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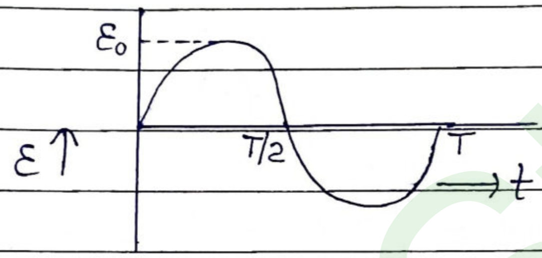
Alternating Currents

* Alternating EMF :-

An electromotive farce (emf) whose magnitude changes continuously with time and whose direction reverses periodically is know as an alternating emf.



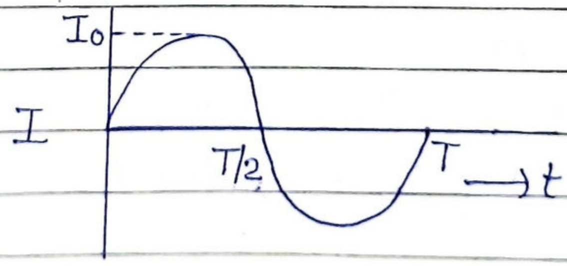
It is given by $\mathcal{E} = \mathcal{E}_0 \sin \omega t$

→ In general votage in india is given as 220 V and 50 Hz.

→ In USA, it is 110 V and 60 Hz.

* Alternating Current :-

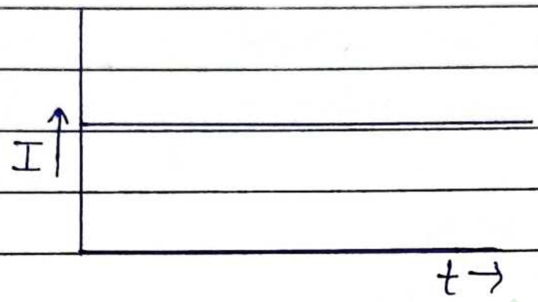
Alternating current (AC) is an electric current that periodically reverses its direction, and changes its magnitude continuously with time.



It is given by $I = I_0 \sin \omega t$
where I_0 is maximum value of current.

* Direct Current or Steady current :-

A current whose magnitude and direction remain constant with time is called direct current (DC) or steady current.



It's frequency is zero.

Time period $\Rightarrow T = \frac{1}{f} = \frac{1}{0} = \infty$.

* Average value or mean value of AC :-

Mean value of an alternating current is the total charge flown for one half cycle divided by the time taken to complete the half cycle i.e. time period T/2.

* Derivation :-

let dq be the small amount of charge in small time dt.

$$dq = I dt$$

but $I = I_0 \sin \omega t$

then $dq = I_0 \sin \omega t \, dt$

integrating on both side -

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$$\int_0^q dq = \int_0^{T/2} I_0 \sin\omega t\, dt$$

$$[q]_0^q = I_0 \int_0^{T/2} \sin\omega t\, dt$$

$$[q-0] = I_0 \left[\frac{-\cos\omega t}{\omega}\right]_0^{T/2}$$

$$q = \frac{-I_0}{\omega}\left[\cos\omega t\right]_0^{T/2}$$

$$q = \frac{-I_0}{\omega}\left[\cos\omega \frac{T}{2} - \cos 0\right]$$

we know that $\omega = 2\pi F$

$$\omega = \frac{2\pi}{T}$$

so, $$q = \frac{-I_0}{\omega}\left[\cos \frac{2\pi}{T} \times \frac{T}{2} - 1\right]$$

$$q = \frac{-I_0}{\omega}\left[\cos\pi - 1\right]$$

$\because \cos\pi = -1$

$$q = \frac{-I_0}{\omega}[-2]$$

$$q = \frac{2I_0}{\omega}$$

$$\boxed{q_{AC} = \frac{2I_0}{\omega}} \text{ —— (I)}$$

let I_m be the value of DC which would generate same amount of charge.

$$\boxed{q_{DC} = I_m \times \frac{T}{2}} \text{ —— (II)}$$

As per defination, equating (I) and (II)

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$$q_{DC} = q_{AC}$$

$$I_m \times \frac{T}{2} = \frac{2I_0}{\omega} \qquad \because \omega = \frac{2\pi}{T}$$

$$I_m \times \frac{T}{2} = \frac{2I_0}{2\pi} \times T$$

$$\boxed{I_m = \frac{2I_0}{\pi}}$$

or $I_m = 0.637\, I_0$

or $I_m = I_0\, 63.7\,\%$

Note :- Average value of alternating current for a complete cycle, i.e. Total charge flown in One cycle, is always zero.

Average or mean value of Alternating Emf :-

It is defined as the value of steady Emf which would generate same amount of charge as it generate by. alternating for Emf in the same circuit for half time period.

Derivation :-
let dq be the small amount of charge in small time dt.

$$dq = I\,dt$$
$$dq = \frac{\varepsilon}{R}\,dt$$

we know, $\varepsilon = \varepsilon_0 \sin \omega t$

$$dq = \frac{\mathcal{E}_0 \sin\omega t}{R} dt$$

Integrating on both side —

$$\int_0^q dq = \frac{\mathcal{E}_0}{R}\int_0^{T/2} \sin\omega t\, dt$$

$$[q-0] = \frac{\mathcal{E}_0}{R}\left[-\frac{\cos\omega t}{\omega}\right]_0^{t/2}$$

$$q = -\frac{\mathcal{E}_0}{R}\left(\cos\omega t\right)_0^{T/2}$$

$$q = -\frac{\mathcal{E}_0}{R\omega}\left[\cos\omega\frac{T}{2} - \cos 0\right]$$

$$q = -\frac{\mathcal{E}_0}{R\omega}\left[\cos\frac{2\pi}{T}\times\frac{T}{2} - 1\right]$$

$$q = \frac{-\mathcal{E}_0}{R\omega}[-2]$$

$$\boxed{q_{AC} = \frac{2\mathcal{E}_0}{R\omega}} \text{ — (i)}$$

let $\mathcal{E}_m$ be the value of DC which would generate same amount of charge.

$$q_{DC} = I_m \times \frac{T}{2}$$

$$\boxed{q_{DC} = \frac{\mathcal{E}_m}{R}\times\frac{T}{2}}$$

As per defination, equating (i) and (ii) :-

$$q_{AC} = q_{DC}$$

$$\frac{2\mathcal{E}_0}{R\omega} = \frac{\mathcal{E}_m}{R}\times\frac{T}{2}$$

$$\frac{2\varepsilon_0 \times T}{R \times 2\pi} = \frac{\varepsilon_m}{R} \times \frac{T}{2}$$

$$\frac{2\varepsilon_0}{\pi} = \varepsilon_m$$

$$\because \boxed{\varepsilon_m = \frac{2\varepsilon_0}{\pi}}$$

$$\varepsilon_m = 0.637\,\varepsilon_0 \Rightarrow \varepsilon_m = \varepsilon_0\, 63.7\%$$

Note :- Avarage value of alternating emf for full cycle is zero.

Root Mean Square (RMS) value of alternating Current :-

The RMS value of an AC is the direct current value that would provide the same power transfer (by AC) to a given resistance.

RMS value of function =

$$\text{RMS value} = \sqrt{\frac{1}{T}\int_0^T [f(x)]^2\,dx}$$

where T = Time period.

~~RMS value of function =~~

Note from Matematics : $\boxed{\cos(2A) = 1 - 2\sin^2 A}$

Derivation :-

let dH be the small amount of heat in small time dt.

$$dH = I^2 R\,dt$$

$$dH = (I_0 \sin\omega t)^2 R\,dt$$

$$dH = I_0^2 \sin^2\omega t\; R\,dt$$

Integrating on both side :

$$\int_0^H dH = I_0^2 R \int_0^T \sin^2\omega t \, dt$$

$$[H]_0^H = I_0^2 R \int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt \qquad \{2\sin^2\theta = 1-\cos 2\theta\}$$

$$[H-0] = \frac{I_0^2 R}{2}\left[\int_0^T (1-\cos 2\omega t)\, dt\right]$$

$$H = \frac{I_0^2 R}{2}\left[\int_0^T 1\, dt - \int_0^T \cos 2\omega t \, dt\right]$$

$$H = \frac{I_0^2 R}{2}\left[[t]_0^T - \left[\frac{\sin 2\omega t}{2\omega}\right]_0^T\right]$$

$$H = \frac{I_0^2 R}{2}\left[[T-0] - \frac{1}{2\omega}(\sin 2\omega T - \sin 0)\right]$$

$$H = \frac{I_0^2 R}{2}\left[(T - \frac{1}{2\omega}\left(\sin 2 \times \frac{2\pi}{T} \times T - \sin 0\right)\right]$$

$$H = \frac{I_0^2 R}{2}\left[T - \frac{1}{2\omega}(\sin 4\pi - 0)\right]$$

$$H = \frac{I_0^2 R}{2}\left[T - \frac{1}{2\omega}(\cancel{\sin 4\pi}(0-0)\right] \qquad \because \sin 4\pi = 0$$

$$\boxed{H_{ac} = \frac{I_0^2 RT}{2}} \quad \text{——} \quad (1)$$

let I_{RMS} be the value of DC which would generate same amount of heat.

$$H_{ac} = I_{RMS}^2 RT \quad \text{——} \quad (2)$$

As per defination equate (1) and (2) :-

$$H_{dc} = H_{ac}$$

$$I_{RMS}^2 RT = \frac{I_0^2 RT}{2}$$

$$I_{RMS}^2 = \frac{I_0^2}{2}$$

take square root on bothside —

$$\boxed{I_{RMS} = \frac{I_0}{\sqrt{2}}}$$

or $I_{RMS} = 0.707\, I_0$

or $I_{RMS} = 70.7\, I_0\ \%$

RMS value of alternating emf :-

The root means square (r.m.s) value of alternating e.m.f. is defined as the value of steady voltage, which would generate the same amount of heat in a given resistance in a given time.

Derivation :-

let dH be the same amount of heat in small time dt.

$$dH = I^2 R dt$$

$$dH = \left(\frac{\varepsilon}{R}\right)^2 R dt.$$

$$dH = \frac{\varepsilon^2}{R^2} R dt$$

$$dH = \frac{\varepsilon^2}{R} dt$$

$$dH = \frac{(\mathcal{E}_0 \sin \omega t)^2}{R} dt$$

$$dH = \frac{\mathcal{E}_0^2 \sin^2 \omega t}{R} dt$$

integrating both side

$$\int_0^H dH = \frac{\mathcal{E}_0^2}{R} \int_0^T \sin^2 \omega t \, dt$$

$$[H]_0^H = \frac{\mathcal{E}_0^2}{R} \int_0^T \sin^2 \omega t \, dt$$

$$[H-0] = \frac{\mathcal{E}_0^2}{R} \int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt$$

$$H = \frac{\mathcal{E}_0^2}{2R} \left[\int_0^T 1 \, dt - \int_0^T \cos 2\omega t \, dt\right]$$

$$H = \frac{\mathcal{E}_0^2}{2R} \left[[t]_0^T - \left[\frac{\sin 2\omega t}{2\omega}\right]_0^T\right]$$

$$\boxed{H_{ac} = \frac{\mathcal{E}_0^2 T}{2R}} \quad \text{—— (1)}$$

Let $\mathcal{E}_{RMS}$ be the value of steady Emf which would generate same amount of heat.

$$H_{dc} = I_{RMS}^2 R T$$

$$H_{dc} = \frac{E_{RMS}^2 R T}{R^2}$$

$$H_{dc} = \frac{E_{RMS}^2 T}{R} \quad \text{—— (2)}$$

As perdefination, equate ① and ② —

$$H_{dc} = H_{ac}$$

$$\frac{\mathcal{E}_{RMS}^2 T}{R} = \frac{\mathcal{E}_0^2 T}{2R}$$

$$E_{RMS}^2 = \frac{\mathcal{E}_0^2}{2}$$

take square root both side :-

$$\boxed{E_{RMS} = \frac{E_0}{\sqrt{2}}}$$

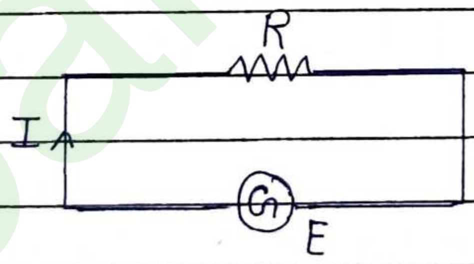
or $E_{RMS} = 0.707\ \mathcal{E}_0$

or $E_{RMS} = 70.7\ \mathcal{E}_0\ \%$

* Circuit Analysis :-

① circuit containing Resistance only :-

let a Resistance is connected with an AC source.



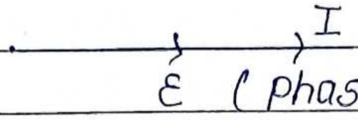
$$I = \frac{\mathcal{E}}{R} \quad \text{(ohm's law)}$$

Alternating emf, $\mathcal{E} = \mathcal{E}_0 \sin\omega t$ — ①

$$I = \frac{\mathcal{E}_0 \sin\omega t}{R} \qquad \therefore I_0 = \frac{\mathcal{E}_0}{R}$$

$$I = I_0 \sin\omega t \quad — ②$$

Now compare the phase of equation ① and ②. it is clear that I and ε are in same phase.



Also $\phi = 0°$ (Phasar diagram)

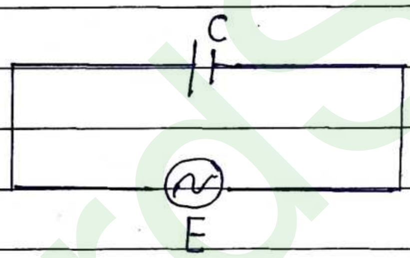
where, ϕ is phase difference.

Phase diagram.

wave farm - Graph ①

② Circuit Containing capacitor only :-

let a capacitor is connected with an AC Source.



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

$$\because q = C\varepsilon$$

$$I = \frac{d(C\varepsilon)}{dt}$$

$$\varepsilon = \varepsilon_0 \sin\omega t \quad \text{———} \quad ①$$

$$I = \frac{d(C\varepsilon_0 \sin\omega t)}{dt}$$

$$I = C\varepsilon_0 \frac{d(\sin\omega t)}{dt}$$

$$I = \cancel{\omega}C\,\varepsilon_0 \cos\omega t \cdot \omega$$

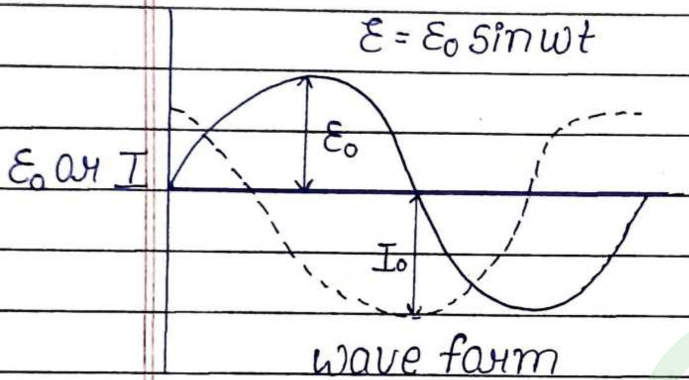
$$I = \omega C \varepsilon_0 \cos\omega t$$

$$I = \frac{\varepsilon_0}{\frac{1}{\omega C}} \cos\omega t \qquad \because I_0 = \frac{\varepsilon_0}{R} \text{ or } \frac{\varepsilon_0}{\frac{1}{\omega C}}$$

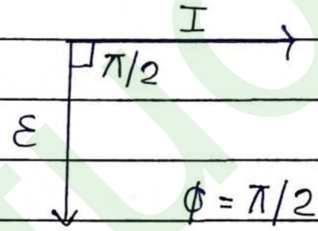
$I = I_0 \cos \omega t$

$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ —— (11)

Now on comparing the phase of equation (1) and (2), it is clear that current leads emf by $\pi/2$.

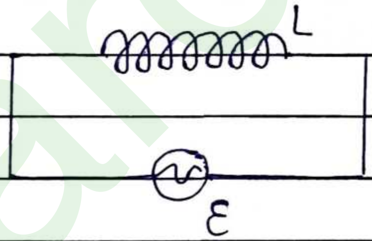


wave form



phasor diagram.

(3) Circuit Containing inductor only :-



$\mathcal{E} = L\frac{dI}{dt}$

$dI = \frac{\mathcal{E}dt}{L}$

$\because \mathcal{E} = \mathcal{E}_0 \sin \omega t$ —— (1)

$dI = \frac{\mathcal{E}_0}{L} \sin \omega t \, dt$

integrating on both side —

$\int dI = \frac{\mathcal{E}_0}{L} \int \sin \omega t \, dt$

$$I = \frac{\varepsilon_0}{L}\left(\frac{-\cos\omega t}{\omega}\right)$$

$$I = -\frac{\varepsilon_0}{\omega L}\cos\omega t$$

$$I = -I_0\cos\omega t$$

$$I = I_0\sin\left(\omega t - \frac{\pi}{2}\right) \quad \text{—} (2)$$

$\because \cos\theta = \sin(90-\theta)$

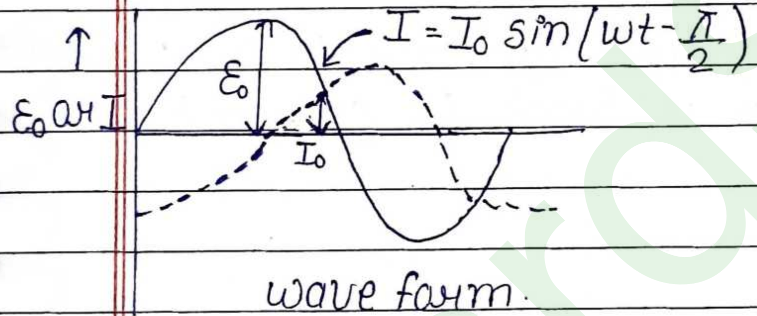
$\cos\theta = -\sin(-90^\circ+\theta)$

$\cos\theta = -\sin(\theta - 90^\circ)$

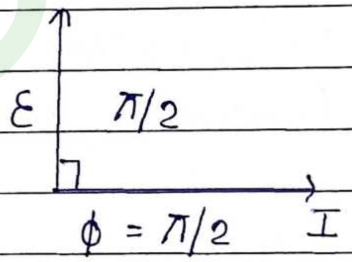
$\cos\omega t = -\sin\left(\omega t - \frac{\pi}{2}\right)$

Comparing (1) and (2), it is clear that I lag ε by $\pi/2$.

$$\varepsilon = \varepsilon_0 \sin\omega t$$



wave farm.



phasor diagram.

* **Inductive reactance :-**

Inductive rectance is the name given to the opposition (by inductor) to a changing current flow. This is measured in ohms, just like resistance.

It is denoted by 'X_L'.

$$X_L = \omega L$$

ω = Angular frequency

L = Self inductance.

$$X_L = 2\pi f L$$

SI unit is ohm (Ω).

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* **Capacitive Reactance** :- Capacitive Reactance is the name given to the opposition (by capacitor) to a changing current flow. This is measured in ohms, just like resistance.

- It is denoted by X_C.

$$X_C = \frac{1}{\omega C}$$

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

- SI unit is ohm (Ω).

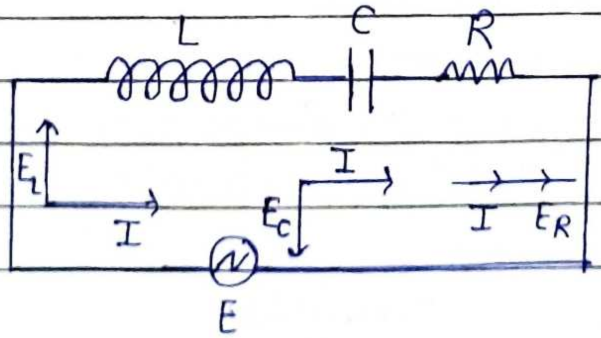
Note :- For DC current, time period is infinite. So Resistance offered by capacitor to DC current is infinite. Hence it block DC current throught it.

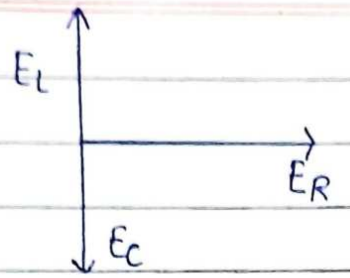
~~Inde~~

Impedance of AC circuit :-

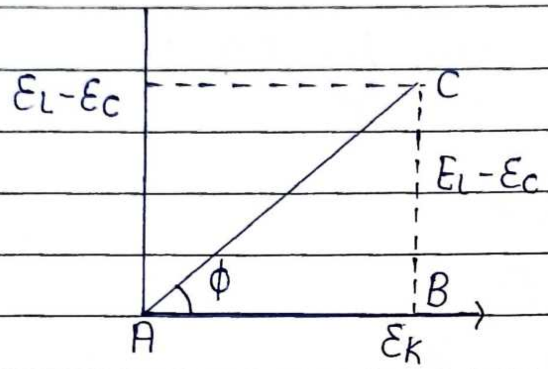
- It is an analogy of Resistance offered by circuit.
- Measured in ohm.
- It is denoted by Z.

* **LCR Circuit or Impedance Triangle** :-





* current and voltage both can lead in LCR circuit.



we know that, $\mathcal{E}_R = I_0 R$

$$\mathcal{E}_C = I_0 X_C$$

$$\mathcal{E}_L = I_0 X_L$$

<u>Net emf of LCR circuit</u> :

$$\mathcal{E}_0 = \sqrt{(\mathcal{E}_L - \mathcal{E}_C)^2 + \mathcal{E}_R^2}$$

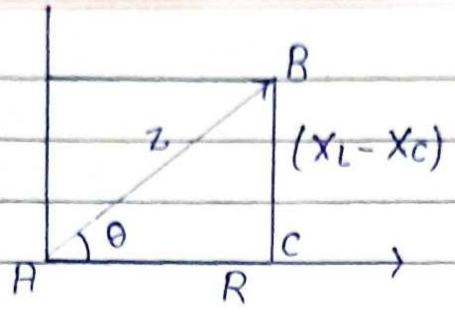
$$\mathcal{E}_0 = \sqrt{(I_0 X_L - I_0 X_C)^2 + (I_0 R)^2}$$

$$\mathcal{E}_0 = \sqrt{I_0^2 \left[(X_L - X_C)^2 + R^2 \right]}$$

$$\mathcal{E}_0 = I_0 \sqrt{(X_L - X_C)^2 + R^2}$$

$$\frac{\mathcal{E}_0}{I_0} = \sqrt{(X_L - X_C)^2 + R^2}$$

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



Phase difference is given by $\tan\phi$

$$\tan\phi = \frac{X_L - X_C}{R}$$

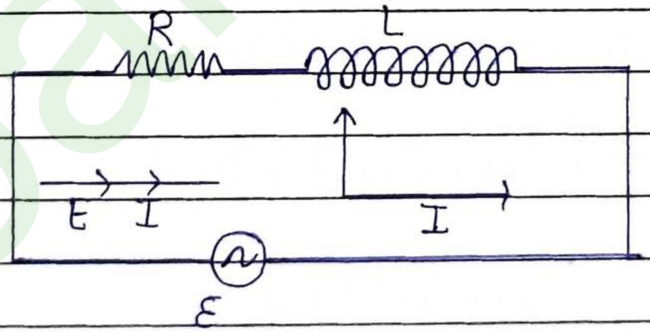
$$\tan\phi = \frac{E_L - E_C}{E_R}$$

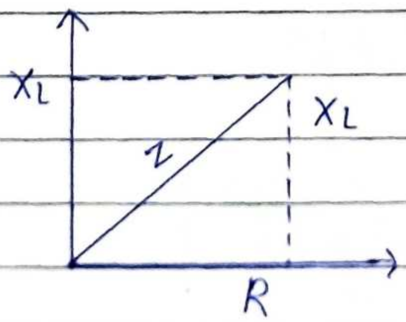
Power factor, $\cos\phi = \frac{R}{Z}$

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

current $\Rightarrow$ $I = \frac{V}{Z}$

R-L series circuit :-





Impedance z ; $Z = \sqrt{X_L^2 + R^2}$

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

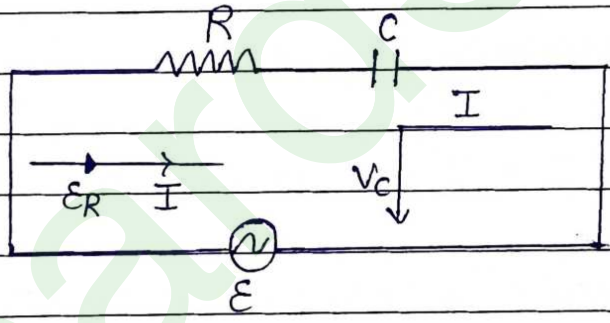
$$\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$

Power factor, $\cos\phi = \frac{R}{Z}$

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

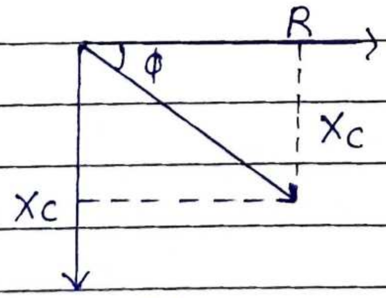
Current, $I = \frac{V}{Z}$

R-C series circuit :-



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

hence $Z = \sqrt{X_C^2 + R^2}$



$$\tan\phi = \frac{X_C}{R}$$

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

Power factor, $\cos\phi = \frac{R}{Z}$

Resultant voltage, $V = \sqrt{V_C^2 + V_R^2}$

current $\Rightarrow I = \frac{V}{Z}$

* Resonance in RLC series circuit :-

The resonance of a series RLC circuit occurs when the inductive and capacitive reactances are equal in magnitude but cancel each other because they are 180 degrees apart in phase.

At resonance, $X_L = X_C$

$Z = \sqrt{R^2}$

$Z = R$ minimum impedance

As it allows minimum resistance so, current become maximum.

$\because I = \frac{V}{R}$ (Maximum current)

Resonance Frequency :-

Frequency at which resonance occurs.

At resonance, $X_L = X_C$

$$\omega L = \frac{1}{\omega C}$$

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

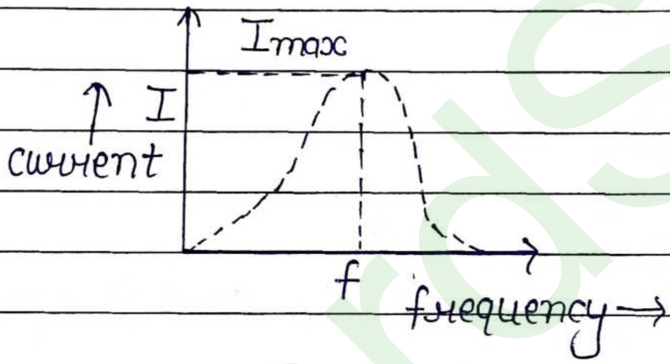
$$f^2 = \frac{1}{(2\pi)^2 LC}$$

{When $X_L = X_C$ then LCR circuit behave like pure resistive circuit under this conductor.
$\phi = 0$}

Square root on both side :-

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

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



Resonance curve :

* Quality factor :-

It is defined as the ratio of potential drop across 'L' or 'C' to the potential drop 'R'.

$$Q = \frac{\text{Potential drop 'L'}}{\text{Potential drop 'R'}}$$

$$Q = \frac{IXL}{IR}$$

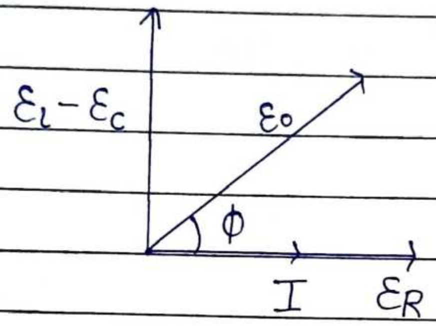
or

$$Q = \frac{\text{Potential drop 'C'}}{\text{potential drop 'R'}}$$

$$Q = \frac{IXC}{IR}$$

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

Average Power Associated with RLC circuit :-



$$\boxed{P = \frac{\varepsilon_0 I_0 \cos\phi}{2}}$$

or $P = \frac{\varepsilon_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos\phi$

$$\boxed{P = \varepsilon_{RMS} I_{RMS} \cos\phi}$$

where $\cos\phi$ is power factor and is equal to

$$\text{Power factor} = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$\therefore$ power factor $= \cos\phi = \frac{R}{Z} = \frac{\text{Resistance}}{\text{Impedance}}$

Special case :-

(i) For resistance : $\phi = 0$

$P = \varepsilon_{RMS} I_{RMS} \cos 0$

$P = \varepsilon_{RMS} I_{RMS}$

$\left.\begin{array}{l} V = -ve \\ I = -ve \end{array}\right\} P = +ve$

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2) For capacitor : $\phi = \pi/2 \,/\, 90°$

$$P = \mathcal{E}_{RMS} I_{RMS} \cos 90°$$
$$P = 0$$

3.) For Inductor : $\phi = \pi/2$

$$P = \mathcal{E}_{RMS} I_{RMS} \cos 90°$$
$$P = 0$$

Power factor :- It is defined as the ratio of true power to the actual power.

$$P = \mathcal{E}_{RMS} I_{RMS} \cos\phi$$
$$\cos\phi = \frac{P}{\mathcal{E}_{RMS} I_{RMS}} = \frac{\text{True Power}}{\text{Apparent power or Actual power}}$$

Average Power Associated with capacitor Only :-

Capacitors do not dissipate energy. Hence Average power power used by capacitors is zero.

Average Power Associated with Inductor only :-

Inductor do not dissipate energy. Hence Average power power used by inductors is zero.

Note :- Hence all power consumed in RLC circuit is by Resistor only.

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* Wattless Current :-

The current which consume zero power is called wattless current.

Generally, the current in inductor only or capacitor only is known as wattless current.

Energy Stored in Inductor :-

let the current is given to the inductor, then Emf induced in it.

$$\varepsilon = L\frac{dI}{dt}$$

we know that,

$$P = \frac{w}{t}$$

$$w = Pt$$

$$dw = Pdt$$

$$dw = \varepsilon I dt$$

$$dw = L\frac{dI}{dt} I dt$$

$$dw = LIdI$$

integratting on both side :

$$\int dw = L\int I dI$$

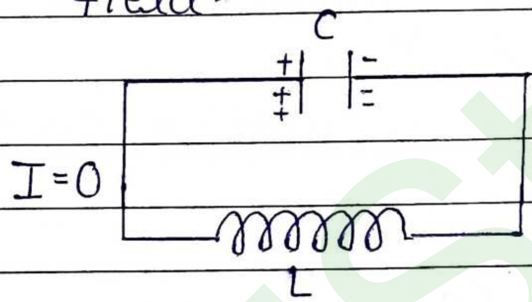
$$w = \frac{LI^2}{2}$$

$$\because \boxed{U = \frac{1}{2}LI^2}$$

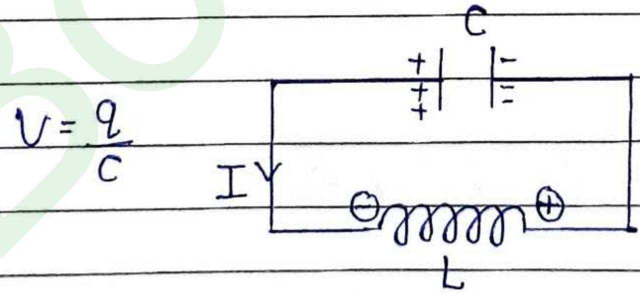
* LC Oscillation :-

An LC oscillation involves the transfer of energy between an inductor (L) and a capacitor (c) in an electrical circuit.

- **Charging the capacitor :**
  when the capacitor is fully charged, all energy is stored in its electric field.



- **Discharging through Inductor :**
  The capacitor discharges through the inductor, creating a current and building up a magnetic field around the inductor. The electric field energy converts to magnetic field energy.



- **Inductor charging capacitor :**
  Once the capacitor is fully discharged, the inductor's magnetic field collapses, inducing a current that

charges the capacitor with opposite polarity. The magnetic field energy converts back to electric field energy.

- Continuous Oscillation :

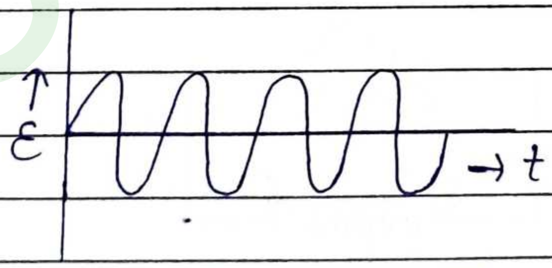
This process repeats, leading to undamped oscillations of charge, current and voltage in the circuit, analogous to the mechanical oscillations of a mass-spring system.

Equation of LC Oscillation circuit :

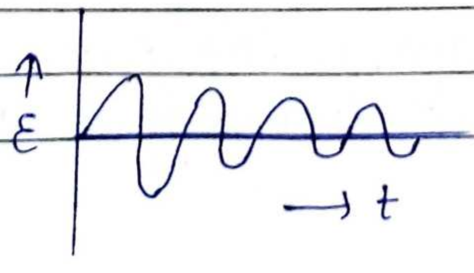
$$\frac{d^2q}{dt^2} + \frac{q}{LC} = 0$$

There are two types of oscillations :-

(i) Undamped oscillations :- The oscillation in which there is no loss of energy is called undamped oscillation.



(ii) Damped oscillations :- The oscillation in which there is loss of energy.



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* Transformer :-

It is the device which is used to step up or step down the input voltage.

Principle :- It is based on the principle of mutual inductance (electromagnetic induction).

Construction :-

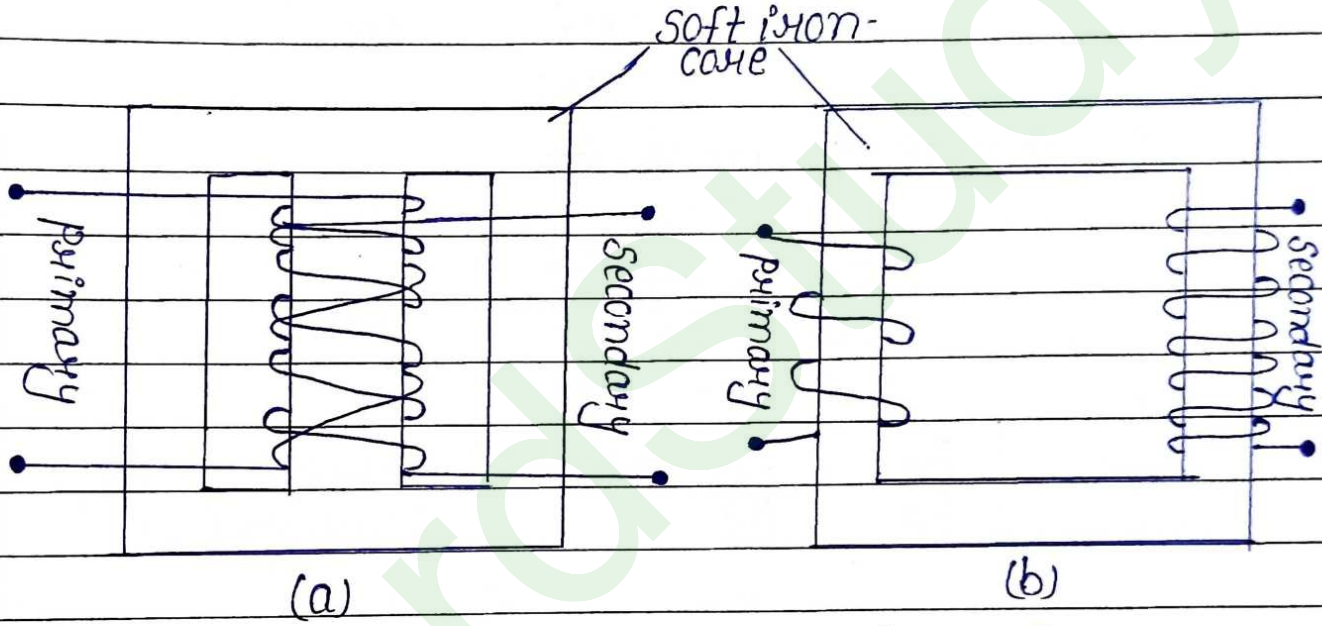

fig- Two arrangement for winding of primary and secondary coil in a transformer :
(a) two coils on top of each other.
(b) two coils on separate limbs of the core.

Working :-

When AC input is given to primary current in primary change due to which flux link with the coil changes and due to change in flux emf will induced which is called primary emf (E_p).

Due to mutual inductance, the same flux

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will link to the secondary and hence due to change in flux, the emf will induce in secondary called secondary emf (E_s).
we know,

$$E = \frac{N d\phi}{dt}$$

$$E_p = N_p \frac{d\phi}{dt} \quad \text{— ①}$$

$$E_s = N_s \frac{d\phi}{dt} \quad \text{— ②}$$

Divide ② by ① :-

$$\frac{E_s}{E_p} = \frac{N_s \frac{d\phi}{dt}}{N_p \frac{d\phi}{dt}}$$

$$\boxed{\frac{E_s}{E_p} = \frac{N_s}{N_p} = K}$$ where K is transformation ratio.

$P = EI$ also, $E_s I_s = E_p I_p$

$$\boxed{\frac{E_s}{E_p} = \frac{I_p}{I_s} = K}$$

Special case i) if $K > 1$
$N_s > N_p$
$E_s > E_p$
Hence, transformer is called step up.

(ii) if $K < 1$
$N_s < N_p$
$E_s < E_p$
Hence, transformer is called step down.

(iii) if $K = 1$

$N_S = N_P$

$\varepsilon_S = \varepsilon_P$

Hence, transformer is ideal.

Efficiency of Transformer :-

It is defined as the ratio of output power to the input power.

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$\boxed{\eta = \frac{E_S I_S}{E_P I_P}}$$

$$\eta\% = \frac{\varepsilon_S I_S}{\varepsilon_P I_P} \times 100$$

Loss due to transformers :-

The main types of energy losses in a transformer are :

(i) Core Losses (Iron losses) :- Occur in the iron core due to alternating magnetic flux, consisting of Hysteresis Loss (energy spent magnetizing/demagnetizing the core) and Eddy current Loss (heat from induced circulating currents).

ii) Copper Losses (I^2R Losses) :-

Occur in the windings due to the resistance of the copper wire, generating heat as current flows. These are load-dependent.

iii) Flux Leaking Losses :-

Some magnetic flux produced by the primary winding doesn't link with the secondary winding.

iv) Hummings (vibrations) :-

Slight energy loss due to care laminations vibrating and producing sound.

Uses of Transformer :-

- It is used to step down the voltages in various small projects like welding purpose.
- It is used to regulate the voltage in voltage regulators which are used in costly appliances like AC, refrigerators etc.
- In the long distance transmission.

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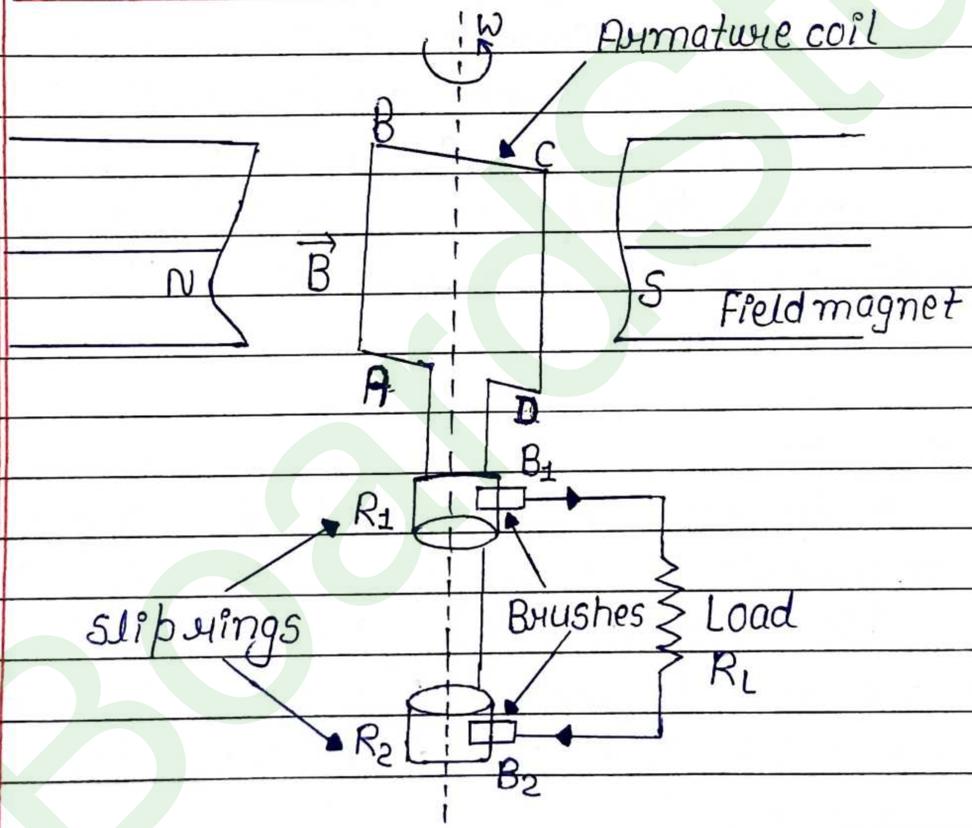
* AC Generator / AC Dynamo / Alternator :-

It is a device which convert mechanical energy into electrical energy.

Principle :-

It is based on the phenomenon of electromagnetic induction i.e; whenever there is a change in magnetic flux, emf will be induced.

Construction :



The essential part of AC Generator are shown in figure :

(1) Armature :- ABCD is a rectangular armature coil. It consist of large number of insulated copper wire wound over a laminated soft iron core.

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(ii) Field magnet :- 'N' and 'S' are the pieces of strong electromagnet in which the armature coil is rotated. The magnetic field is of the order of 1 to 2 T.

(iii) Slip rings :- 'R_1' and 'R_2' are the two hollow metallic rings to which two ends of armature coil are connected. The rings rotate the rotation of coil.

(iv) Brushes :- B_1 and B_2 are two flexible metal plates or carbon rods. They are fixed and are kept in light contact with 'R' and 'R_2' respectively. The function of Brushes is to pass on the current from armature coil to external load resistance (R).

Working :-

As the armature coil is roated in the magnetic field, angle 'θ' between the magnetic field and area vector of the coil changes due to which the magnetic flux linked with the coil changes and hence Emf is induced.

To start with, let a plane of coil is $\perp$ar to the plane of paper in with the m.F linked with coil is maximum at this position.

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let the coil is rotated anti-clockwise, AB moves inward and CD moved outward. the amount of magnetic flux linked with the coil changes and according to the fleming's Right hand rule, the current induced in AB is from A to B and in CD is from C to D. Therfore the current in external circuit flows from X to Y.

After half rotation, AB and CD will interchange their position and therefore and induced current in them also interchange their position and therefore, the induced current in them also interchange their position. Thus in this case the current in external circuit flows from Y to X. In this way, alternating current and alternating emf is produced.

Derivation :-

we know that,

$$\phi = NBA\cos\theta$$

$$\phi = NBA\cos\omega t$$

$\because \theta = \omega t$, $\omega = \frac{\theta}{t}$

Now,

$$\varepsilon = -\frac{d\phi}{dt}$$

$$\varepsilon = -\frac{d(NBA\cos\omega t)}{dt}$$

$$\varepsilon = -NBA\frac{d(\cos\omega t)}{dt}$$

$$\varepsilon = -NBA(-\sin\omega t)\,\omega$$

$$\varepsilon = NBA\omega\sin\omega t$$

$$\mathcal{E} = NBA\omega \sin\omega t$$

$$\mathcal{E}_0 = NBA\omega \qquad (\because \sin\omega t = 1)$$

$$\because \mathcal{E} = \mathcal{E}_0 \sin\omega t$$

This is the equation of alternating Emf.

* Choke coil :- A choke coil is an electrical appliance used for controlling current in AC circuit.

→ If we used a resistance 'R' for the same purpose, a lot of energy would be wasted in the form of heat.

→ The choke coil is consist of a number of turns of thick copper wire wound closely over a laminated soft iron core.

→ The inductive reactance of choke coil can be given as $X_L = \omega L$

the current can be given as,

$$I = \frac{\mathcal{E}}{X_L}$$

→ For reducing low frequency alternating current, choke coil with laminated soft iron core are used. They are called Audio frequency choke.

→ For reducing high frequency alternating current, air cored chokes are used. They are called R.F. choke

(Radio frequency).