac{V_m I_m}{2}$

and a fluctuating part:

$\Rightarrow \dfrac{V_m I_m}{2}\cos(2\omega t)$



frequency is double that of voltage

in current waves.

Hence, power for the whole cycle is

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

or $P = V \times I$ (Watt)

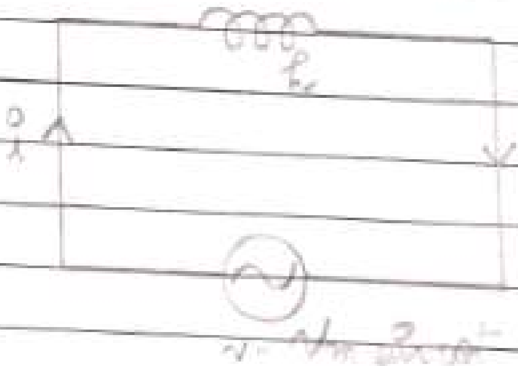
where,

V = rms value of applied voltage.

I = rms value of the current.

AC through Pure Inductive Circuit

$$v = L\frac{di}{dt}$$



Now, $v = V_m \sin(\omega t)$

$$\therefore V_m \sin(\omega t) = L\frac{di}{dt}$$

$$\therefore di = \frac{V_m}{L}\sin(\omega t)\,dt$$

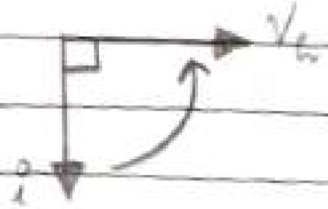
Integrating both sides we get,

$$i = \frac{V_m}{L}\int \sin(\omega t)\,dt$$

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

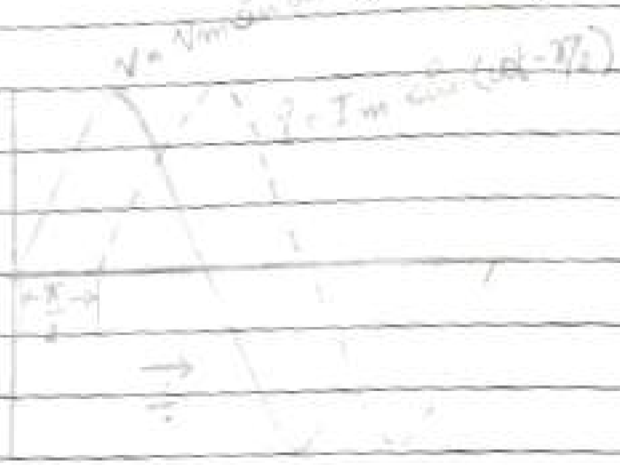
$$\therefore i = \frac{V_m}{L\omega}\sin\left(\omega t - \frac{\pi}{2}\right)$$

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



Max value of i is $I_m = \frac{V_m}{\omega L}$ (when $\sin\left(\omega t - \frac{\pi}{2}\right)$ is unity)

$$i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$$



Power

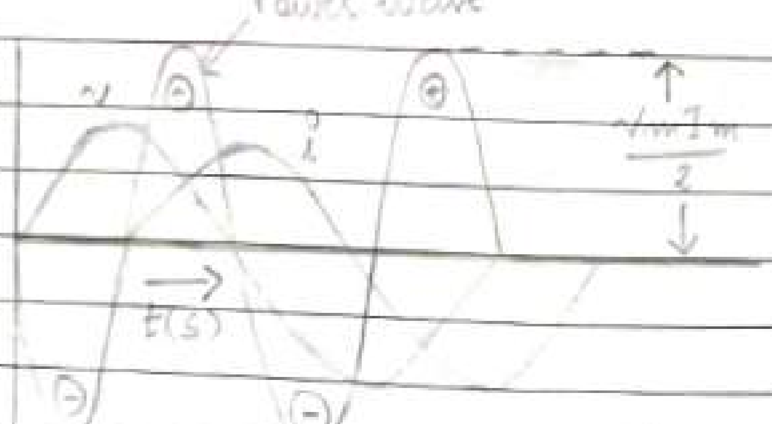
Instantaneous power $= vi = V_m I_m \sin\omega t \sin\left(\omega t - \frac{\pi}{2}\right)$

$= V_m I_m \sin(\omega t)\cos(\omega t)$

$= \frac{V_m I_m}{2} \sin(2\omega t)$

Power for whole cycle is $P = \frac{V_m I_m}{2} \int_0^{2\pi} \sin 2\omega t \, dt$

$= \underline{\underline{0}}$



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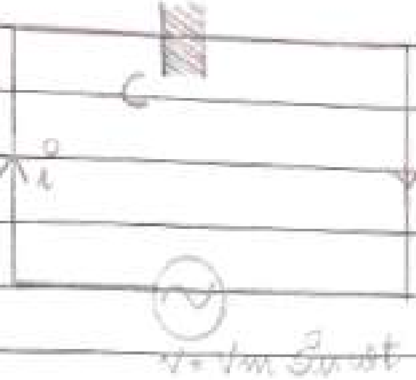
AC through Pure Capacitive Circuit

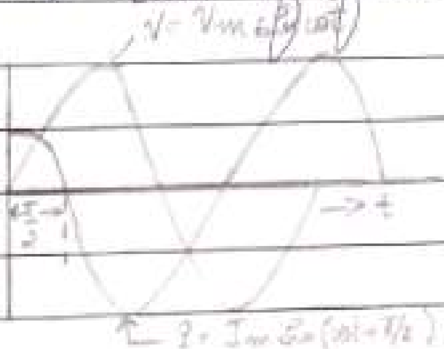
v = p.d developed between plates at any instant.
q = charge on plates at that instant



$q = Cv$ {where C is the capacitance}

$= CV_m \sin(\omega t)$ {sub $v = V_m \sin(\omega t)$}

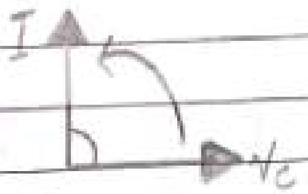
current i is given by the rate of flow of charge.



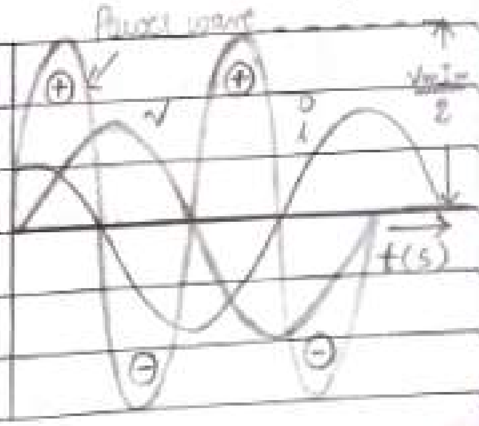
$\therefore i = \frac{dq}{dt}$

$= \frac{d}{dt}(CV_m \sin \omega t)$

$= CV_m \omega \cos \omega t$ or



$i = \frac{V_m}{1/C\omega} \sin\left(\omega t + \frac{\pi}{2}\right)$



$I_m = \frac{V_m}{1/C\omega} = \frac{V_m}{X_C}$

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

$P = vi$
$= V_m \sin(\omega t) . I_m \sin\left(\omega t + \frac{\pi}{2}\right)$

$$V_m I_m \sin\omega t \cos\omega t$$

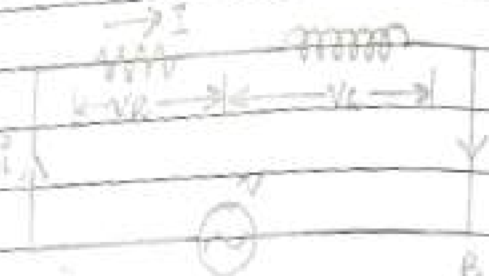
$$= \frac{V_m I_m}{2} \sin 2\omega t$$

Power for the whole cycle

$$= \frac{V_m I_m}{2} \int_0^{2\pi} \sin 2\omega t \, dt$$

$$= \underline{\underline{0}}$$

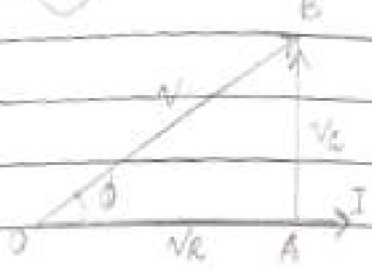
AC through RL circuit



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

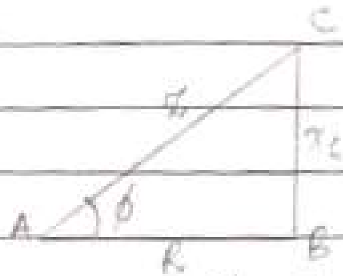
$$= \sqrt{(IR)^2 + (I.X_L)^2}$$

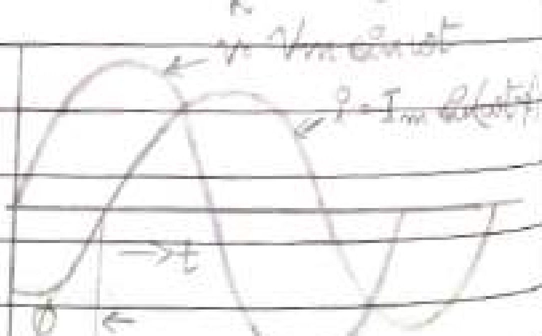
$$= I\sqrt{R^2 + X_L^2}$$



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

The quantity $\sqrt{R^2 + (X_L)^2}$ is known as the impedance (Z) of the circuit.

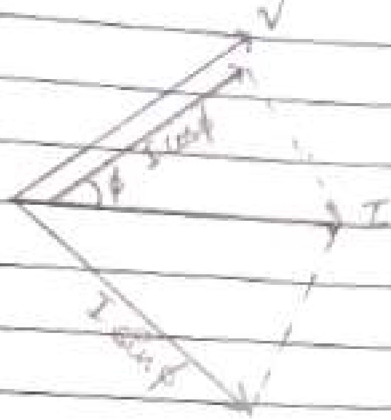




$$Z^2 = R^2 + X_L^2$$

the applied voltage V leads current I by an angle φ such that

$$\tan\phi = \frac{V_L}{V_R} = \frac{I \cdot X_L}{I \cdot R}$$



$$= \frac{X_L}{R}$$

$$= \frac{\omega L}{R}$$

$$= \frac{\text{Reactance}}{\text{Resistance}}$$

$$\phi = \tan^{-1}\frac{X_L}{R}$$

I has been resolved into its two mutually perpendicular components, $I\cos\phi$ along the applied voltage V and $I\sin\phi$ in quadrature.

The mean power consumed by the circuit is given by the product of V and that component of the current I which is in phase with V.

$$P = V \times I\cos\phi$$

$$= \text{rms voltage} \times \text{rms current} \times \cos\phi$$

Q - Factor of a Coil

$$Q\text{-Factor} = \frac{1}{\text{power factor}}$$

$$= \frac{1}{\cos\phi} = \frac{Z}{R}$$

$$Q = 2\pi \times \frac{\text{maximum energy stored}}{\text{energy dissipated per cycle}}$$

Power Factor

cosine of the angle of lead or lag

the ratio $\frac{R}{Z} = \frac{\text{resistance}}{\text{impedance}}$

the ratio $\frac{\text{true power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volts-amperes}} = \frac{W}{VA}$

Active and Reactive Components of Circuit Current I

- Active component is that which is in phase with the applied voltage V i.e $I \cos\phi$.
- it is also known as 'wattful' component.
- Reactive component is that which is quadrature with V i.e $I \sin\phi$
- It is also known as 'wattless' or 'idle' component.

Active, Reactive and apparent Power

- Apparent power (S)

It is given by the product of r.m.s values of applied voltage and circuit

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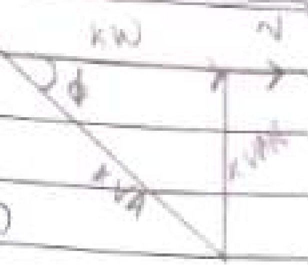
current.



$$S = VI$$
$$= (IZ).I$$
$$S = (IZ).I = I^2 Z \text{ volt-amperes (VA)}$$

Active power (P or W)

Active component which is obtained by multiplying kVA by $\cos\phi$ and this gives power in kW.

$$P = I^2 R$$
$$= VI\cos\phi \text{ watts.}$$

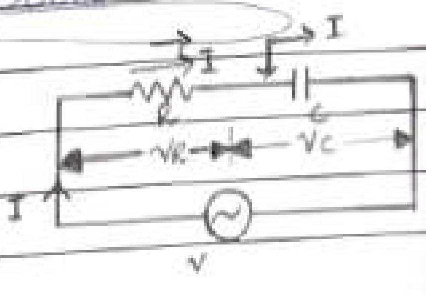
Reactive power (Q)

The reactive component known as reactive kVA and is obtained by multiplying kVA by $\sin\phi$.

It is written as kVAR (kilo VAR)

$$Q = I^2 X_C$$
$$= I^2 \times Z\sin\phi$$
$$= I \times (IZ)\sin\phi$$
$$= VI\sin\phi \text{ volt-amperes-reactive (VAR)}$$

A.C Through RC Series Circuit



$$V = \sqrt{V_R^2 + (-V_C)^2}$$
$$= \sqrt{(IR)^2 + (-IX_C)^2}$$
$$= I\sqrt{R^2 + X_C^2}$$

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

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

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

Current leads voltage by ϕ

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

Voltage triangle

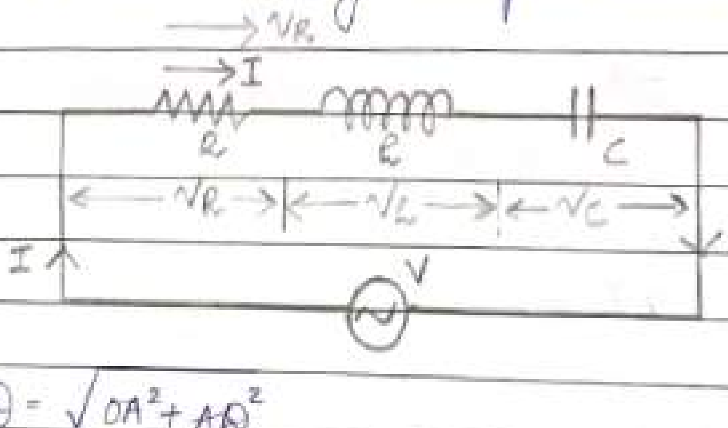
Impedance triangle

RLC Series Circuit

$V_R = IR$ = voltage drop across R - in phase with I

$V_L = I.X_L$ = voltage drop across L - leading I by $\pi/2$

$V_C = I.X_C$ = voltage drop across C - lagging I by $\frac{\pi}{2}$.



$$OD = \sqrt{OA^2 + AD^2}$$

OR

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

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

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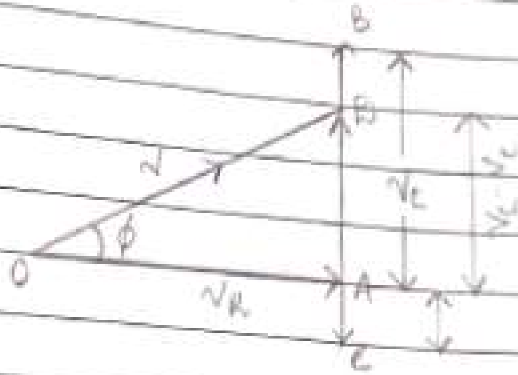
$$I = \frac{V}{\sqrt{R^2+(X_L-X_C)^2}}$$

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



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

(impedance)^2 = (resistance)^2 – (net reactance)^2

$$Z^2 = R^2 + (X_L-X_C)^2$$

$$Z^2 = R^2 + X^2$$

phase angle ϕ

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

$$= \frac{X}{R}$$

$$= \frac{\text{net reactance}}{\text{resistance}}$$

Power factor is $\cos\phi = \frac{R}{Z}$

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

$$= \frac{R}{\sqrt{R^2+X^2}}$$

- resulting current in an R-L-C circuit is given by $i = I_m \sin(\omega t \pm \phi)$
- The +ve sign is to be used when current

leads i.e. $x_C > x_L$

- The -ve sign is to be used when current lags i.e when $x_L > x_C$.
- Symbolic notation : $Z = R + j(x_L - x_C)$

$$Z = \sqrt{R^2 + (x_L - x_C)^2}$$

It phase angle is $\phi = \tan^{-1}\left[\frac{x_L - x_C}{R}\right]$

$$Z = Z \angle \tan^{-1}\left[\frac{x_L - x_C}{R}\right]$$

$$= Z \angle \tan^{-1}[X/R]$$

if $V = V\angle 0$

then $I = \frac{V}{Z}$

Summary of Results of Series AC Circuits

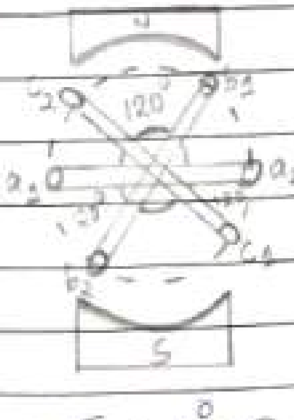
Type of impedance	Value of impedance	phase angle for current	Power factor
• Resistance only	R	0°	1
• Inductance only	ωL	90° lag	0
• Capacitance only	$1/\omega C$	90° lead	0
• Resistance and Inductance	$\sqrt{[R^2 + (\omega L)^2]}$	$0 < \phi < 90^\circ$ lag	$1 > p.f > 0$ lag
• Resistance & capacitance	$\sqrt{[R^2 + (-1/\omega C)^2]}$	$0 < \phi < 90^\circ$ lead	$1 > p.f > 0$ lead
• R.L.C	$\sqrt{R^2 + (\omega L \sim 1/\omega C)^2}$	b/w 0° & 90° lag or lead	b/w 0 and unity lag or lead.

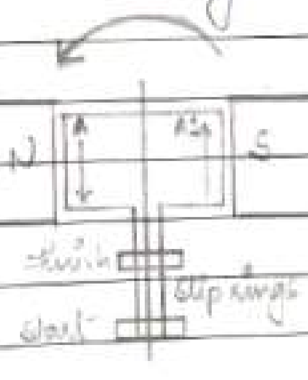
Three Phase System

Comparison between polyphase system and single phase system

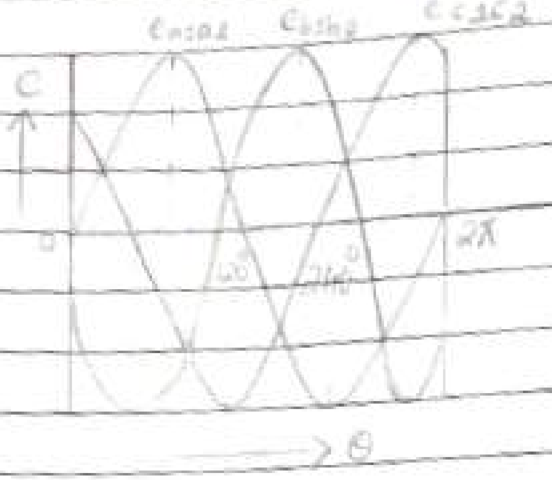
Poly phase system	Single phase system
• Power generation is cheaper	• Power generation is costly.
• High pf of efficiency	• Low pf of efficiency
• Uses less material for a given capacity.	• Uses more material
• Apparatus are economical.	• Apparatus are costly.
• Polyphase motors have uniform torque.	• Pulsating torque
• Parallel operation is very smooth.	• Not smooth.

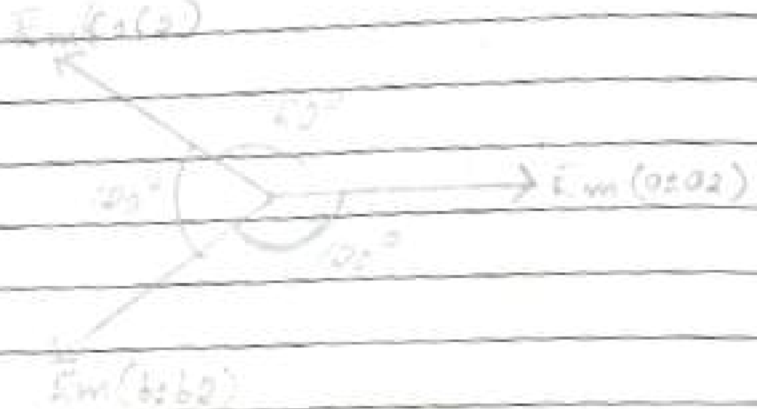
Production of Three Phase Voltage





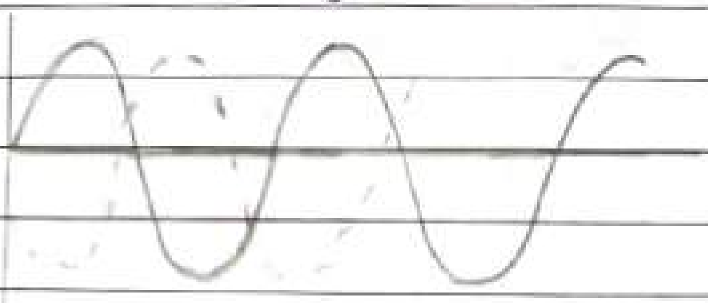
- $E_{aa_1} = E_m \sin\theta$
- $E_{bb_1} = E_m \sin(\theta - 120)$
- $E_{cc_1} = E_m \sin(\theta - 240)$





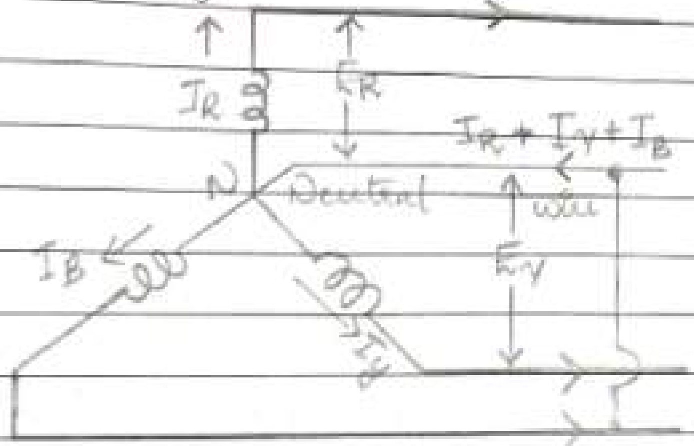
Phase Sequence or phase order

- phase sequence is meant the order in which the three phases attain their peak or maximum positive values.
- The phase sequence can be reversed by interchanging any pair of lines.

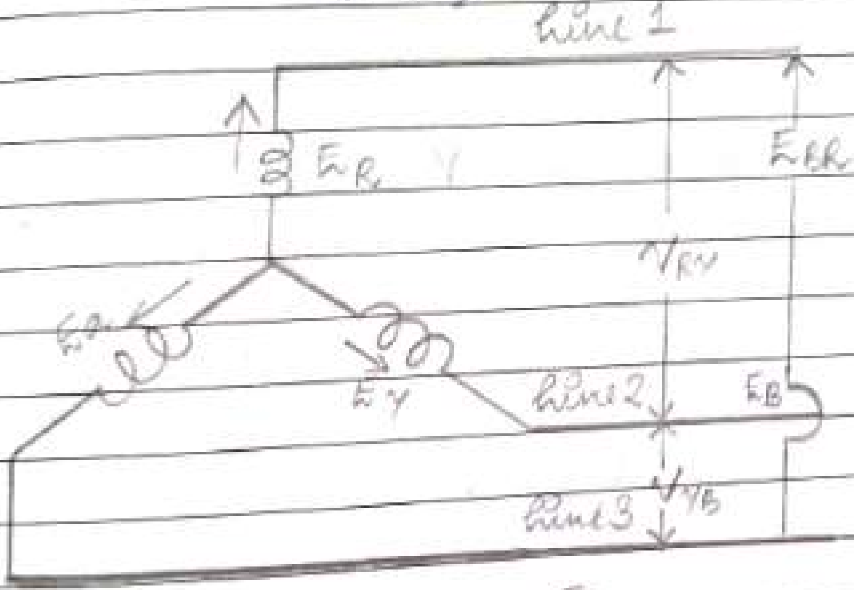


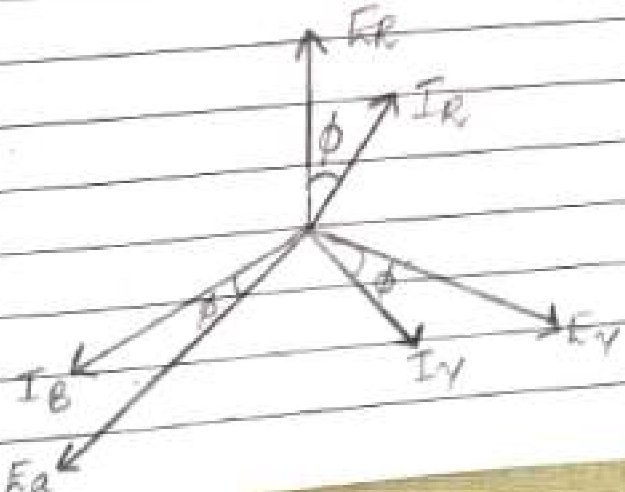
Star Connected System

The similar ends 'start' ends of three coils (it could be 'finishing' ends also) are joined together at point N.



Phase Voltage and line voltage





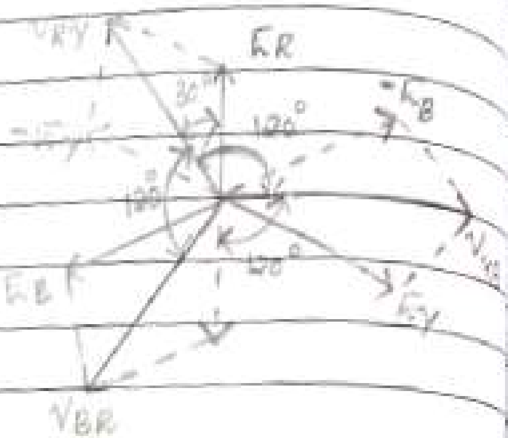
- If $E_R = E_Y = E_B$
Let E_{ph} be the phase e.m.f.,

$V_{RY} = 2 \times E_{ph} \times \cos(60/2)$

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

$= 2 \times E_{ph} \times \frac{\sqrt{3}}{2}$

$= \sqrt{3} E_{ph}$



Similarly,

$V_{YB} = E_Y - E_B$
$= \sqrt{3} \cdot E_{ph}$ {vector difference}

& $V_{BR} = E_B - E_R$
$= \sqrt{3} \cdot E_{ph}$

where V_{RY}, V_{YB}, V_{BR} are line voltages, generally represented as V_L

Hence star connection,

$V_L = \sqrt{3} E_{ph}$.

Note:

- Line voltages are 120° apart.
- Line voltages are 30° ahead of their respective phase voltages.
- The angle between the line currents and the corresponding line voltages is

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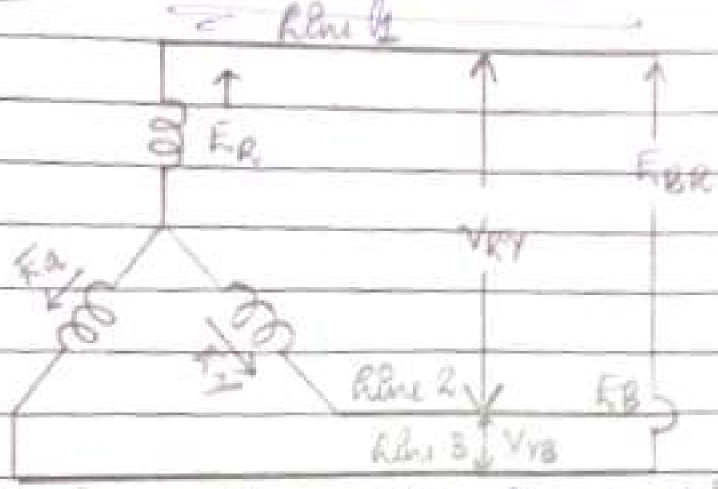
$(30+\phi)$ with current lagging.

Line currents and phase currents



each line is in series with its individual phase winding, hence the line current in each line is the same as the current in the phase winding to which the line is connected.

Current in line 1 = I_R
Current in line 2 = I_Y
Current in line 3 = I_B
Since $I_R = I_Y = I_B$

Assume, Iph be the phase current

$\therefore$ line current $I_L = I_{ph}$

Power

The total active or true power in the circuit is the sum of the ~~three~~ phase powers. Hence, total active power = 3 phase power

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Module - 1

* Gas Discharge Tubes :

Disadvantages :

- Higher response time.
- Lower discharge capacity.
- Lower lifespan.

* Vaccum Tubes :

Disadvantages :

- Bulky, hence less suitable for portable products.
- Higher operating voltages generally required.
- High power consumption; needs heater supply that generates waste heat and yields lower efficiency, notably for small-signal circuits.

* After the development of vaccum tubes, electronics has gone through 3 major stages of development.

- Stage 1 : 1920 - 1950 Vaccum tubes ruled the world of electronics.
- Stage 2 : 1950 - 1960 Invention of Transistors.
- Stage 3 : 1960 - present Invention of Integrated Circuits.

* Transistors :

- Electrons flow through solid instead of vaccum - Solid State Devices.

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- Semiconductor Device.
- Initially made of Germanium.
- Silicon almost entirely replaced Germanium
  - Easily available
  - Available in sand and rock.

Disadvantages:
- Cost is high
- Low performance.

* Integrated Circuits (IC chips):

Advantages:
- Extremely small in size.
- Low power consumption.
- Reliability
- Reduced cost
- Very small weight
- Easy replacement.

* It contains 100s or 1000s of transistors.

* Nanoelectronics:

- Nanotechnology
- Special attention to transistors.
- Design is different from traditional transi[stors]

Limitations:
- High cost.
- Cannot be used for heavy loads.

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* Different fields in nanoelectronics

* Nanofabrication

To design arrays or layers of nanoelectronic devices.

* Nanomaterials electronics

→ Dielectric property - high

Dielectric : It is an electrical insulator than can be polarized by an applied electric field.

→ Electron or hole characteristics - high.

* Moore's Law : The law states that the number of transistors in a dense integrated circuit doubles about every two years.

* Josephson Effect : Flow of electric current between two pieces of superconducting material separated by a thin layer of insulating material.

* Superconductivity : Below a certain temperature, materials enter a superconducting state and offer no resistance to the passage of electrical current.

* Quantum mechanic property : Science dealing with the behaviour of matter and light on the atomic and subatomic scale. These properties include the interactions of the particles with one

another and with electromagnetic radiation. (i.e. light, X-rays, and gamma rays).

- Nanolithography

It is the science of etching, writing or printing to modify a material surface with structures under 100 nm.

* Applications of Nanoelectronics

- Nanoradio
- Nanocomputers.

* Energy production

- Solar cells
- Bio-nano generators - work like a fuel cell. (converting glucose into energy artificially).

* Applications

- Entertainment and Communication
- Control and Instrumentation
- Applications in medical science
- Applications in defence

* Electronic Components

- Resistor
- passive element : elements which do not generate power.

- Unit : ohm, kilo ohm, mega ohm

⇒ mega ohm is used for very high resistances.
eg. Insulation, earth resistance etc.

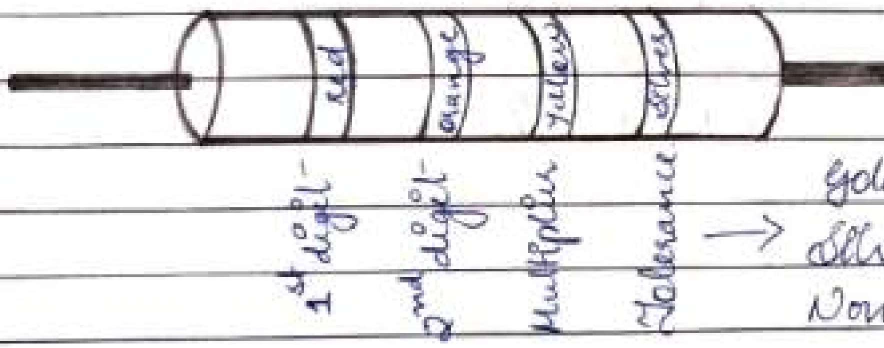
⇒ Device used to measure very high resistance is known as megger.

* Specifications of resistor

- Resistance value
- Tolerance (error) : permissible plus or minus resistance deviation.
- Wattage rating (max power) : Maximum power in Watts.
- Voltage rating : $\frac{V^2}{R} = P$; $V = \sqrt{P.R}$
- Temperature coefficient of resistance : Rate of change of nominal resistance as a function of temperature.

⇒ Nominal resistance : The average of the minimum and the maximum allowed values.

* Colour coding of Resistor



→ Gold : 5%
Silver : 10%
None : 20%

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Color	Digit	Multiplier	Tolerance(%)
Black	0	$10^0(1)$	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

Q1) Find the resistance from the following colour combination:

1) red, red, yellow, gold.

$22 \times 10^4 \pm 5\%$

2) blue green orange silver

$65 \times 10^3 \pm 10\%$

3) black violet green

$7 \times 10^5 \pm 20\%$

* Fixed Resistors

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- Wire-Wound Resistors

- a ceramic-core wound with a drawn wire having accurately-controlled characteristics

- Coils are made of alloys of Copper and Chromium.

- Materials must have high thermal stability, tensile strength and capacity to withstand high temperature.

- Insulating material used is nylon or baked enamel. Coated with entire wire.

- Exit terminals are made of Cu.

- The material should have high resistance and resistivity.

- The wounding should be perfect.

Advantages

- Can withstand large power.
- Used in high temperature situation
- Carries very high current
- Can with stand mechanical shock and vibration.
- Can be used in high voltage circuits.

- Disadvantages
- Not suitable for high frequency applications.
- Cost is high.
- Large size and weight.
- Carbon Composition Resistors
- Two types of construction :
- Slug : Carbon granules are mixed with an organic binder and molded into a pellet-shape around the terminal leads.
- Second type : Carbon resistive material is deposited on a glass tube attached to the terminal leads by a conductive cement.
- A thick organic resin case is molded around the assembly.
- Advantages :
- Small in size
- Cheap
- Wide resistance range
- Disadvantages :
- Not useful for above 5W applications
- Resistance vary with aging
- Resistors easily get heated.

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- Carbon Film Resistors

- Depositing very thin film of carbon on to a substrate by vacuum sputtering.

*) vaccum sputtering :

- Thin and thick film resistors.

* Advantages

- Available for all resistive values
- Good frequency properties
- Available in every miniature size
- Can replace wire wound resistors in high voltag applications.

* Disadvantages

- Cannot withstand high temp.
- Chemically reactive and unstable.
- Have higher inherent inductance.

* Variable resistors

* Volume Control Type Potentiometer :

- Made of carbon
- Long handle.

- Advantages

- Size is comparatively small
- Low weight
- Wide resistance range

- Trimmer Potentiometer

- Shorty trimpot
- Central moving arm is spring loaded

- Advantages

- Small size and weight
- Low cost
- Available for all resistance values.

- Rheostat

- Wire wound type

- Advantages

- Large current carrying capacity.
- Capable of handling high voltages
- Rheostats are precision resistors with low tolerance.

- Disadvantages

- Costly
- Bulky, weight is more

* Maintenance required - wires can easily be broken.

* Harmonics

A harmonics of such a wave is a wave with a frequency that is a positive integer multiple of the frequency of the original wave, known as the fundamental frequency. The original wave is called the 1st harmonic, the following harmonics are known as higher harmonics.

* Capacitor

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a capacitor is known as capacitance.

- Fixed capacitor
- Variable capacitor

* Capacitance

Capacitance is the ratio of the amount of electric charge stored on a conductor to a difference in electrical potential. There are two closely related notions of capacitance.

- That are :
- Self Capacitance
- Mutual Capacitance

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Any object that can be electrically charged exhibits self capacitance.

•) SI unit : Farad (F)
{Practical capacitors are in microfarads or pico-farads}

• Fixed Capacitor

• Capacitance doesn't vary with external factors.
• Capacitor that ~~shows~~ stores fixed amount of electric charge.
• There are 4 types of fixed capacitors :
•) Paper capacitors
•) Mica capacitors
•) Ceramic capacitors
•) Electrolytic capacitors.

★ Paper Capacitors

• Paper capacitor is a capacitor that ~~was~~ uses paper as the dielectric to store electric charge.
• Tissue or cellulose paper called craft paper.
• Craft paper is sandwiched between 2 aluminium foils.
• The entire unit is rolled to form a cylinder.
• The paper sheet is covered or soaked with oil or wax to protect from outside harmful environment.

- Used in the high voltage and high current applications.

* Mica capacitors

- Mica is used as dielectric material.
- Muscovite mica is most frequently used for constructing the dielectric of mica capacitors.
- It consists of plates of aluminium foil separated by sheet of mica.

* Advantages

- Good mechanical strength.
- Can be used for high temperature.
- High voltage and high frequency applications.
- High insulation resistance.

* Disadvantages

- Chance of unavailability
- Silver migration occurs at high DC voltages, high temperature and high humidity.

* Ceramic Capacitors

- Ceramic materials is used to construct the dielectric and conductive metals are used to construct the electrodes.
- Ceramic disc is coated on 2 sides with a metal, such as Cu or Ag.
- Tinned wire is placed as leads.

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- The entire unit is coated with plastic and marked with capacitor value.

* Advantages

- Wide range of capacitance
- Cheap
- Light weight
- highly reliable

* Disadvantages

- High voltage capacitors are not available.
- High capacitors are not available.
  (capacitances)

* Electrolytic capacitors

- Consists of aluminium foil electrode which has an aluminium oxide film covering on one side.
- Aluminium plate serves as positive plate. aluminium oxide acts as dielectric.

* Advantages

- High capacity in small volume.
- Lower cost per microfarad.

* Disadvantages

- Large leakage resistance
- Will work only in DC.

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* Variable capacitors

- Used for tunning
eg: Air gang capacitor
- Trimmer capacitor.

* Tantalum capacitors

- Another type of electrolytic capacitors.
- Tantalum is used instead of aluminium.
- Larger C in small size.
- Less leakage current.

* Inductors

- Long wires wound on insulating former.
- Fixed and Variable.

* Fixed

- Give constant inductance.
- No of turns do not change.

* Variables

- Inductance can be changed over a specified range.
- Inductance varied by changing the position of core.

* Transformers

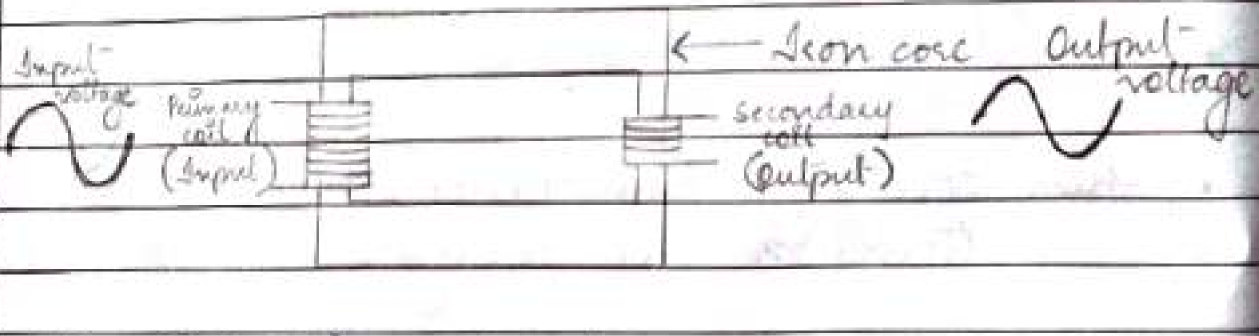
Two inductors having same core.

- One is primary, the other is secondary
- It transforms one or more electrical parameters from one circuit to another.
- There are 2 types of transformers:

» Step up transformer
» Step down transformer

★ Step up transformer

★ Step down transformer



★ Classification of Transformers

- Based on their current capacity and frequency range:

» Power Transformers.
» Audio frequency Transformers
» Impedance Transformers
» Pulse Transformers.

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* Power transformers

- Operating frequency 50 Hz or 60 Hz
- Handle large powers.

* Audio Frequency Transformers

- Transform electrical signals in audio frequen-
-cy range.
- Application : Audio Amplifier.

* Impedance Transformers

- Transform impedance level
- Transform the output impedance of one circuit in such a way that is matches input impedance of another circuit.

* Pulse Transformers

- Transform pulses.
- Transform pulses may have change in ampli-
-tude or polarity.
- Uses

:) Pulse generating circuit
:) Pulse amplifiers.

- Small leakage current and capacitance.
- K greater than 99%.

Semiconductors

* Energy band diagram

- Energy band : The range of energies possess by electrons in a solid.

- Valance band : -> Electrons have least binding energy, more orbital energy.
  -> The range of energy possessed by valance electrons called valance band.

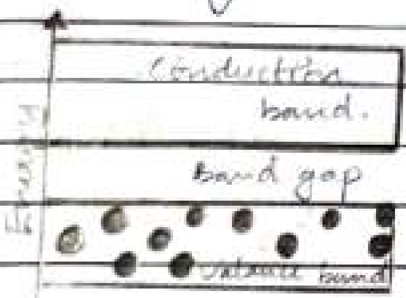
- Conduction band : -> When certain energy is applied to valance electrons, they will become conduction electrons.
  -> The range of energy possessed by free electrons is called conduction band.

- Forbidden band or gap : -> The separation between valance and conduction band in energy band diagram.
  -> The energy required to lift the electron from valance to conduction band should

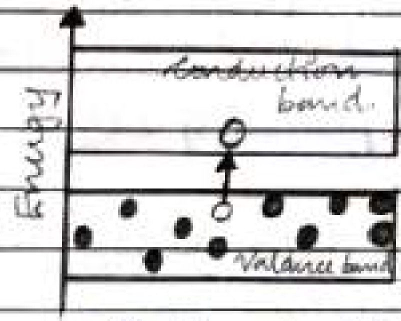
: be greater than the energy gap Eo

* Classification of materials

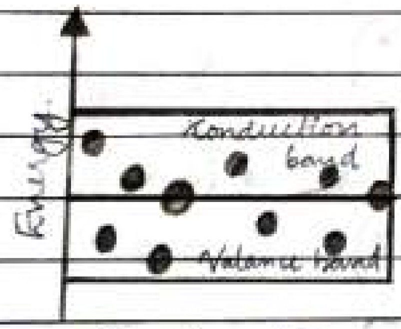
· According to energy band diagram



Insulator



Semiconductor

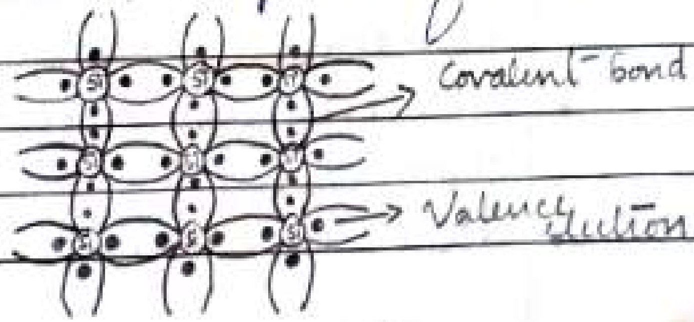


Conductor.

* Classification of Semiconductors

· Intrinsic Semiconductor :

·) Pure form of semiconductor.
·) Impurity should be less than one part impurity in 100 million ($1/10^8$) parts of semiconductors.



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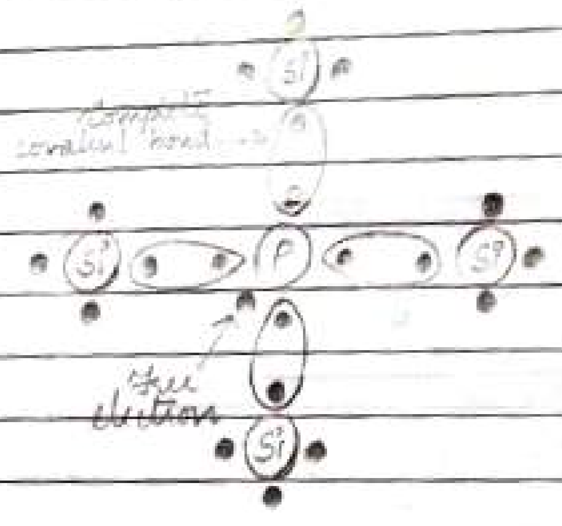
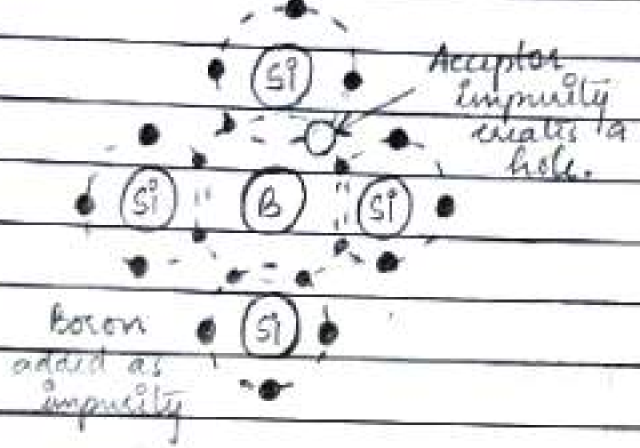
* Extrinsic Semiconductor
  - Impure form of semiconductor.
  - Doping
  - Conduction of semiconductor material is improved by doping.
  - Doped by pentavalent atom - donor doping
  - Doped by trivalent atom - acceptor doping

* N-type Semiconductor



- The pentavalent atoms are Sb, P, Bi and As.
- These materials include five electrons in their outer shell.
- The four electrons will make covalent bonds using the adjacent atoms and the fifth electron will be accessible like a current carrier.
- Electrons are the majority carriers in N type semiconductor.
- Holes are minority carriers.

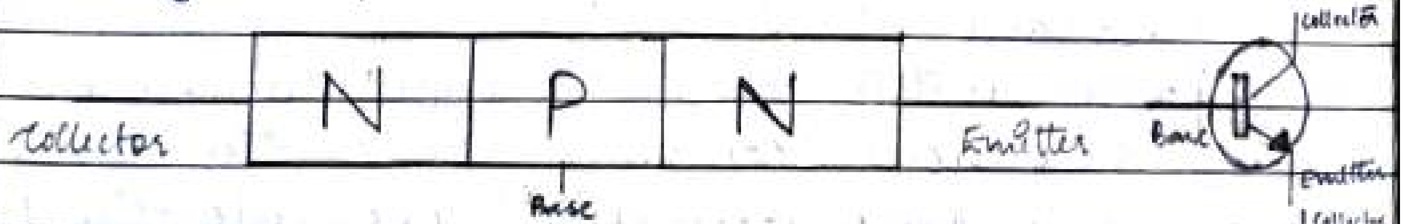
* P-type Semiconductors

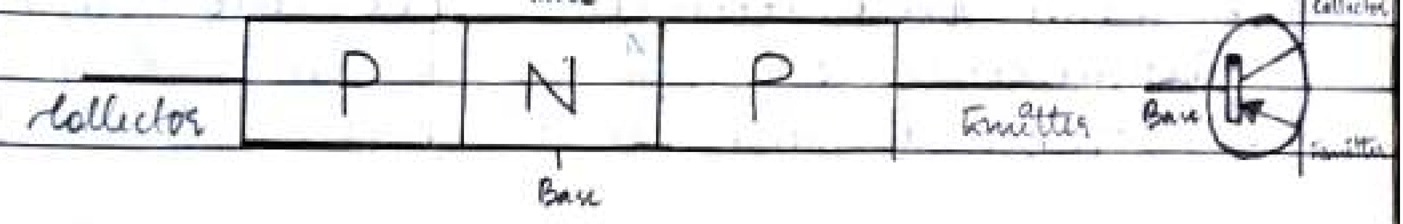


- When a trivalent impurity is added to a pure semiconductor a large number of holes are crea-
-ted in it.
- trivalent impurities are boron, aluminium, thallium, Gallium and Indium.
- Major current carriers are holes.
- Minor current carriers are electrons.

★ Bipolar Junction Transistors (BJT)

- 3 doped semiconductor regions - Emitter, base, collector - provided with terminals.
- 2 pn junctions
- Base emitter junction and base collector
- Npn & pnp.





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* Emitter

- Heavily doped
- Supply majority carriers to the base
- Always forward biased with respect to base

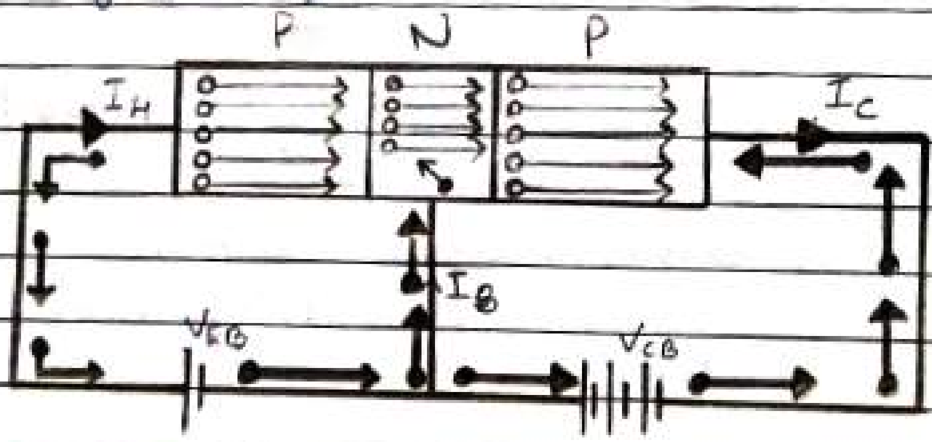
* Base

- Lightly doped
- Very thin

* Collector

- Moderately doped
- Always reverse biased with respect to base.

* Working of PNP transistor



- The emitter-base junction is connected in forward biased.
- The emitter push the holes in the base region.
- These holes constitute the emitter current.
- When these ~~electrons~~ holes move into the N-type semiconductor material or base, they get combined with the electrons.

- The collector base region is connected in reverse biased.
- The holes which collect around the depletion region when coming under the impact of negative polarity collected or attracted by the collector. This develops the collector current.

* Working of NPN transistor

- The transistor in which one p-type material is placed between two n-type materials is known as NPN transistor.
- The NPN transistor amplifies the weak signal enter into the base and produces strong amp-lify signals at the collector end.
- In NPN transistor, the direction of movement of an electron is from the emitter to collector region due to which the current constitutes in the transistor.
- Such type of transistor is mostly used in the circuit because their majority charge carriers are electrons which have high mob-ility as compared to holes.

- The forward biased voltage ~~V_{EB}~~ is applied across the emitter-base junction, and the reversed biased voltage is applied across the collector-

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base junction.
- The forward biased voltage V_{EB} is small as compared to the reverse bias voltage V_{CB}.
- When the forward bias is applied across the emitter, the majority charge carriers move towards the base.
- This causes the emitter current I_E. The electrons enter into the P-type material and combine with the holes.

- The base of the NPN transistor is lightly doped.
- Due to which only a few electrons are combined and remaining constitutes the base current I_B.
- This base current enters into the collector region. The reversed bias potential of the collector region applies the high attractive force on the electrons reaching collector junction.
- Thus attract or collect the electrons at the collector.
- The whole of the emitter current is entered into the base. Thus, we can say that the emitter current is the sum of the collector & the base current.

- Transistor Configurations

- Common Base Configuration

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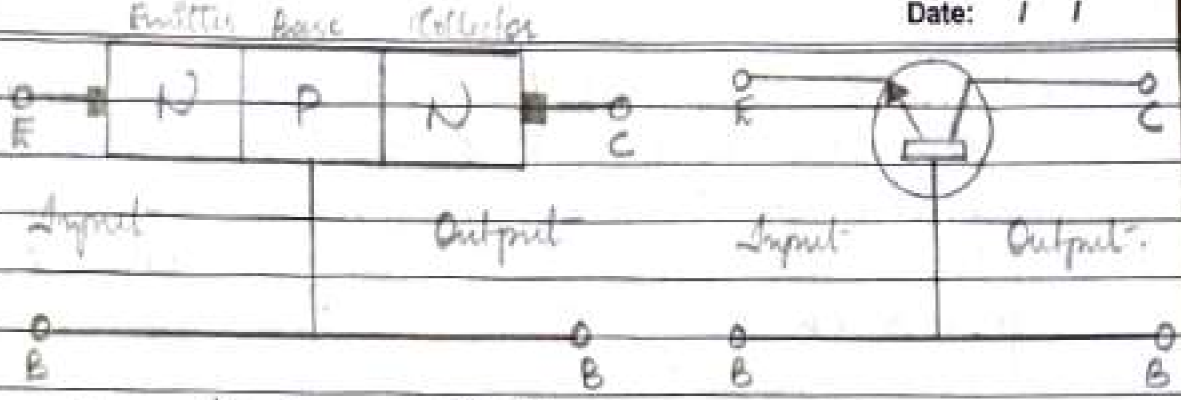

- The input is applied between the base and emitter terminals and the corresponding output signal is taken between the base and collector terminals with the base terminal grounded.
- The input parameters are V_{EB} and I_E and the output parameters are V_{CB} and I_C.
- The input current flowing into the emitter terminal must be higher than the base current and collector current to operate the transistor.

$$\text{current gain } (\alpha) = \frac{\text{output current}}{\text{input current}} = \frac{I_C}{I_E}$$

α is the common base current gain. It is also known as amplification factor. Its value is less than 1 (around 0.98).

$$\text{Voltage gain} = \frac{\text{Output voltage}}{\text{input voltage}} = \frac{V_{CB}}{V_{EB}}$$

therefore the output collector current is less than the input emitter current.

- The current gain is equal or less than unity.

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- In CB configuration, a positive input produces a positive output and hence input and output are in phase. So, there is no phase reversal between input and output in a CB amplifier.

- If CB configuration is considered for amplification, it has low input impedance and high output impedance.

- The input and output signals are in-phase in this configuration.

- The amplifier circuit configuration of this type is called as non-inverting amplifier circuit.

- The construction of this configuration circuit is difficult because this type has high voltage gain values.

Characteristics

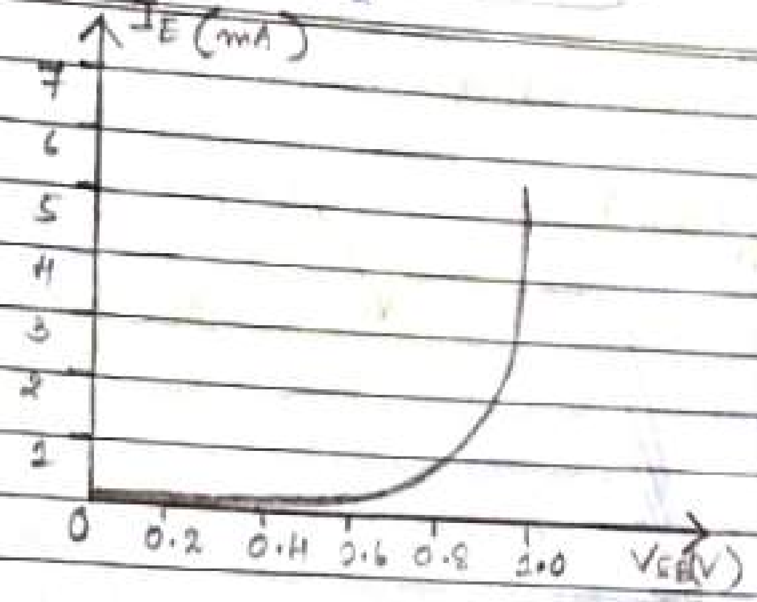
Input characteristics:

Between input current (I_E) and input voltage (V_{EB}) for different output voltage.

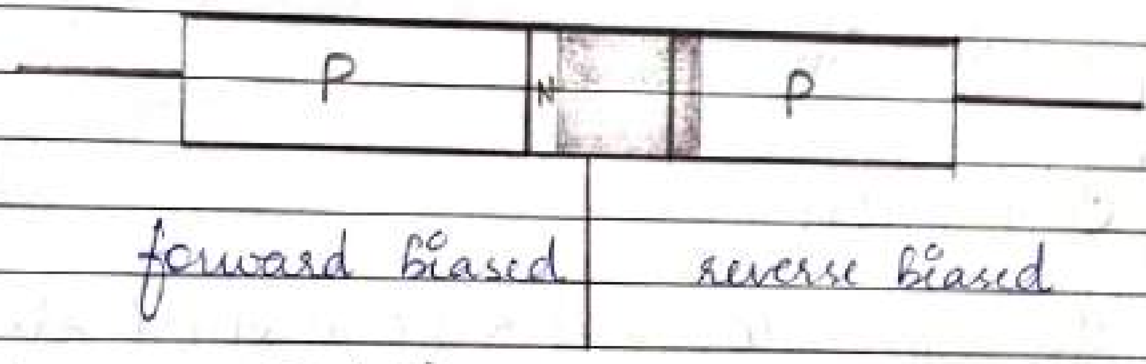
Output characteristics:

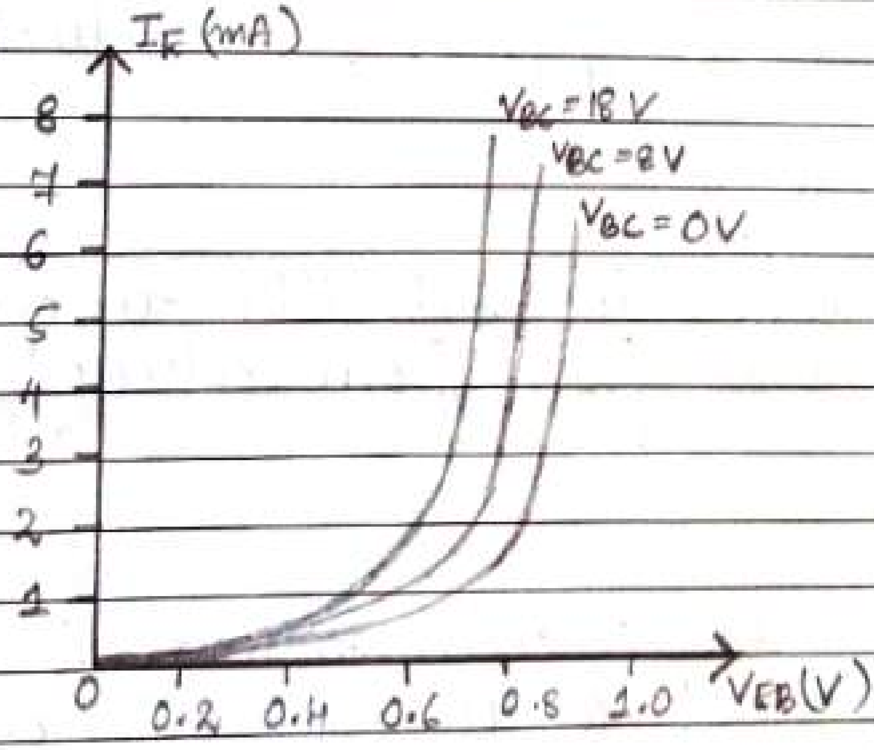
Between output current (I_C) and output voltage (V_{CB}) for different input currents.

Input Characteristics



Early Effect (Base width modulation)





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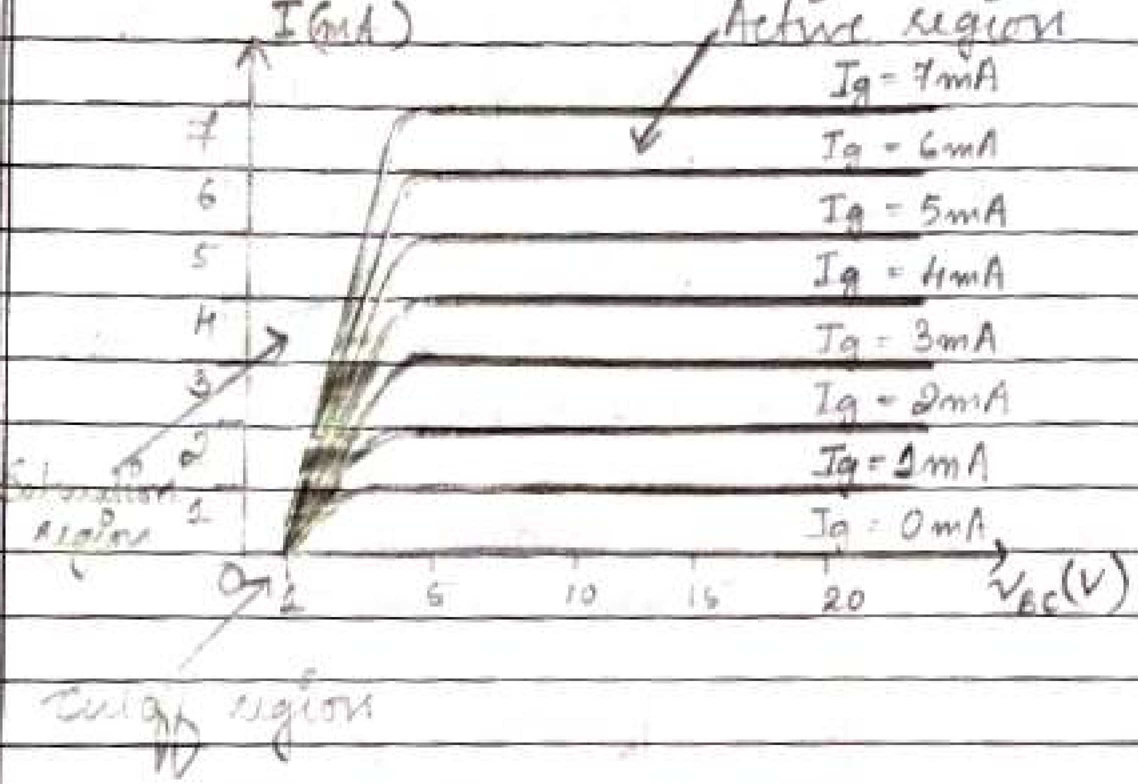
Output Characteristics



Saturation :

The transistor acts like a short circuit. Current freely flows from collector to emitter.

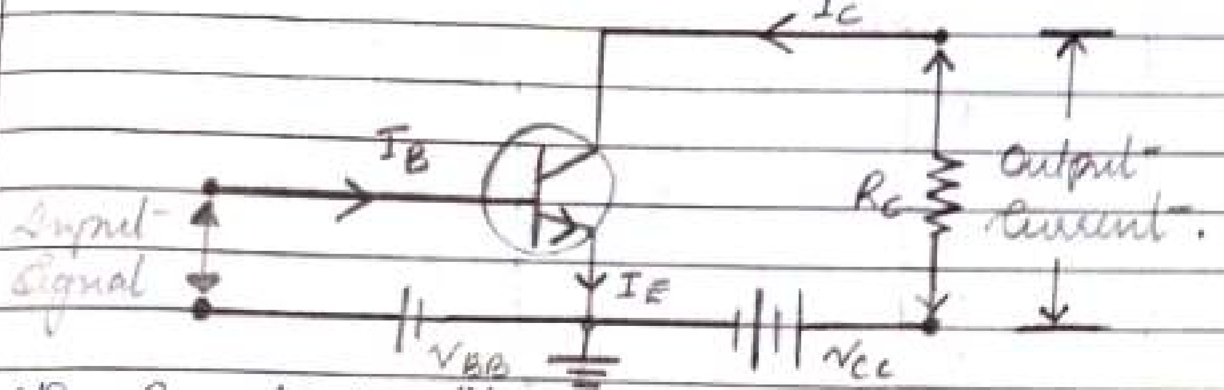
Cut-off :

The transistor acts like an open circuit. No current flows from collector to emitter.

Active :

The current from collector to emitter is proportional to the current flowing into the base.

Common Emitter Configuration



* The input circuit is connected between emitter and base, and the output circuit is taken from the collector and emitter.

* Common Emitter Current Gain (β)

Base current amplification factor is defined as the ratio of the output and input current in a common emitter configuration.

$$\beta = \frac{I_C}{I_B} \quad -(1)$$

$$\left[\begin{array}{l} I_E = I_b + I_C \\ I_B = I_E - I_C \end{array}\right]$$

$$\alpha = \frac{I_C}{I_E} \quad -(2)$$

From (1) & (2)

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

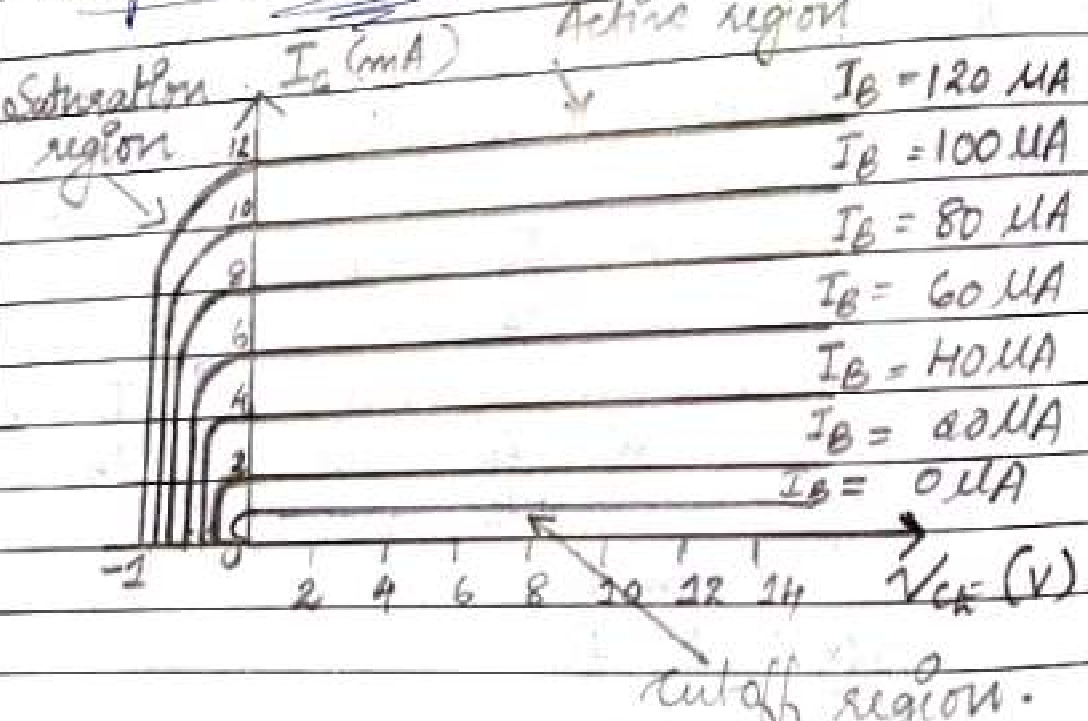
$$\frac{1}{\beta} = \frac{I_E}{I_C} - \frac{I_C}{I_C}$$

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

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

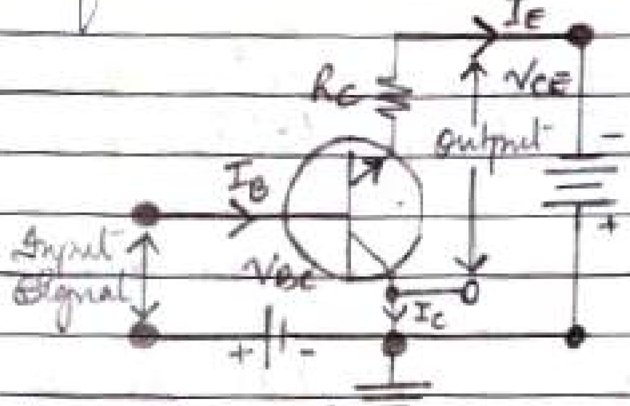
Input Characteristics

Output Characteristics



Common Collector Configuration

- Input circuit is connected between emitter and base and the output is taken from the collector and emitter.



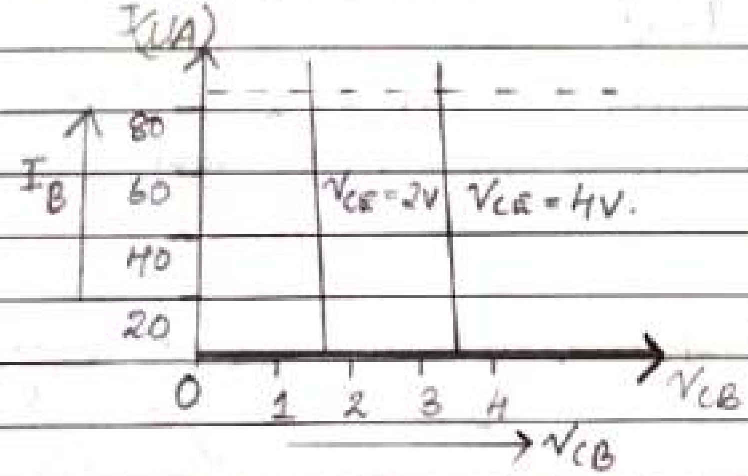
Current Gain:

$$\gamma = \frac{I_E}{I_B}$$

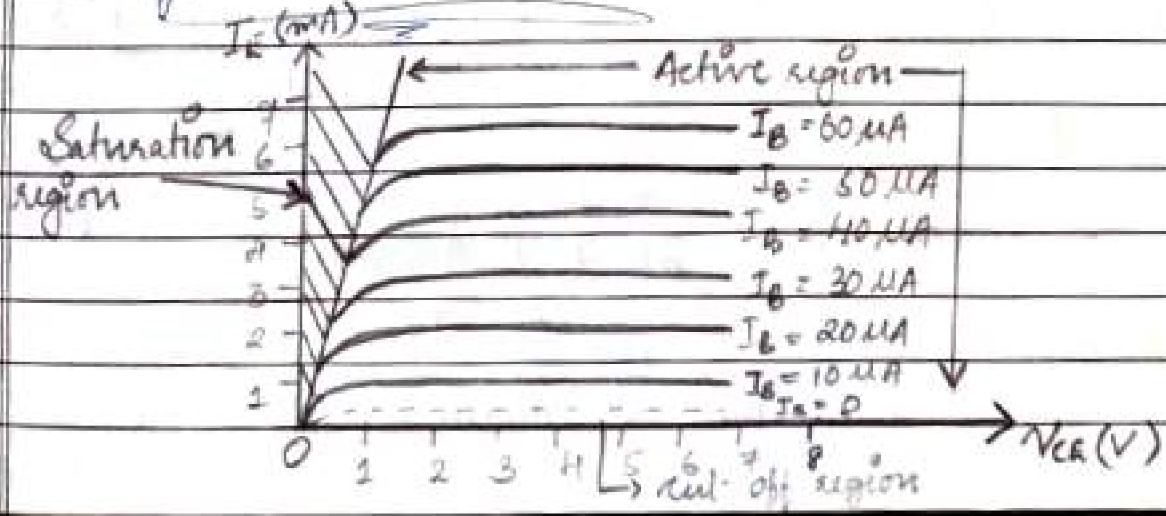
$$I_B = I_E - I_C$$

$$\gamma = \frac{1}{1-\alpha}$$

Input Characteristics



Output Characteristics



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Module 5

Basic Electronic Circuits and Instrumentation

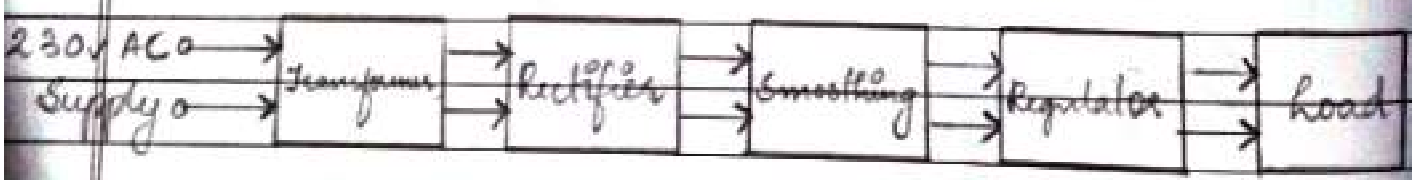
- **Rectifiers:**

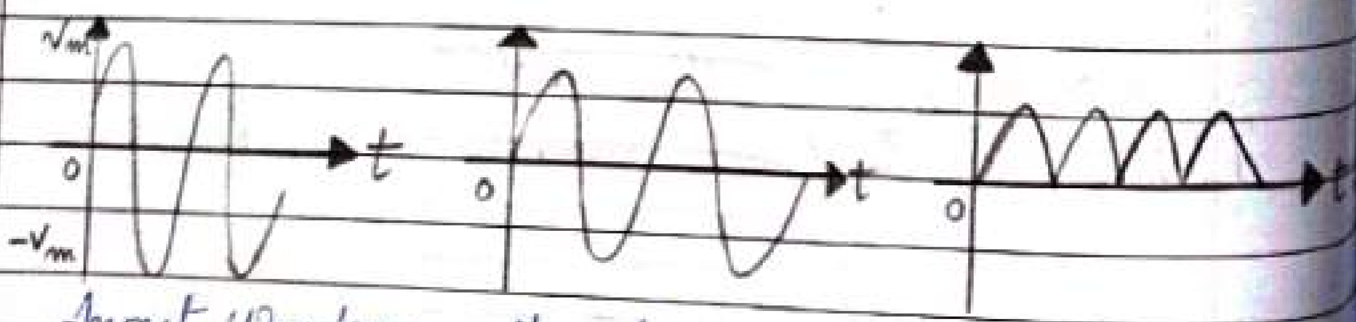
A rectifier is an electrical device that converts alternating current, which periodically reverses direction, to direct current, which flows in only one direction. The reverse operation is performed by the inverter. The process is known as rectification.

- **Power Supply**

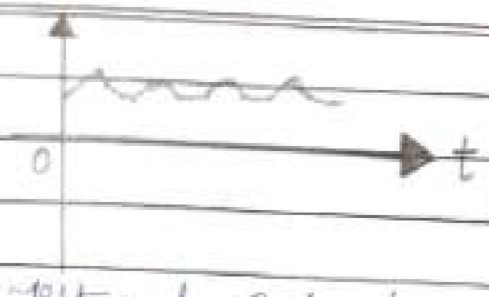
A power supply is an electrical device that supplies electric power to an electrical load.

- **Block Diagram of DC Power Supply**

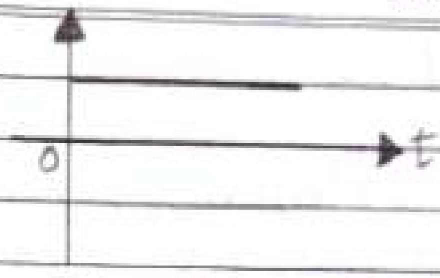




Input Waveform   Transformer Output   Rectified Output

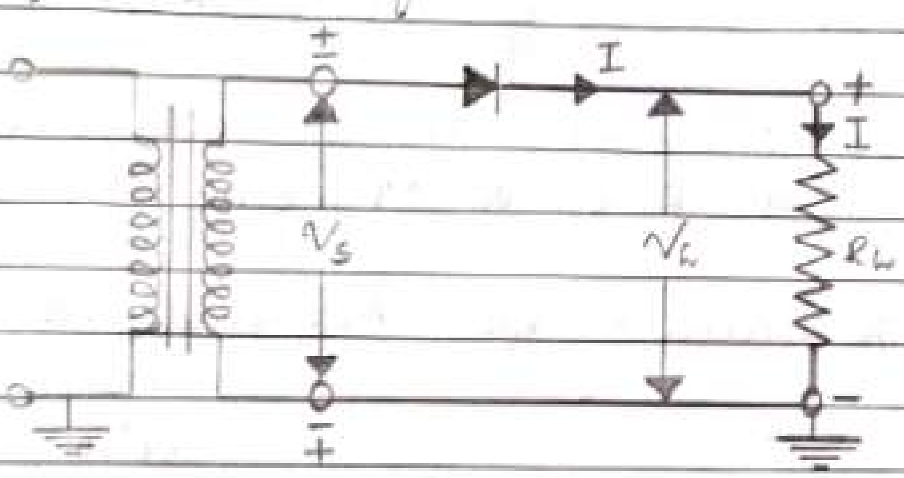


Filtered Output

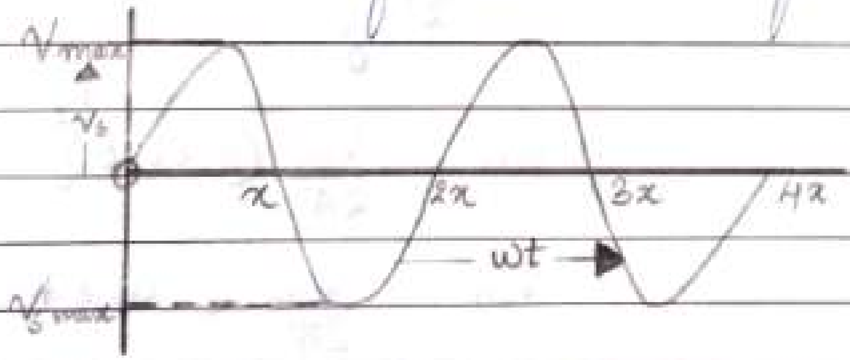


Pure dc output

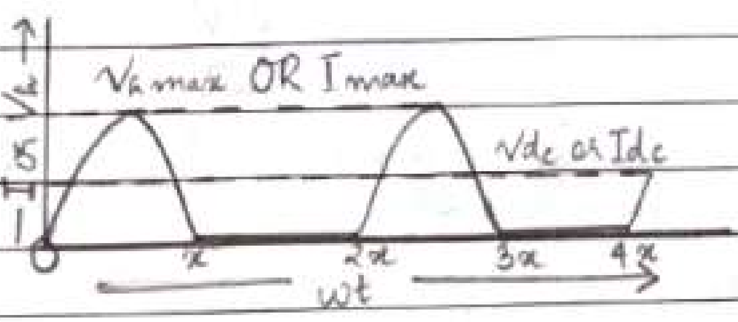
* Half wave Rectifier



Half-Wave Rectifier



Input Voltage Waveform



* Peak Inverse Voltage
* Maximum reverse biased voltage appears across the diode.
* Half wave rectifiers, PIV = Vm
* Average Values of Voltage & Current
* Let instantaneous input voltage be
$v = V_m \sin\omega t = V_m \sin\theta$

* Average value = V_{dc} = $\dfrac{\text{Area under the wave in one cycle}}{\text{base}}$

$$V_{dc} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\theta \, d\theta$$

$$V_{dc} = \frac{V_m}{2\pi}\left(-\cos\theta\right)_0^{\pi}$$

$$V_{dc} = \frac{V_m}{2\pi}\left(-\cos\pi + \cos 0\right)$$

$$= \frac{V_m}{2\pi}(1+1)$$

$$= \frac{2V_m}{2\pi}$$

$$V_{dc} = \frac{2V_m}{2\pi} = \frac{0.637\, V_m}{2} = 0.316\, V_m$$

Similarly,

$$I_{dc} = \frac{2I_m}{2\pi} = \frac{0.637\, I_m}{2} = 0.316\, I_m$$

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- $I_m = \frac{V_m}{R_L}$

- RMS value of voltage & current

RMS value $= \sqrt{\frac{1}{2\pi}\int_0^{\pi}(I_m \sin\omega t)^2 d(\omega t) + \frac{1}{2\pi}\int_{\pi}^{2\pi} 0 \, d(\omega t)}$

$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi} \sin^2\omega t \, d(\omega t)}$

$= \sqrt{\frac{I_m^2}{4\pi}\int_0^{\pi} 2\sin^2\omega t \, d(\omega t)}$

$= \frac{I_m}{2}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1-\cos(2\omega t)\, d(\omega t)}$

$= \frac{I_m}{2}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1 \, d\omega t - \int_0^{\pi}(\cos 2\omega t)\, d\omega t}$

$= \frac{I_m}{2}\sqrt{\frac{1}{\pi}[\pi - 0]}$

$= \frac{I_m}{2} = \underline{0.5 I_m}$

||ly $V_{rms} = V_m/2$

* Ripple Factor (γ)

- Ratio of rms value of ac component of load current to the average value of load current.

Ripple factor $= \frac{\text{r.m.s value of a.c. component}}{\text{value of d.c. component}}$

$= \frac{I_{ac}}{I_{dc}}$

By definition, the effective or r.m.s value of total load current is given by:

or $$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$$

$$I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

Dividing throughout by I_{dc}, we get

$$\frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

But I_{ac}/I_{dc} is the ripple factor

$$\therefore \text{Ripple factor} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$I_{rms} = \frac{I_m}{2}, \quad I_{dc} = \frac{I_m}{\pi}$$

$$\text{Ripple factor} = \sqrt{\left(\frac{I_m \times \pi}{I_m \times 2}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2}{4} - 1}$$

$$= \sqrt{\frac{\pi^2 - 4}{4}} = \frac{\sqrt{\pi^2 - 4}}{2}$$

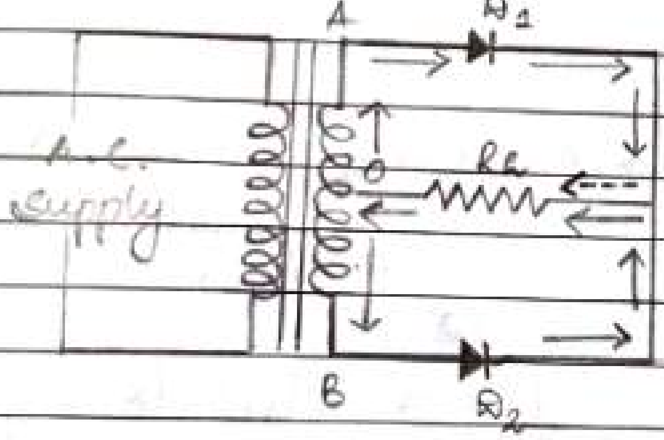
$$= \frac{\sqrt{9.8596 - 4}}{2} = \frac{2.42}{2} = 1.21$$

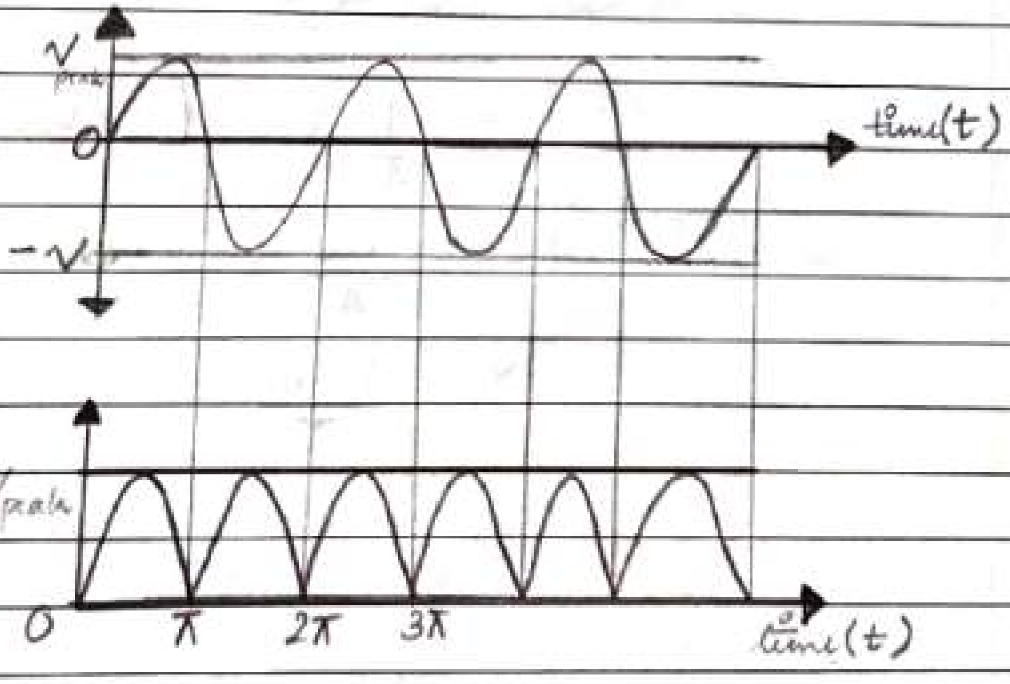
* Voltage regulation

Measure of variation of dc output voltage as a function of dc current.

$$\% \text{ regulation} = \frac{(V_{no\ load} - V_{full\ load}) \times 100}{V_{full\ load}}$$

* Full Wave Rectifier





Average value

$$V_{avg} = \frac{\text{Area under the wave in one cycle}}{\text{base}}$$

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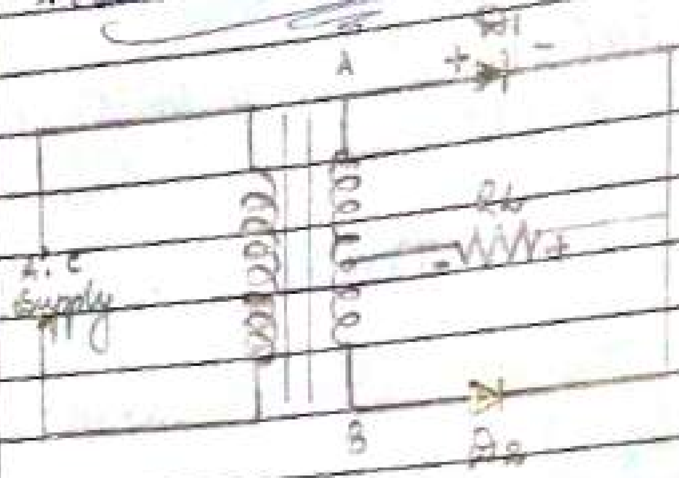
* Peak Inverse Voltage



Applying KVL

$-V_m - V_m - V_D = 0$

$V_D = 2V_m$

$PIV = 2V_m$

* Average value

$$V_{avg} = V_{dc} = \frac{\text{Area under the wave in one cycle}}{\text{base}}$$

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin\theta \, d\theta \quad \{v = V_m \sin\theta$$

$$= \frac{1}{\pi} \times V_m \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{V_m}{\pi}\left[-\cos\pi + \cos 0\right]$$

$$= \frac{2V_m}{\pi}$$

$$V_{dc} = 0.637 V_m$$

∴ Similarly,

$$I_{dc} = \frac{2I_m}{\pi}$$

$$= 0.637 I_m$$

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* RMS value of voltage & current

$$\text{RMS value} = \sqrt{\frac{1}{\pi}\int_0^{\pi}(I_m \sin\omega t)^2 d\omega t + \frac{1}{\pi}\int_{\pi}^{2\pi} 0 \, d\omega t}$$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi} \sin^2\omega t \, d(\omega t)}$$

$$= I_m \sqrt{\frac{1}{2\pi}\int_0^{\pi} 2\sin^2\omega t \, d(\omega t)}$$

$$= \frac{I_m}{\sqrt{2}}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1-\cos(2\omega t) \, d(\omega t)}$$

$$= \frac{I_m}{\sqrt{2}}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1 \, d\omega t - \int_0^{\pi}\cos(2\omega t) d\omega t}$$

$$= \frac{I_m}{\sqrt{2}}\sqrt{\frac{1}{\pi}\times[\pi - 0]}$$

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

Similarly,

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

* Ripple factor

$$R.F = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

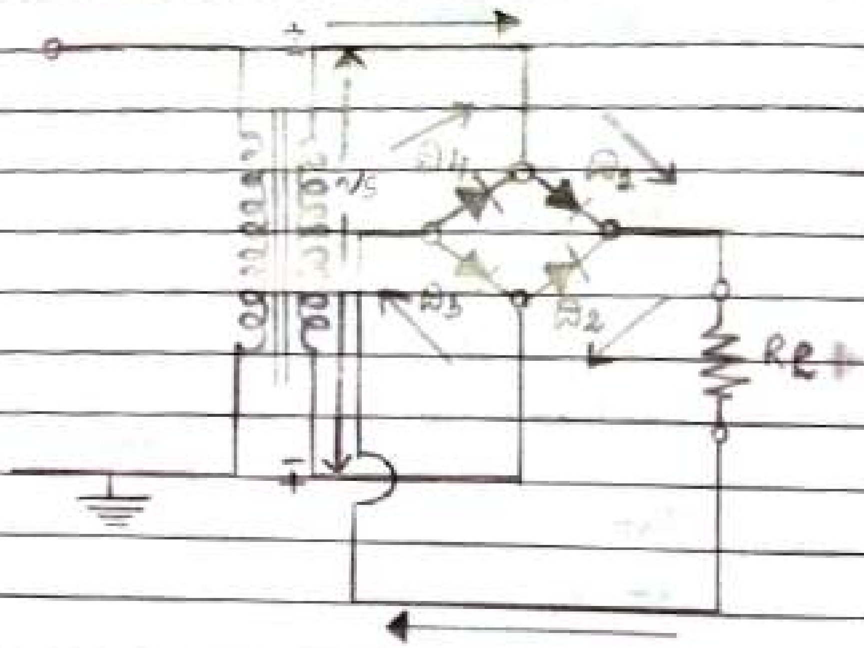
$$= \sqrt{\left(\frac{I_m}{\sqrt{2}} \times \frac{\pi}{2 I_m}\right)^2 - 1}$$

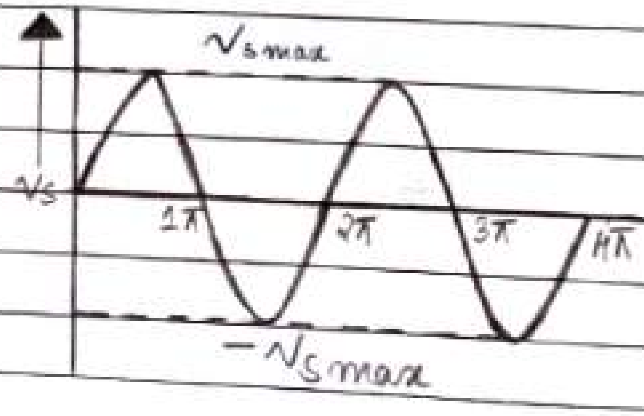
$$= \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2 - 8}{8}} = \frac{1.363}{2\sqrt{2}}$$

$$= \underline{\underline{0.482}}$$

★ Bridge Rectifiers





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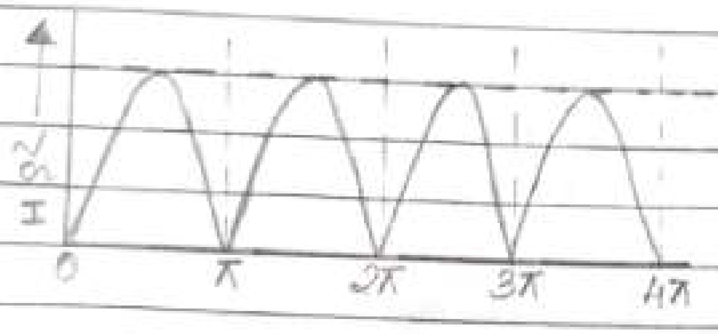
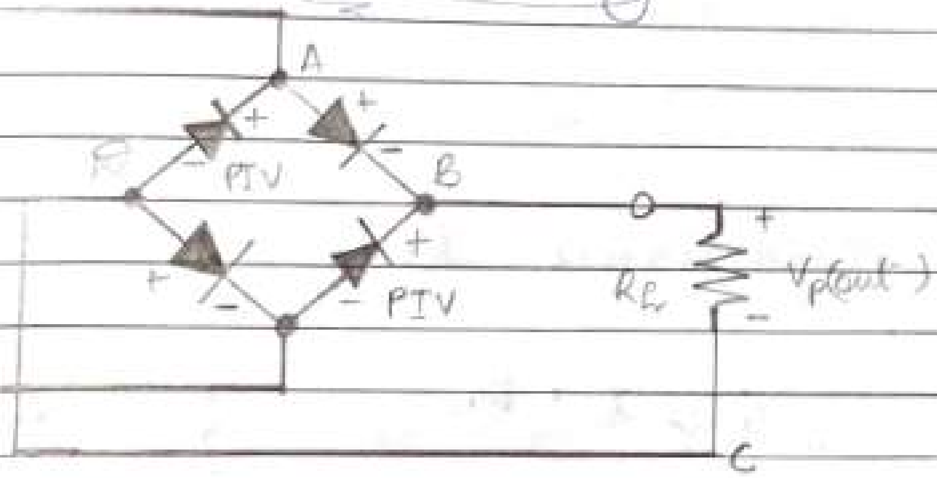
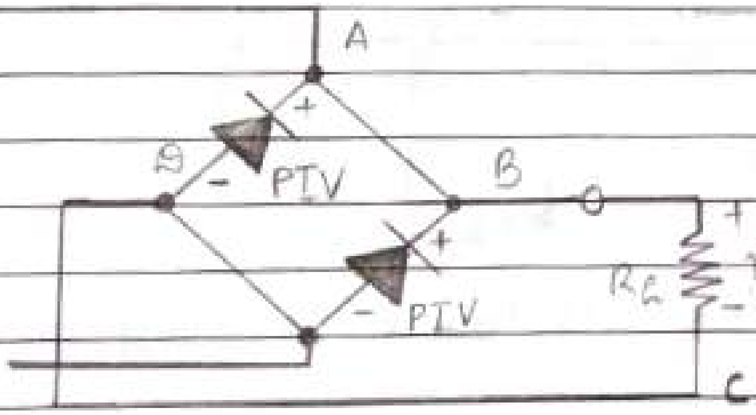


* Peak Inverse Voltage





- Applying KVL

$V_d - V_p = 0$

$V_d = V_p$

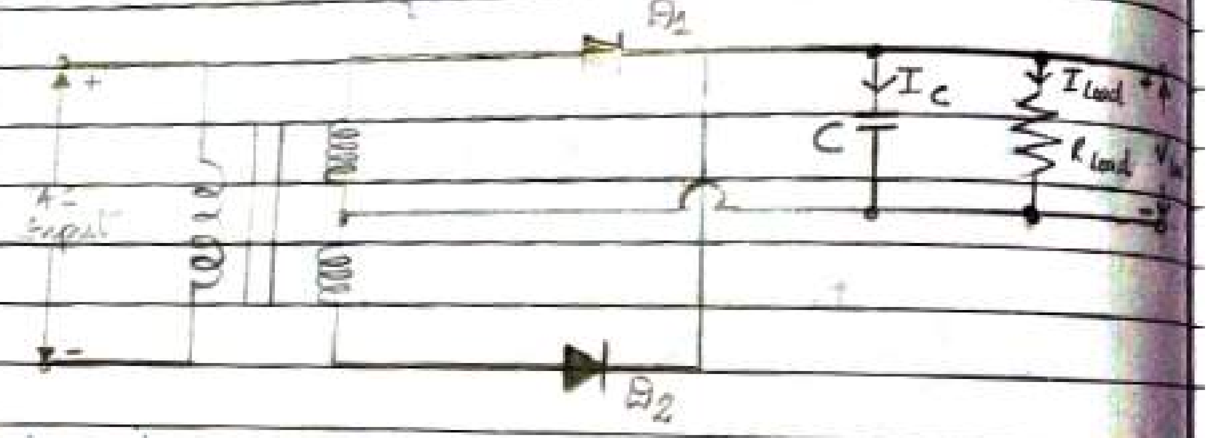
$V_{dm} = V_{pm}$

$PIV = V_{pm}$

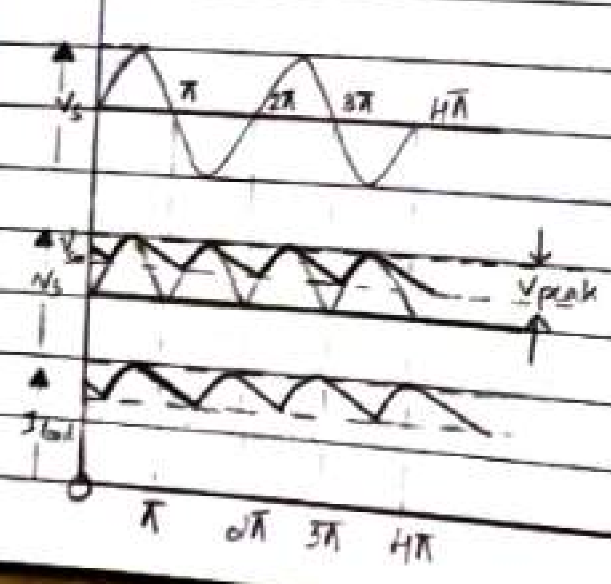
* Filters

- Presence of AC component is the cause of fluctuation - ripple
- A circuit which removes the ripple from the output without affecting DC value
- Shunt capacitance
- Series inductance

* Shunt capacitance filter



- Shunt capacitor reactance is very small than load resistance.



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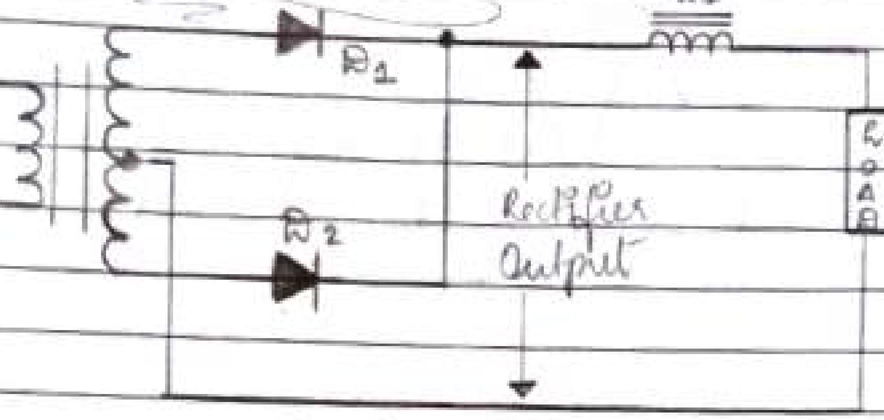
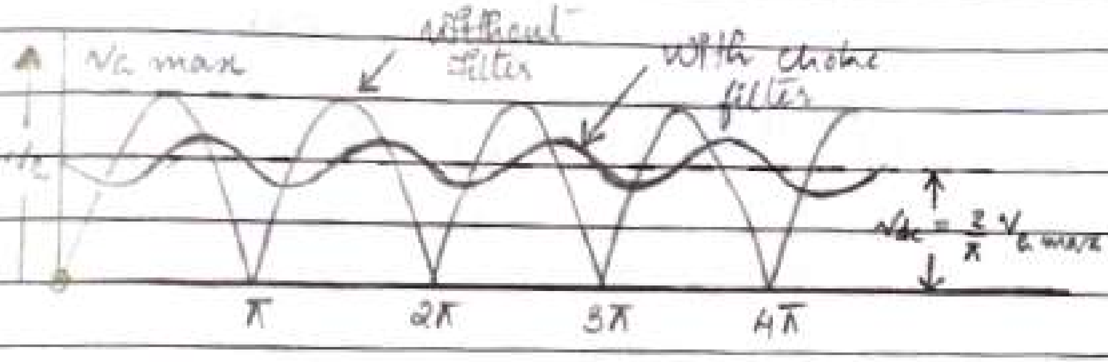
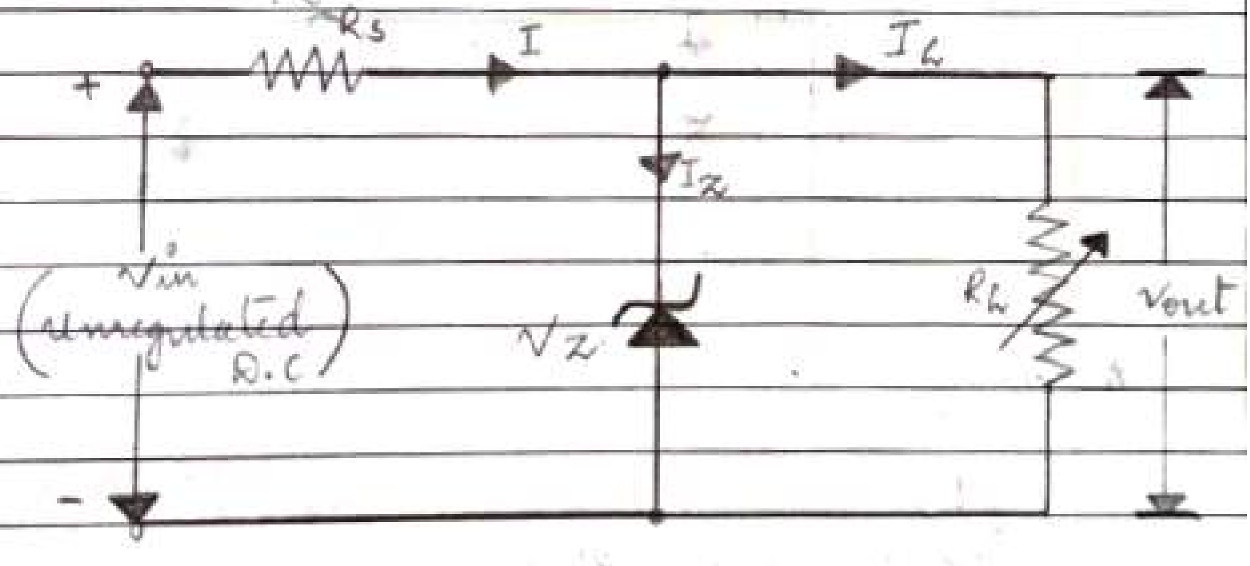
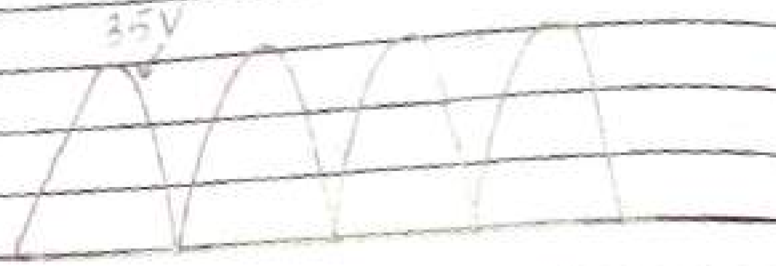
★ Series Inductance Filter

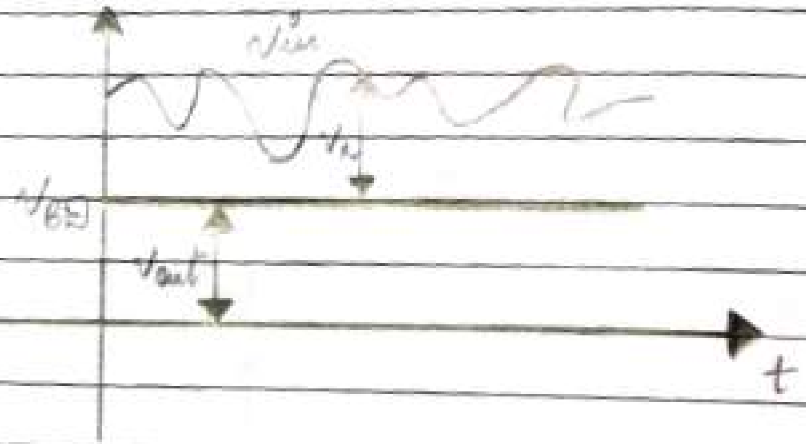




★ Zener Voltage Regulator

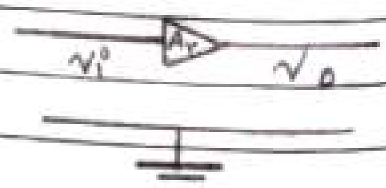


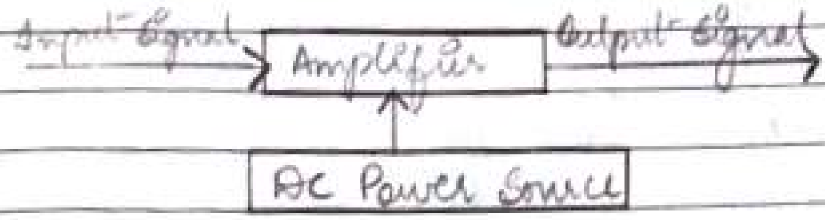




★ **Amplifiers**

- Make the voltage or current of input signal large without changing the shape of signal.
- Output signal must be an exact replica of input signal.
- Earth point





★ Characteristics of amplifiers

- Input resistance : Effective resistance appears across input terminals.
- Output resistance : Effective resistance appears across output terminals.
- Voltage gain : $A_V = V_o/V_i$

$$\text{Voltage gain} = \frac{\text{Output voltage}}{\text{input voltage}}$$

$$A_V = \frac{V_o}{V_i}$$

- Current gain :

$$A_i = \frac{I_o}{I_i}$$

- Power gain :

$$A_p = \frac{P_o}{P_i}$$

★ Decibels

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- unit of gain
- No of bels = $\log_{10} \frac{P_o}{P_i}$
- No of Decibels = $10^{\log_{10}\left(\frac{P_o}{P_i}\right)}$

★ Decibel power gain

$$A_p(dB) = 10 \log_{10} \frac{P_o}{P_i}$$

★ Decibel voltage gain

$$A_v(dB) = 20 \log_{10} \frac{V_o}{V_i}$$

★ Decibel current gain

$$A_i(dB) = 20 \log_{10} \frac{I_o}{I_i}$$

★ Ideal Amplifier

- The amplifiers gain, (A) should remain constant for varying values of input signal.
- Gain is not ~~be~~ affected by frequency. Signals of all frequencies must be amplified by exactly the same amount.
- The amplifiers gain must add noise to the output signal. It should remove any noise that ~~is~~ already exists in

the input signal.

- The amplifiers gain should not be affected by changes in temperature giving good temperature stability.

- The gain of the amplifier must remain stable over long period of time.

- Classification of amplifiers

- Based on inputs

-) Small signal amplifiers

These are designed to amplify very small signal voltage levels of only a few micro-volts (uV) from sensors or audio signals.

-) Large signal amplifiers (audio power amplifiers or power switching amplifiers).

Large signal amplifiers are designed to amplify large input voltage signals or switch heavy load currents as you would find driving loudspeakers.

- Based on biasing condition

-) Class A
-) Class B

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- Class AB
- Class C

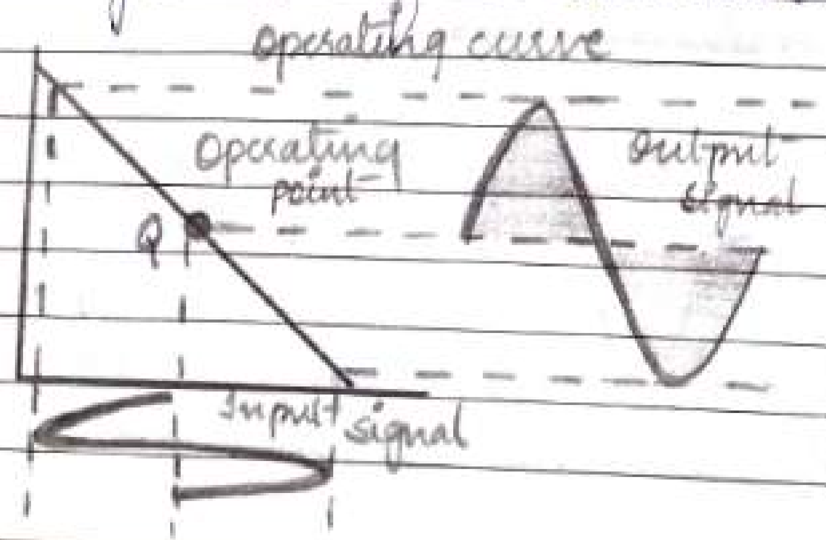
- Class A

- The most commonly used type of power amplifier configuration is the class A amplifier.

- The class A amplifier is the simplest form of power amplifier that uses a single switching transistor in the standard common emitter circuit configuration as seen previously to produce an inverted output.

- The transistor is always biased "ON" so that it conducts during one complete cycle of the input signal waveform producing minimum distortion and maximum amplitude of the output signal.

- Operates over a linear portion of characteristics - Q point at the center of linear portion of characteristics.

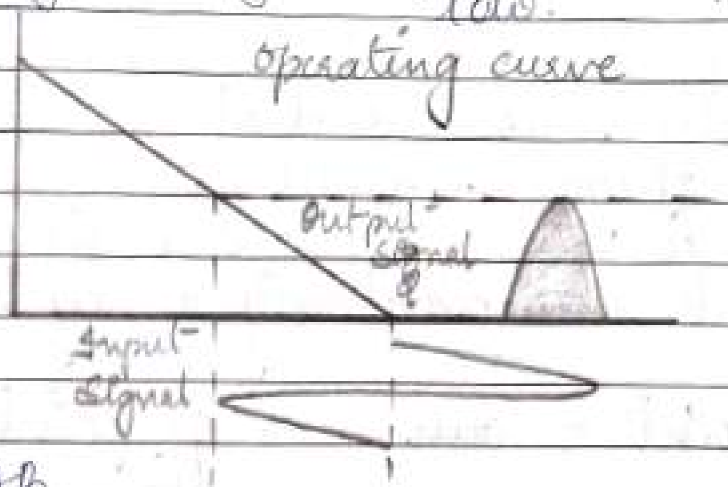


.) Class B

..) Q point is in cut off region.

..) Output current is only for half cycle.

..) Efficiency is high - power dissipation is low.

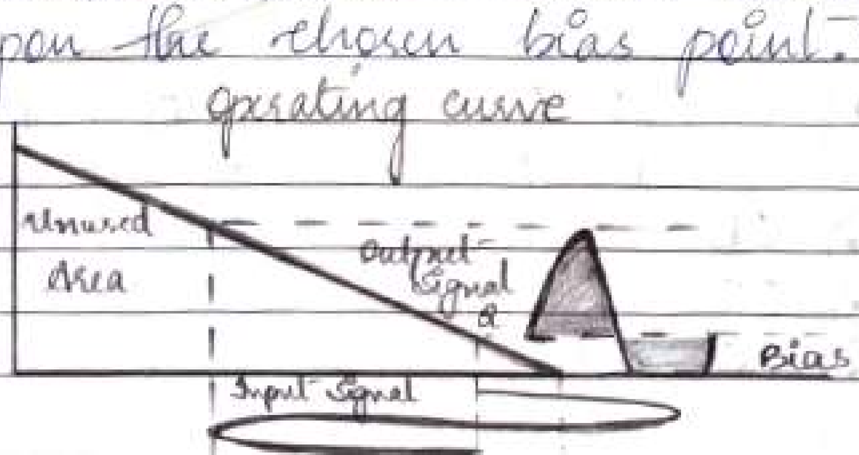


.) Class AB

..) Combination of the "class A" and the "class B" type amplifiers.

..) The AB classification of amplifier is currently one of the most common used types of audio power amplifier design.

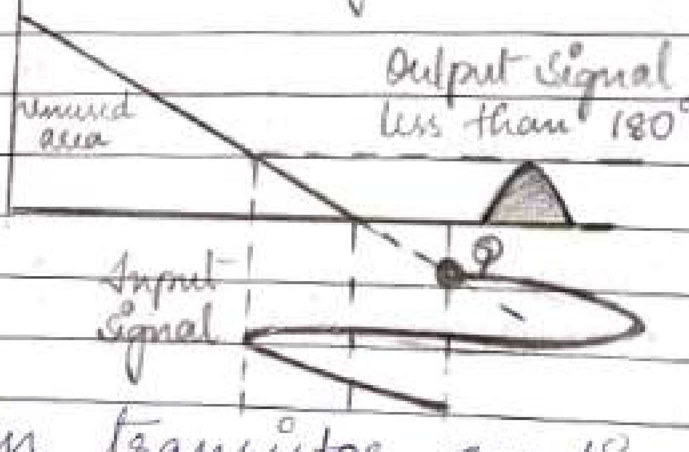
..) Conduction angle of a class AB amplifier is somewhere between 180° and 360° depending upon the chosen bias point.



- Class C

  - Current flow as plu pulses.
  - The greatest efficiency but the poorest lineari-ty.
  - Heavily biased so that the output current is zero for more than one half ~~cycle~~ of an input sinusoidal signal cycle.
  - Q point - ~~cutt~~ cut off point
  - Conduction angle for the transistor is significantly less than 180 degrees.

Operating curve



- Based on transistor configuration

  - CB
  - CE
  - CC

- Based on coupling

  - Resistance - Capacitance coupling

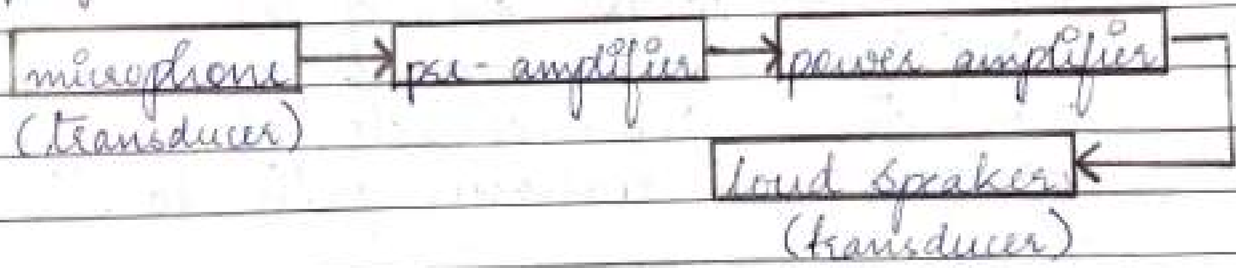
    Individual stages of the amplifier are connected together using a resistor-capacitor combination.

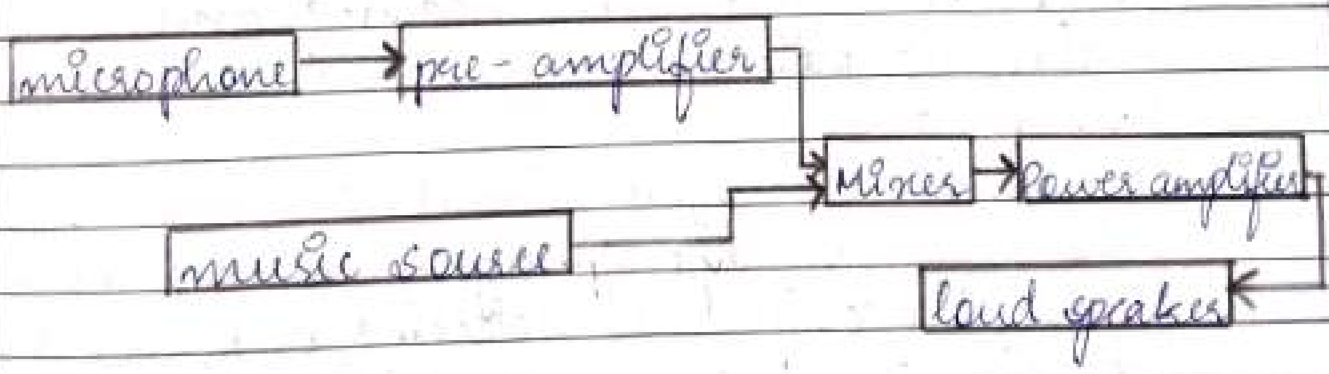
  - Transformer coupling - impedance matching

  - Direct coupling

- Public Address System

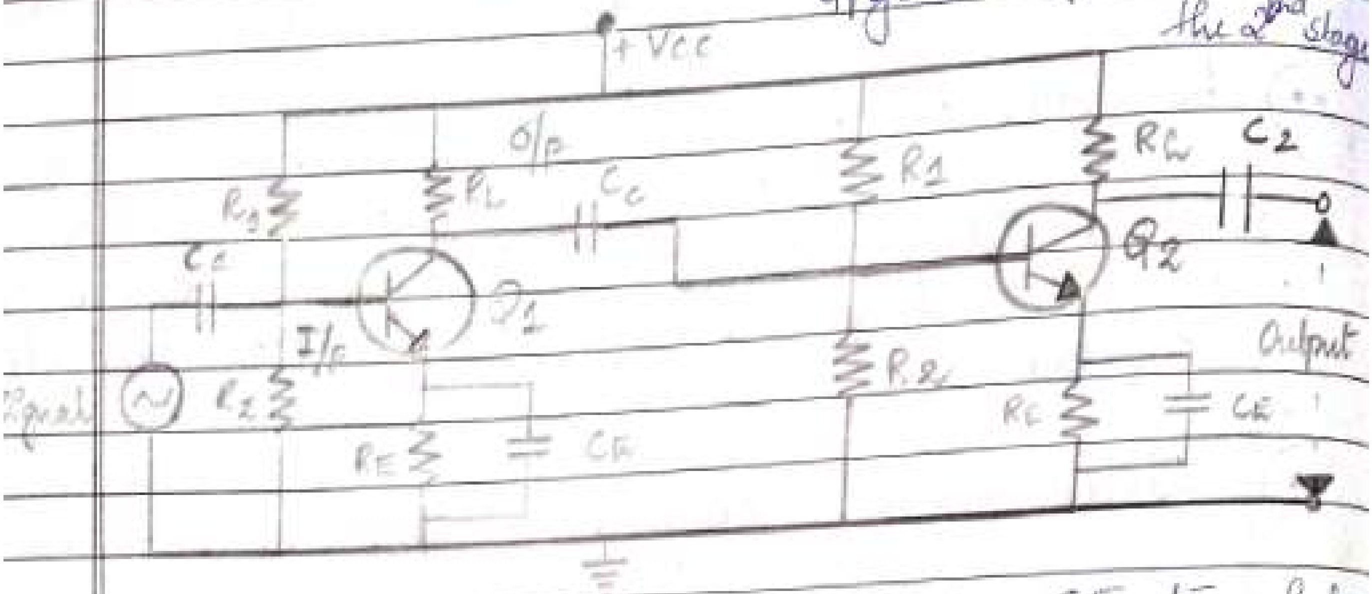
  System that amplifies sound, so more people can hear it.





- RC Coupled Transistor Amplifiers

Q_1 gives $180°$ phase shift to the 2^{nd} stage



Construction: 2 single stage CE transistor amplifier.

Specification:

CE amplifier : invert amplifier

C_C (coupling capacitor) : connects 1^{st} and 2^{nd} stage.

C_1 : input coupling capacitor used to couple input signal to the base of Q_1.

C_2 : Output coupling capacitor used to couple output signal from collector to load.

C_E : gives low reactance path to the emitter signal.

R_1, R_2, R_E : give proper biasing and stablization to network.

Working:

when an input signal is passed through C_1 it couples the i/p signal to the base Q_1. Then the output is collected by R_L and given to the coupling capacitor (C_c). This is then converted to the input signal of the 2^{nd} stage. Hence the ~~ouptput~~ output recieved at R_L is passed through the C_2, which couples the o/p from collector to the load.

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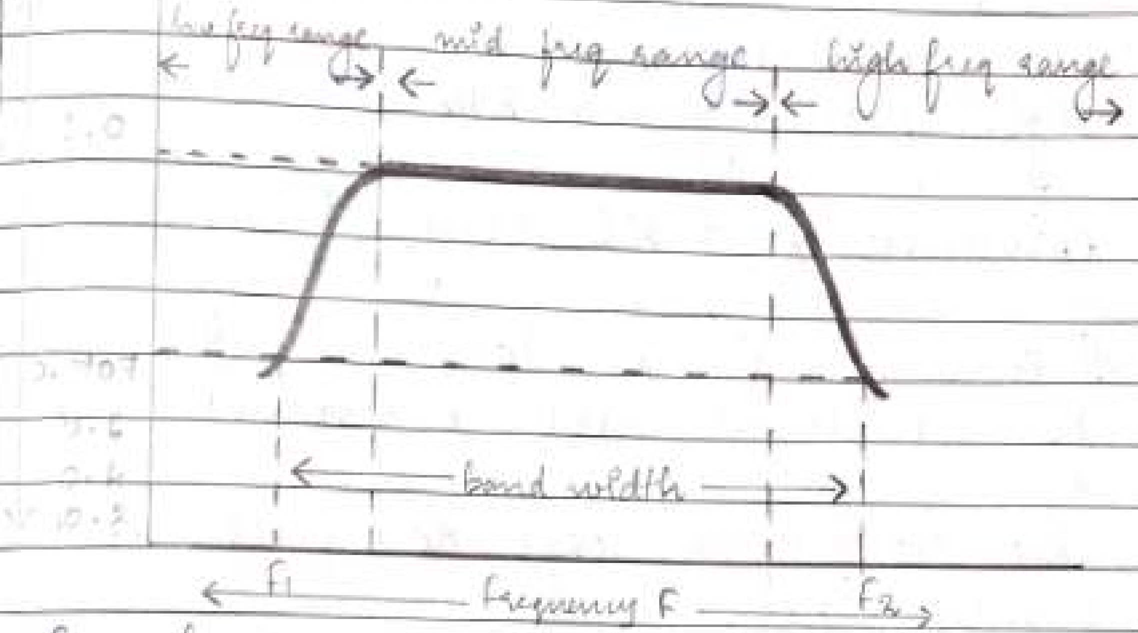
Frequency Response of RC coupled amplifier



Low frequency region : low gain

* Cc in series; Impedence is considered

$$X_C = \frac{1}{\omega C}$$

$$= \frac{1}{2\pi F C} \qquad \{\omega = 2\pi F\}$$

* As F increases gain increases.

High Frequency Region : high gain

* Impedence low
* Capacitor acts as a short circuit
* Output voltage ↓ses gain ↑ses

* Cut off frequency is used to choose the band width.

Lower frequency : F_1
Higher frequency : F_2

* band width : $f_2 - f_1$

* half power point - $\frac{1}{\sqrt{2}}$ = 3dB point

Lower frequency = 50 Hz
Higher frequency = 20 KHz

Advantages of RC coupled amplifier

* It used the resistor and the capacitor which are not expensive so the cost is low.
* The circuit is very compact and extremly light.
* The frequency responce of RC coupled amplifier is excellent.
* It offers a constant gain over a wide frequency band.

Disadvantages of RC coupled amplifier

* It has low voltage and power gain.
* It is unsuitable for low frequency application.
* It has poor impedence matching because its output impedence is several times larger than the device, at its end terminals.
* It has the tendency to become noisy with times.
* It has narrow bandwidth.

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Transistor Biasing

- DC biasing is a static operation.
- Bias establishes the DC operating point for proper operation of an amplifier.

Modes	EBJ	CBJ	Applications
Cutoff	Reverse	Reverse	Switching applications in
Saturation	Forward	Forward	digital circuits
Active	Forward	Reverse	Amplifier
Reverse active	Reverse	Forward	Performance degradation.

Voltage Divider Biasing

- The operating point Q is independent of beta - Good stabilization.
- Beta depends on doping concentration.

Electronic Instrumentation System

* Measurement

The process of determining the am-
-ount, degree or capacity by compari-
-son with the accepted standards of
the system units being used.

* Electronic Instrument

It is a device for determining the value or magnitude of a quantity or variable such as voltage, current or resistance.

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Performance Parameters

Accuracy

It is the degree of closeness with which the instrument reading approaches the true value of the quantity to be measured.

Precision

It is a measure of consistency or repeatability of measurement. This means when a quantity is measured repeatedly, the instrument should give the same value i.e, successive readings do not differ.

Resolution

The smallest change in a measurement variable to which an instrument will respond.

Sensitivity

It is the ratio of change in the output (response) of the instrument to a change of input or measured variable.

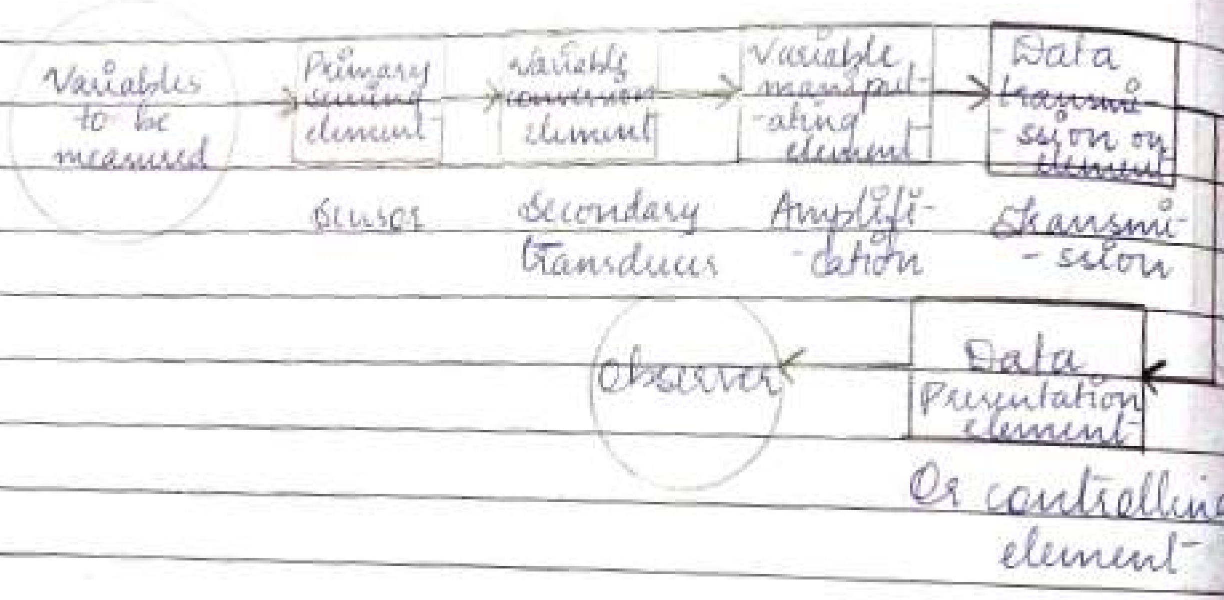
Expected Value

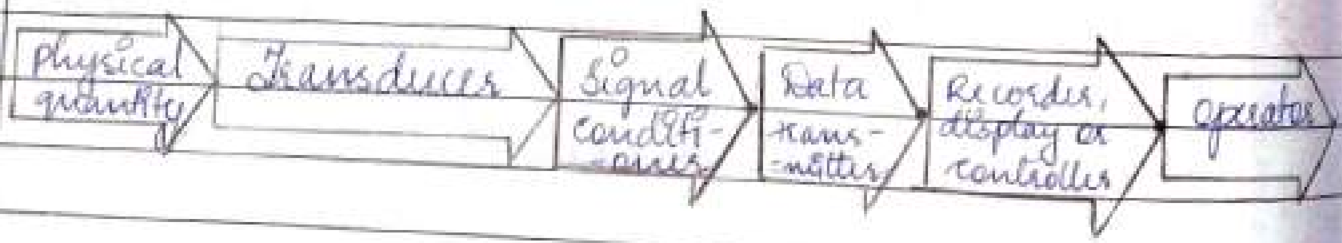
It is the desired value of measured quantity or the most probable value that is expected to obtain.

Errors

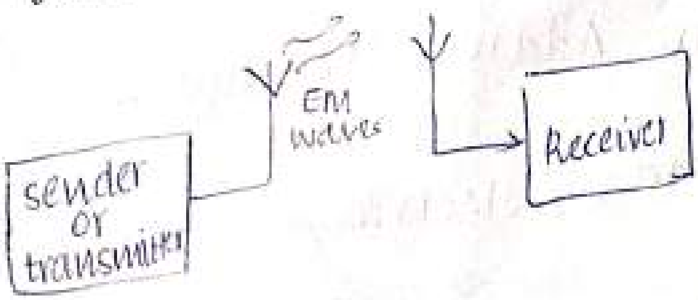
It is the derivation of the true value from the desired value.

Electronic Instrumentation System





Electronic communication



Modulation

changing amplitude, frequency, phase of carrier wave

- Base band signal will be enclosed in carrier
  messages are usually in low freq. (20 Hz – 3 kHz)

Need for modulation

(i) $E = h\nu$
when ν is ↓, E ↓
modulation is done to high freq.

(ii) Radiation is efficient only at high freq.

(iii) radiation can only be done with antennae
if no modulation, then l will be ↑
low freq. is modulated with high freq.
Thus freq., amplitude, phase of carrier wave is changed to that of modulating wave

freq. change → frequency modulation

amplitude change → amplitude modulation

so if f ↑, $\lambda = \frac{c}{f}$ so λ will be less

$\lambda/4$: quarter wave antennas

antennae height should be less

all freq. we use lie in same band. so frequency gets mixed
when different freq. is used for modulation, they will never mix so lie in diff. freq.
so receiver can tune in station they wish

$v_c = V_c \sin(\omega_c t + \phi)$

V_c : peak value (amplitude)

ϕ_c : phase

v_c : voltage of carrier

Analog modulation/continuous wave modulation

2 types

Amplitude modulation (AM)

Angle modulation

(a) Frequency modulation (FM)

(b) Phase modulation (PM)

Digital modulation

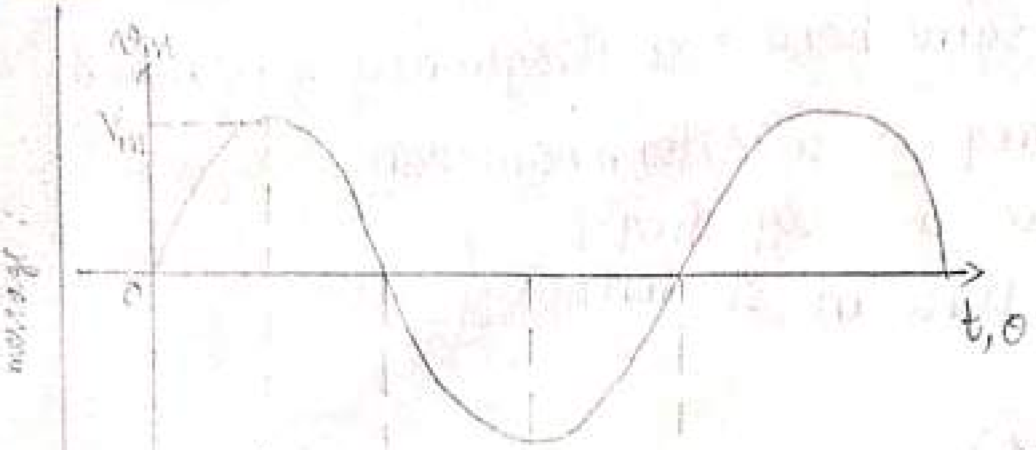
(i) ASK : amplitude shift keying

(ii) FSK : Frequency shift keying

(iii) PSK : phase shift keying

Amplitude modulation

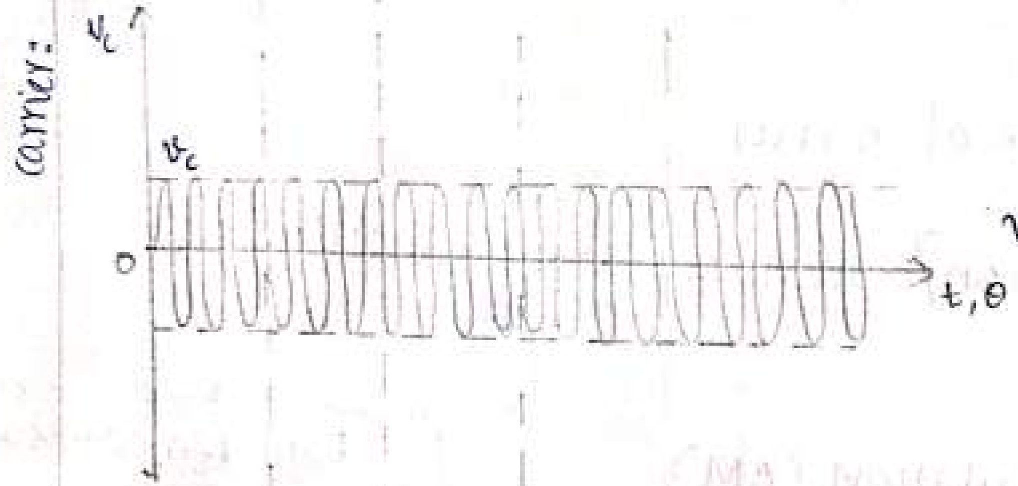
In process of amplitude modulation, instantaneous amplitude of high frequency carrier wave is varied in proportion to the instantaneous amplitude of the message voltage value, keeping frequency and phase of carrier wave a constant.



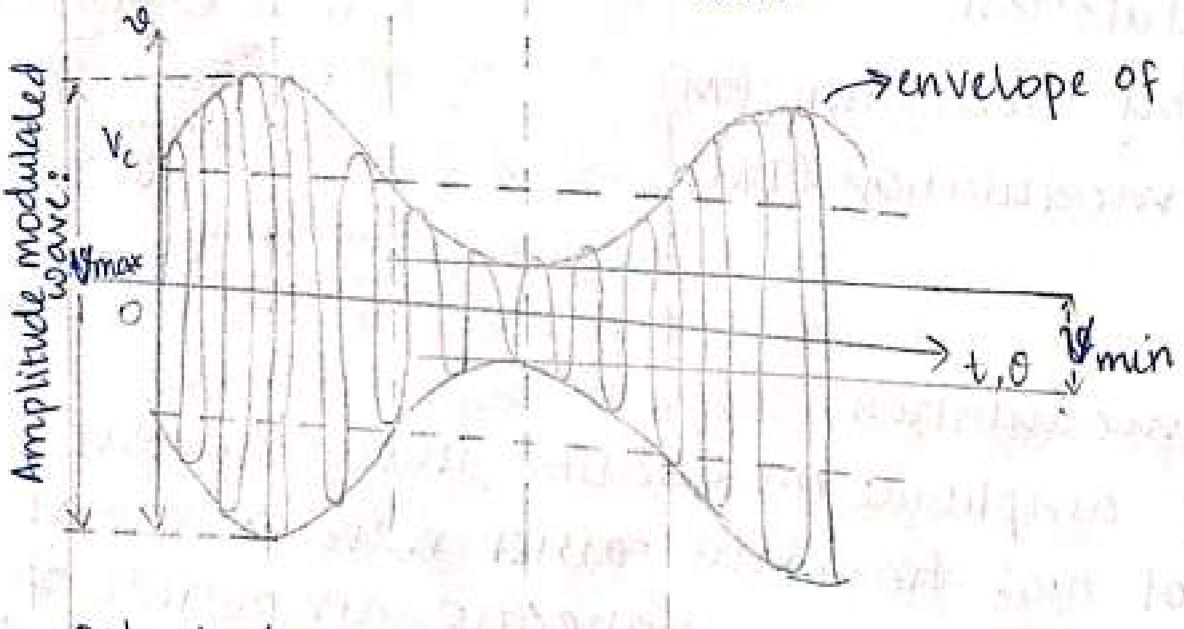
v_m: message or modulating voltage

$\omega_m = 2\pi f_m$

$v_m = V_m \sin \omega_m t$ —(1)



$v_c = V_c \sin \omega_c t$ —(1)



- only instrument which display electrical waveform is CRO
- AM index : also called depth of A.M.

$$m = \frac{V_m}{V_c}$$

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \qquad 0 \leq m \leq 1$$

when message wave voltage is 0, $m = 0$

when $m = 1$, $V_m = V_c$

when $m > 1$, no signal is received by receiver

This is called over modulation distortion

happens when message amplitude overlaps carrier amplitude

$$v_m = V_m \sin \omega_m t \quad \text{—(1)}$$

$$v_c = V_c \sin \omega_c t \quad \text{—(2)}$$

AM wave is,

$$v = A \sin \omega_c t$$

where $A = V_c + v_m$

$$A = V_c + V_m \sin \omega_m t$$

UDSF GECT

$$v = (V_c + V_m \sin \omega_m t) \sin \omega_c t$$

$$v = \underbrace{V_c \sin \omega_c t}_{\text{full carrier}} + V_m \sin \omega_m t \sin \omega_c t$$

$\sin A \sin B = \frac{1}{2}[\cos(A-B) - \cos(A+B)]$

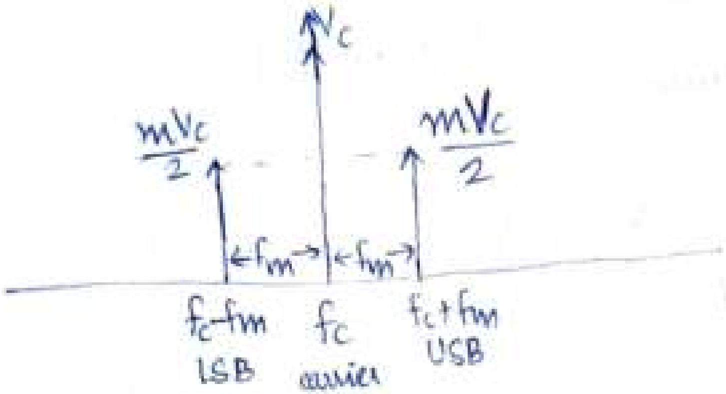
$$v = V_c \sin \omega_c t + \frac{V_m}{2} \cos(\omega_c - \omega_m)t - \frac{V_m}{2} \cos(\omega_c + \omega_m)t$$

$$m = \frac{V_m}{V_c} \qquad \therefore V_m = mV_c$$

$$v = \underbrace{V_c \sin \omega_c t}_{\text{Full carrier}} + \underbrace{\frac{mV_c}{2} \cos(\omega_c - \omega_m)t}_{\text{LSB}} - \underbrace{\frac{mV_c}{2} \cos(\omega_c + \omega_m)t}_{\text{USB}}$$

LSB : lower side band

USB : upper side band



Bandwidth of AM = $2 \times f_m$

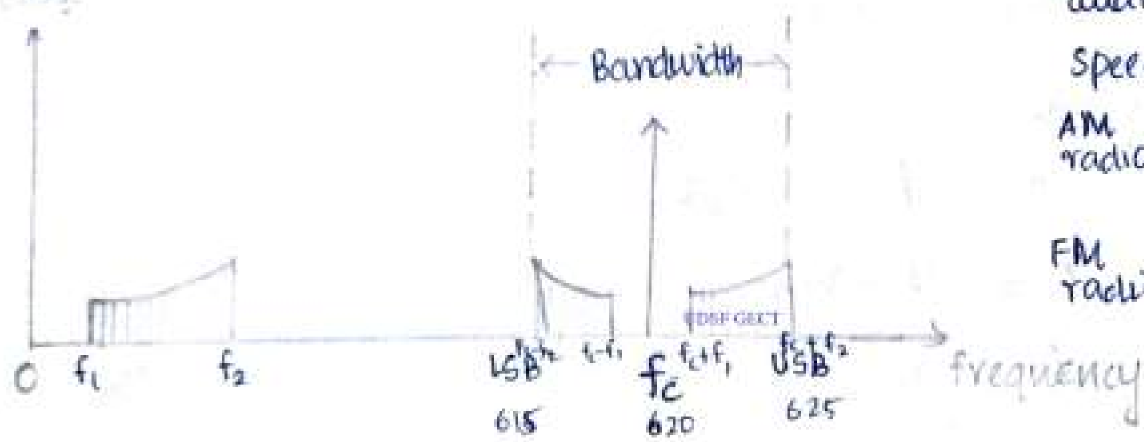
Frequency spectrum of AM when modulated by a base band of f_1 to f_2

audio : 20 Hz – 20 kHz

Speech : 20 Hz – 3 kHz

AM radio : 20 Hz to 5 kHz (f_1, f_2)

FM radio : 20 Hz to 15 kHz



DSB - FC

Bandwidth = $2 \times f_2$ = $2 \times$ highest modulating frequency

- For different voltages $v_1, v_2, v_3 \dots v_n$, modulation index will be $m_1, m_2, m_3 \dots m_n$

Then, $m_{effective} = \sqrt{m_1^2 + m_2^2 + m_3^2 \dots + m_n^2}$

Power in A.M.

$v = V \sin \omega t$

$$P = \frac{\left(\frac{V}{\sqrt{2}}\right)^2}{R}$$

$$v = \underbrace{V_c \sin \omega_c t}_{\text{carrier}} + \underbrace{\frac{mV_c}{2} \cos(\omega_c - \omega_m)t}_{\text{LSB}} - \underbrace{\frac{mV_c}{2} \cos(\omega_c + \omega_m)t}_{\text{USB}}$$

$$P_t = P_c + P_{LSB} + P_{USB}$$

$$P_c = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{V_c^2}{2R}$$

$$P_{LSB} = \frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R} = \frac{m^2 V_c^2}{8R}$$

$$P_{USB} = \frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R} = \frac{m^2 V_c^2}{8R}$$

$\therefore$ Total power,

$$P_t = \frac{V_c^2}{2R} + \frac{m^2 V_c^2}{8R} + \frac{m^2 V_c^2}{8R}$$

$$= \frac{V_c^2}{2R} + \frac{m^2 V_c^2}{4R}$$

$$\boxed{P_t = \frac{V_c^2}{2R}\left[1 + \frac{m^2}{2}\right]}$$

$$\boxed{P_t = P_c\left[1 + \frac{m^2}{2}\right]}$$

* Calculate total power transmitted from an ordinary AM radio transmitter whose carrier frequency is 800kHz at 100W power and modulated to a depth of
(i) 0%. (ii) 10%. (iii) 50%. (iv) 100%.

→ Ans $f_c = 500\ kHz$

$P_c = 100\ W$

(i) $P_{t_1} = P_c\left(1 + \frac{m^2}{2}\right)$ given $m = 0$

$P_{t_1} = 100\ (1+0)$

$P_{t_1} = 100\ W$

(ii) $P_{t_2} = P_c\left(1 + \frac{m^2}{2}\right)$ $m = \frac{10}{100}$

$= 100 \times \left(1 + \frac{1}{200}\right)$

$= 100 \times \frac{201}{200} = 100.5\ W$

(iii) $P_{t_3} = P_c\left(1 + \frac{m^2}{2}\right)$ $m = \frac{50}{100} = \frac{1}{2}$

$= 100\left(1 + \frac{1}{8}\right)$

$= 100 \times \frac{9}{8} = 112.5\ W$

(iv) $P_{t_4} = P_c\left(1 + \frac{m^2}{2}\right)$ $m = \frac{100}{100} = 1$

$= 100\ \left(1 + \frac{1}{2}\right)$

$= \cancel{100}^{50} \times \frac{3}{\cancel{2}} = 150\ W$

Balanced modulation

carrier wave will be zero

- Therefore, only LSB and USB will be there

DSB – SC

- Here same signal is send twice.
- So a filter is used.
- Filter will select either LSB or USB.
- This is called Single side band (SSB).
  SSB has only one band.
- When bandwidth is less, we can save power and we can include more channels.

Disadvantages of SSB

- High cost
- some information may be cut

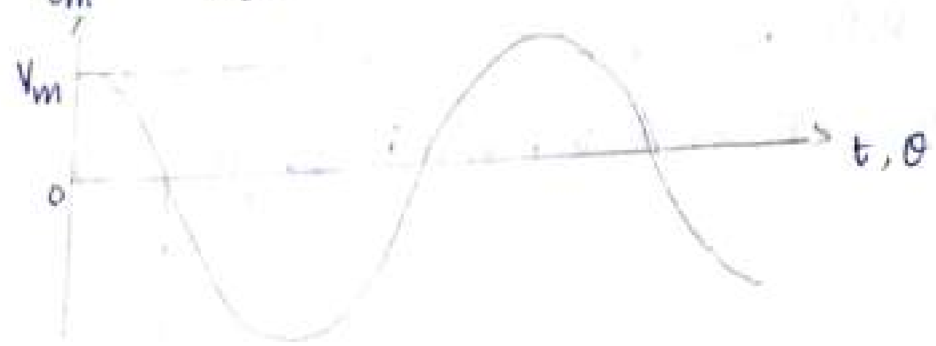
HAM : Hobby amateurs

→ In T.V., U.S.B + a part of L.S.B is used for signal.
This is called vestigial side band
vestige

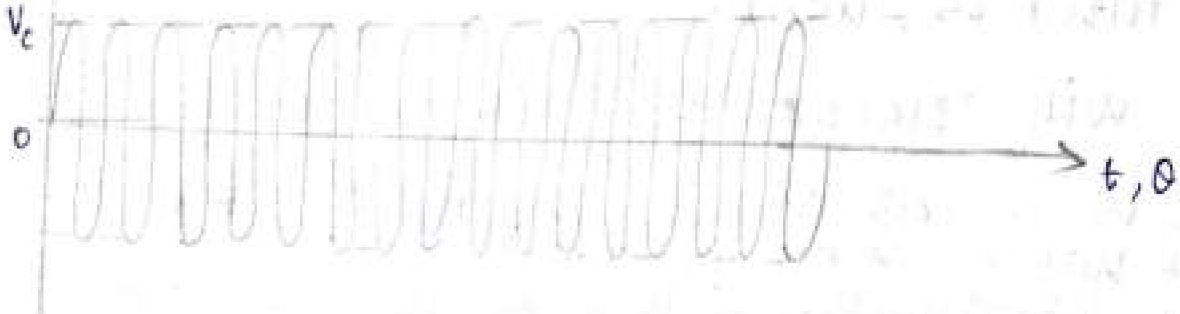
Frequency modulation (FM)

- In the process of frequency modulation, the instantaneous frequency of a high frequency carrier is varied in proportion to the instantaneous amplitude of the message/modulating voltage, keeping the amplitude and phase of the carrier a constant.

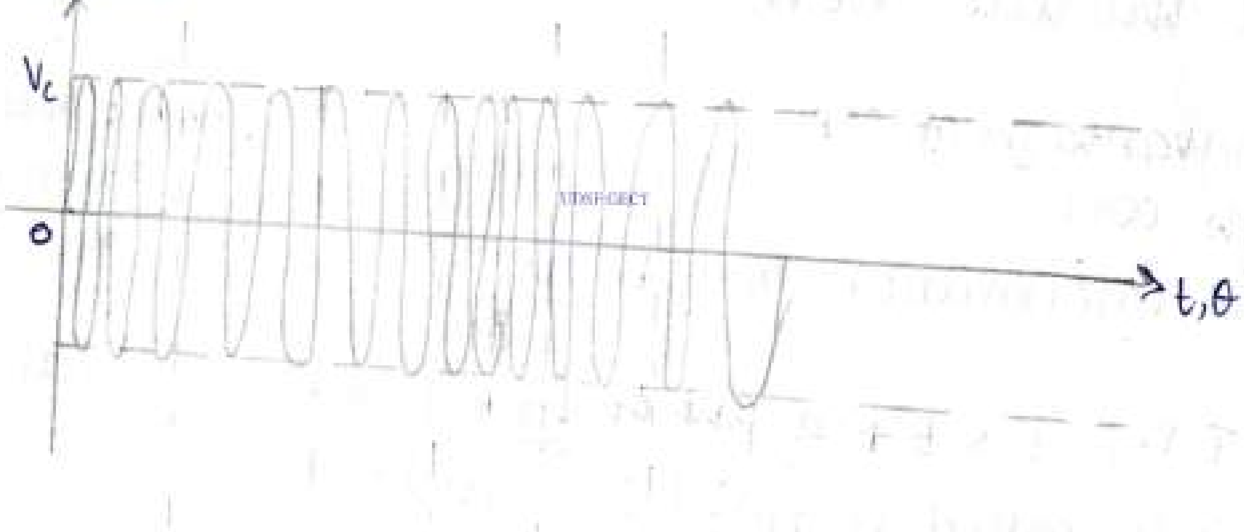
message or modulating signal
v_m



v_c carrier



FM wave



- message signal is $v_m = V_m \cos \omega_m t$ —(i)
- carrier signal is $v_c = V_c \cos \omega_c t$ —(ii)

  $f = f_c + k v_m f_c$; frequency deviation
- FM wave is $v = V_c \sin \theta$ —(iii)

  $\theta = \int \omega \, dt$

  $\omega = \omega_c + k\omega_c V_m \cos \omega_m t$

$$\theta = \int [\omega_c + k\omega_c V_m \cos \omega_m t] \cdot dt$$

$$\theta = \omega_c t + \frac{k\omega_c V_m \sin \omega_m t}{\omega_m}$$

$$\theta = \omega_c t + \frac{(k f_c V_m)}{f_m} \sin \omega_m t$$

$$\boxed{\theta = \omega_c t + \frac{\delta}{f_m} \sin \omega_m t} \rightarrow (A)$$

Maximum frequency deviation,

$$\boxed{\delta = k V_m f_c}$$

$$m_f = \frac{\delta}{f_m}$$

$\boxed{\frac{\delta}{f_m} = \text{modulation index of FM wave}}$

$$\text{FM index} = \frac{\text{Max. freq. deviation}}{\text{modulating frequency}}$$

compare m of AM and FM

AM	FM
• $m = \frac{V_m}{V_c}$ • $0 \leq m \leq 1$	• $m_f = \frac{\delta}{f_m} = \frac{k f_c V_m}{f_m}$ • $m_f > 0$ • If $m_f < 1$, it is called narrow band F.M. → used for point to point communication • If $m_f > 1$, wide band F.M. → used for music, radio broadcasting

$\therefore$ (A) $\Rightarrow$

$$\theta = \omega_c t + m_f \sin \omega_m t$$

FM wave is,

$$v = V_c \sin(\omega_c t + m_f \sin \omega_m t)$$

Bessel function : sine of sine wave

* A wave is defined as $v = 10 \sin(10^8 t + 8 \sin 300t)$
Estimate amplitude, frequency of carrier, m_f, max. freq. deviation and modulating frequency

$\cancel{V_c = 10}$ $\cancel{\omega_c = 10^8}$

$\rightarrow$

$$v = 10 \sin(10^8 t + 8 \sin 300t)\ V$$

$$v = V_c \sin(\omega t + m_f \sin \omega_m t)$$

$V_c = 10\ V$

$\omega_c = 10^8 \Rightarrow f_c = \dfrac{10^8}{2\pi} = 1.59 \times 10^7\ Hz = \underline{15.9\ MHz}$

$m_f = 8$

$\cancel{\dfrac{\delta}{f_m} = m_f}$ $\quad \omega_m = 300$

$\cancel{\delta = m_f \times f_m}$ $\quad f_m = \dfrac{300}{2\pi} = \underline{47.7}\ Hz$

$$\frac{\delta}{f_m} = m_f$$

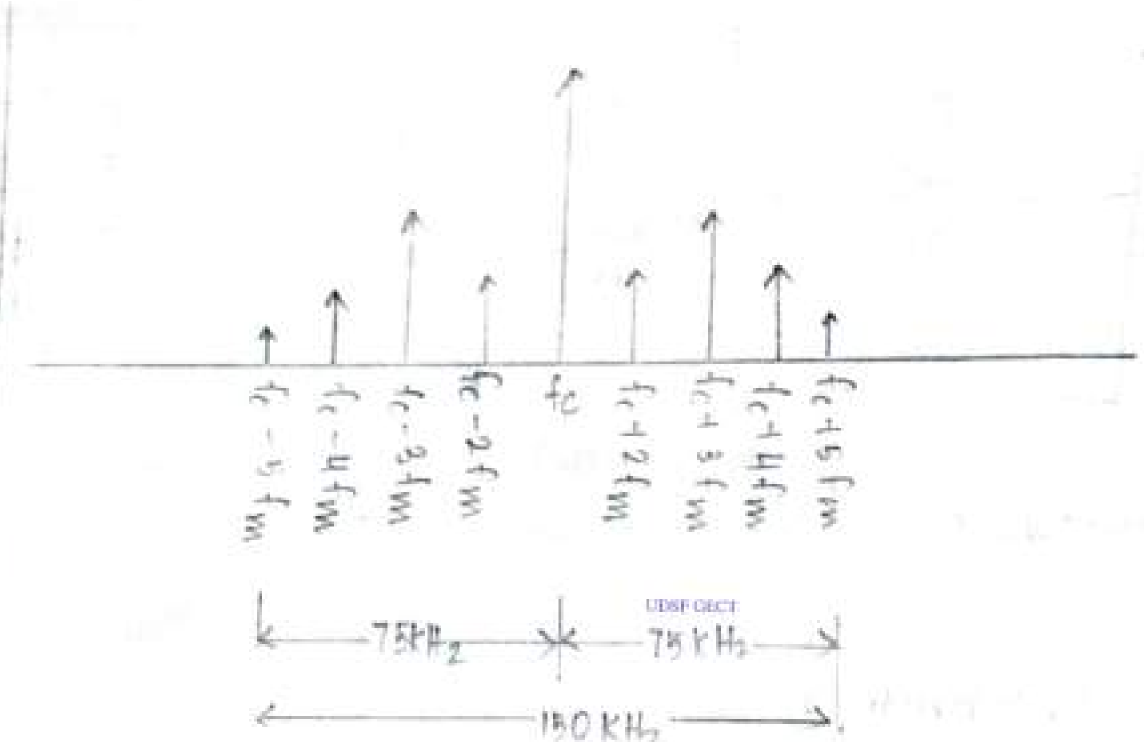
$$\delta = 47.7\ Hz \times 8 = 381.6\ Hz$$

- $v = V_c \sin(\omega_c t + m_f \sin \omega_m$ ...

Bessel function.

$$= I_0 \sin \omega_c t \pm I_1 \sin(\omega_c \pm \omega_m)t$$
$$\pm I_2 \sin(\omega_c \pm 2\omega_m)t$$
$$\pm I_3 \sin(\omega_c \pm 3\omega_m)t$$

$I_0, I \ldots \Rightarrow$ Jacobians. varies for all m_f, f_m



Comparison of FM and AM

- FM $\Rightarrow$ highly quality because FM is highly noise immune (amplitude is constant $\Rightarrow$ noise is clipped)
  - $\Rightarrow$ carrier wave is of high frequency range, Thus, noise do not get in it
  - $\Rightarrow$ all power is useful $\rightarrow$ signals can be taken out
  - $\Rightarrow$ Frequency re-usage $\rightarrow$ FM Freq. range 30 MHz – 300 MHz

frequency do not go out of LOS (line of sight), thus frequencies won't interfere

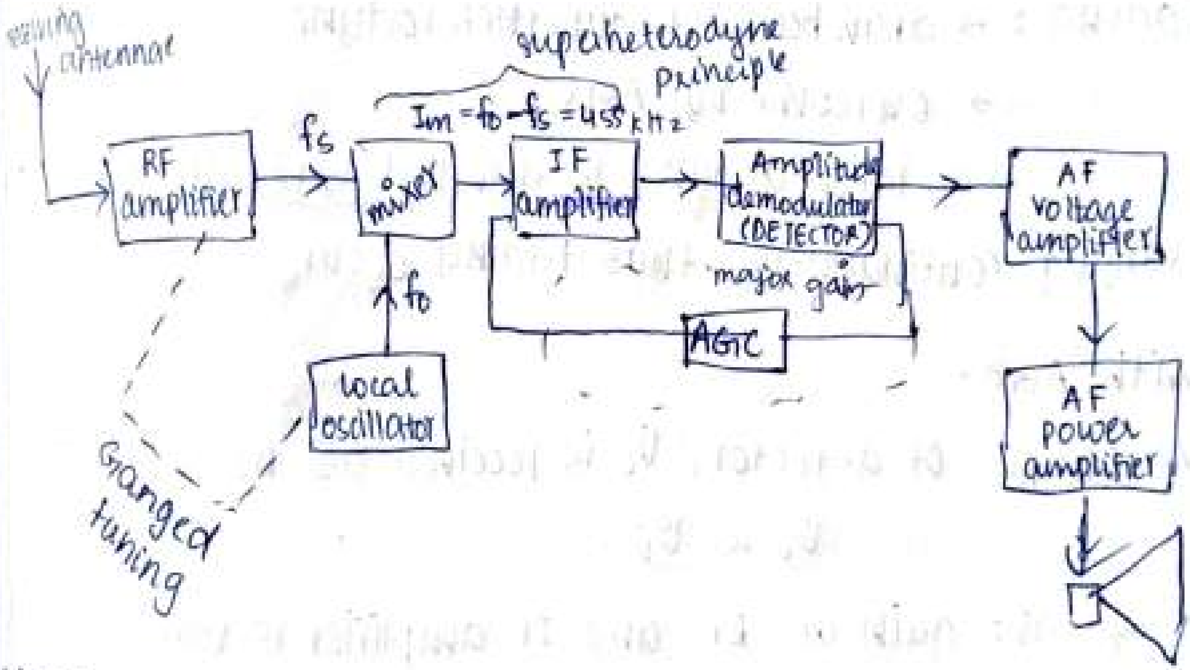
∴ same frequencies can be FM (reused) without interference

FM. Fidelity ↑ → quality high

Limitation :
· high bandwidth
∴ amplifying circuits are complicated
∴ stations ↓

→ space wave propogation : Range of distance from antenna to station

Super heterodyne AM radio receiver
(mix)



· Receiving antennae : based on principle of Faraday's law of EMI

· AM → medium wave 620 - 1650 kHz
short wave 1650 kHz - 3 MHz } Band
10 kHz : bandwidth

FM → 88 MHz - 108 MHz ; band
150 kHz : bandwidth

- Mixer (local oscillator) : IM : $f_0' - f_s$ => intermediate frequency

  $f_0 - f_s$ is constant

  AM → $f_0 - f_s = 455$ kHz

  FM → $f_0 - f_s = 10.7$ MHz

- Audio frequency voltage amplifier → gain in this stage changes (voltage)

  $v_0 = A v_i$ => if fluctuates, then output also varies

  ∴ as $v_i \uparrow$, A should be decreased => v_0 become steady

  This reducing A is called Automatic gain control [AGC]

- Fading : → drawback of superheterodyne
  → overcome by AGC
  → as large distance is travelled, intensities are varying continuously, thus fading occur

- With AGC:

  At output of detector, v_0 is received as DC level

  $$v_0 \propto v_i$$

  ∴ The gain of RF and IF amplifier is varied

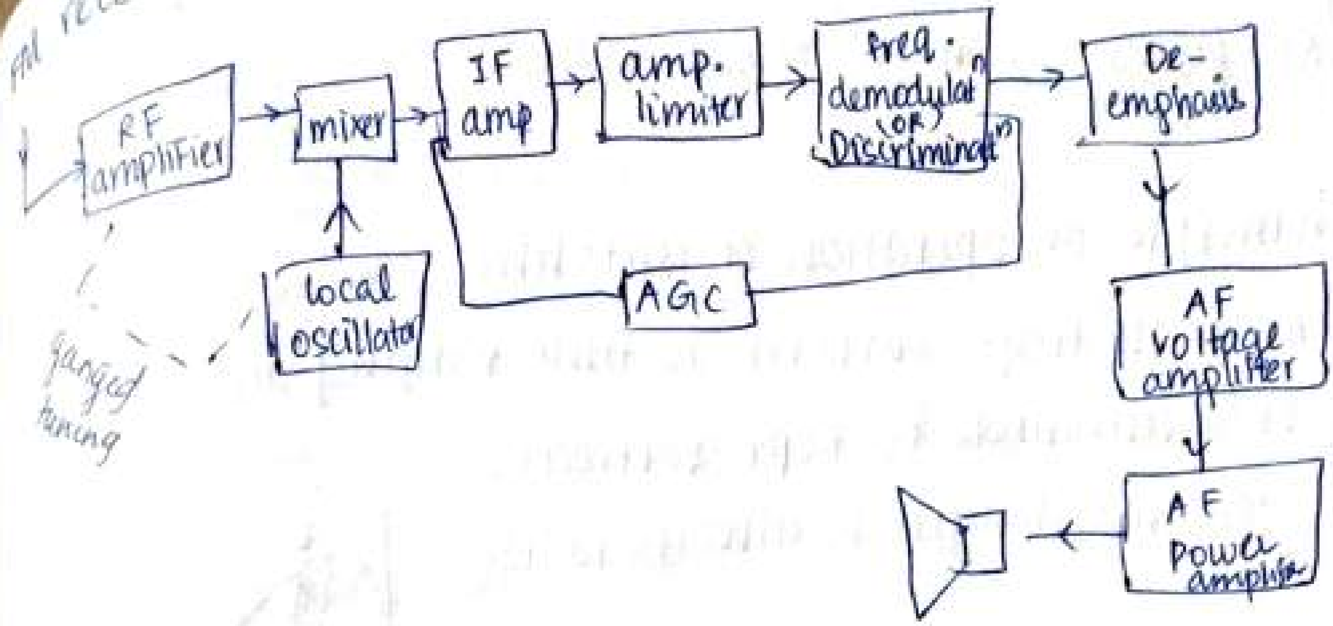
  → as $v_i \uparrow$, A is $\downarrow$

  → automatic gain control

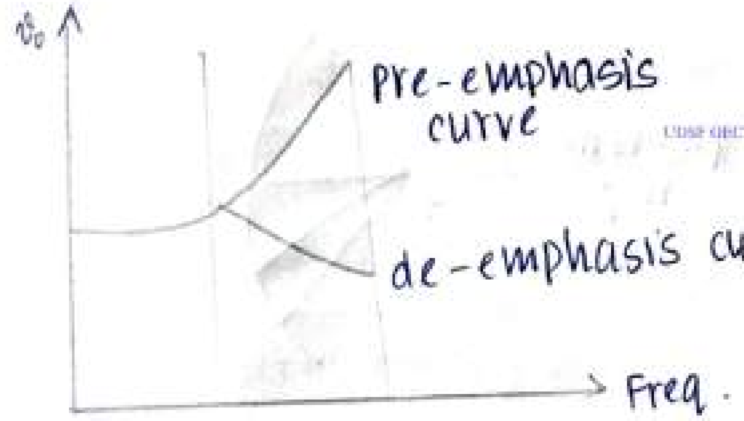
- AGC produce control signal that control gain of IF amplifier (also RF amplifier)

  Thus controlling v_0 of detector/discriminator

FM receiver



De-emphasis ⇒ smaller gain at receiver
⇒ actual signal can be taken

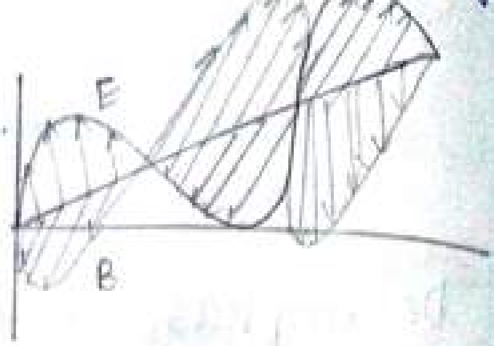


- Antennae : EMF induced → current produced
- RF amp. : Selects freq. (150 KHz) and amplify if other frequency gets it, it is tuned
- Mixer : Sender frequencies are mixed with a local freq. s $f_0 - f_s = 1M = 10.7$ MHz
- Amplitude limiter : extra noises are taken out with high amplitude
- Discriminator : audio freq. are seperated, gain is made strong

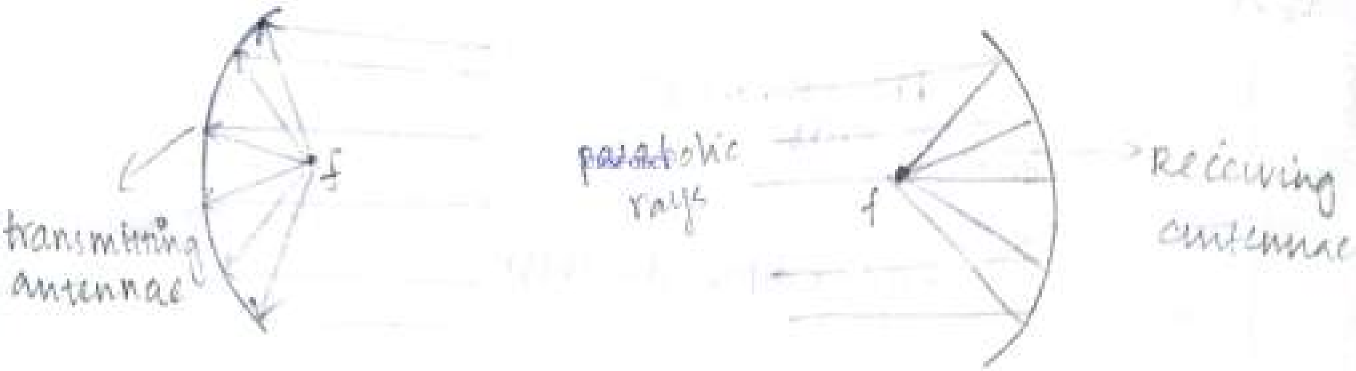
- AF voltage amp. : for voltage control → gain changes
- AF power : high power signal

Principle of operation of antenna

- At high freq., current is time varying accelerated charges
It's antennae is kept vertical.
$\lambda/4$ wavelength is always radiated



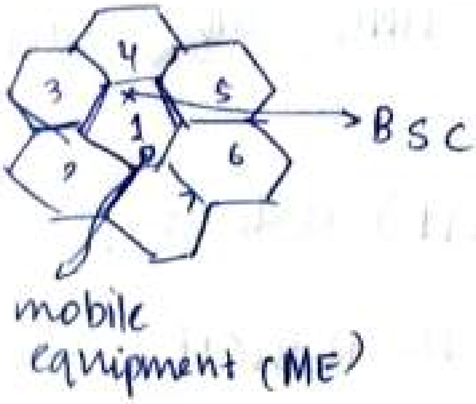
Parabolic reflector (Dish)



Applications
- microwave tower
- teleplone
- television
- DTH (direct to home)
- Wireless LAN and WAN
- radio telescope (weather forecast)
- RADAR
- To navigate

GSM and mobile communication

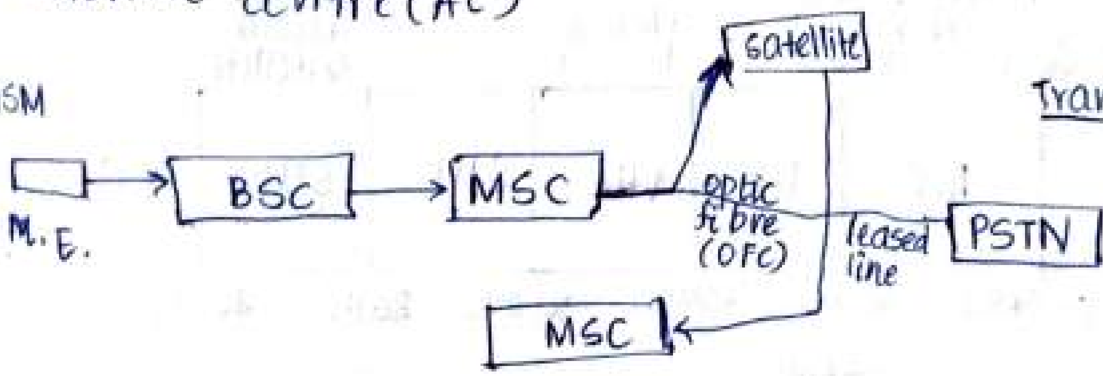
- GSM : Global system for mobile communication
- There is a base station controller (BSC) at each centre



MSC : mobile switching Centre

- SIM : subscriber identify module : it is unique for each mobile
- code from ME → BSC → threshold limit
- Freq. band is fixed for each service provider
- VLR : visiting location register
- HLR : Home location register
- All BCS's are connected to an MSC
- Authentic centre (AC)

GSM



Transmitter receiver

- carrier frequency is alloted by BSC.
- PN code : Pseudo random Noise
- CDMA : code deficient multiple access

Here, many signals can be passed in same medium without any interference

→ Eg: Time division multiple access (TDMA)

→ Frequency " " " (FDMA) ; many freq can be passed at same time. Since diff. freq, they do not mix

- Subscriber Trunk Dialling (STD) code :
- PSTN : Public switched telephone network

Advantages

- only communication when persons are in motion
- SMS, MMS, videos, pictures can be shared
- Teleconference, videoconference ..

Drawbacks

- emit radiations which is hazardous

Range of Frequencies

Band	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
Use	Telegraphy	marine navigation	AM radio broadcast		FM radio broadcast		microwave radar satellite	
Range	10 kHz – 30 kHz	30 kHz – 300 kHz	300 kHz – 3000 kHz (or) 3 MHz	3 MHz – 30 MHz	30 MHz – 900 MHz	900 MHz – 3 GHz	3 GHz – 30 GHz	30 GHz –

VLF : very low frequency

LF : low frequency

MF : medium frequency

HF : high frequency (for long distance communication)

•– Morse code

- above 1MHz : sky wave propogation
- VHF : very high Frequency
- FM radio broadcast : 88MHz-108 MHz
- UHF : ultra high frequency
- SHF : super high frequency
- EHF : extra high frequency
- Bands and ranges
  - L band → 1GHz-2GHz (satellite, mobile, radar, microwave)
  - S band → 2 to 4 GHz
  - C band → 4 to 8 GHz
  - X band → 8 to 12 GHz
  - K_u band → 12 to 18 GHz
  - K band → 18 to 27 GHz
  - K_a band → 27 to 40 GHz

Ku : under K

Ka : above K

Block diagram of an electronic Instrumentation system

- Transducer : convert energy of one form to electrical energy