Basic Electrical Engineering.

Current Flow

* Current :→ a flow of electricity which results from the ordered directional movt of electrically charged particles.
  The flow of electrons is termed electron current.

→ Electrons (Negative to positive).
→ Current flow (positive to negative).

* Current is of two types
  ① DC current
  ② AC current.

Since, current is the rate of flow of charge.

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

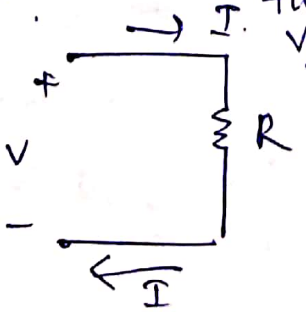
Current density, $J = \frac{I}{A}$.

Source and load.

Source :- A device which delivers energy into a system is a source.

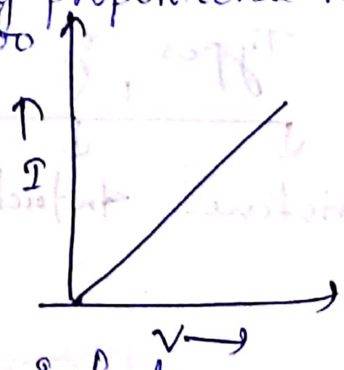
load :- A device which consumes energy from a system is a load.

Ohm's Law :- It states that current through a conductor betn two points is directly proportional to the voltage across the two points.



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

$$\Rightarrow V = IR$$



Soumya Souraja Panda.

Limitations of ohm's law.

① This law cannot be applied to unilateral networks.

→ A unilateral network has unilateral elements like diode, transistor etc which do not have same voltage current relation for both directions of current.

② Ohm's law is also not applicable for non-linear elements.

③ If temperature changes, ohm's law cannot be applicable.

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

$$i = \frac{Q}{t}.$$

If n electrons pass through the cross-section of a conductor in time t, the total charge passed through the conductor, $Q = n \times e$

$$i = \frac{Q}{t} = \frac{ne}{t}.$$

$R \propto L$

$R \propto \frac{1}{A}.$

$R \propto \frac{L}{A} \Rightarrow R = \frac{\rho L}{A}.$

L = length of conductor

A = Area of cross-section of the conductor

ρ = Restivity (ohm-metre)

3 Types of load

- Resistive
- Inductive
- Capacitive

Q) An electric heater draws 3.5 A from a 110 V source. The resistance of the heating element is approximately,

Q) How many milliamperes of current flow through a circuit with a 40 V source and 6.8 kΩ of resistance?

Q) What is the voltage source for a circuit carrying 2A of current through a 36Ω resistor?

Q) Calculate the resistivity of a material with a resistance of 2 and a cross-sectional area and length of 25 cm² and 15 cm respectively.

Q) <u>Conductance & Conductivity</u>.

> Conductance (is ~~repri~~ reciprocal of resistance. (denoted by G)

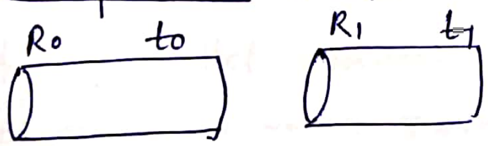
$$R = \frac{\rho L}{A}$$

$$G = \frac{1}{R} = \frac{1}{\rho L/A} = \frac{1}{\rho}\cdot\frac{A}{L} = \frac{\sigma A}{L}$$

σ = Conductivity.

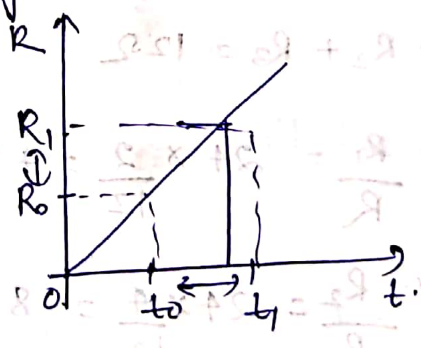
unit = siemens/metre

<u>Temperature coefficient of Resistance</u>.



$R_0 \uparrow \rightarrow R_1$.

$t_0 \uparrow \rightarrow t_1$.



$(R_1 - R_0) \propto (t_1 - t_0)$ — (I)

$(R_1 - R_0) \propto R_0$ — (II)

Combining eqⁿ (I) & (II), we get

$R_1 - R_0 \propto R_0(t_1 - t_0)$

$R_1 - R_0 = \alpha R_0 (t_1 - t_0)$

$R_1 = R_0 + \alpha R_0 (t_1 - t_0) = R_0[1 + \alpha(t_1 - t_0)]$

$$\boxed{R_1 = R_0[1 + \alpha(t_1 - t_0)]}$$

α = Temp coeff. of resistance ($(°C)^{-1}$)

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

$\Rightarrow \rho = \frac{RA}{L}$

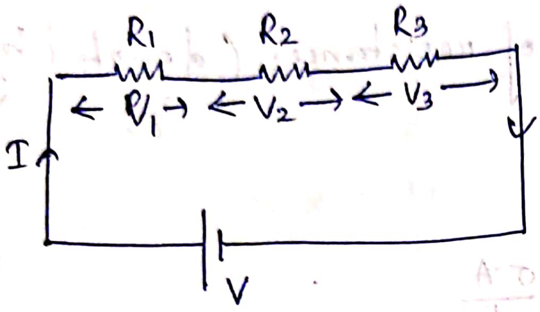
~~If the temp ↑ses~~

$\boxed{\rho \propto R}$

$\boxed{\rho_1 = \rho_0 [1 + \alpha (t_1 - t_0)]}$

α = Temp. coeff. of resistivity.

Resistance in Series



$V = V_1 + V_2 + V_3$.

$\Rightarrow V = IR_1 + IR_2 + IR_3$

$\Rightarrow IR = IR_1 + IR_2 + IR_3$

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

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

$\frac{1}{G} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}$

Voltage Divider Rule

$R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 6\Omega$; $V = 24V$.

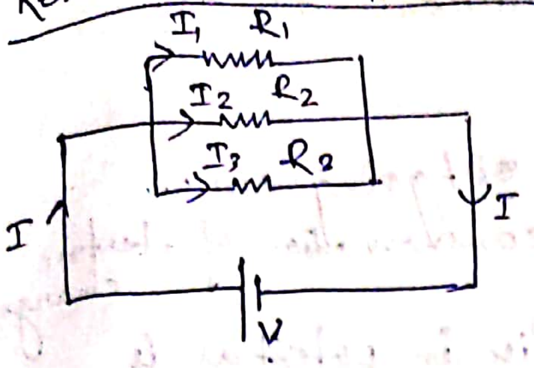
$R = R_1 + R_2 + R_3 = 12\Omega$

$V_1 = V \cdot \frac{R_1}{R} = 24 \times \frac{2}{12} = 4V$

$V_2 = V \cdot \frac{R_2}{R} = 24 \times \frac{4}{12} = 8V$

$V_3 = V \cdot \frac{R_3}{R} = 24 \times \frac{6}{12} = 12V$

Resistances in parallel.



$$I = I_1 + I_2 + I_3.$$

$$\Rightarrow \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

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

$$G = G_1 + G_2 + G_3.$$

Q) The temperature coefficient of resistance of a wire is 0.0008°c. If the resistance of the wire is 8 Ω at 0°c. what is the resistance at 100°c. ?

Power in Series.

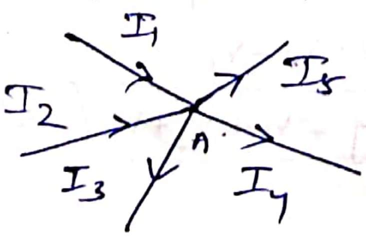
In series connectn, when two elements are connected in series with power P_1 & P_2, then total power is given by

$$\boxed{P_{T\,(s)} = \frac{P_1 P_2}{P_1 + P_2}}$$

In parallel connectn, the total power with those two elements having power P_1 and P_2 will be

$$\boxed{P_{T\,(P)} = P_1 + P_2}$$

Kirchhoff's law.



Node:- A node is a point where two or more branches are connected.

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

$$\Sigma I = 0$$

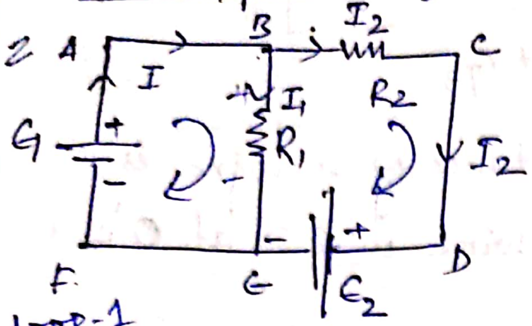
A branch is an element (~~xxx~~ R, C, ~~$~~ etc)

It states that "Algebraic sum of currents at any point or node is zero."

"Sum of ingoing current = Sum of outgoing current"

→ KCL is based on the principle of conservation of electric charge.

2. **Kirchhoff's Voltage law.**



Note:- Rise in potential is considered as positive and fall in potential is considered as negative.

loop-1

$E_1 - R_1(I_1 - I_2) = 0$

$E_1 - I_1R_1 + I_2R_2 = 0$

loop 2

$-E_2 - R_1(I_2 - I_1) - R_2I_2 = 0$

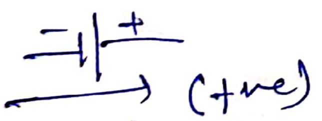
$\Rightarrow E_2 = -I_2R_2 - R_1I_2 + R_1I_1$

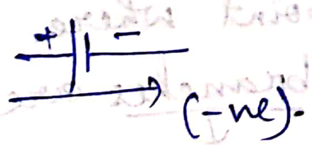
→ It states that algebraic sum of potential drop of various branches and emf. in any closed circuit or mesh is equal to zero.

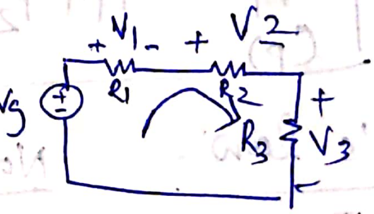
$$\sum IR + \sum E = 0$$

→ KVL is based on the law of conservation of energy.

$$V = \frac{E/W}{Q}$$







$V_g - V_1 - V_2 - V_3$

$\Rightarrow \boxed{V_g = V_1 + V_2 + V_3}$

CHAPTER - 2

AC THEORY

→ An electrical quantity is said to be "alternating" if it changes its magnitude and direction continuously with time. The term AC is nothing but alternating current and the circuit that carries AC is called AC circuit.

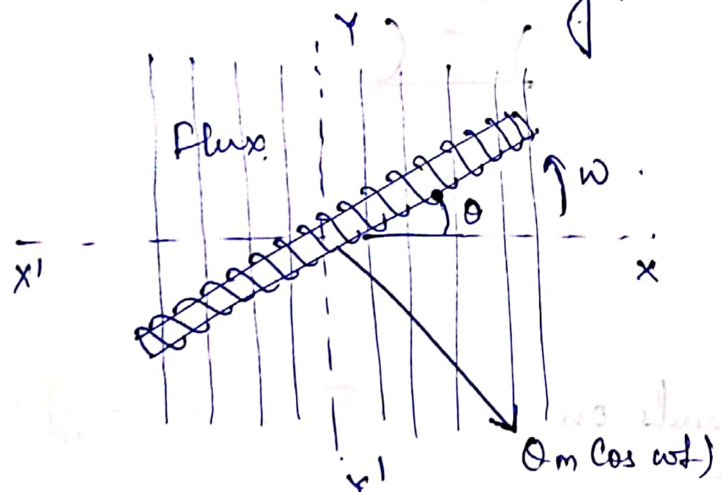
→ This alternating quantity may be periodic or non-periodic

Generatⁿ of Alternating emf.

Faraday's law :- Whenever, flux linking with a conductor changes, an emf is induced across it. The amount of emf induced depends on rate of change of flux.

flux :- The total no. of electric field lines passing a given area in a unit time is called as electric flux

* A voltage can be produced by rotating coil in a magnetic field or by rotating magnetic field keeping the coil stationary.



Let us consider a coil having 'N' no. of turns is rotating in a uniform magnetic field at an angular velocity of w radian/sec.

It starts from initial position of x-x and rotated by an angle θ in time t, sec. in anticlockwise directⁿ

$\theta = wt$

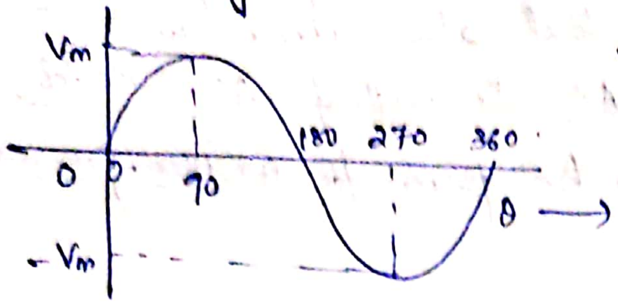
At this instant flux ⊥r to the coil is $\phi_m \cos wt$,
ϕ_m is the maxᵐ possible flux.

By faraday's law

$$E = -N\frac{d\phi}{dt} = -N\frac{d}{dt}\phi_m \cos wt$$

$$E = N\phi_m w \sin wt \Rightarrow E = V_m \sin wt$$

Hence, the voltage produced will depend on the value of $\sin \omega t$ and the curve obtained for different values of θ is a 'sine curve'.



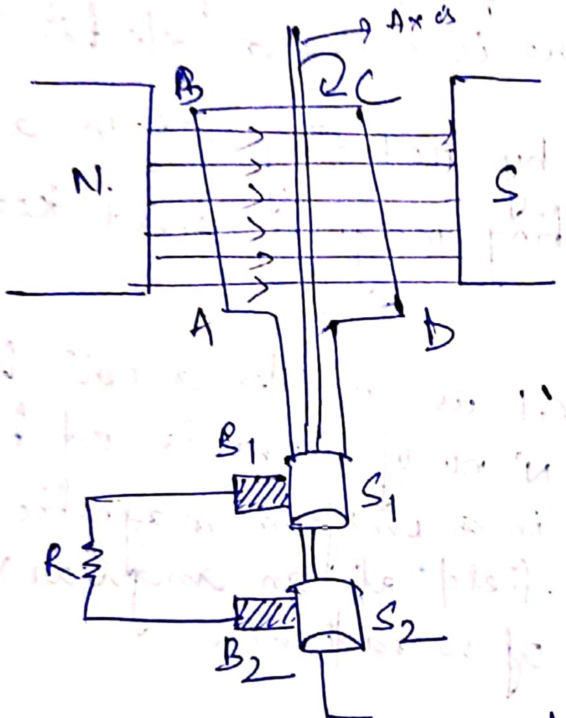
"The emf induced is therefore known as Sinusoidal emf"

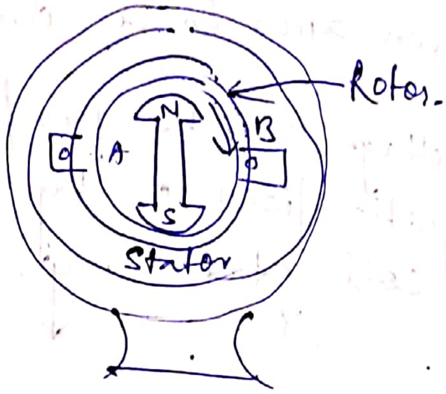
$e = V_m \sin\theta$

$= V_m \sin \omega t$

$e = V_m \sin(2\pi f t)$ $\quad$ f = freq of revolution of coil

$I = I_m \sin(\omega t \pm \phi)$





The magnitude of emf depends on
1. No. of turns of the coil
2. Strength of the magnetic field.
3. Speed of the coil.

Fleming's Right Hand Rule

(magnetic field) Index | Thumb. (Thrust or motion)

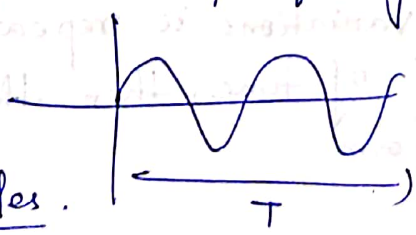
Current middle

Difference b/w AC and DC

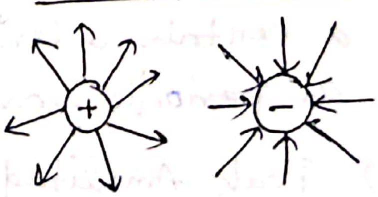
Direct Current	Alternating Current
1. DC stands for direct current.	1. AC stands for Alternating current.
2. DC flows in only one direction.	2. AC reverses its direction periodically.
3. Magnitude of current may be constant or vary with time but in only one direction	3. Magnitude of current vary with time.
4. The frequency of DC is zero.	4. The frequency of AC is 50 Hz / 60 Hz. → 50 Hz in India
5. DC can be stored	5. AC cannot be stored
6. Voltage cannot be changed easily.	6. Voltage can easily be changed using transformer
7. DC is portable	7. AC is not portable.
8. Useful for low voltage/ power electronic devices.	8. Used for heavy loads like motors, lights, heating elements etc.

* **Frequency**:- The no. of waves that pass a fixed point in unit time is frequency.

$$f = \frac{1}{T}$$

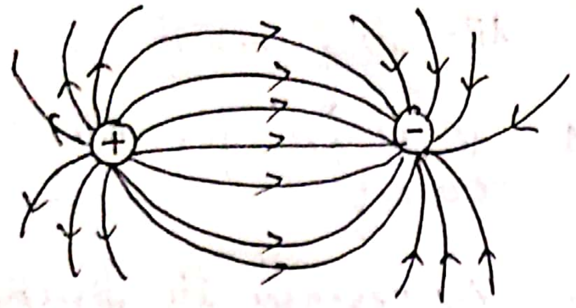


Electric field lines



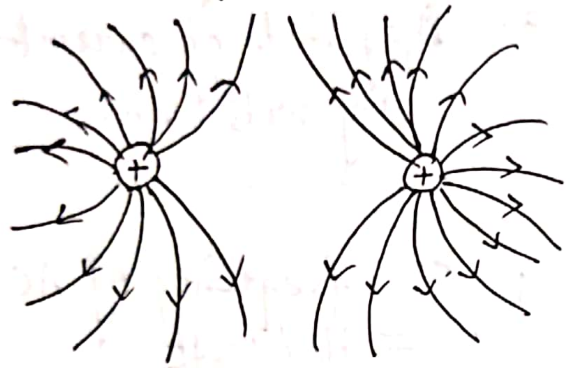
$$f = \frac{\text{No. of cycles}}{\text{unit time}}$$

a) Betⁿ Two Equal & opposite charges



* Electric field lines are drawn to specify the direction of electric field

b) Betⁿ Two Equal and like charges.

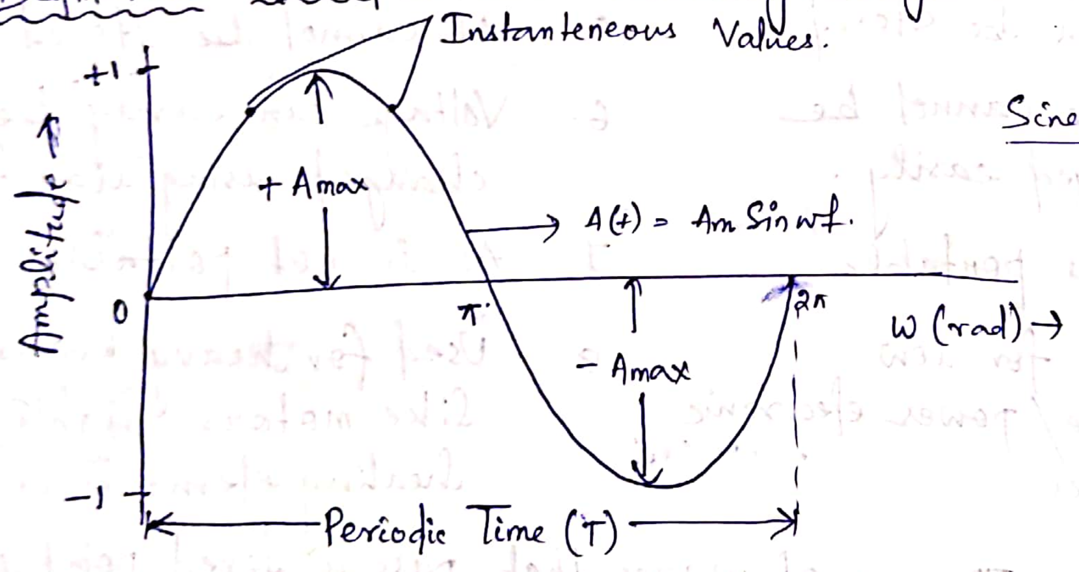


* Electric field

⇒ The field around a charged conductor.

⇒ The net electric field inside a conductor is always zero.

Definations Related to an alternating voltage or current.



1) Periodic Waveform.

If the same set of variations is repeated indefinitely after a certain interval of time, then the waveform is known as periodic waveform.

2) Peak Amplitude.

It is the maximum value reached by the alternating quantity in a cycle either in positive or negative half cycle. It is also known as crest value. It is denoted by Am

3) **Cycle** :- The interval of time during which a complete set of non-repeating waveform variation occurs is called cycle. It may be positive or negative cycle.

4) **frequency** :- It is defined as the number of cycles completed by an alternating quantity in one second. Its unit is Hertz (Hz).

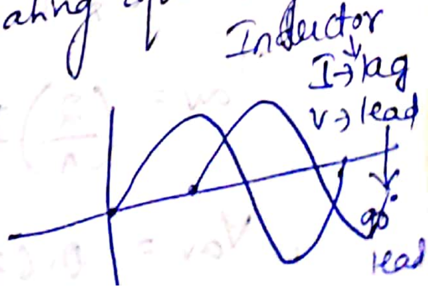
1 Hz = 1 cycle/sec.

5) **Angular frequency** :- It is the angular distance (angle) covered by alternating quantity in one second. It is also known as angular velocity, $\omega = 2\pi f$.

6) **Time period** :- It is defined as the time required for an alternating quantity in one second. It is denoted by T.

7) **phase**

It is the angular measurement of alternating quantity which specifies the position of wave.



8) <u>phase difference.</u>

The difference betn the phases of the two alternating quantities is called as phase difference.

Different Types of values of Alternating voltage & current

1. Instantaneous value

It is defined as the value of alternating quantity at any instant of time. It is represented by $i(t)$ or $v(t)$.

ex:- $v(t) = V_m \sin(\omega t + \phi)$

2. Average value.

The average value of an AC voltage or current in an AC circuit is the mathematical mean of all instanteneous values in a sine wave.

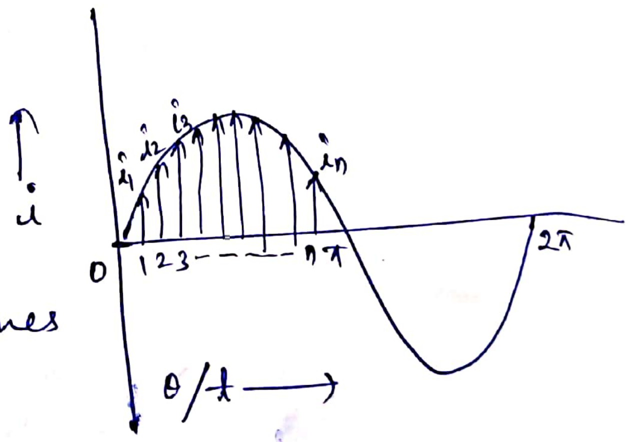
For an alternating current, the avg value is defined as that value of DC current which transfers across any circuit the same charge as it transfered by the alternating current during the same time under the same condn.

It is represented by I_{avg} or V_{avg}.

Two Methods

① Graphical Method

$$I_{av} = \frac{i_1 + i_2 + i_3 + \cdots i_n}{n}$$



I_{av} = Avg value of current

$i_1, i_2, i_3 \ldots$ instanteneous values of current

n = no. of instants

→ The avg value over a complete cycle is zero. ?

② Analytical Method

$$I_{av} = \frac{\text{Area under the half cycle}}{\text{length of Base of half cycle}}$$

* Avg value = 0.637 × Max value.

3) RMS value

The RMS value of an alternating current is given by the value of dc current which when flowing through a given circuit for a given time, produces the same amount of heat as produced by the alternating current, which when flowing through the same circuit for same time.

In other words, the RMS value is defined as the square root of means of square of instanteneous values.
It is represented by V_{rms} or I_{rms}.

Two Methods

① Graphical.

$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}}$$

Ⓘ Analytical.

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$$

4) Form factor

It is the ratio of RMS value of an alternating quantity to the avg value of the same quantity.

$$FF = \frac{\text{RMS value}}{\text{Avg value}} = \frac{0.707 I_m}{0.637 I_m} = 1.11 \text{ (sine wave)}$$

5) Peak factor / crest / Amplitude factor

$$\text{Peak factor} = \frac{\text{Max value}}{\text{RMS value}}$$ 1.414.

PHASOR DIAGRAM

Vector
phasor ⟩ Both Magnitude and directⁿ.

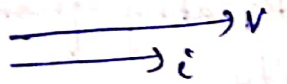
→ The difference betⁿ a vector and phasor is that the direction and magnitude of a vector is fixed whereas phasor quantity is a quantity having directⁿ & magnitude both are changing with time in cyclic order.

→ In AC supply, the voltage, current etc are the phasor quantities.

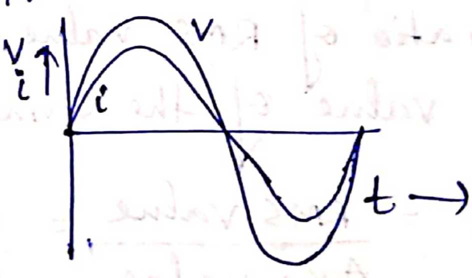
Phasor diagram. :- The diagram drawn between current and voltage in AC circuits, So, Hence, a diagram showing the phase relation b/w current and voltage of the ckt is known as "phasor diagram".

IN PHASE-

Two waveforms are said to be in phase if they begin simultaneously and end simultaneously. They also reach their maxᵐ value in the same time, but their amplitude may be different.



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

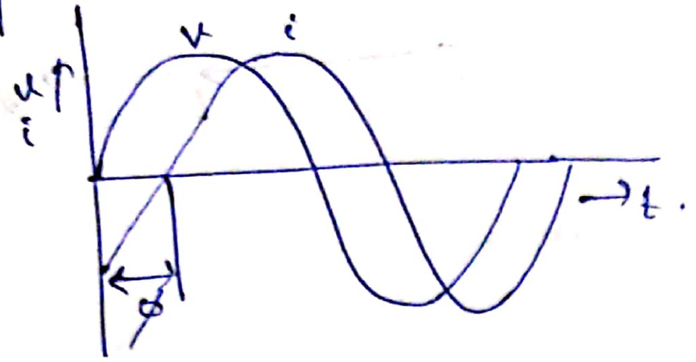


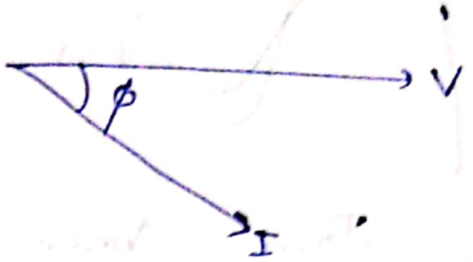
Both V and I reaches to their max value in same time.

LAGGING & LEADING QUANTITIES

The term lead or lag are used to describe the relative positions in time of two sinusoidal quantities that are not in phase.

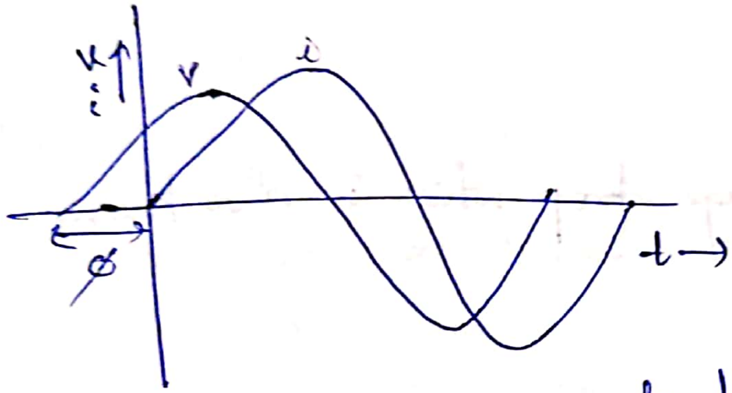
The quantity which is ahead in time is said to be lead, while the quantity that is behind in time is said to be lag.

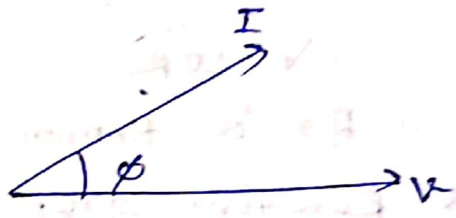




$v = V_m \sin \omega t$.

lagging current. $i = I_m \sin(\omega t - \phi)$

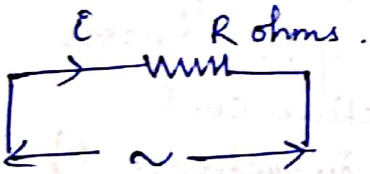




$v = V_m \sin \omega t$.

leading current, $i = I_m \sin(\omega t + \phi)$

CIRCUIT CONTAINING PURE RESISTANCE



The fig shows that a circuit containing a pure resistance of R ohms connected across a sinusoidal voltage represented by $v = V_m \sin \omega t$. If 'i' is the instanteneous current flowing through the pure resistance

$$i = \frac{v}{R}$$

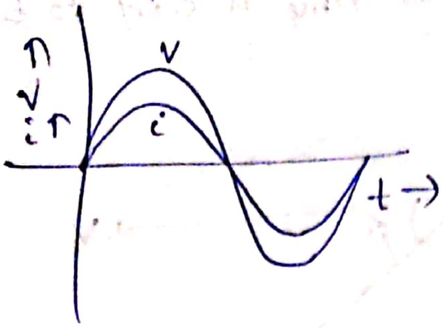
$$\Rightarrow i = \frac{V_m \sin \omega t}{R}$$

$$\Rightarrow \boxed{i = I_m \sin \omega t.}$$

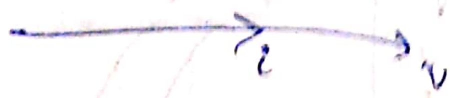
$v = V_m \sin \omega t$.

'I' & 'V' are in phase.

Waveform



Phasor diagram



$$I_{max} = \frac{V_{max}}{R_{max}}$$

$$R = \frac{V_{max}}{I_{max}} = \frac{V_{max}/\sqrt{2}}{I_{max}/\sqrt{2}} = \frac{V_{rms}}{I_{rms}}$$

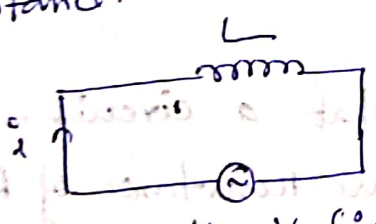
$$R = \frac{V}{I}.$$

$$V = IR$$

RI is known voltage drop which is also known as Resistive drop.

Purely Inductive Circuit

A pure inductive circuit is that which has negligible resistance.



An AC supply voltage of $V = V_m \sin\omega t$ is given across a pure inductive coil having self inductance of 'L' Henry.

Then, $V = L\frac{di}{dt}$.

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

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

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

Integrating both sides

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

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

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

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

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

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

$\cos\theta = \sin\left(\frac{\pi}{2} - \theta\right)$

$-\cos\theta = -\sin\left(\frac{\pi}{2} - \theta\right)$

$= \sin\left(-\frac{\pi}{2} + \theta\right)$

$$I_{max} = \frac{V_{max}}{WL}$$

The unit of 'WL' is ohm which is the opposition ~~opp~~ offered by pure inductive coil to the electric current through it. It is also called as Inductive reactance denoted by X_L

$$X_L = WL$$

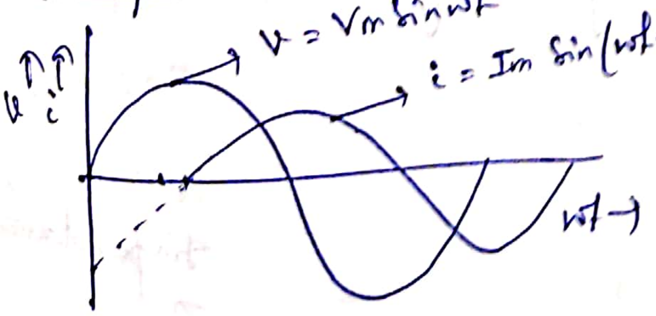
$$X_L = 2\pi f L \text{ ohms.}$$

$$WL = \frac{V_{max}}{I_{max}}$$

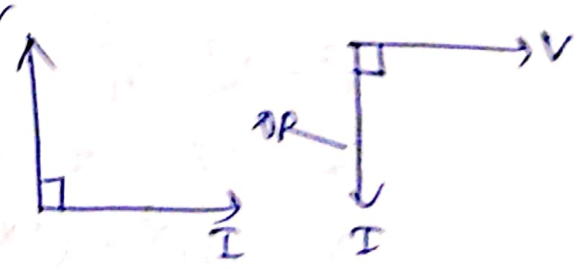
$$X_L = \frac{V_{max}/\sqrt{2}}{I_{max}/\sqrt{2}} = \frac{V_{rms}}{I_{rms}}$$

$\boxed{V = IX_L}$ → Inductive voltage drop.

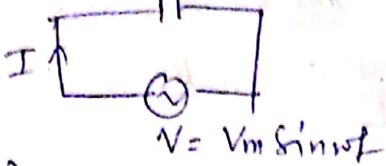
Waveform.



Phasor diagram.



Pure Capacitive ckt



$Q = CV$

$i = \frac{dQ}{dt}$; $\Rightarrow i = \frac{d}{dt}(CV)$

$\Rightarrow dQ = i\,dt$ ✗ $\Rightarrow i = C\frac{dV}{dt}$

$\Rightarrow$

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

$\Rightarrow i = CV_m \omega \cos \omega t$

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

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

$C\omega V_m = I_m$

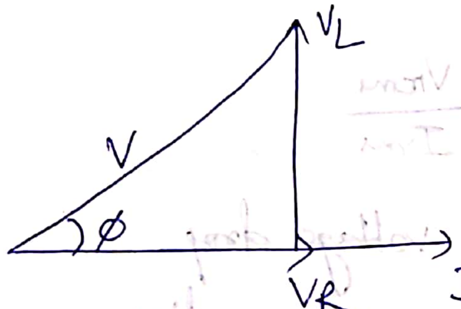
$C\omega = \frac{I_m}{V_m}$

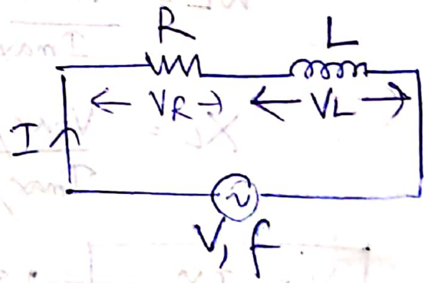
$\Rightarrow \frac{1}{C\omega} = \frac{V_m}{I_m}$

$\Rightarrow X_C = \frac{V_m}{I_m}$ (Ω)

$V = IX_C$ (Capacitive voltage drop).

R-L series circuit.





ϕ = phase Angle betn voltage supply, V and current I.

$V^2 = V_R^2 + V_L^2$

$V_R = IR$, $V_L = IX_L$

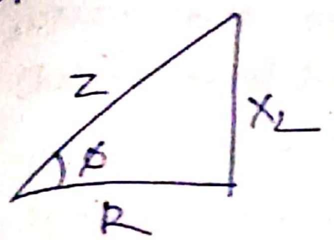
$V^2 = (IR)^2 + (IX_L)^2$

$V^2 = I^2(R^2 + X_L^2)$

$\left(\frac{V}{I}\right)^2 = R^2 + X_L^2 \Rightarrow \frac{V}{I} = \sqrt{R^2 + X_L^2} \Rightarrow Z = \sqrt{R^2 + X_L^2}$

Impendance ↗ (Z)

Impedance Triangle



The three sides of the triangle represent impedance, inductive reactance and resistance. This triangle is known as impedance triangle.

$\frac{V}{I} = Z$, $\frac{V_L}{I} = X_L$, $\frac{V_R}{I} = R$

$\tan\phi = \frac{X_L}{R}$.

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

Apparent power, True power, reactive power.

Apparent power :- The product of rms values of voltage and current (VI) is called the apparent power and measured in volt amperes or kilovolt amperes (KVA)

$$S = VI \quad KVA$$

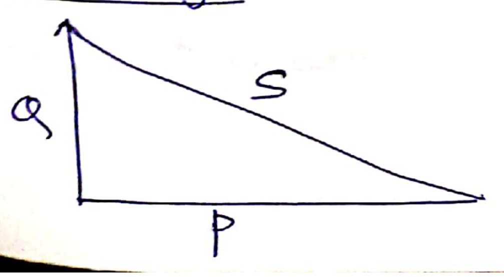
True power. - It is obtained by multiplying the apparent power by the power factor. and is measured in watts or kilowatts.

$$P = VI\cos\phi \quad KW.$$

Reactive power :- The product of apparent power and sine of the angle b/w voltage & current, $\sin\phi$ is called reactive power. It is measured in Volt-Amp. Reactive of kilo-volt Ampere Reactive (KVAr)

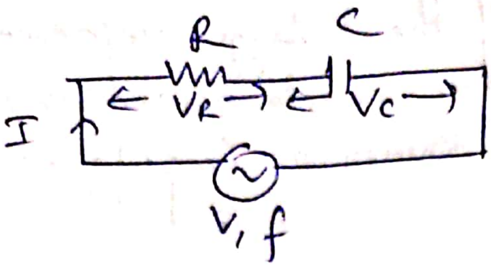
$$Q = VI\sin\phi \quad KVAr.$$

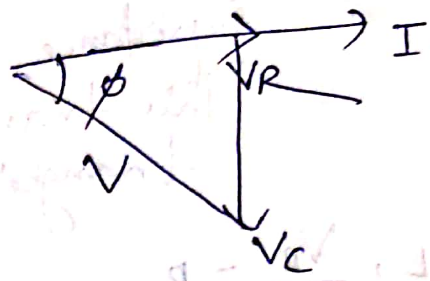
Power Triangle



S = Apparent power (KVA)
P = True power (KW)
Q = Reactive power (KVAr)

R-C Series ckt





$$V^2 = V_R^2 + V_C^2$$

$$\Rightarrow V^2 = (IR)^2 + (IX_c)^2$$

$$\Rightarrow V^2 = I^2 [R^2 + X_c^2]$$

$$\Rightarrow \left(\frac{V}{I}\right)^2 = R^2 + X_c^2$$

$$\Rightarrow Z = \sqrt{R^2 + X_c^2}$$

$$\phi = \tan^{-1} \frac{X_c}{R}$$