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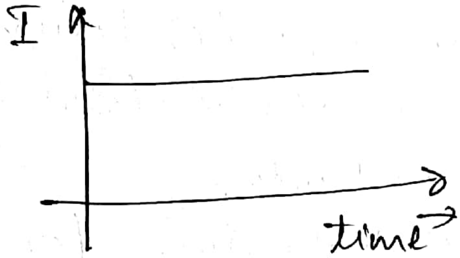
D.C CIRCUITS : A Direct Current always remains constant and does not vary with time. The D.C current characterises the flow of Electric charge in one particular direction



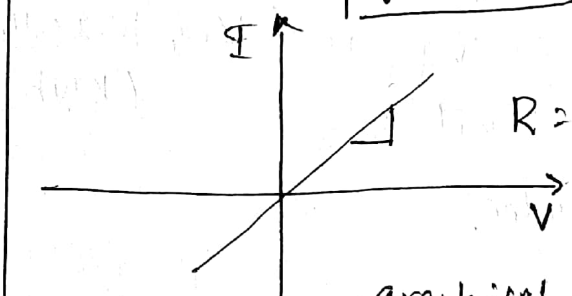
A D.C circuit consists of constant voltage sources, constant current sources and their interconnection with resistances only.
The study of D.C circuits necessiates the study of the various elements of an Electric circuit.

OHM'S LAW : At constant Temperature, the current flowing through any conductor is directly proportional to the potential difference between the two ends of the conductor.

$I \propto V$ at constant temperature

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

$\boxed{V = IR}$ $R \rightarrow$ constant, known as Resistance of the conductor.



$R = \frac{1}{\text{Slope}}$

$\text{Slope} = \frac{\Delta I}{\Delta V}$

graphical representation of Ohm's Law.

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LIMITATIONS OF OHM'S LAW :

(i) Ohm's law does not hold good for Non-linear devices such as Zener diodes, Voltage regulators, etc.

(ii) Ohm's law does not hold good for Non-metallic conductors such as Silicon carbide, Polymers, etc. For such devices VI - relation is of the form
$V = KI^m$ where $K, m \rightarrow$ constants.

(iii) Ohm's law does not hold good for Arc lamps because of their Non-linear characteristics.

ELECTRICAL ENERGY (W) : It is the total amount of Electrical Workdone in an Electric Circuit.

$$W = \text{Power} \times \text{time} = VI \times t \text{ watt-sec}$$

$$W = \frac{V^2}{R} t = I^2Rt \text{ watt-sec}$$

NOTE : As the 'watt-sec' is a very small unit, Electrical Energy is measured in larger units i.e 'Kilo Watt Hour' (KWh)
The Practical Unit of energy is 'Kilo Watt Hour' (KWh) whose trade name is 'Unit'

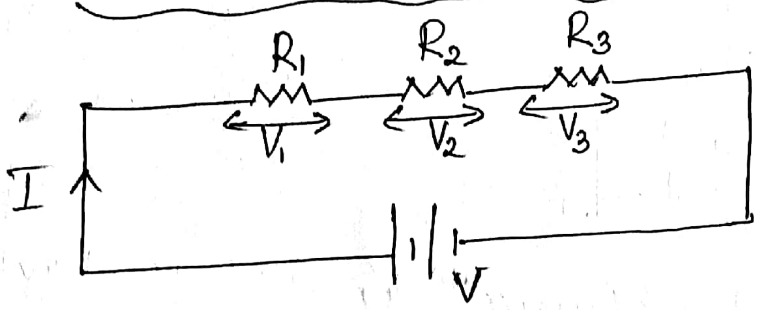
$$1 \text{ KWh} = 3.6 \times 10^6 \text{ joules.}$$

ELECTRICAL POWER (P) :- The Rate at which Electrical work is done in an Electric circuit is called Electrical Power.

$$P = \frac{W}{t} = \frac{VI.t}{t}$$

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

RESISTANCES IN SERIES (R_s) :



$$V = V_1 + V_2 + V_3$$

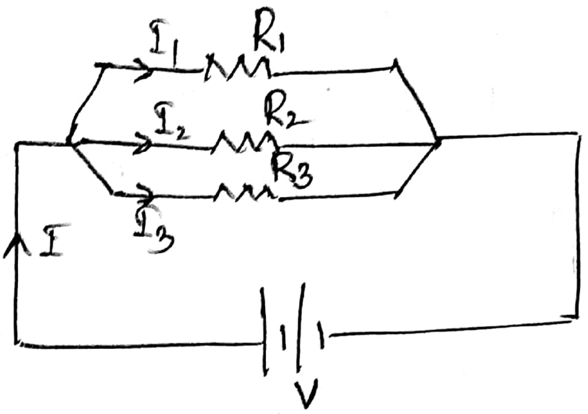
$$I R_s = IR_1 + IR_2 + IR_3$$

$\therefore$ Total Resistance $\boxed{R_s = R_1 + R_2 + R_3}$

If there are 'n' Resistances connected in Series

$$\boxed{R_s = R_1 + R_2 + R_3 + \dots\dots + R_n}$$

RESISTANCES IN PARALLEL : (R_p)



$$I = I_1 + I_2 + I_3$$

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

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

If there are 2 Resistances connected in Parallel

$$\boxed{R_p = \frac{R_1 R_2}{R_1 + R_2}}$$

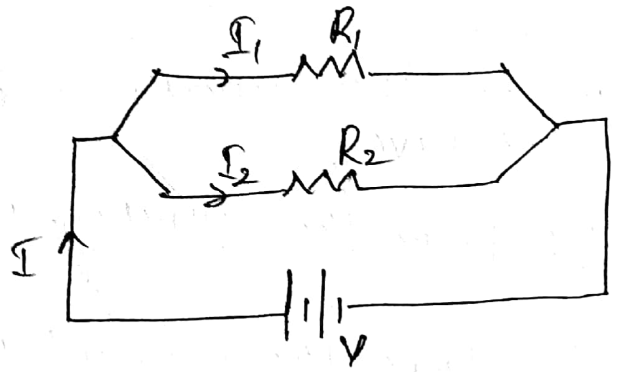
If there are 3 Resistances connected in parallel

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

If there are 'n' Resistances connected in parallel

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

CURRENT IN A PARALLEL BRANCH :



$$I = I_1 + I_2 \quad \ldots\ldots (a)$$

As voltage across Parallel combination is Constant,

$$V = I_2 R_2 = I_1 R_1$$

$$\frac{I_2}{I_1} = \frac{R_1}{R_2}$$

$$\frac{I_2}{I_1} + 1 = \frac{R_1}{R_2} + 1$$

$$\frac{I_2 + I_1}{I_1} = \frac{R_1 + R_2}{R_2}$$

On Re-arranging, $$\frac{I}{I_1} = \frac{R_1 + R_2}{R_2}$$

$$\therefore \boxed{I_1 = \frac{I R_2}{R_1 + R_2}}$$

Similarly $$I_2 = \frac{I R_1}{R_1 + R_2}$$

In general,

$$\text{Branch Current} = \frac{\text{Total Current} \times \text{The other Resistance}}{\text{Sum of the Two Resistances.}}$$

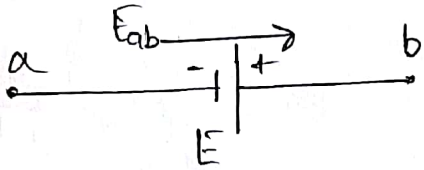
NOTE :

(i) Currents flowing towards the junction are are taken as '+ive'.

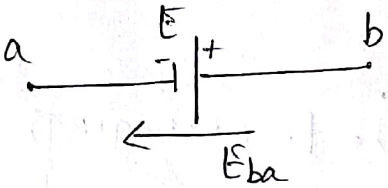
(ii) Currents flowing away from the junction are taken as -ive.

(iii) All the voltage rises are taken as '+ive' and all the voltage drops are taken as '-ive'.

(iv)

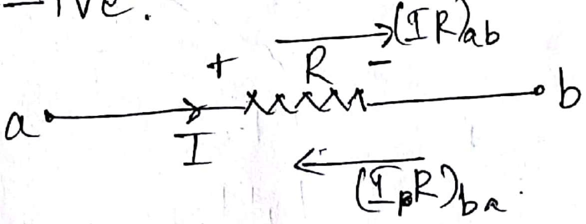


when the battery is traced from a to b, 'E_{ab}' is +ive.



when the battery is traced from b to a, 'E_{ba}' is -ive.

(v)



The voltage drop $(IR)_{ab}$ is -ive.

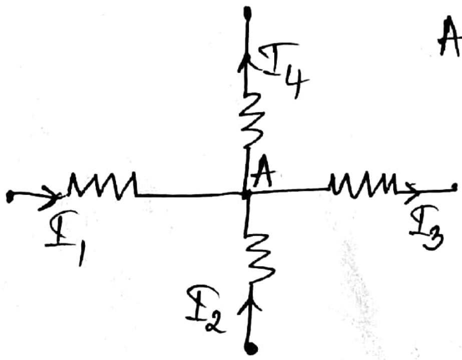
The voltage drop $(IR)_{ba}$ is +ive.

KIRCHOFFS LAWS : (i) Current law (ii) Voltage law.

(i) KIRCHOFFS CURRENT LAW (KCL) : The Algebraic Sum of all the Currents meeting at any junction of an Electrical Circuit is zero.

Mathematically, i.e $\sum I = 0$.

Eg:- Consider junction 'A' of an Electrical Circuit shown below.



According to Kirchoff's current law,

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

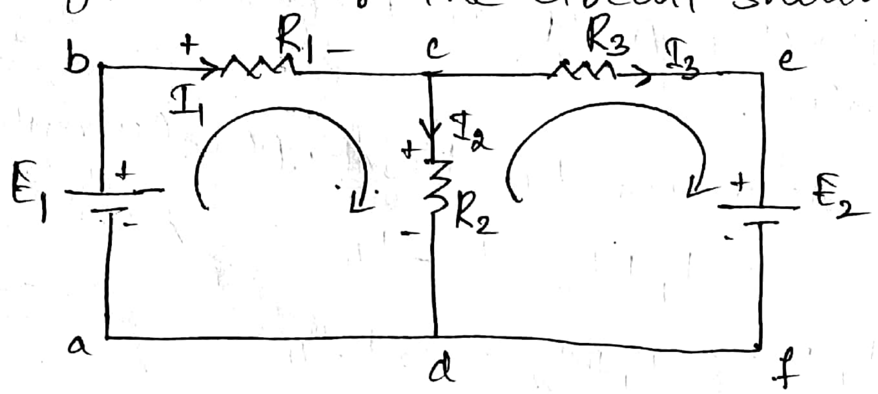
$$I_1 + I_2 = I_3 + I_4$$

KCL can also be stated as " At any junction of an Electric Circuit, the sum of all the Currents entering the junction is equal to the Sum of all the Currents leaving the junction"

KIRCHHOFF'S VOLTAGE LAW (KVL) : In any closed electrical circuit, the algebraic sum of all the EMFs and the Resistive drops is equal to zero.

Mathematically, i.e $\sum E + \sum IR = 0$.

Eg: Consider the circuit shown in fig below,



According to KVL,

for the closed loop abcda :

$$+E_1 - I_1R_1 - I_2R_2 = 0.$$

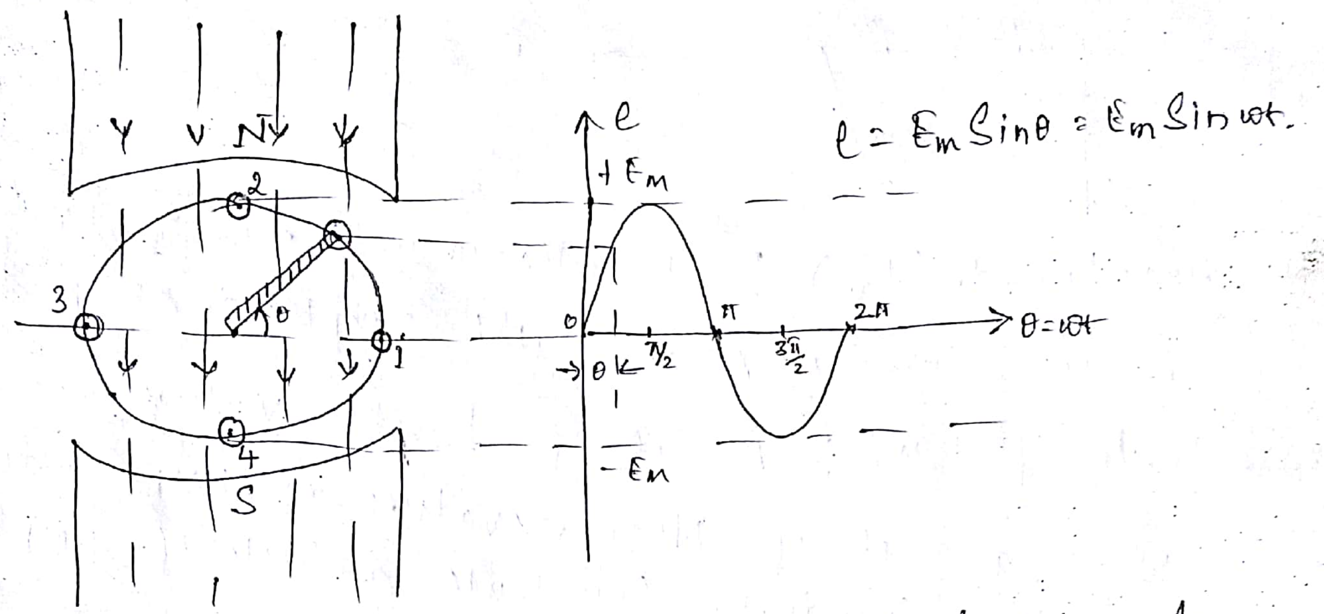
$$I_1R_1 + I_2R_2 = E_1$$

for the closed loop dcefd :

$$+I_2R_2 - I_3R_3 - E_2 = 0.$$

$$I_2R_2 - I_3R_3 = E_2$$

GENERATION OF A.C VOLTAGE :



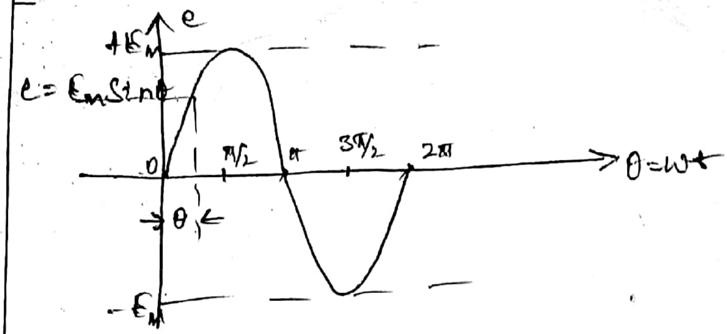
The EMF Induced in the conductor is given by

$e = BlvSin\theta = E_m Sin\omega t$ where, $l \rightarrow$ Length of the Conductor (m)
$B \rightarrow$ Flux density (wb/m²)
$v \rightarrow$ Velocity
$\omega \rightarrow$ Angular Velocity.

* When the Conductor is rotating from Position 1 to 2 and 2 to 3 i.e from $\theta = 0$ to $\theta = \pi$, it is rotating under the influence of North pole & the direction of the Induced EMF is +ive.
* Similarly when the Conductor is rotating from Position 3 to 4 & 4 to 5 i.e from $\theta = \pi$ to $\theta = 2\pi$, it is rotating Under the influence of South pole & the direction of Induced EMF is -ive.

DEFINITIONS :

(i) Instantaneous Value : (e) The Value of EMF induced in the Conductor at any instant



(ii) __Amplitude (E_m)__ : The Maximum Value of EMF induced in the conductor is called amplitude.

(iii) __Cycle of EMF__ : A Set of Positive values together with a Set of Negative values of EMF induced in the conductor constitute a cycle of EMF induced.

(iv) __Frequency (f)__ : It is defined as the number of cycles of EMF induced in the conductor per second.

(v) __Time Period (T)__ : It is the time taken to complete one cycle of the EMF induced ($T = 1/f$)

__ADVANTAGES OF SINUSOIDAL WAVEFORMS :__

(i) Many Phenomena occuring in the nature are of Sinusoidal in nature Eg: Motion of a Pendulum, Vibration of Strings in Musical instruments, etc.

(ii) The Derivative & Integral of a Sinusoidal function is also Sinusoidal in nature. This makes the mathematical analysis of an Electrical Circuit much easier.

(iii) When the Current in a Capacitor or Inductor is Sinusoidal in nature, the Voltage across them is also Sinusoidal. This is not true for Other waveforms.

(iv) For any disturbance in the Circuit, the Shape of the Sinusoidal waveform remains the same which is not true for other waveforms.

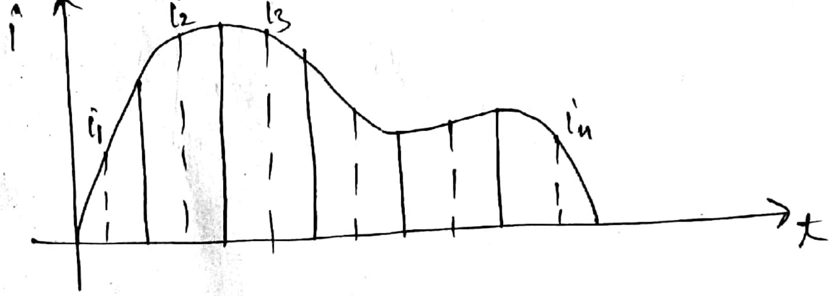
(V) When a three phase Sinusoidal voltage is applied to the windings of a motor, it produces a revolving magnetic field, which has the Capacity to do work. Most of the A.c motors used in Industrial or other applications work on this Principle.

EFFECTIVE VALUE OF AN ALTERNATING CURRENT (R.M.S VALUE)

Defn/:

The effective or rms value of an Alternating Current is equal to the steady Current, which produces the same amount of heat as produced by the alternating Current, when passed through the Same resistance for the Same time.

EFFECTIVE VALUE OF AN ALTERNATING CURRENT REPRESENTED BY ANY WAVEFORM :- [I or I_{rms}]



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The Wave form is divided into 'n' equal parts, each interval is equal to 't/n' seconds. Let $i_1, i_2 \ldots i_n$ be the Mid-ordinates of these intervals.

Heat Produced during first interval $= i_1^2 R\, t/n$

Heat Produced -1- Second interval $= i_2^2 R\, t/n$

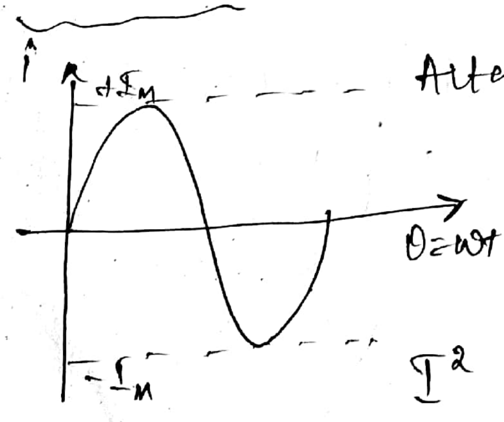
Heat Produced during n^{th} interval $= i_n^2 R\, t/n$

∴ The total Heat Produced in 't' seconds $\Big\}$ $H = \dfrac{(i_1^2 + i_2^2 + \ldots + i_n^2) Rt}{n}$

$$I^2 Rt = \frac{(i_1^2 + i_2^2 + \ldots + i_n^2) Rt}{n}$$

Effective or RMS value of an Alternating Current $\Big\}$ $I = \sqrt{\dfrac{i_1^2 + i_2^2 + \ldots + i_n^2}{n}}$

EFFECTIVE VALUE OF AN ALTERNATING CURRENT WHICH IS SINUSOIDALLY VARYING :



Alternating current $\Big\}$ $i = I_m \sin\theta$

The effective value of Current is

$$I^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2 \cdot d\theta = \frac{1}{2\pi}\int_0^{2\pi} I_M^2 \sin^2\theta \cdot d\theta$$

$$I^2 = \frac{I_m^2}{2\pi}\int_0^{2\pi}\left(\frac{1-\cos 2\theta}{2}\right).d\theta = \frac{I_m^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}$$

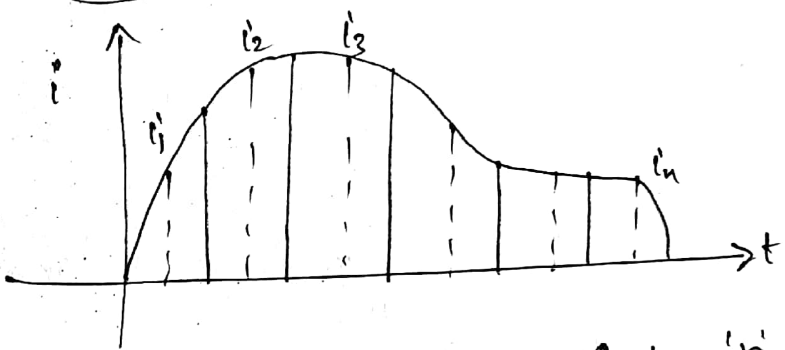
$$I^2 = \frac{I_m^2}{4\pi}\times\left[(2\pi-0)-0\right]$$

$$\boxed{I \text{ or } I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m}$$

AVERAGE VALUE OF AN ALTERNATING CURRENT (I_{av})

Defn: The Average value of an Alternating current is equal to that steady current, which transfers the same amount of charge, as transferred by the alternating current across the same circuit and in the same time.

AVERAGE VALUE OF AN ALTERNATING CURRENT REPRESENTED BY ANY WAVEFORM :



Divide the waveform into 'n' equal parts, so that duration of each interval is 't/n' seconds. Let 'q' be the charge transferred across the circuit in 't' sec.

Charge transferred during first interval = $i_1 \frac{t}{n}$

Charge transferred -"- second interval = $i_2 \frac{t}{n}$

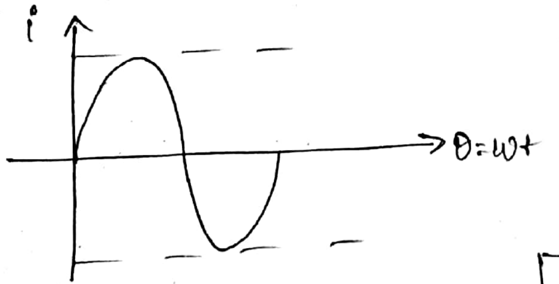
⋮

Charge transferred during n^{th} interval = $i_n \frac{t}{n}$

∴ The total charge transferred in 't' seconds } $q = I_{av} t = \frac{(i_1 + i_2 + \dots + i_n) t}{n}$

$$\therefore \boxed{I_{av} = \frac{i_1 + i_2 + \dots + i_n}{n}}$$

AVERAGE VALUE OF AN ALTERNATING CURRENT REPRESENTED BY A SINUSOIDAL WAVEFORM :



$$I_{av} = \frac{1}{\pi}\int_0^{\pi} i \cdot d\theta = \frac{1}{\pi}\int_0^{\pi} I_m \sin\theta \cdot d\theta$$

$$= \frac{I_m}{\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{I_m}{\pi}\left[-1-(-1)\right]$$

$$\boxed{I_{av} = \frac{2 I_m}{\pi} = 0.637 \, I_m}$$

NOTE :- The Average value of an Alternating Current represented by a sine wave over one complete cycle is zero.

FORM FACTOR (K_f) :- The Form Factor of an Alternating quantity represented by a sinusoidal waveform is defined as the ratio of RMS value to its Average value.

$$\text{Form factor } K_f = \frac{\text{rms value}}{\text{Average value}} = \frac{I_{rms}}{I_{av}}$$

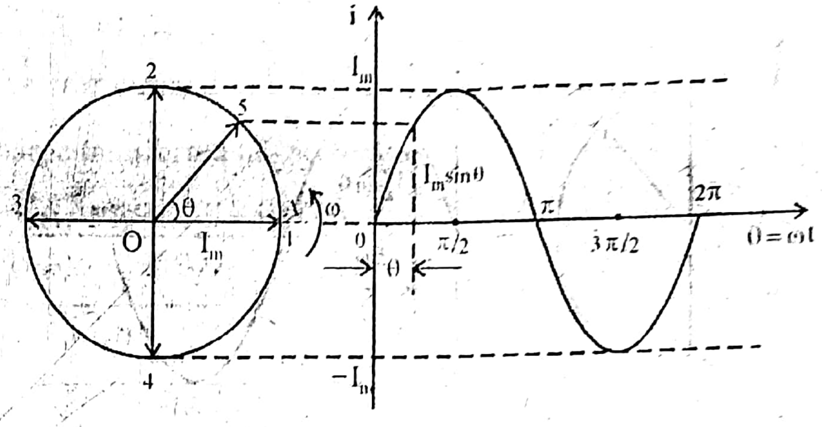
$$K_f = \frac{0.707 I_m}{0.637 I_m} = 1.11, \text{ for a sine wave.}$$

PEAK FACTOR (K_p) :- The Peak factor of an Alternating quantity represented by a sinusoidal waveform is defined as the ratio of Maximum value to its rms value.

$$\text{Peak Factor } K_p = \frac{\text{Maximum value}}{\text{rms value}} = \frac{I_m}{I_{rms}}$$

$$K_p = \frac{I_m}{0.707 I_m} = 1.414, \text{ for a sine wave.}$$

PHASE & PHASE - DIFFERENCE :



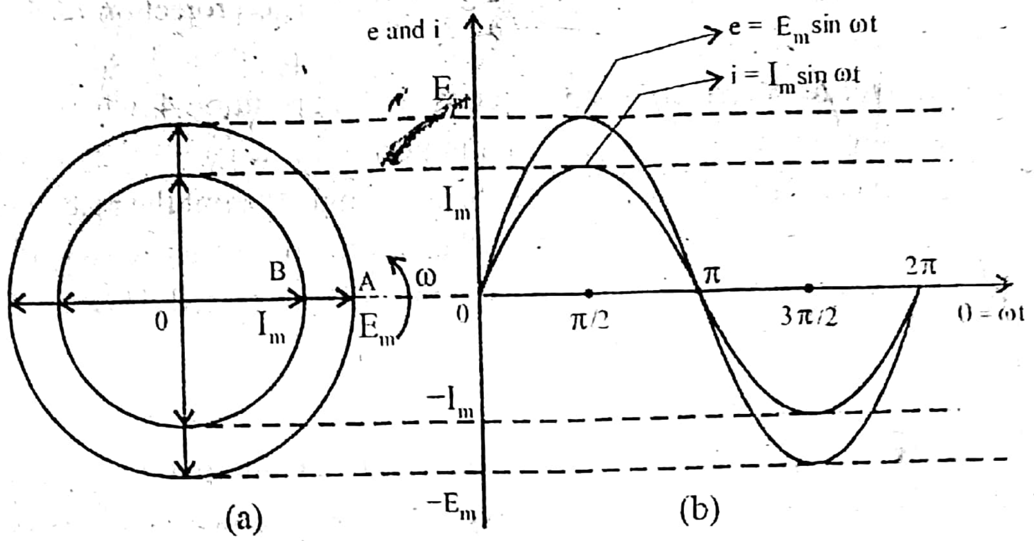
Defn : The phase of an Alternating quantity at any instant is the angle through which the Rotating Vector representing the alternating has rotated through, from the reference axis.

↳ At position-1, the phase is zero, ~~At~~ other instant, Say at position-5, the phase is 'θ'.

↳ The phase of the Alternating quantity varies from 0 to 2π.

PHASE - DIFFERENCE : The Phase difference between two alternating quantities is the angle difference between the two rotating vectors, representing the two alternating quantities.

IN- PHASE :



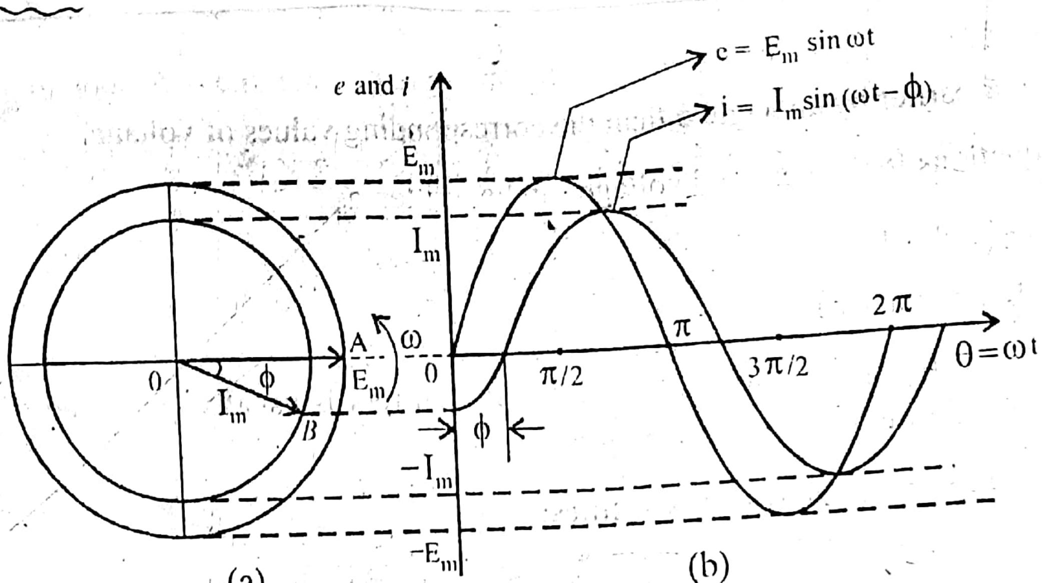
↳ Two Alternating quantities are said to be in phase with each other, when their corresponding values occur at the same time.

↳ The voltage & current equations are,

$e = E_m \sin\omega t$

$i = I_m \sin\omega t.$

PHASE LAG :



(a) (b)

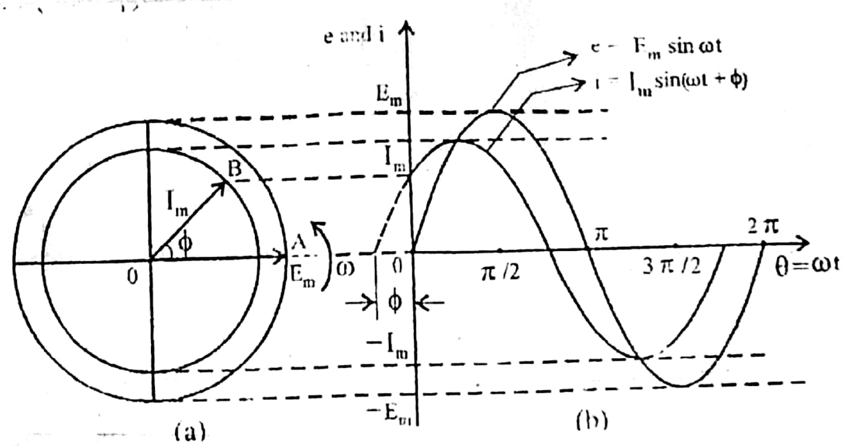
↳ The current is said to lag the voltage by an angle ϕ, when the corresponding values of current occur later by an angle ϕ, than the corresponding values of voltage.

↳ The current & voltage eqns. are,

$e = E_m \sin \omega t$

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

PHASE - LEAD :



↳ The current is said to lead the voltage by an angle ϕ, when the corresponding values of current occur earlier by an angle ϕ than the corresponding values of voltage.

↳ The current & voltage equns. are,

$e = E_m \sin \omega t$

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

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