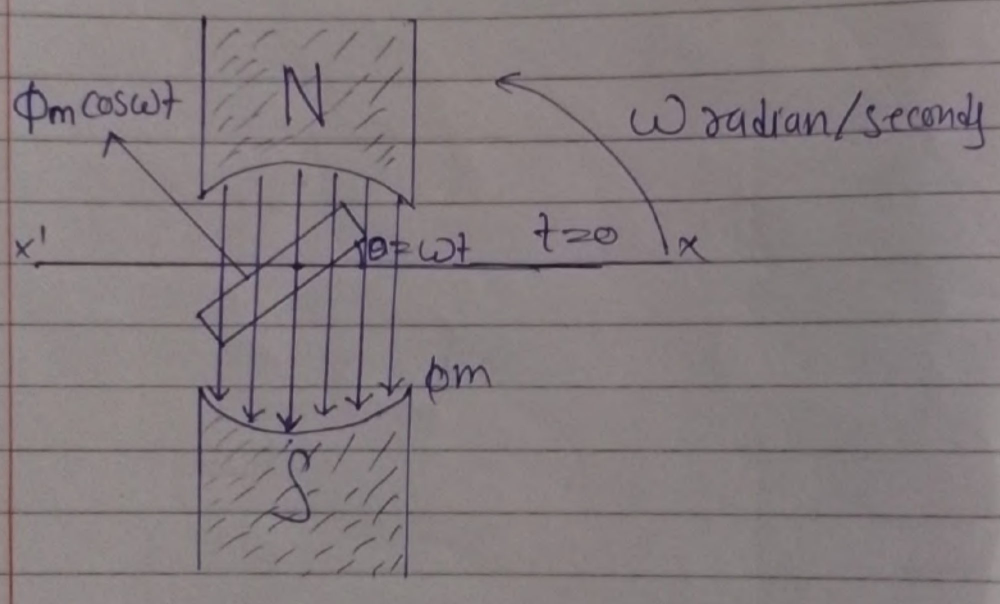
Unit-2

Significance of A.C Circuit

Generation of Sinasudal A.C voltage –

when a conductor is rotated in a magnetic field and alternating EMF is generated in the conductor and alternating EMF will also be generated by changing the magnetic field with in the stationary quile. The EMF thus generated build up depand upon the strength of the magnetic field the number of turns in the quile and the speed current which in the quile or the magnetic field rotates.



Consider A quile with n turn rotation in a uniform magnetic field with an angular valocity ω radian/seconds as show in fig let the time measures from the x axis with the plane of the quile flux ϕm links the quile after time t the quile moves through an angle $\theta = \omega t$

In this position the component of the flux which is perpandicular to the plane or the quile is $\phi = \phi_m \cos \omega t$

where flux linkages

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

Emf induceed $e = -\frac{dN\phi}{dt}$

$\Rightarrow e = -\frac{d}{dt} N(\phi_m \cos \omega t)$

$\Rightarrow e = -\phi_m N(-\sin \omega t)\omega$

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

when the quile makes an angle $\theta = 90^\circ$, $\sin\theta = 1$

Hence the EMF induceed in the quile is maximum

$\therefore E_m = \omega \phi_m$

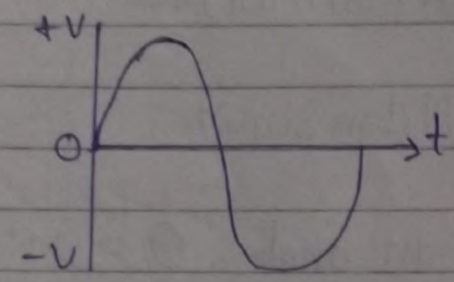
$\boxed{e = E_m \sin \omega t}$

or $\boxed{e = E_m \sin\theta}$

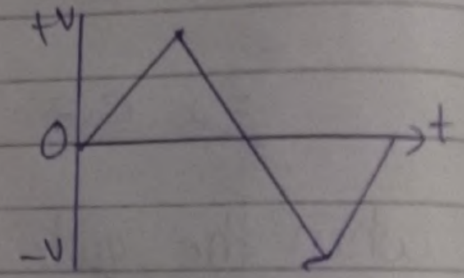
The induceed EMF Varies as sin function of time angle ωt and when EMF is ploted against time a sin curve which state

A.C Terminology:- An alternating voltage or current change its magnitude and direction at regular current varies as a sin function of the time for angle θ (θ = ωt) the following important terms are generally used in alternating quantities.

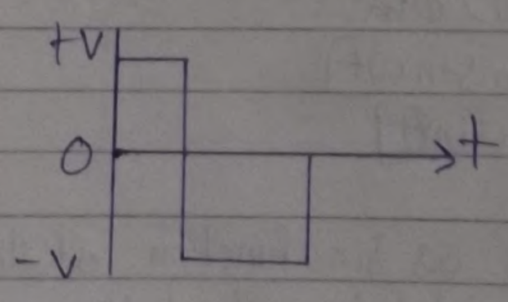
Wave forms:- It is define as the graph between magnitude of alternating quantity (on y axis) against time



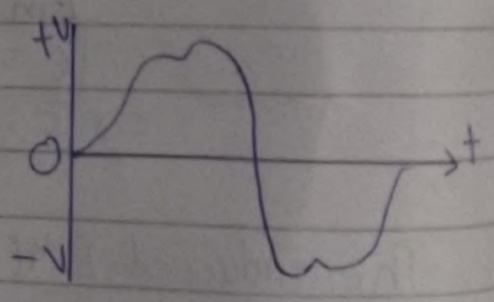
Sin wave



Triangular wave



Square wave



Complex wave

Important terms –

Cycle – ~~oneeor~~ one complete set off positive and negative values off Alternating quantity is known as cycle.

A cycle may also be sometimes specified in term of angular major in that case one complete cycle is said to be spread over 360° or 2π radian

Instantaneous values – The value of Alternating voltage or current at any instant is called its instantaneous value and it represented by small latter that is e for emf, v for voltage and i for current

Frequency – The number of cycle is pass through in 1 second is called the frequency in Hz

$$f = \frac{PN}{120}$$

∴ f = frequency, P = number of polls, N = speed in RPM

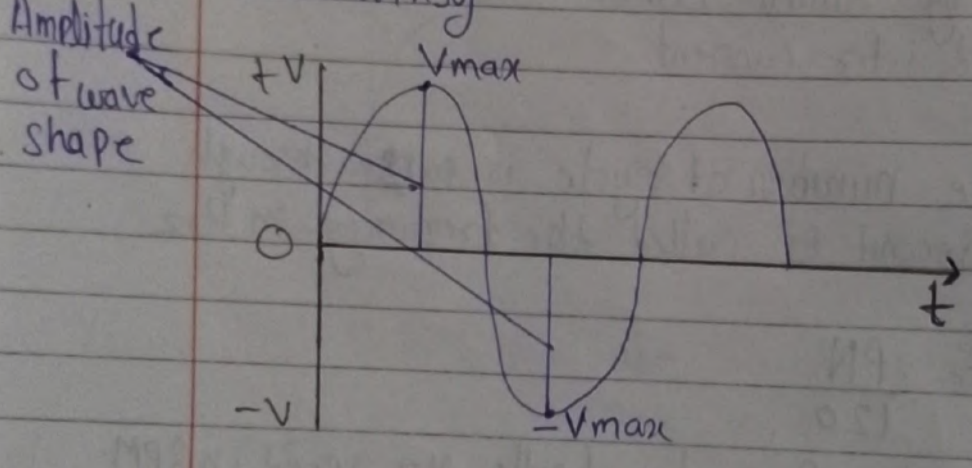
Time Period :- Time taken by an alternating voltage or current to complete one cycle is known as its time period.

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

Angular Valocity – The Angular distance covered per Second is defined as Angular valocity it is represented by ω and expressed in radian per second

$$\boxed{\omega = 2\pi f}$$

Amplitude – The maximum value either positive or negative of an alternating quantity is known as its Amplitude, The Amplitude of an alternating emf voltage or current is expressed by e_{max} V_{max} and I_{max} respectively



Values of Alternating voltage or current -

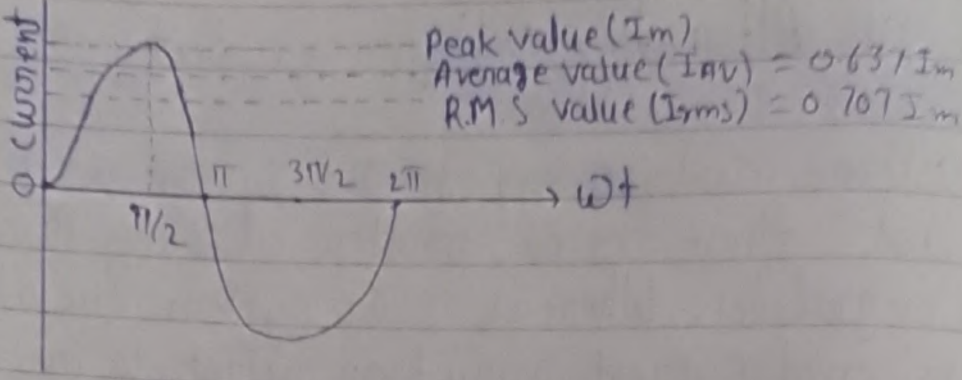
The voltage and current in D.C system are constant show that there is no problem of ~~spacing there~~ Specifying their magnitudes. Whereas, in a.c system, the alternating voltage and current vary from instant to instant So the question arises how to express the magnitude of alternating voltage and current. The following three ways are adopted to express the magnitude of these quantities:

(i) Average value or mean value.
(ii) R.M.S value or Effective value
(iii) Peak value

Average value :- The Average value of an alternating quantity is define as the value which is obtain by Averaging all the instantenous value over a period of half cycle

Average value of current for a sin wave = 0.637 × maximum value of current

R.M.S Value: The R.M.S value of an alternating current is define by the Steady (D.C) current which when flows through a resister of non resistance for a given time produces the same amount of heat hence produces by the alternating current when flow through the same resister for the same time is called effective or R.M.S value



Sinasudal A.C. Current wave

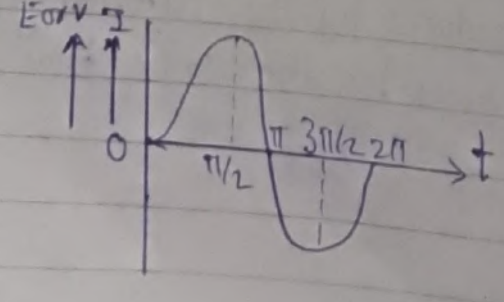
R.M.S value of alternating current or voltage

$(I_{rms}$ or $V_{rms}) = \dfrac{\text{maximum value of alternating current or voltage}}{\sqrt{2}}$

$$I_{rms} \text{ or } V_{rms} = \frac{I_m \text{ or } V_m}{\sqrt{2}}$$

$$I_{rms} = 0.707 I_m$$
or $$V_{rms} = 0.707 V_m$$

Peak Value — The maximum value attend by an alternating (current or voltage)/(quatity during 1cycle which called it's Peak value a Sinasudal alternating quantity often its maximum value of 90° So in fig the peak value of an alternating voltage or current is represented by E_m, V_m and I_m



Form factor :- The form factor of an alternating current wave shape is defined as the ratio of its R.M.S value to the Average value of current over a off cycle, it denoted by K_f

$$K_f = \frac{\text{R.M.S value of current } (I_{rms})}{\text{Average value of current } (I_{AV})}$$

For sin wave

R.M.S value of current $(I_{rms}) = 0.707\, I_{max}$
Average value of current $(I_{av}) = 0.637\, I_{max}$

$$K_f = \frac{0.707\, \cancel{I_{max}}}{0.637\, \cancel{I_{max}}}$$

$$\cancel{K_f}\ \boxed{K_f = 1.11}$$

Peak factor (K_p) – The ratio of maximum value to RMS value of an alternating quantity is called peak factor

$$K_p = \frac{\text{Maximum value of current } (I_m)}{\text{R.M.S value of current } (I_{rms})}$$

This is also called creast factor or amplitude factor

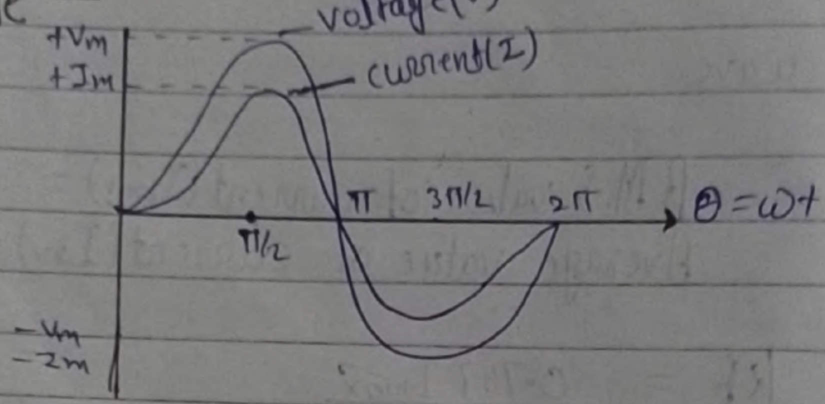
for a sine wave

$$K_p = \frac{I_{max}}{I_{max}/\sqrt{2}} = \sqrt{2}$$

$$\boxed{K_p = 1.414}$$

Normally the RMS value of current or voltage of an alternating waves is specified. ~~as~~ If Peak factors of a wave is known it's maximum value can be determine which is neccessary to calculate the Ri losses because these depand upon the value of maximum value

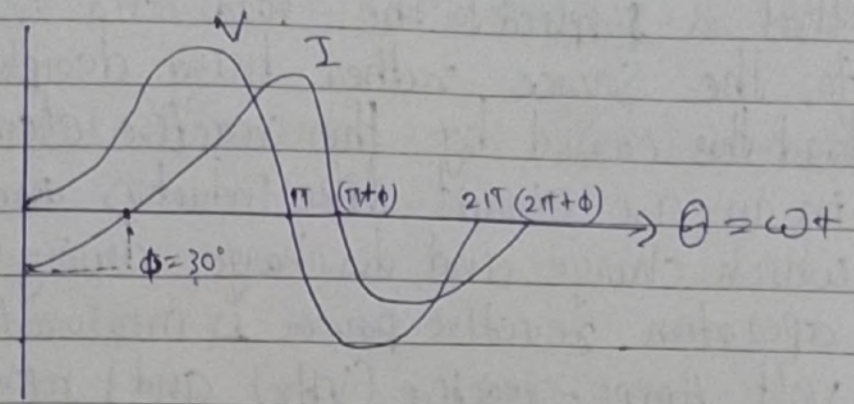
Phase —



It is the phase angle position of A.C. quantity to alternating wave shape are ~~see~~ set to the phase when they reach maximum and zero value at the same time there maximum value may be different thing magnitude

$$V = V_m \sin \omega t$$
$$I = I_m \sin \omega t$$

Phase Difference -



If two alternating quantity do not reach their zero value in the same direction Sinatanistionaly than they have phase difference.

The phase difference of phase angle between to A.C quantities on the same difference axis is known as phase difference

$$V = V_m \sin \omega t$$
$$I = I_m \sin(\omega t - \phi)$$

Power in A.C. Circuit - in A.C. circuit there are three types of power.

(i) Active power (P)
(ii) Reactive power (Q)
(iii) Apprent Power (S)

Active Power(P)/Real Power/True Power - The active power is the power which is actually utilized in the circuit normally at low the active power perform the usefull work. It is also called true power or real power. It is measured in watt and represanted by P. $\boxed{P = VI\cos\phi}$ watt

Reactive power(Q) — Reactive power is the power that is supplied to the load and written to the Source rather being deciplated in the load this caused by the reactive element in an a.c circuit like inductors and capicitors which charge and dis charge during normal operation. reactive power is measured as volt-Amps-reactive (VAr) and is represented by Q

$$\boxed{Q = VI\sin\phi \ \ VAr}$$

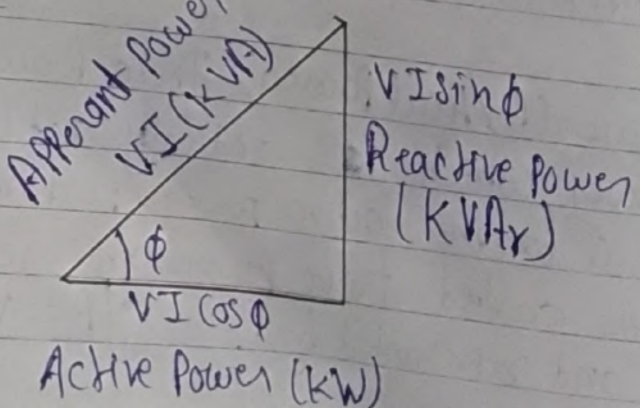
Aperant Power — Apperant power is the total Power in a circuit in includes both diciplated (active) and return (reactive) power. Apperant power is measured in volts Amps (VA) and it represented by S

$$\boxed{S = VI \ (VA)}$$

Apperant power = Active power + Reactive power

$$S = P + jQ$$

Power triangle —



Reactance – In electric circuit/system Reactance is the opposition of the flow of current due to that element.

The unit of Reactance is Ω (ohm) and Reactance is denoted by x

This is of two types

(i) Capacitive Reactance (X_c)
(ii) Inductive Reactance (X_L)

Impedeance – Electrical impedeance is the measure of the opposition that a circuit present to a current when a voltage is applied.

It is denoted by the symbol Z and expressed in Ω (ohm) this is a complex quantity in which resistance is real part and reactance exist as imagenary part.

$$\boxed{Z = R + JX}$$

Admittance – Admittance is a measure of how much current is admitted in a circuit admittance is a inverce of impedance. admittance has kits most obevious utility in dealing with parallel A.C circuit.

The unit of admittance is $\mho$ (mho) and dennoted by Y

$$\boxed{Y = \frac{1}{Z}}$$

Power factor — The cosine of angle between voltage and current in an A.C. circuit it is not as power factor equal to the ratio of Active power to Apperant power is called the power factor of the circuit for Sinasudal voltage and current wave the power factor is given by

$$\text{Power factor} = \frac{VI\cos\phi}{VI}$$

$$\text{Power factor} = \cos\phi$$

In A.C Circuit if the circuit is inductive the current legs when the voltage and the power factor is reffered to as legging however in a capecitive circuit current leaves the voltage and power factor is said to the leading

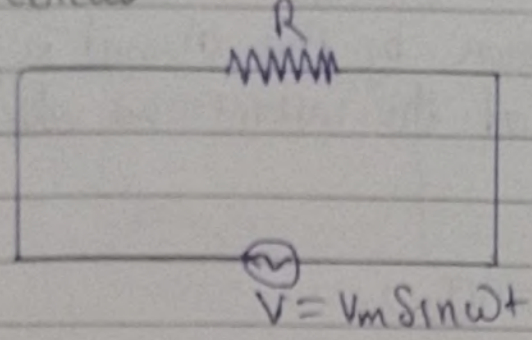
Power factor of the circuit can be written as.

$$\text{Power factor} = \cos\phi = \text{cosine of angle between } V \text{ and } I$$

$$\text{Power factor} = \frac{R}{Z} \text{ (Resistance)}$$

$$\text{Power factor} = \frac{VI\cos\phi}{VI} = VI$$

Pure Resistive circuit –



The circuit containing A pure Resistive of R Ω is so show in fig and alternating voltage $v = V_m \sin\omega t$ has been applied

The instantenous value of current is given by

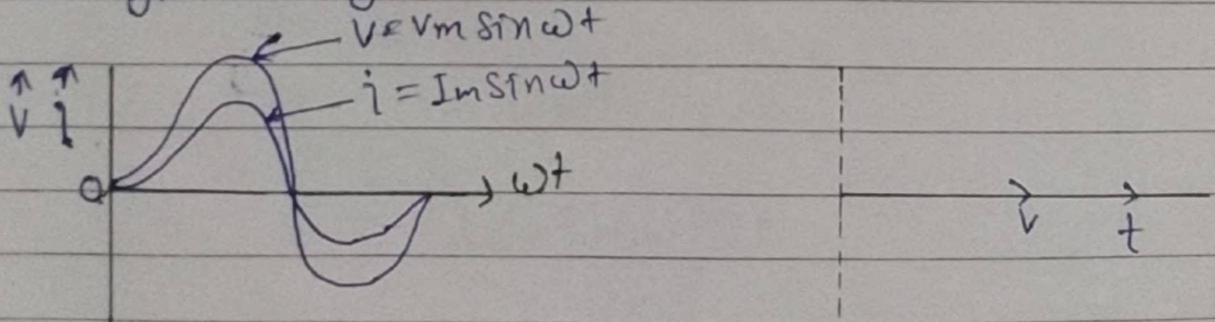
$$I = \frac{V}{R} = \frac{V_m \sin\omega t}{R} \quad \left(\because I_m = \frac{V_m}{R}\right)$$

and instantenous current $\boxed{I = I_m \sin\omega t}$

It is clear that current is in phase with voltage for purely Resistive circuit.

(In Resistive circuit)

Wave form and Phaser diagram – The sin wave and vactor representation of $V = V_m \sin\omega t$ and $I = I_m \sin\omega t$ are given in fig



Power in Resistive circuit - The instantaneous value of Power drawn by this circuit is given by the product of the instantaneous value of voltage and current

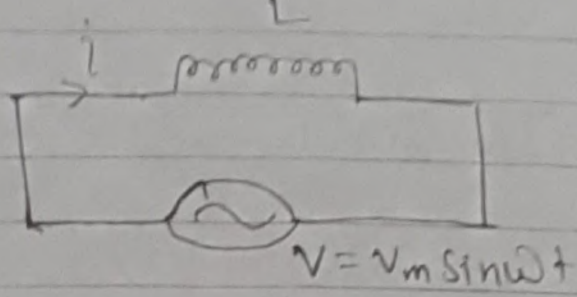
$$P = VI$$
$$P = V_m \sin\omega t \times I_m \sin\omega t$$
$$P = V_m I_m \sin^2\omega t$$
$$P = V_m I_m \left(\frac{1-\cos 2\omega t}{2}\right)$$
$$P = \frac{V_m I_m}{2} - \frac{V_m I_m \cos 2\omega t}{2}$$

The average value of $\frac{1}{2} V_m I_m \cos 2\omega t$ over a complete cycle is zero

$$P = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$
$$\boxed{P = VI}$$
or $\boxed{P = V_{rms} I_{rms}}$

The Power in a purely resistive circuit is equal to the product of the R.M.S value of voltage and current

Pure inductive circuit –



The circuit containing a pure inductor of L henry is show in fig and alternating voltage $v = V_m \sin\omega t$ has been applied.

Hence Self induced EMF at any instant

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

Applied voltage $v = -e'$

$$\Rightarrow v = -\left(-L\frac{di}{dt}\right)$$

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

The applied voltage to the circuit be represented by

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

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

$$di = \frac{1}{L} V_m \sin\omega t \, dt$$

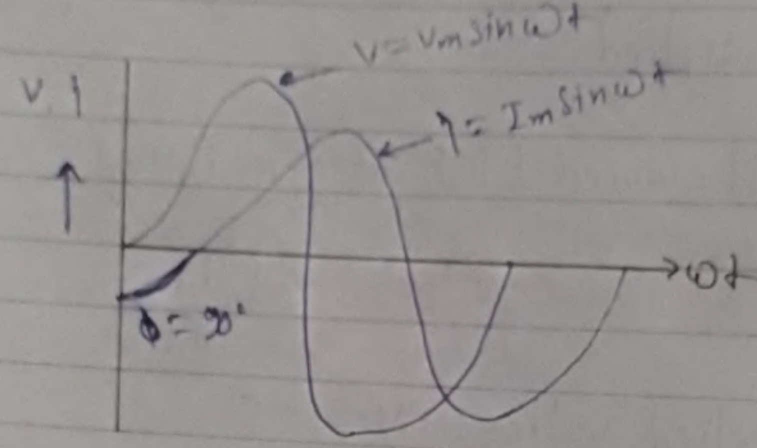
$$\int di = \int \frac{V_m \sin\omega t}{L} dt$$

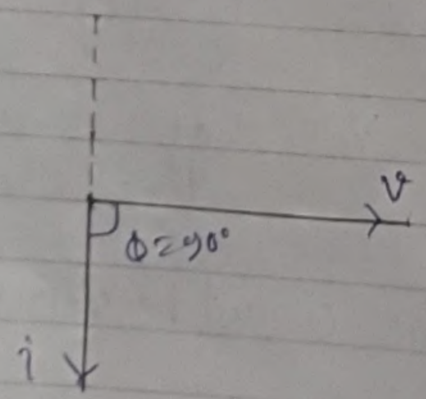
$$i = \frac{V_m}{\omega L}(-\cos\omega t)$$

$$i = -I_m \sin(\pi/2 - \omega t)$$

$$i = I_m \sin(\omega t - \pi/2)$$

Wave form and phasor diagram —
(in Inductive circuit)





Power in Inductive circuit

$$P = v \times i$$

$$P = V_m \sin\omega t \times I_m \sin(\omega t - 90°)$$

$$P = -V_m I_m \sin\omega t \cos\omega t$$

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

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

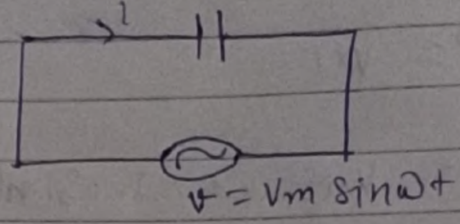
Power for the complete cycle

$$P = \frac{V_m I_m}{2} \int_0^{2\pi} \sin 2\omega t \, dt = 0$$

$$\boxed{P = 0}$$

A pure inductive circuit does not consume any power.

Pure capacitive circuit



The circuit containing A pure capacitor C farad is show in fig and alternating voltage $v = V_m \sin\omega t$ has been applied

The applied voltage

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

then $i =$ C x Rate of change of potential difference

$$i = C \times \frac{dV}{dt}$$

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

$$i = C \times V_m \cos\omega t . \omega$$

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

$$i = \frac{V_m \cos\omega t}{1/\omega C}$$

$$\because X_c = \omega C$$

$$i = \frac{V_m}{X_c} \cos\omega t$$

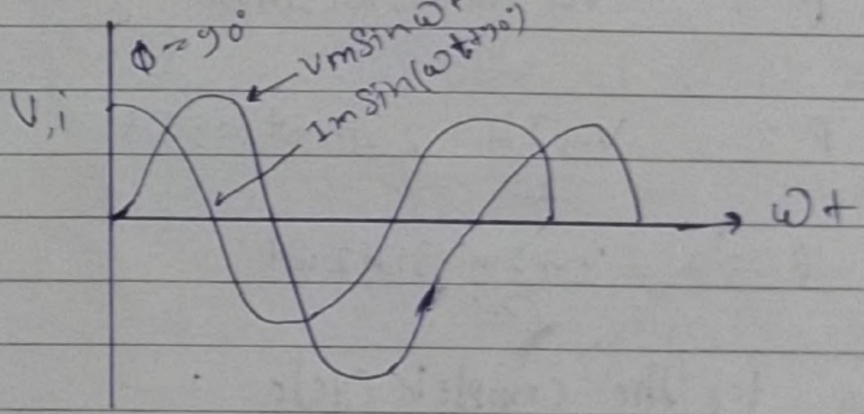
$$i = I_m \cos\omega t$$

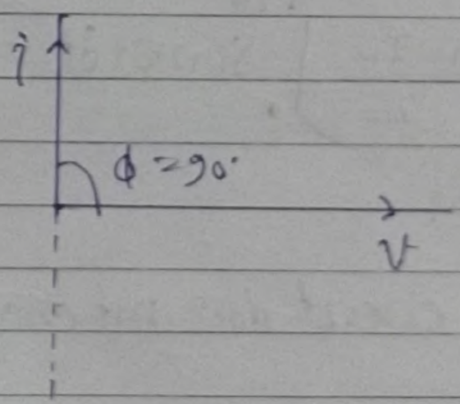
$$i = I_m \sin(\omega t + \pi/2)$$

$$i = I_m \sin(\omega t - 90)$$

Wave form and phasor diagram (for capacitive circuit) —

The sine wave and vector representation of $v = V_m \sin \omega t$ and $I = I_m \sin(\omega t + 90^\circ)$





Power in capacitive circuit —

$$P = v \times i$$

$$P = V_m \sin\omega t \times I_m \sin(\omega t + 90^\circ)$$

$$P = V_m I_m \sin\omega t \sin(\omega t + 90^\circ)$$

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

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

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

Power for the complete cycle.

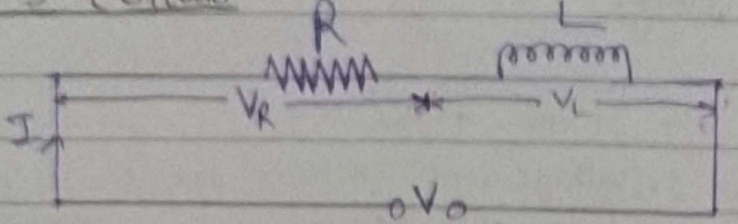
$$P = \frac{V_m I_m}{2} \int_0^{2\pi} \sin 2\omega t \, dt = 0$$

$$\boxed{P = 0}$$

A pure capacitive circuit does not consume any power.

Series

R-L Series circuit -



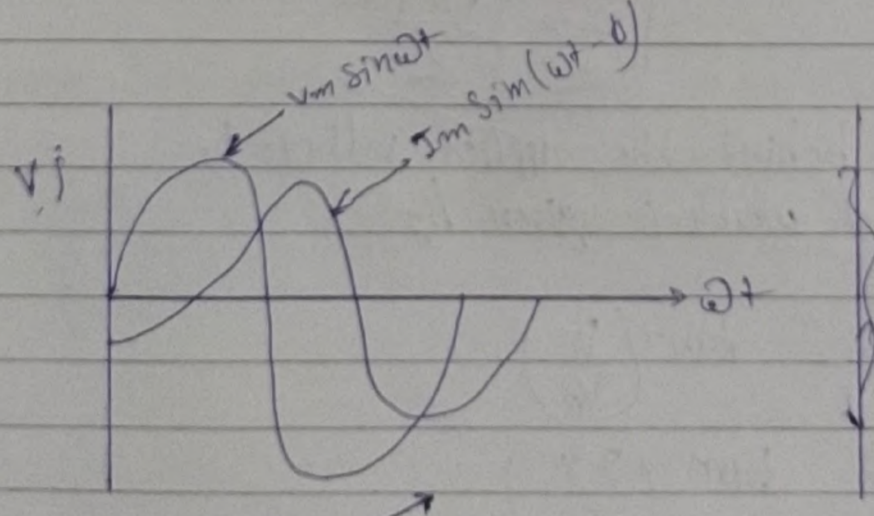
The circuit containing of Resistance are in series with and inductance L is show in fig and alternating voltage v has been applied

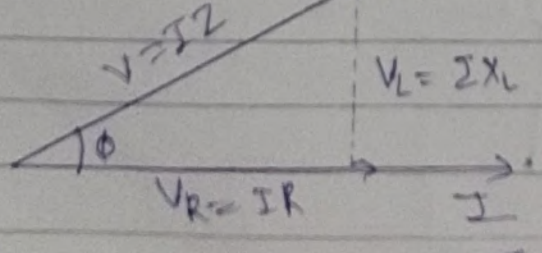
let $V =$ RMS value of applied voltage

$V_R =$ voltage across the resistance R
$V_L =$ voltage across the inductance
~~R~~ $I =$ RMS value of the curren flowing in the circuit

let $V = V_m \sin\omega t$
$i = I_m \sin(\omega t - \phi)$

wave form and phasor diagram (for R-L circuit) —





~~Power in~~

Applied voltage

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

where $V_R = IR$ voltage across resistance and $V_L = IX_L$ voltage Inductive voltage drop

$$V = \sqrt{(IR)^2 + (IX_L)^2}$$

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

Current flowing through the circuit

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

$\sqrt{R^2+X_L^2}$ is called the Impedeance of the circuit and is denoted by a symbol Z.

Impedeance of the circuit $Z = \sqrt{R^2 + X_L^2}$

hence,

$$\boxed{I = \frac{V}{Z}}$$

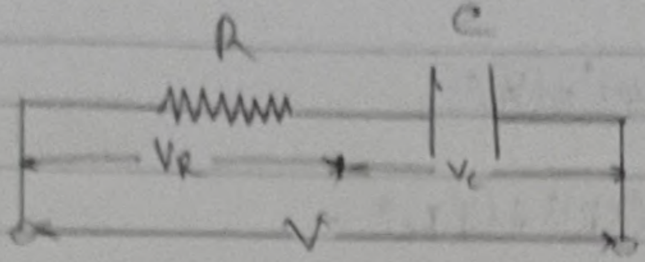
Current legs behind the applied voltage by an angle ϕ which is given by

$$\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right)$$

$$\phi = \tan^{-1}\left(\frac{IX_L}{IR}\right)$$

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

Series R.C circuit —



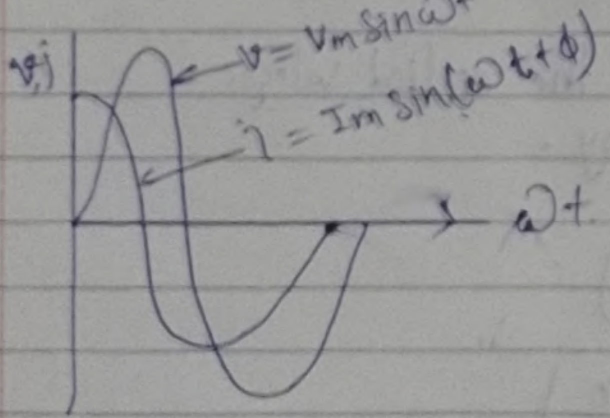
The circuit containing of resistance are in series with an capacitor c is shown in fig and alternating voltage v has been applied

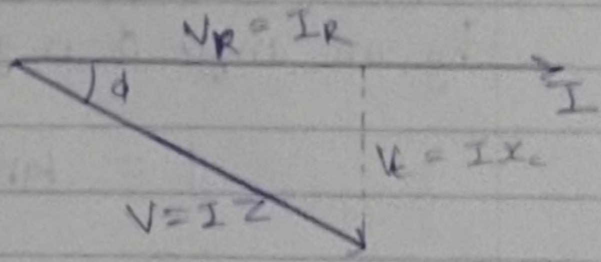
let
V = RMS value of applied voltage
V_R = Voltage across the Resistance R
V_C = Voltage across the capacitor C
I = RMS value of the current flowing in the circuit

let

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

Wave form and phasor diagram (for R-C circuit) —





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Applied voltage -

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

$$V = \sqrt{(IR)^2 + (IX_C)^2}$$

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

Current $\boxed{I = \frac{V}{\sqrt{R^2 + X_C^2}}}$

$\sqrt{R^2 + X_C^2}$ is called the Impedeance of the circuit and is denoted by A Symbol Z

impedeance of the circuit

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

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

Current is lead behind ~~forward~~ the applied voltage by an angle ϕ is given by -

$$\phi = \tan^{-1}\left(\frac{V_C}{V_R}\right)$$

$$\phi = \tan^{-1}\left(\frac{IX_C}{IR}\right)$$

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