UNIT I

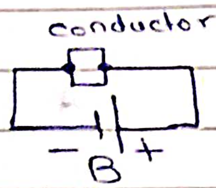
Mrs. M. S. Bhosale.

Electric & Magnetic Circuits

* Voltage OR Potential difference – (V)

The current flows from higher potential to lower potential in the electrical circuit. The difference between the electrical potentials (or pressure) at any two given points in the electrical circuit is known as voltage or potential difference.

Equation of voltage $V = I \cdot R$



Where I - current

R - Resistance

Unit – The SI unit for voltage is "Volt". & is represented by the letter 'V'.

* Current – (I)

It is the flow rate of electric charge through a conducting medium with respect to time.

OR

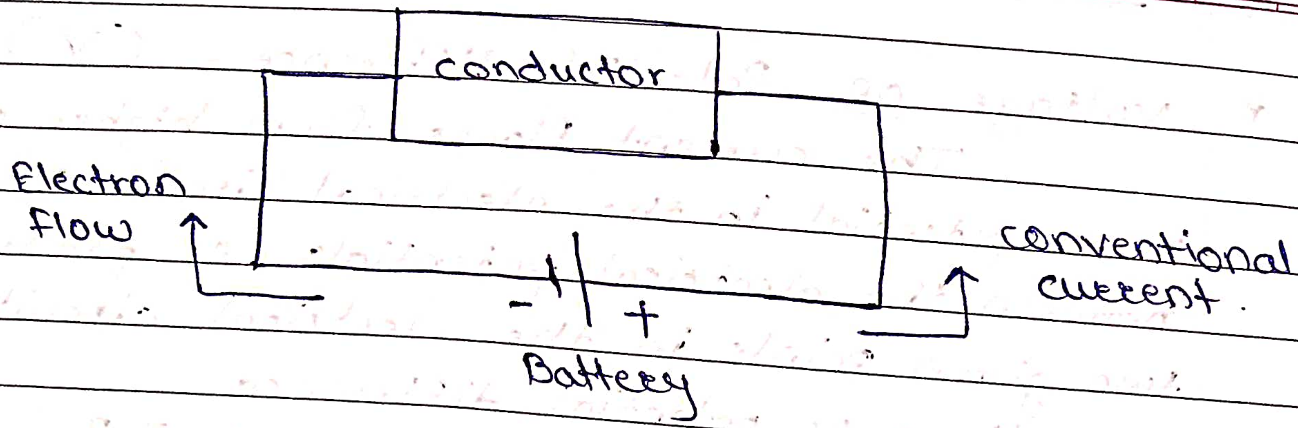
Free electrons move from the negative charge to positive charge. This movement of free electrons is called as an electric current.

$$\text{current} = I = \frac{\text{Total charge transferred } (Q)}{\text{Time period } (T)}$$

$$\therefore \quad I = \frac{Q}{T} \quad \text{OR} \quad \frac{V}{R}$$

The unit of electric current is Ampere & it is denoted by 'A'.

* Electron flow – Negative terminal to +ve terminal
* Current flow – positive —〃— to –ve terminal



* Resistance - (R) -

The opposition to the flow of electrons is called as resistance. (R).

The resistance is measured in ohms. (Ω).

$$R = V/I \quad \underline{\underline{OR}} \quad R = \frac{\text{Volts}}{\text{Ampere}}$$

* Power - (P).

power is the amount of energy transferred/ converted per unit time.

Unit of power is watt equal to joule/sec.

$$P = VI = \frac{V^2}{R} = I^2R$$

* EMF - Electromotive force.

The force which causes electrons to move is called as electromotive force.

voltage is also electromotive force.

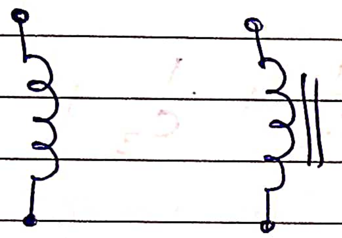
* Inductance (L) -

Inductance is the tendency of an electrical conductor to oppose a change in the electric current flowing through it. 'L' is used to represent the inductance.

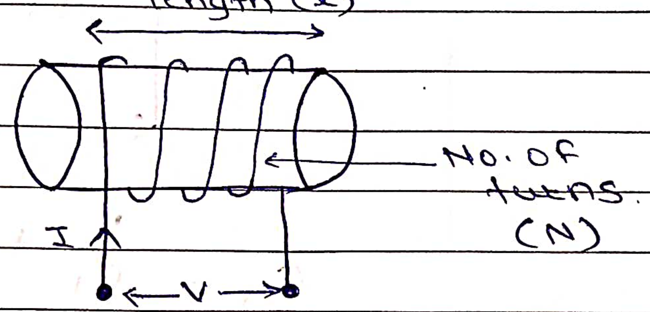
The flow of electric current creates the magnetic field around the conductor.

The SI unit of Inductance is 'Henry' & it is denoted by 'H'.

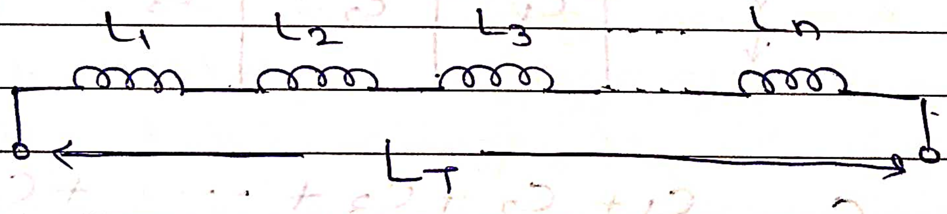
Symbol -



Air core Iron core.



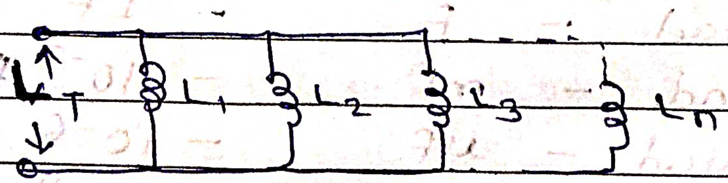
① Series connection of Inductance -



$$L_T = L_1 + L_2 + L_3 + \cdots + L_n$$

Series combination of Inductors

② parallel connection of Inductance -



$$L_T = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_n}$$

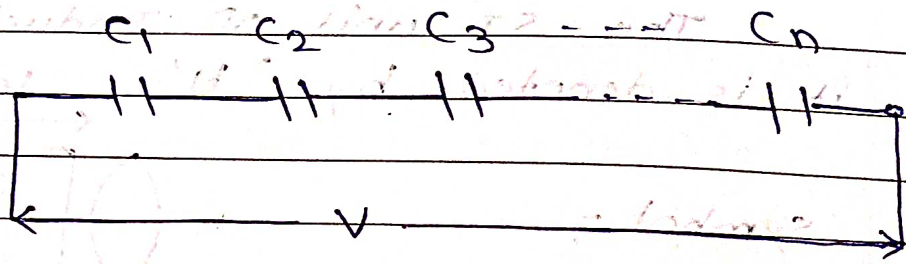
parallel combination of Inductors

* Capacitance (C) –

Capacitance is the ability of a component to collect & store energy in the form of an electrical charge.

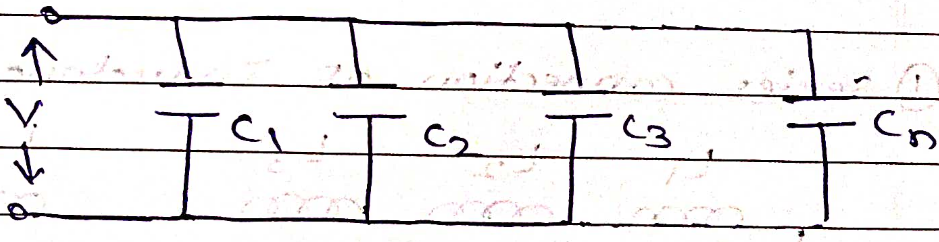
Unit of capacitance is farad (F).

① Capacitors in series –



$$C_T = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_n}$$

② Capacitors in parallel –



$$C_T = C_1 + C_2 + C_3 + \cdots + C_n$$

Other units of capacitance –

farad	F	1 F
milifarad	mF	10^{-3} F
microfarad	µF	10^{-6} F
nanofarad	nF	10^{-9} F
picofarad	pF	10^{-12} F

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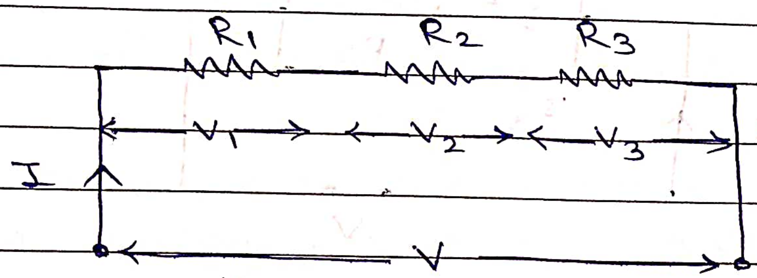
* Resistance - (R)

The opposition to the flow of electrons is called as resistance (R).

The resistance is measured in ohm's. (Ω)

$$R = \frac{V}{I} \quad \text{OR} \quad R = \frac{\text{volt}}{\text{ampere}}$$

(1) Resistors in series -



Consider three resistors R_1, R_2 & R_3 are connected in series as shown in fig.

Current I flows from R_1, R_2 & R_3.

Let V_1 be the voltage generated across R_1.

V_2 be the voltage generated across R_2

& V_3 be the voltage generated across R_3

the total voltage is V.

$$\therefore \quad V = V_1 + V_2 + V_3$$

$$\text{but} \quad V = IR$$

$$\therefore \quad I \cdot R = I \cdot R_1 + I \cdot R_2 + IR_3$$

$$IR = I (R_1 + R_2 + R_3)$$

$$\therefore$$

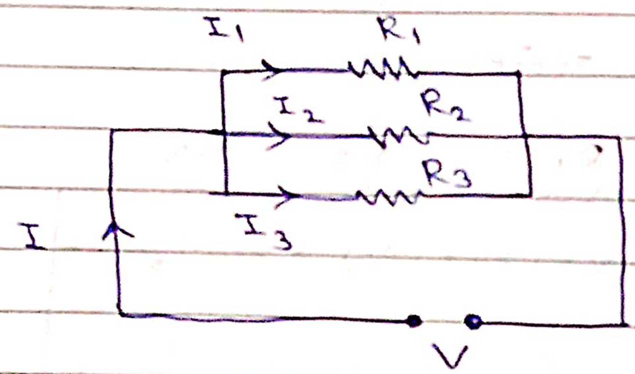
$$\boxed{R = R_1 + R_2 + R_3}$$

Total resistance is the sum of the values of indivisual resistances.

② Resistors are in parallel combination

Fig shows a parallel ckt consisting of three resistances R_1, R_2 & R_3 connected in parallel across a source.

Let I_1, I_2 & I_3 be the currents in the resistances R_1, R_2 & R_3 respectively



The total current I is equal to sum of the currents flowing through the indivisual resistances

$$I = I_1 + I_2 + I_3$$

As $I = V/R$

$$V/R = I = V/R_1 + V/R_2 + V/R_3$$

$$V/R = V/R_1 + V/R_2 + V/R_3$$

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

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

In general,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$

* Numericals on series/parallel connections of R, L & C.

1. Three resistances of 50, 25 & 5 Ω respectively are connected (a) in series (b) in parallel find the equivalent resistance.

2. Three capacitances of $50\mu F$, $100\mu F$ & $90\mu F$ respectively are connected (a) in series (b) in parallel find the equivalent capacitance.

3. Three inductances are connected in series & parallel having values $L_1 = 10H$, $L_2 = 20H$ & $L_3 = 40H$ calculate equivalent inductance for both the combination.

Kirchhoff's Laws -

To calculate the complex combinations of resistances or voltage drops Kirchhoff's voltage & current laws are important.

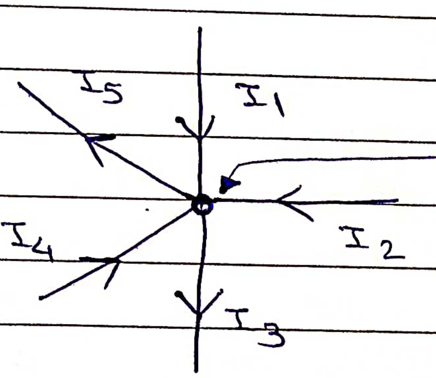
① Kirchhoff's current law - KCL.

Kirchhoff's current law or KCL states that the total current or charge entering a junction is exactly equal to the charge leaving the junction.

OR

The algebraic sum of all the currents entering & leaving a junction must be equal to zero.

$$I_{(Entering)} + I_{(Leaving)} = 0$$



Junction/Node

I_1, I_2, I_4 - In currents

I_3 & I_5 - Out currents.

Here, I_1, I_2 & I_4 are all positive because they are entering to the junction. & I_3, I_5 are leaving the junction so they are negative
∴ equation at junction/node becomes

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

OR

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

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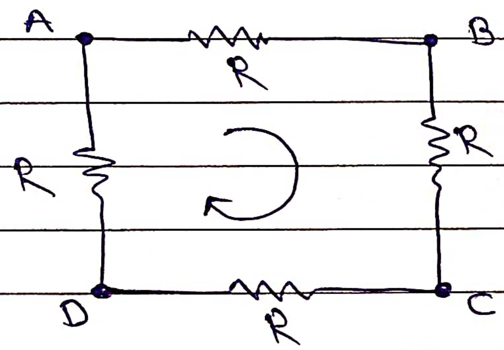
② Kirchhoff's voltage law - KVL

Kirchhoff's voltage law or KVL states that in any closed loop network the total voltage around the loop is equal to the sum of all the voltage drops within the same loop. which is also equal to zero.

OR

The algebraic sum of all voltages within the loop must be equal to zero.

$$\Sigma V = \Sigma IR = 0$$



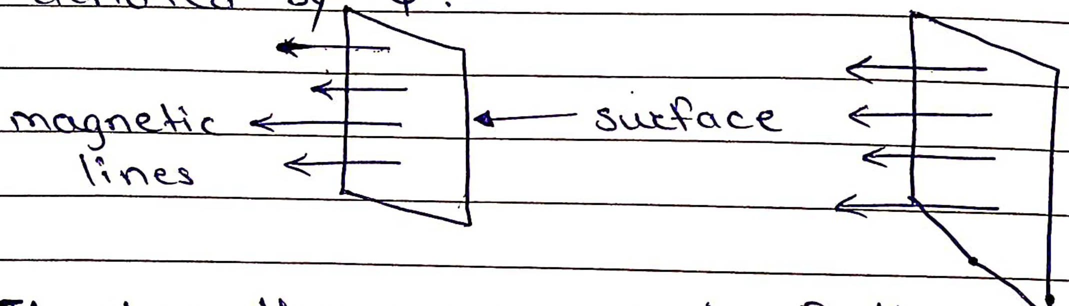
$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0.$$

* Magnetic ckts -

* Magnetic Flux - (ϕ) -

The total number of lines of force in any particular magnetic field is called the magnetic flux.

Unit of magnetic flux is weber (10^8 lines) & denoted by 'ϕ'.



It gives the measurement of the total field that passes through a given surface area.

* Magnetic flux density (B) -

The flux per unit area (a) in a plane at right angles to the flux is known as magnetic flux density (B).

It's unit is tesla (T).

& denoted by 'B'.

$$\therefore B = \phi / a \text{ tesla. or } wb/m^2.$$

* Reluctance (S) -

Reluctance is the resistance offered by the material to the passage of magnetic flux through it and corresponds to resistance in the electric circuit.

Reluctance is directly proportional to the length of the magnetic ckt (l) & inversely proportional to ~~the~~ its cross sectional area (a) & relative permeability (μ_r). It is given by

$$\text{Reluctance, } S = \frac{l}{\mu_0 \mu_r a} \text{ amperes/weber}$$

$$S = Kl/a$$

Where l in metres a in sq. mtrs.

Where K = constant $= 1/\mu_0 \mu_r$.

$$\text{Reluctance} = S = \frac{\text{M.M.F.}}{\phi}$$

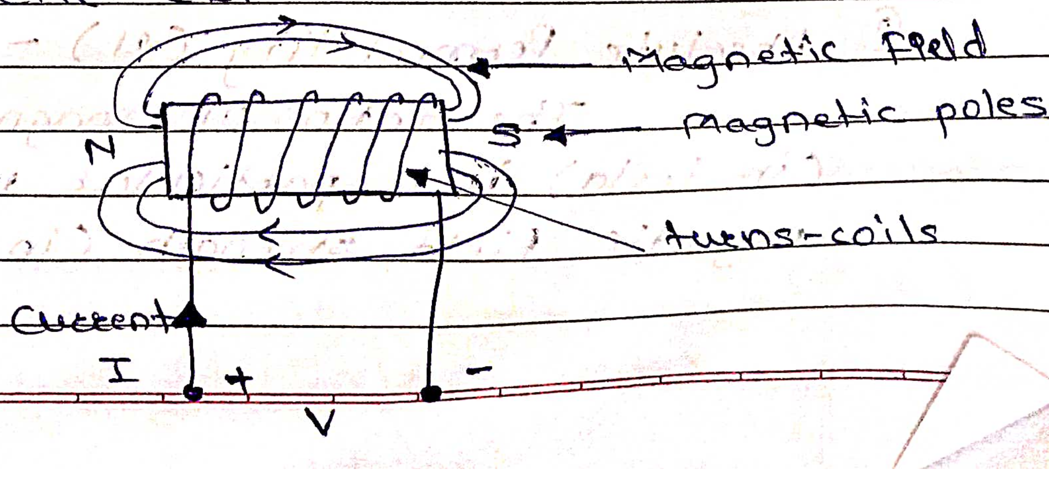
mmf is measured in amperes & flux is measured in weber

$\therefore$ unit is amperes/weber.

It is also defined as the ratio of magneto motive force to magnetic flux.

* MMF - Magneto Motive Force.

As the current flowing in an electric circuit is due to the existence of electromotive force similarly, magnetomotive force (MMF) is required to drive the magnetic flux in the magnetic ckt.



It is given by the product of turns on the magnetizing coil (N) & the current flowing in the coil (I) in amperes.

i.e. MMF = N · I amperes

unit of mmf is amperes as N is constant no.

However mmf's ampere & current's ampere are quite different.

* Permeability (μ) –

① permeability of free space or magnetic space constant (μ_0) –

For a magnetic field in vacuum/free space, the ratio of flux density (in tesla) to the magnetic field strength (in ampers/metre) producing that flux desity is called permeability of free space.

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

unit is Henry per metre.

② Absolute Permeability (μ) –

The ratio of magnetic flux density (in tesla) in a particular medium to the magnetic field strength (in amperes/metre).

$$\mu = \frac{B}{H} \quad \text{~~henry/metre~~}$$

(3) Relative Permeability - (μ_r) -

The ratio of the flux density produced in a material to the flux density produced in a vacuum (or free space) by the same magnetic field strength under identical conditions is called as relative permeability.

$$\mu_r = \frac{B}{B_0}$$

but $B_0 = \mu_0 H$ & $B = \mu H$

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

$$\therefore \mu = \mu_0 \mu_r \quad \text{henry/metre.}$$

for air & non-magnetic material $\mu_r = 1$

$$\therefore \mu = \mu_0$$

* Magnetic field strength - (H) -

The force experienced by a unit North pole placed at any point in a magnetic field is known as magnetic field strength at that point.

unit is newtons/ ~~m~~ weber (N/wb) or amperes per metre (A/m).

* Magnetic leakage -

If the current is passed through the ~~exciting~~ exciting coil wound on the magnetic core having air gap the flux is produced in the core by the coil current.

All this flux cannot pass completely through the core, some flux escapes from the core & completes the circuit through the air. this flux is known as leakage flux.

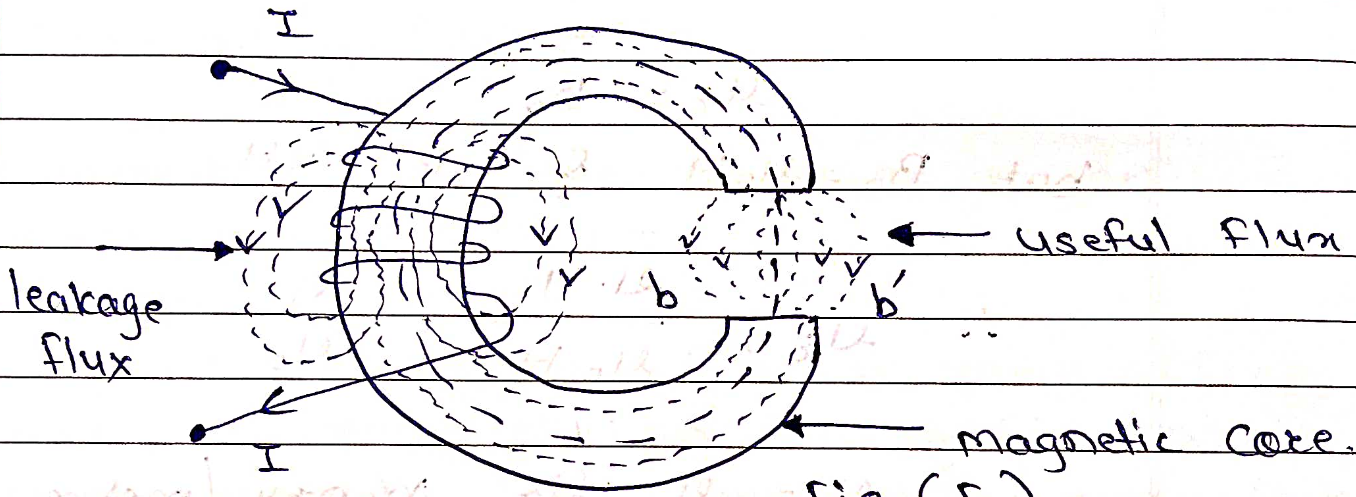


Fig (F).

The ratio of total flux to useful flux is called as Hopkinson's leakage coefficient or leakage factor & it is denoted by 'λ'.

$$\text{Leakage coefficient } \lambda = \frac{\text{Total Flux}}{\text{useful flux}}$$

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* Magnetic Fringing –

The useful flux when sets up in the air gap, it tends to bulge outward at b & b' as shown in fig. (F) because of this bulging, the effective area of the air gap increases & the flux density of the air gap decreases. This effect is known as 'Fringing'.

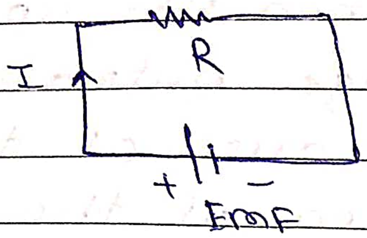
Fringing is directly proportional to the length of the air gap that means if the length increases the fringing effect will also be more & vice versa.

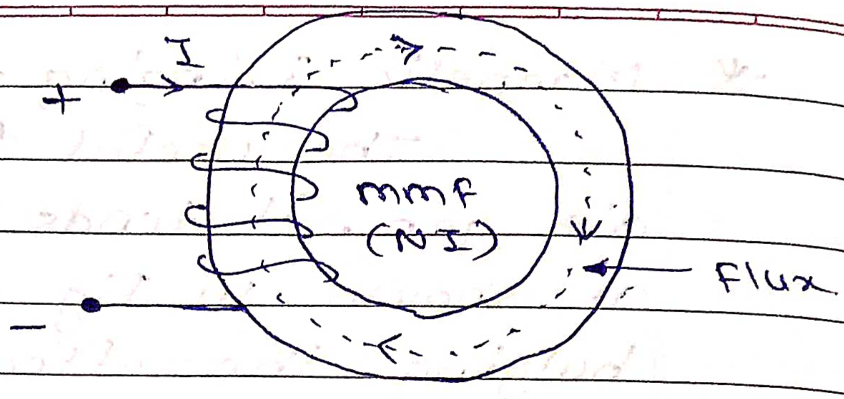
* Faraday's law of Electromagnetic Induction –

* Compare electric & magnetic circuits.

Electrical ckts	Magnetic ckts.
* Electric ckt is a path for electric current.	magnetic ckt is a path for magnetic flux.
* EMF (volt)	MMF (ampere)
* Electric current I (ampere)	magnetic flux ϕ (weber)
* Resistance R (Ω)	Reluctance S (A/wb)
* $I = EMF/R$	$\phi = MMF/S$
* current density, δ (A/m²) $\delta = I/a$	flux density, B (T) $B = \phi/a$
* conductance = 1/R	Permeance = 1/S
* conductivity	permeability

ckt diagram.





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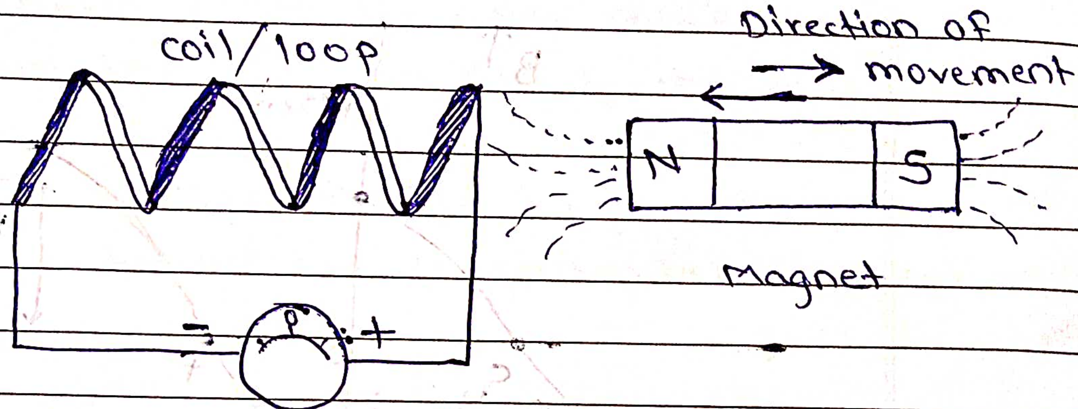
* Faraday's law of Electromagnetic Induction -
This is a basic law of electromagnetism predicting how a magnetic field will interact with an electric current circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction.

Faraday's law states that a current will be induced in a conductor which is exposed to a changing magnetic field.



* Faraday's first law -
Any change in the magnetic field of a coil of wire will cause an emf to be induced in the coil. This emf induced is called as induced emf & if the conductor ckt is closed the current will also circulate through the ckt & this current is called induced current.

* Faraday's Second law -
It states that the ~~magnetic~~ magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil.
The flux linkage of the coil is the product of the number of turns in the coil & flux associated with the coil.

II - Single Phase AC circuits & Three phase AC circuits

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* Generation of single phase sinusoidal voltage -

Alternating current - An alternating current is the current which changes periodically both in magnitude & direction.

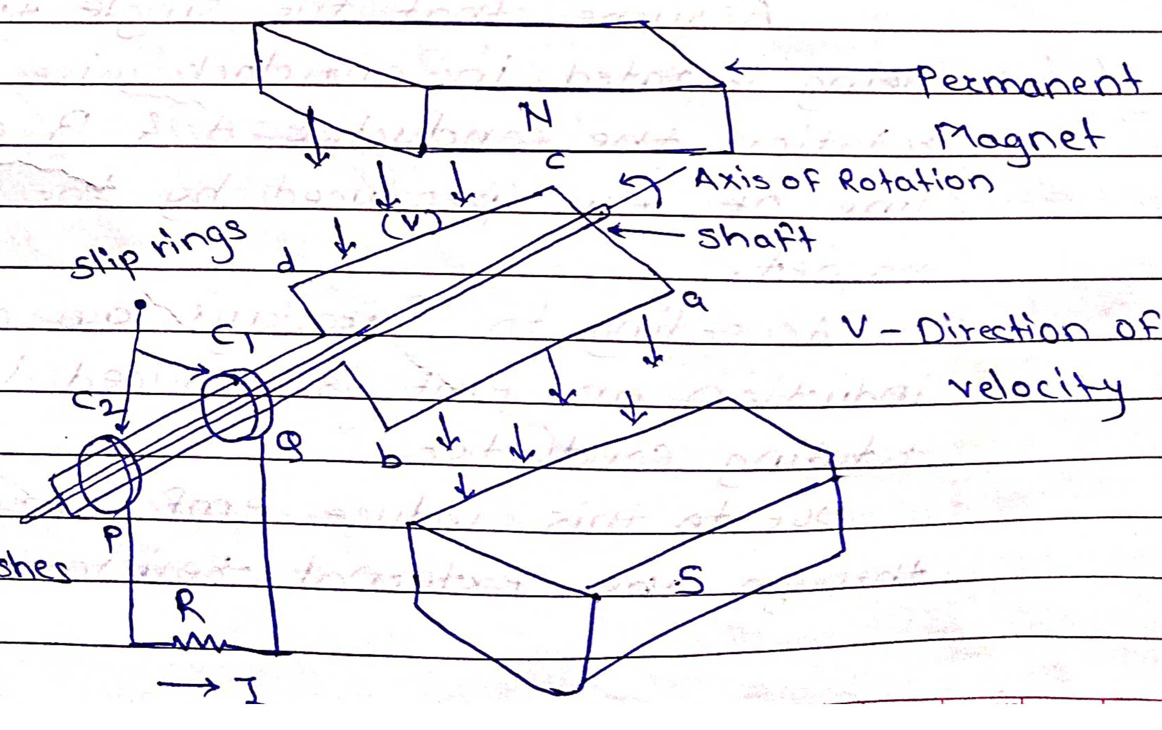
The machines which are used to generate electrical voltages are called 'Generators'.

The generators which generate purely sinusoidal A.C. voltages are called 'Alternator'.

A.C voltage may be generated by rotating a coil in a magnetic field or by rotating a magnetic field within a stationary coil.

The basic principle of an alternator is 'Electromagnetic Induction'. It says that whenever there is a relative motion between the conductor & the magnetic field in which it is kept, an e.m.f. gets induced in the conductor.

Construction of single wave alternator -



It consists of a permanent magnet of two poles. A single turn rectangular coil is kept on the vicinity of the permanent magnet. This coil is made up of same conducting material like copper or aluminium. The coil is made up of two conductors namely a-b & c-d such two conductors are connected at one end to a coil.

The coil is so placed that it can be rotated about it's own axis in clockwise or anticlockwise direction.

The remaining two ends C_1 & C_2 of the coil are connected to the rings mounted on the shaft called slip rings. Slip rings are also rotating members of the alternator.

The two brushes P & Q are resting on the slip rings. The brushes are stationary & are just making contacts with slip rings. The slip rings and brush assembly is necessary to collect the current induced in the rotating coil & make it available to the stationary external resistance.

Assume that the single turn coil is being rotated in anticlock wise direction. Due to rotation the conductor A & B cut magnetic line of flux produced by the permanent magnet.

According to faraday's law of electromagnetic induction an emf is induced into the rotating conductor.

Due to this induce emf current flows through the external resistance 'R'.

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Generation of single phase AC sinusoidal signal –

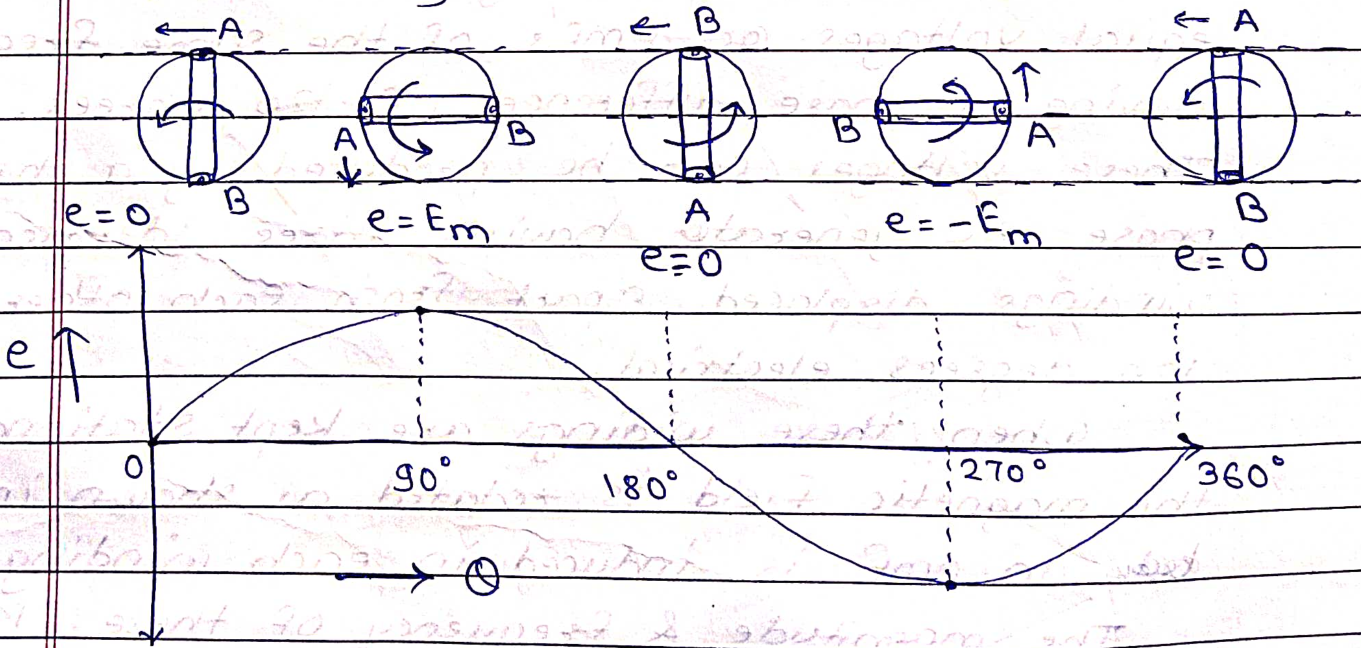
consider the stationary coil places inside the uniform magnetic field. The load is connected across the coil with the help of brushes & the slip rings.

when the coil rotates in the anticlockwise direction at constant angular velocity (ω) the electromotive force induces in the coil.

The cross sectional view of the coil at different position is shown in fig. below.

The magnitude of the emf induced in the coil depends on the rate of ~~ch~~ the flux cut by the conductor.

The figure below shows that the no current induces in the coil when they are parallel to the magnetic line of forces i.e. at the position (1), (3) & (5) & the total flux cut by the conductor becomes zero.



The magnitude of the Induces emf becomes maximum when the conductor becomes perpendicular to the magnetic line of force.

The conductor cuts the maximum flux at this position.

The direction of the emf induces in the conductor is determined by Fleming's Right hand rule.-

When the coil is at position (2) the emf induces in the outward direction whereas at position (4) the direction of emf inducing becomes inward.

In other words, the direction of emf Induces in the conductor at position (2) & (4) becomes opposite to each other.

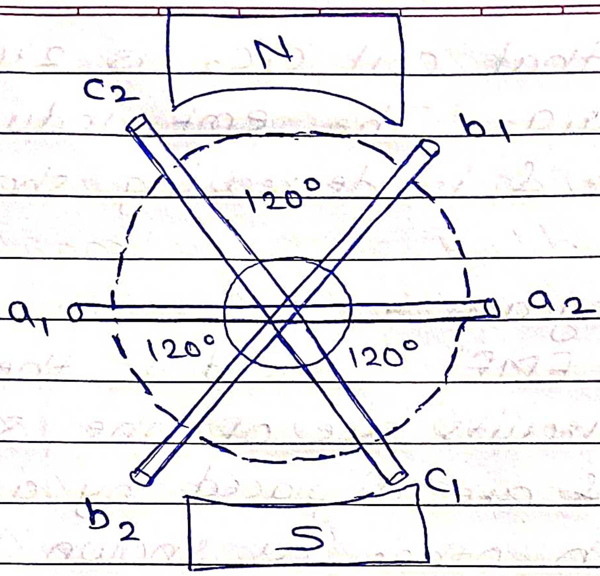
* Generation of three phase supply -

In a 3 phase system, there are three equal voltages or Emf's of the same frequency having a phase difference of 120 degrees.

These voltages can be produced by a three phase AC generator having three identical windings displaced apart from each other by 120 degrees electrical.

- When these widings are kept stationary & the magnetic field is rotated as shown in fig ~~~~ an emf is induced in each winding.

The magnitude & frequency of these EMF's are the same ~~~~ but the displaced apart from one another by an angle of 120 degrees.



Consider three identical coils a_1a_2, b_1b_2 & c_1c_2 as shown in figure. In this a_1, b_1 & c_1 are the starting terminals, whereas a_2, b_2 & c_2 are the finish/end terminals of the three coils.

The phase difference of 120 degrees has to be maintained between the start terminals a_1, b_1 & c_1.

Now let the three coils mounted on the same axis & they are rotated by either keeping coil stationary or moving the magnetic field or vice versa in the anticlockwise direction at ω radiations per second. Three EMF's are induced in the three coils respectively.

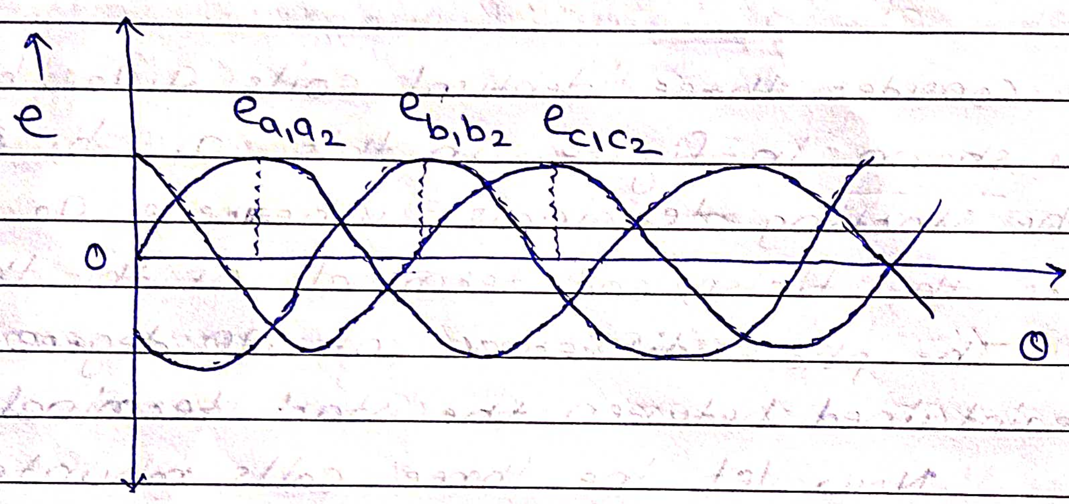
The emf induced in the coil a_1a_2 is zero and is increasing in the positive direction denoted as $e_{a_1a_2}$.

The coil b_1b_2 is 120 degrees electrically behind the coil a_1a_2. The emf induced in this coil is negative & is becoming maximum negative, denoted by $e_{b_1b_2}$.

Similarly, the coil c_1c_2 is 120 degree's electrically behind the coil b_1b_2 or we can also say that coil C_1C_2 is 240 degrees behind the coil a_1a_2. The emf induced in the coil is positive & is decreasing shown by $e_{c_1c_2}$.

phasor diagram -

The EMF's induced in the three coils in 3 phase circuits are of the same magnitude & frequency & are displaced by an angle of 120° from each other as shown below,



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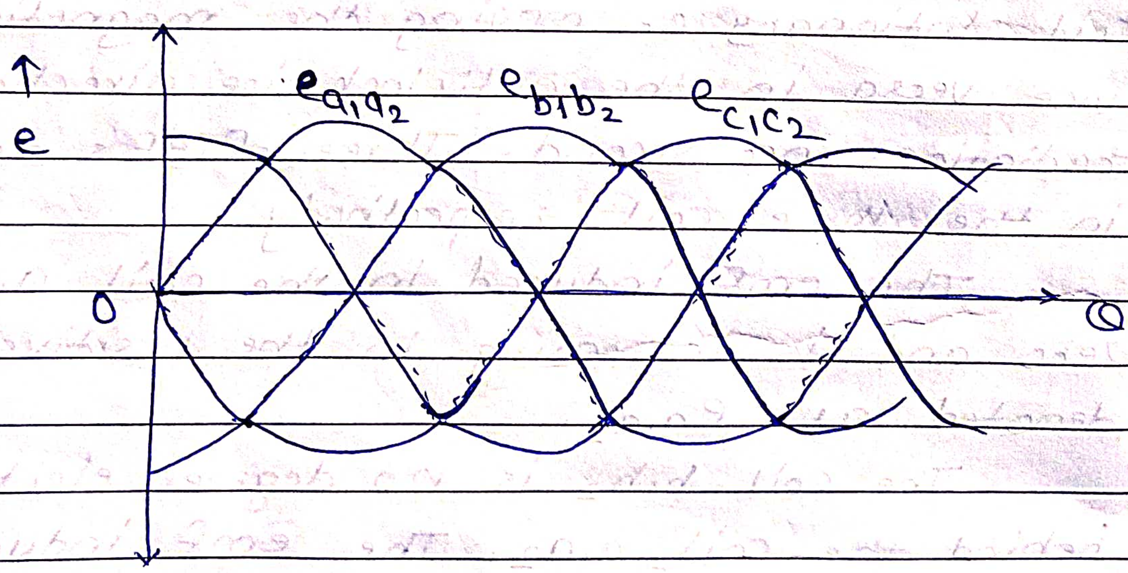

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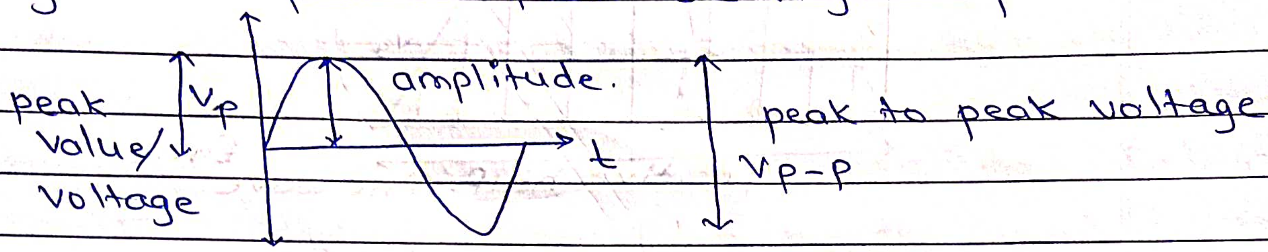
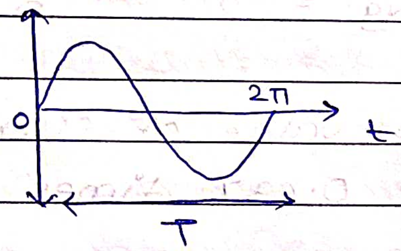
* **Amplitude - (V)**

The maximum value of current or voltage is known as 'Amplitude'. This is represented by either positive peak or negative peak.



* **Time Period - (T)**

The time taken to complete one full cycle is known as 'time period'. denoted by 'T'



* **Frequency (f) -**

The number of cycles in time period T is known as frequency. (F) It is the reciprocal of time period

$$\therefore F = 1/T.$$

It is measured in Hertz.

* **Average value -**

For sinusoidal current or voltage average value is that value which is obtained by averaging all the instantaneous values of its wave over a period of half cycle.

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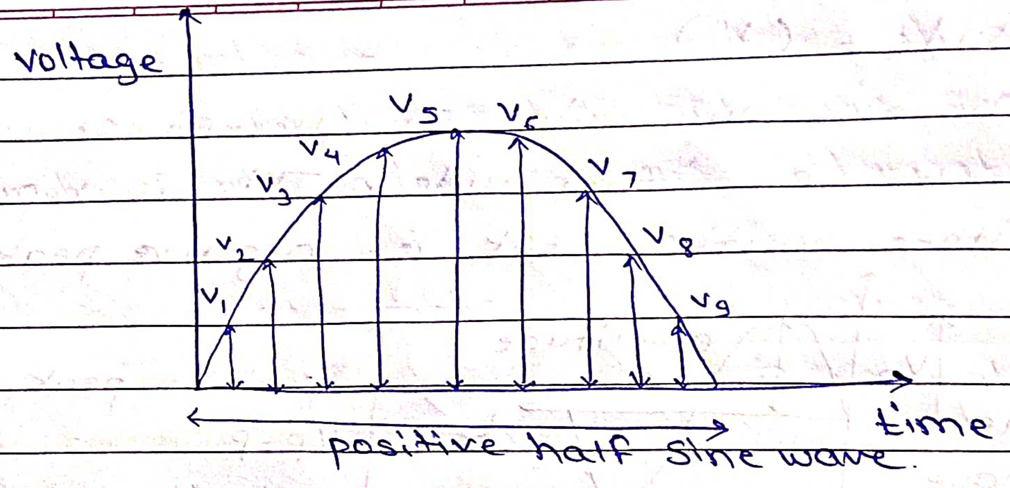


~~Vavg~~

$$V_{avg} = \frac{V_1 + V_2 + V_3 + \cdots V_n}{n}$$

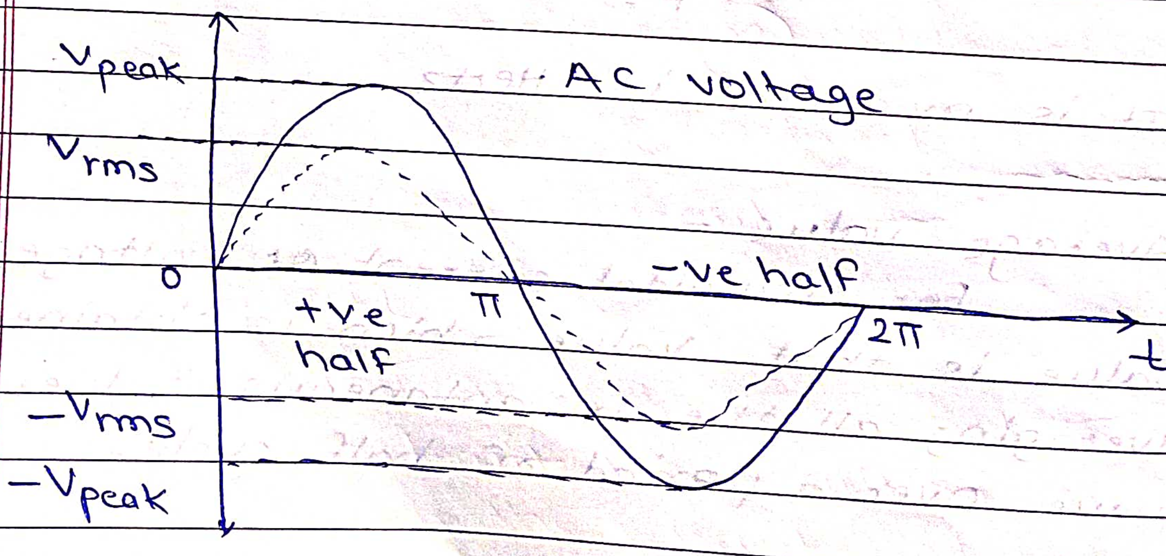
$$I_{avg} = \frac{I_1 + I_2 + I_3 + \cdots I_n}{n}$$

Thus average value of current/voltage for sine wave is 0.637 times its maximum value

$V_{avg} = 0.637\ V_m$ $\quad$ V_m = Peak voltage

$I_{avg} = 0.637\ I_m$ $\quad$ I_m = Peak current

* Root Mean Square (RMS) value -



One full cycle

The RMS (Root Mean Square) value of an alternating current (AC) is the value of direct current (DC) when flowing through a circuit or resistor for the specific time period & produces same amount of heat which produced by the alternating current (AC) when flowing through the same circuit or resistor for a specific time.

$$\text{RMS value} = \frac{1}{\sqrt{2}} \times V_{peak}$$

$$\therefore V_{rms} = 0.707 \times V_p$$

* Form Factor –

It is the ratio of RMS value of an alternating quantity (current or voltage) to the average value of same quantity.

$$\therefore \text{Form factor} = \frac{\text{RMS value}}{\text{Average value}}$$

$$= \frac{0.707 \times V_p}{0.637 \times V_p} = \frac{0.707 \times I_p}{0.637 \times I_p}$$

$$= \frac{0.707}{0.637}$$

$$\therefore \text{Form factor} = 1.11$$

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* Peak factor - Crest factor / Amplitude factor -
It is the ratio between maximum value and RMS value of an alternating wave.

$$\text{peak factor} = \frac{\text{Maximum Value}}{\text{RMS value}}$$

For voltage -

$$P.F = \frac{E_m}{0.707\, E_m} = 1.414$$

For current -

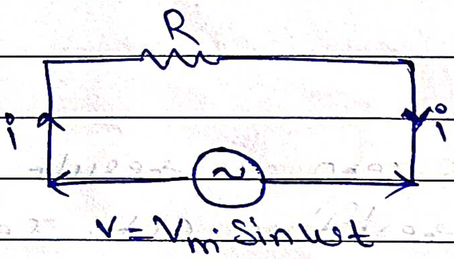
$$P.F = \frac{I_m}{0.707\, I_m} = 1.414$$

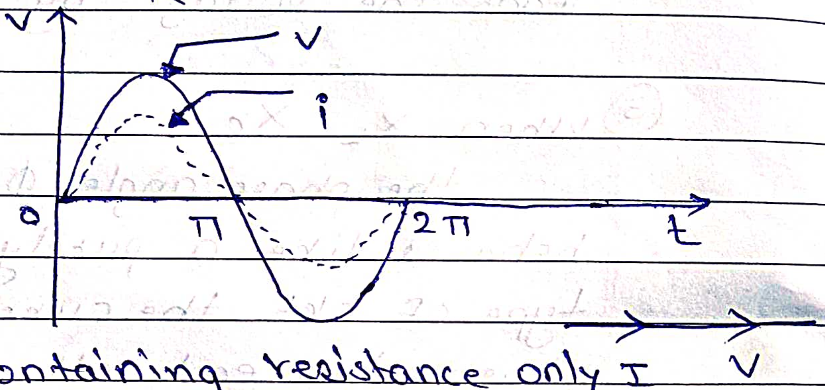
* Purely resistive A.C. circuit –

Consider a purely resistive ckt containing a resistance of 'R' ohms as shown in fig.

Let an alternating voltage represented by the equation $v = V_m \sin \omega t$ be applied across it's terminal. as a result, the alternating current will be set up in the ckt. by ohm's law, the value of the current at any instant will be –

$$i = \frac{v}{R} = \frac{V_m \sin \omega t}{R}$$





A.C. ckt containing resistance only

The current will be maximum (I_m) when $\sin \omega t$ is unity.

$$\boxed{I_m = \frac{V_m}{R}} \quad \text{for } \sin \omega t = 1$$

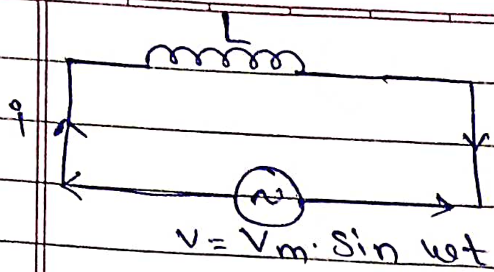
$$i = I_m \sin \omega t.$$

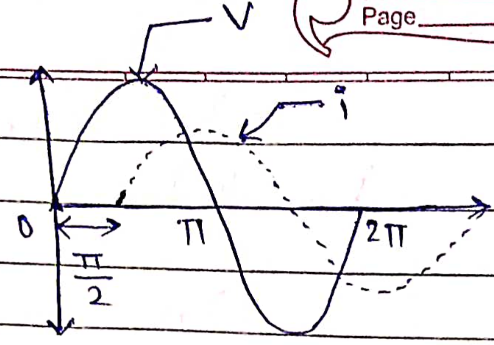
current will be sinusoidal similar to applied vtg. & will be in phase with it.

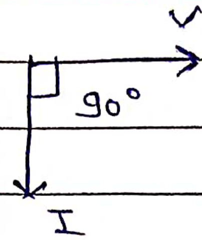
* Purely Inductive A.C. circuit –

consider a purely inductive coil with inductance 'L' henries & almost negligible ohmic resistance. connected across an a.c. supply as shown in fig. let the alternating vtg be

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







The resulting alternating current flowing thro' the coil will set up an alternating field. The changing flux linking with the coil will induce an emf of self induction in it & it is given by

$$e = -L\frac{di}{dt}$$ (as $-ve$ vtg is in out of phase with i/p)

Since the ohmic resistance of the coil is negligibly small the applied voltage will have to overcome the emf of self induction only.

∴ Applied voltage ~~V~~ is equal but opposite to the emf of self induction at every instant. i.e.

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

Substituting $v = V_m \sin \omega t$ in above eqn

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

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

Integrating both sides,

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

$$i = \frac{V_m}{\omega L}(-\cos \omega t)$$

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

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

The current will be maximum (I_m) when $\sin\left(\omega t - \frac{\pi}{2}\right)$ will be unity.

$$I_m = \frac{V_m}{\omega L}$$

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

Note - When a sinusoidal alternating voltage is applied to a purely inductive circuit the resulting current is also sinusoidal & lags 90° behind the applied voltage. (or voltage leads the current by 90°)

Inductive reactance -

$$I_m = V_m / \omega L$$

For rms

$$\frac{I}{0.707} = \frac{V}{0.707 \cdot \omega L}$$

$$I = \frac{V}{\omega L}$$

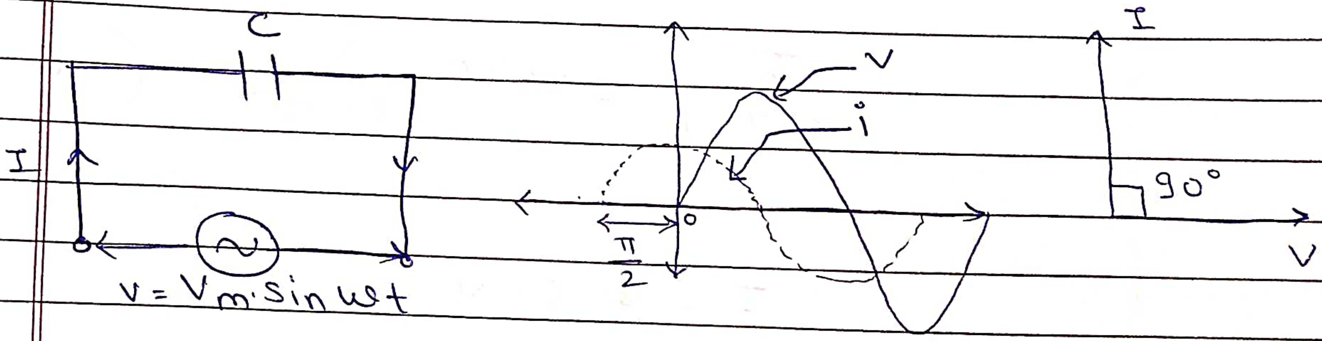
$$\boxed{I = \frac{V}{X_L}} \quad \text{as } X_L = \omega L$$

& $X_L = \omega L$

$$\boxed{X_L = 2\pi f L}$$

* Purely Capacitive A.C. circuit -

When a capacitor is connected across an a.c. supply its charging & discharging during alternate quarter cycles, gives rise to an alternating current in the circuit.



The instantaneous charge (q) on the capacitor plate is given by

$$q = C \cdot V = C \cdot V_m \cdot \sin \omega t.$$

as $$i = \frac{dq}{dt} = \frac{d}{dt}\left[C \cdot V_m \cdot \sin \omega t\right]$$

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

$$i = \omega \cdot C \cdot V_m \cdot \sin\left[\omega t + \frac{\pi}{2}\right]$$

If $\sin(\omega t + \pi/2) = 1$

then

$\boxed{i = \omega \cdot C \cdot V_m}$ at it's max. level

Note - When a sinusoidal alternating voltage is applied to a purely capacitive circuit, the current that is set up varies sinusoidally with the same frequency as that of the applied voltage & leads it by 90°.

Capacitive reactance –

$$I_m = C \cdot \omega \cdot V_m$$

$$I_m = \omega \cdot C \cdot V_m$$

$$\frac{I}{0.707} = \omega \cdot C \cdot \frac{V}{0.707} \quad (\text{rms.})$$

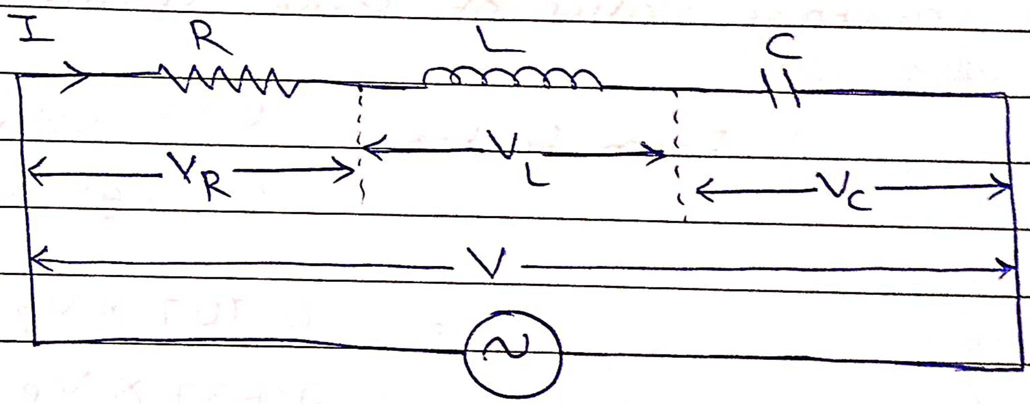
$$I = \omega \cdot C \cdot V = \frac{V}{1/\omega C}$$

$$\boxed{I = \frac{V}{X_c}} \quad \text{as} \quad 1/\omega C = X_c$$

$$\therefore \quad X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$\boxed{X_c = \frac{1}{2\pi f C}}$$

* Single phase AC ckt analysis (R-L-C)—



$V = V_m \sin \omega t$

In RLC series circuit

$X_L = 2\pi f L$ & $X_C = \frac{1}{2\pi f C}$

When the AC Vtg is applied through the RLC series circuit the resulting current I flows through the circuit. and thus the

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voltage across each element will be -

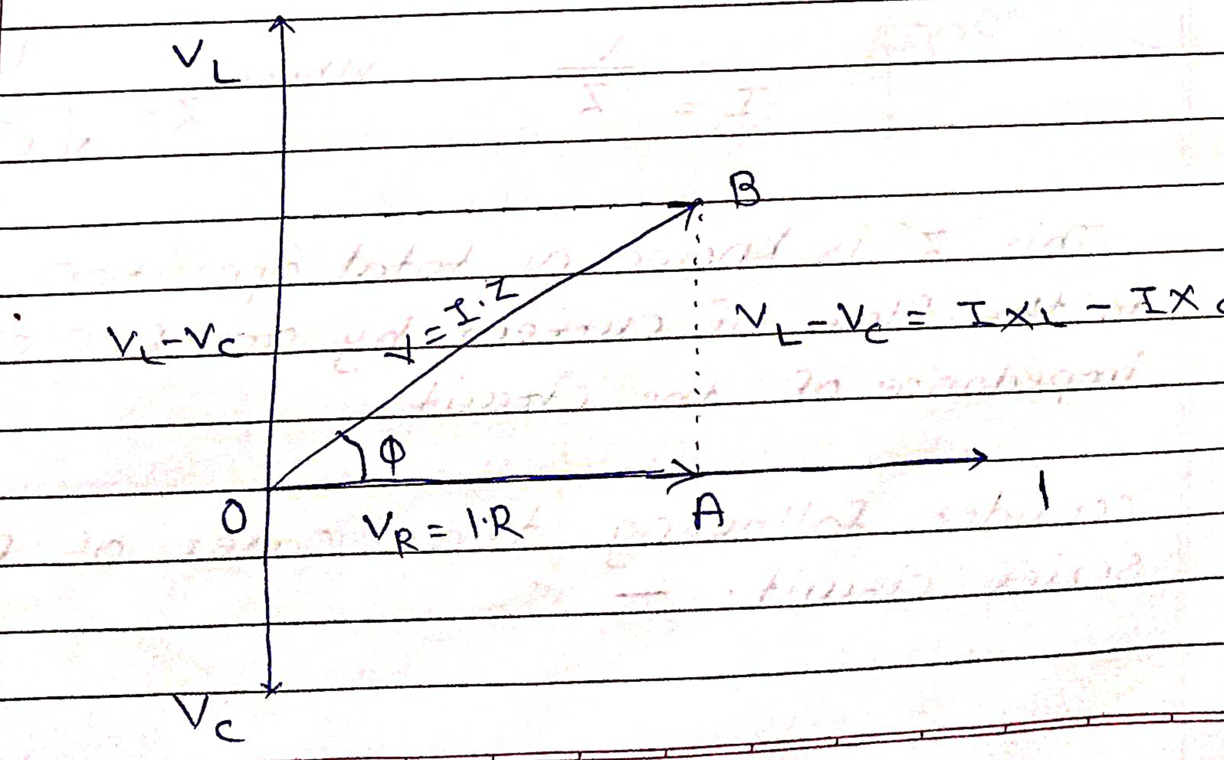
$V_R = I \cdot R$ voltage across the resistance R & is in phase with the current I.

$V_L = I \cdot X_L$ voltage across the inductance L & it leads the current ~~by~~ I by angle of 90°

$V_C = I \cdot X_C$ that is the voltage across capacitor C & it lags the current I by an angle 90°

phasor diagram of RLC series circuit -

The phasor diagram of the RLC series circuit when the circuit is acting as an inductive circuit that means $(V_L > V_C)$ is shown below & if $(V_L < V_C)$ the circuit will behave as a capacitive circuit.



steps to draw phasor diagram of RLC series ckt

① Take current I as the reference.

② The voltage across the inductor L that is V_L is drawn.

③ The voltage across the capacitor C that is V_C is drawn.

The two vectors V_L & V_C are opposite to each other.

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

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

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

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

$$\therefore \quad I = \frac{V}{Z} \qquad \text{where} \qquad Z = \frac{1}{\sqrt{R^2 + (X_L - X_C)^2}}$$

This 'Z' is known as total opposition offered to the flow of current by an RLC ckt is impedance of the circuit.

consider following three cases of RLC series circuit. —

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① When $X_L > X_C$

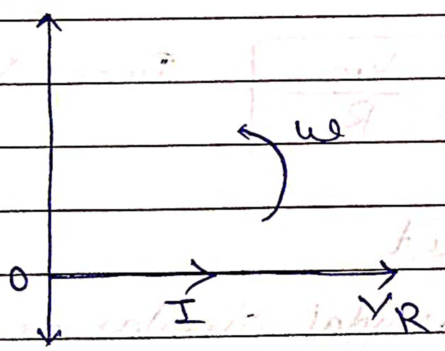
the phase angle ϕ is positive. The circuit behaves as RL series ckt in which the current lags behind the applied voltage & power factor is lagging.

② When $X_C > X_L$ OR $X_L < X_C$

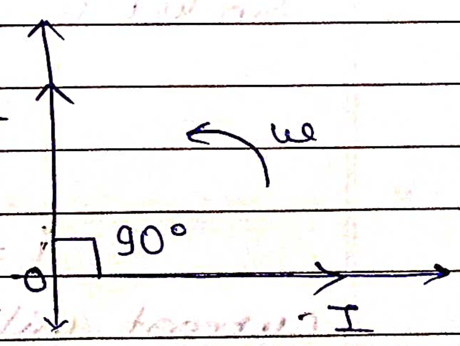
the phase angle ϕ is negative & the ckt acts as series RC ckt in which the current leads the voltage by $90°$.

③ When $X_L = X_C$

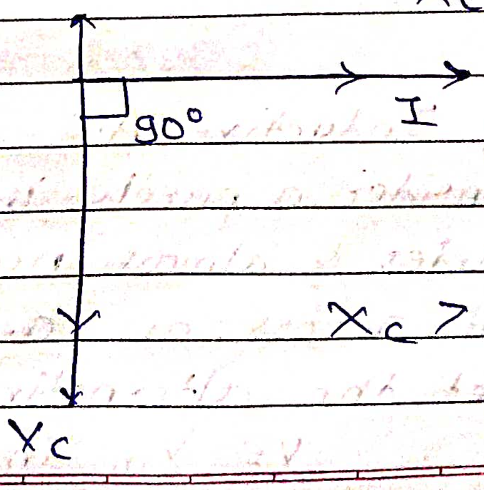
the phase angle ϕ is zero as result the ckt behaves like a purely resistive ckt. In this type of ckt the current and voltage are in phase with each other. The value of power factor is unity.



$X_L = X_C$



$X_L > X_C$



$X_C > X_L$