The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Electrical Engineering

NAME OF COURSE: - ELECTRICAL CIRCUITS AND NETWORK

CODE OF COURSE: - 313332

SEMESTER: - SYEE-3K

SUBJECT TEACHER: - Mr. Jayesh M. Suryawanshi

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Notes

Unit - I

Single Phase A.C Series Circuits

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Unit 1 - Single Phase A.C series Circuits
(16 Marks)

Prepared by: Mr. J.M Suryawanshi Subject: ECN (313332)

1.1 Generation of alternating voltage.

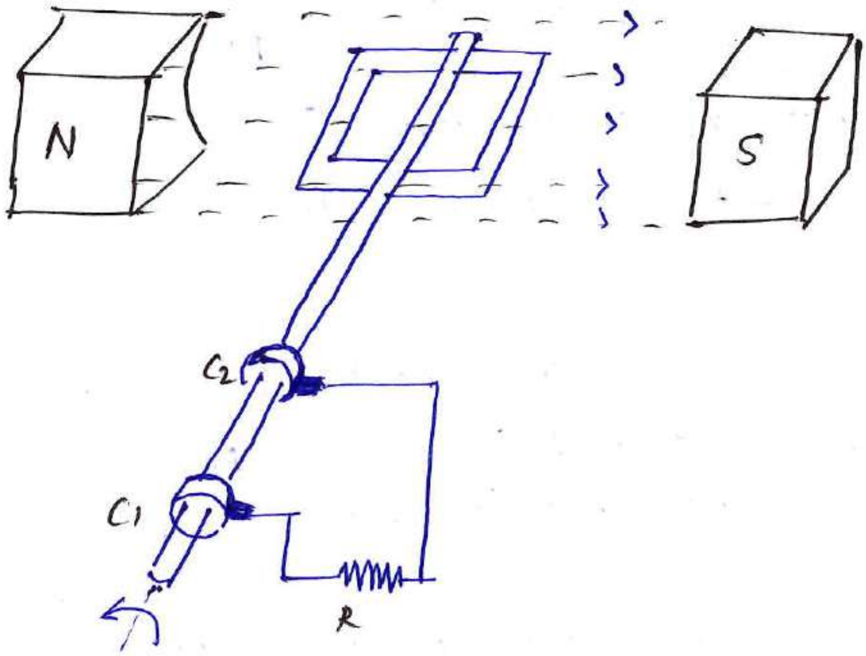
Electrical voltage is generated by a machine called as a generator

The generator converts mechanical energy into Electrical energy. An alternator generates purely sinusoidal AC voltage.

Principle of operation

An alternator works on principle of "Faraday's laws of Electro magnetic Induction"

Construction :-



Explaination:- (1) It consist of parmanent magnet having north pole & south pole.

(2) The direction of line of force (flux) from north pole to south pole.

(3) A rectangular conducting coil placed in magnetic field

(4) Two slip rings C1 & C2 are mounted on the shaft as shaft rotate, the slip ring also rotate.

(5) Brush is mounted on the slip ring. Slip ring rotate, but the brushes are stationary

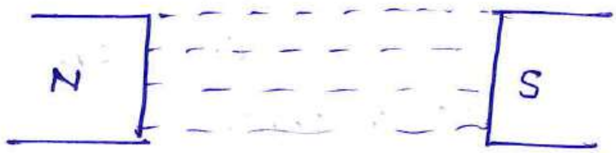
(6) A resistor 'R' (Load) is connected between brushes

Working:

Consider coil rotating in anticlockwise direction

Position 1 ($\theta = 0°$)

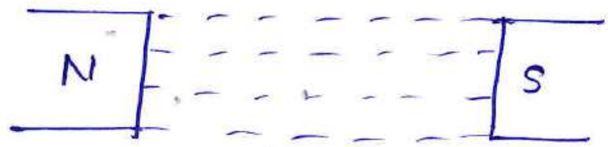
When coil parallel to the magnetic flux then emf induced into coil is zero means no emf induced into coil.



$$e = E_m \sin\theta$$
$$e = E_m \sin 0° = 0$$

Position 2 ($\theta = 90°$)

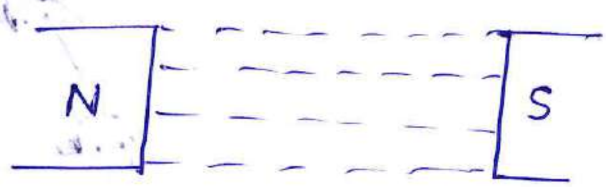
When coil perpendicular to the magnetic flux then emf induced into coil is maximum



$$e = E_m \sin\theta° = E_m \sin 90° = E_m$$

Position 3 ($\theta = 180°$)

When coil parallel with magnetic flux then emf induced in coil is zero means no emf induced into coil



$$e = E_m \sin\theta° = E_m \sin(180°) = E_m \times 0 = 0$$

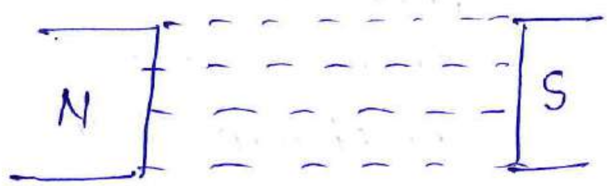
Position 4 ($\theta = 270°$)

When coil perpendicular to mag flux then emf induced in coil is maximum

$$e = E_m \sin\theta° = E_m \sin(270) = E_m \times 1 = E_m$$

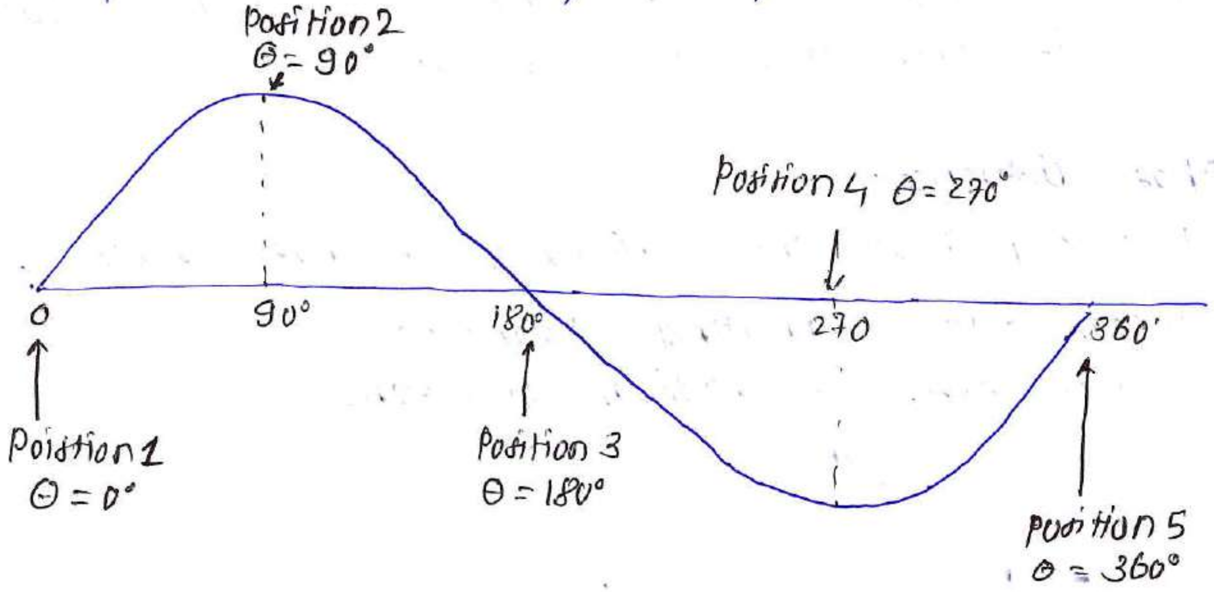
Position 5 ($\theta = 360°$)

when conductor (coil) parallel to magnetic flux then emf induced in coil is zero



$e = E_m \sin(360°) = E_m \times 0 = 0$

Diagram of alternating voltage.

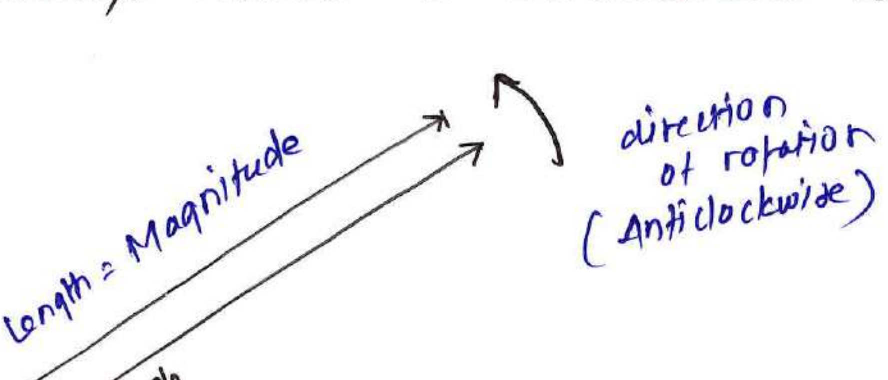


Phasor representation of alternating Quantities.

Phasor representation is similar to vector representation. An alternating quantity represented by a straight line with arrow at the end.

length of arrow indicate magnitude & arrow indicate direction.

Phasor is always rotate in anticlockwise direction



phase or phase angle

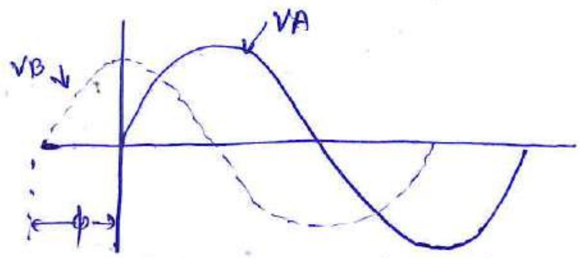
phase or phase angle is defined as the Angle made by phasor with respect to reference axis.

It is represented by ϕ & Unit is degree or radian.

If the phase is measured in anticlockwise direction then it is possitive. if the phase measured in clock wise direction then it is negative.

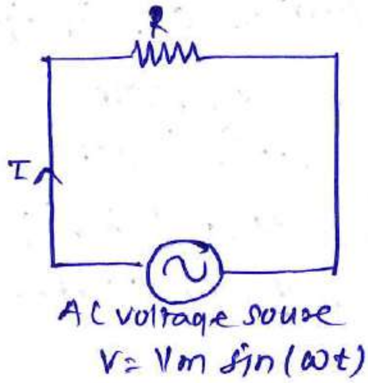
Phase difference:

It is defined as the difference of phase angle between two alternating Quantities.
It is measure in radian or degree.



Let VA & VB are two voltages
phase difference betn two voltages is ϕ.

Purely Resistive (R) AC circuit



Purely resistive AC circuits consist of pure resistor & AC voltage source applied across it.

AC voltage source having instantaneous voltage equation

$$V = V_m \sin(\omega t) \quad \text{—— (1)}$$

Due to this voltage current I flowing through ckt

According to ohm's law

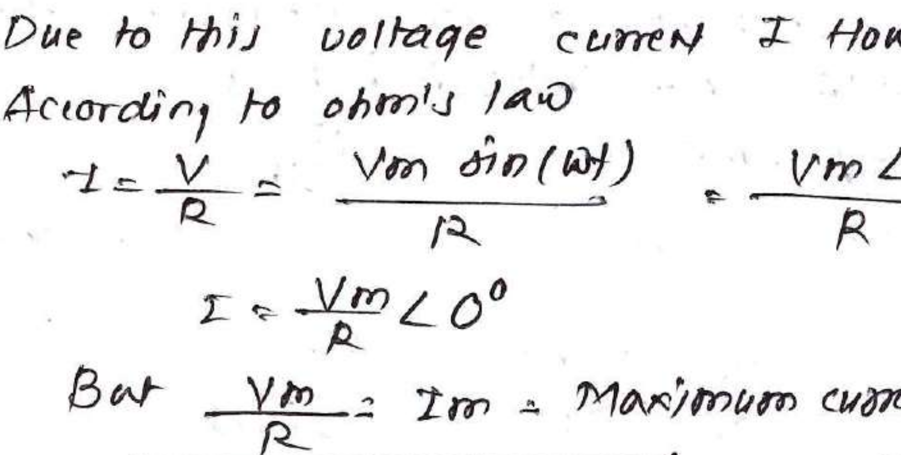
$$I = \frac{V}{R} = \frac{V_m \sin(\omega t)}{R} = \frac{V_m \angle 0^\circ}{R}$$

$$I = \frac{V_m}{R} \angle 0^\circ$$

But $\frac{V_m}{R} = I_m$ = Maximum current

$$\boxed{I = I_m \sin(\omega t)} \quad \text{—— (2)}$$

Voltage & current responce (Waveform) :-

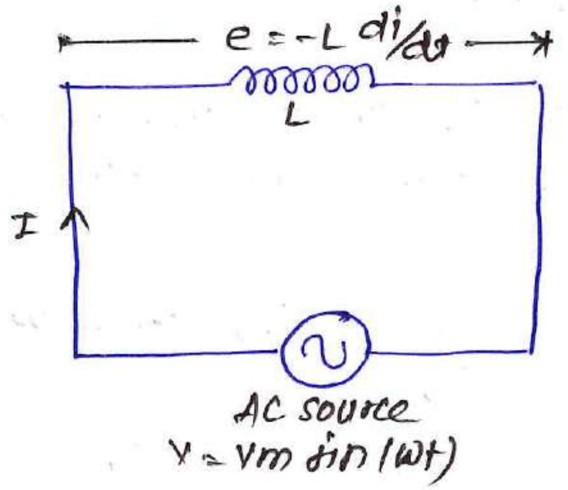


Phasor diagram :-

In case of purely resistive circuits the phase difference between voltage & current is zero.

So we said both voltage & current are <u>In-phase</u>

Purely Inductive AC circuit :-



Purely Inductive AC circuit consist of pure inductor & AC voltage applied across it. Inductor is denoted by 'L' & it measured in 'Henry (H)'

The alternating current produces alternating flux due to this self emf induced into coil.

Self induced emf $e = -L \frac{di}{dt}$

Due to AC voltage source, current I flowing through circuit

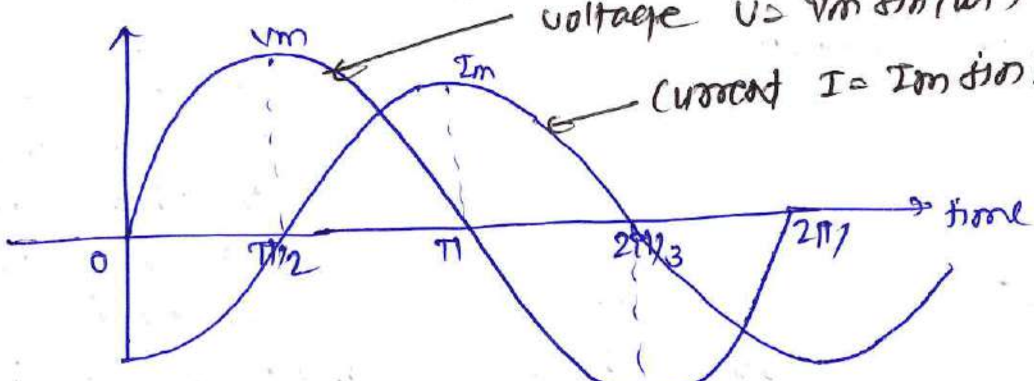
$$I = \frac{V}{X_L} = \frac{V_m \sin(\omega t)}{X_L \angle 90^\circ} = \frac{V_m \angle 0^\circ}{X_L \angle 90^\circ}$$

$$I = \frac{V_m}{X_L} \angle (0^\circ - 90^\circ) = \frac{V_m}{X_L} \angle -90^\circ$$

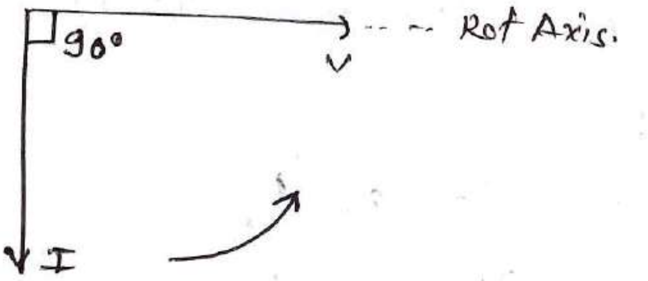
But $\frac{V_m}{X_L} = I_m$ = Maximum current

$$\boxed{I = I_m \sin(\omega t - 90^\circ)} \text{ Amp} \quad \text{or} \quad \boxed{I = I_m \sin(\omega t - \pi/2) \text{ radian}} \text{ Amp}$$

voltage & current responce (Waveform)



phasor diagram:-



Current lags to voltage by an angle 90° or $\pi/2$ radian. for pure inductive circuit.

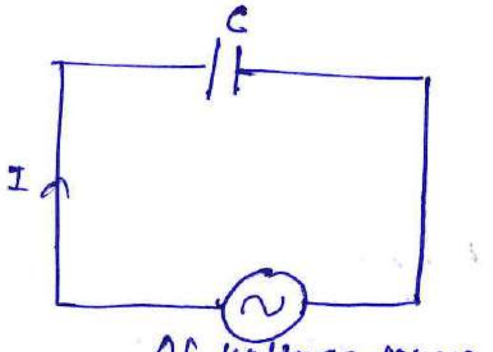
Inductive reactance (X_L)

It is defined as the opposition offered by an inductor to the flow of alternating current. It is SI unit ohm (Ω)

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

where
f = frequency in Hertz
L = Inductor in Henry

Purely Capacitive (C) AC circuit:-



The circuit consist of Capacitor C is connected across voltage source. The capacitor is denoted by C & it is measured in farad.

The capacitor has property to store electrical energy.

when voltage applied to ckt then current I flowing through it

According to ohm's law

$$I = V/X_C = \frac{V_m \sin(\omega t)}{X_C \angle -90^\circ} = \frac{V_m \angle 0^\circ}{X_C \angle -90^\circ}$$

$$\frac{V_m}{X_C} \angle 90^\circ$$

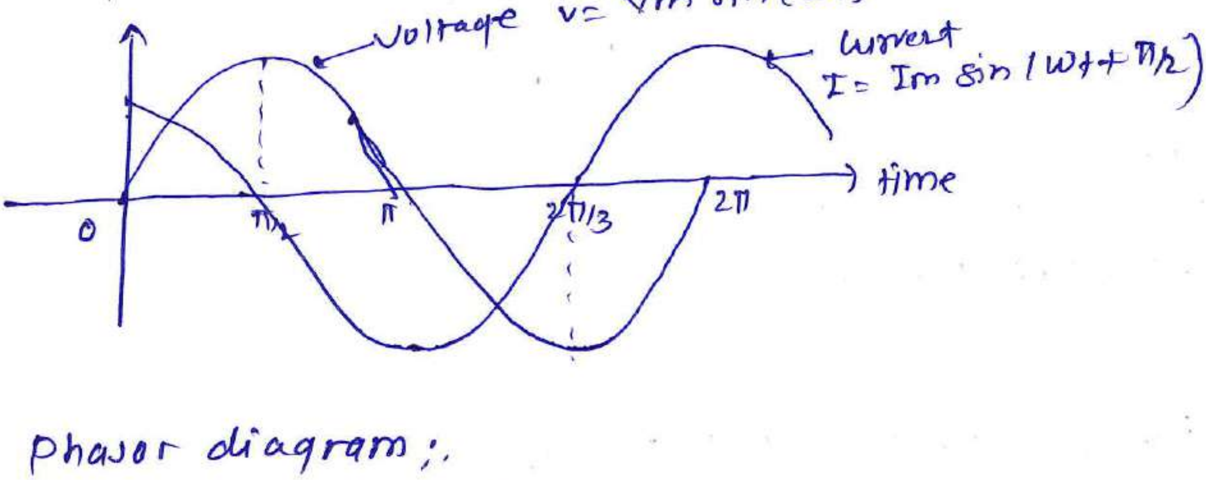
But $\frac{V_m}{X_C} = I_m$ = Maximum current.

$$I = I_m \angle 90^\circ$$

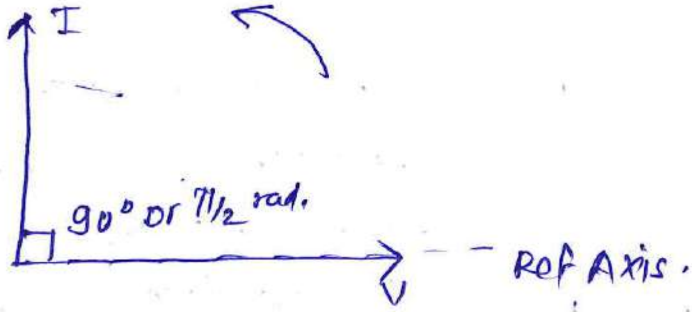
$$I = I_m \sin(\omega t + \pi/2) \text{ or Amp}$$
$$I = I_m \sin(\omega t + 90^\circ) \text{ Amp}$$

where
I_m = Maximum current in Amp
ω = Angular frequency in radian
t = time in sec.

voltage & current responce (Waveform)



Phasor diagram :.



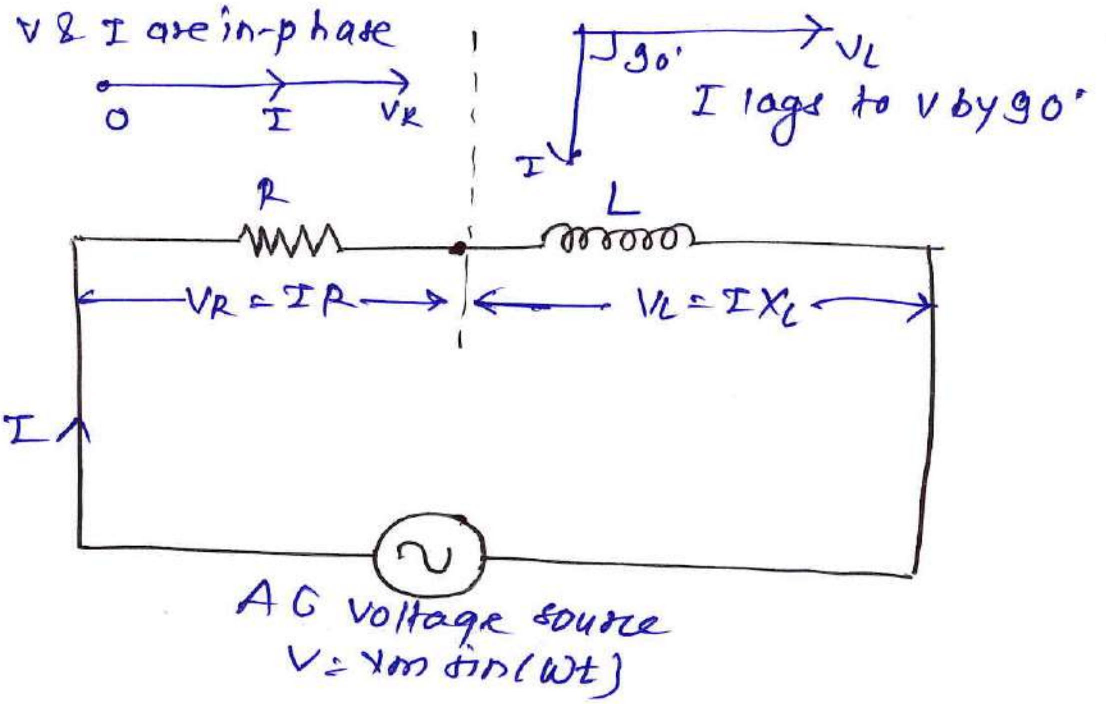
For pure capacitive circuit current leads to voltage V by 90° or $\pi/2$ radian.

Capacitive Reactance (X_C)
It is defined as the opposition offered by the capacitor to the flow of alternating current
SI unit is ohm (Ω)

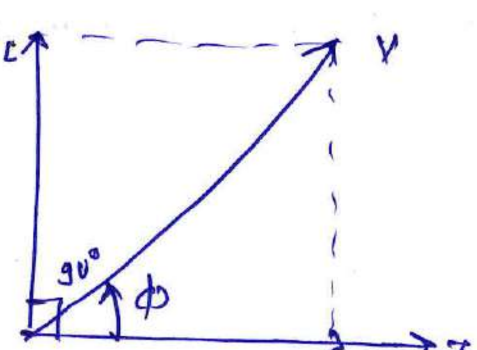
$$X_C = \frac{1}{2\pi f C} \quad \Omega$$

RL Series AC Circuits

In series R-L series circuit the voltage source of instantaneous voltage $v = V_m \sin(\omega t)$ is connected across series combination of R & L



Phasor diagram (Vector diagram):



Applied voltage V is equal to phasor addition of V_R & V_L

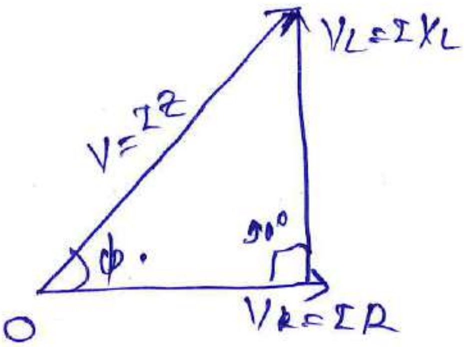
$$\overline{V} = \overline{V_R} + \overline{V_L}$$

$$\overline{V_R} = \overline{IR} \;\&\; \overline{V_L} = \overline{IX_L}$$

$$\overline{V} = \overline{IR} + \overline{IX_L}$$

Voltage triangle:

The sides of triangle represent voltage is called voltage triangle.



Impedance of RL circuit

$$V = \sqrt{V_R^2 + V_L^2}$$
$$= \sqrt{(IR)^2 + (IX_L)^2}$$
$$= \sqrt{I^2(R^2 + X_L^2)}$$
$$V = I\sqrt{R^2 + X_L^2}$$
$$\boxed{V = I|Z|}$$
$$|Z| = \sqrt{R^2 + X_L^2} = \text{Impedance.}$$

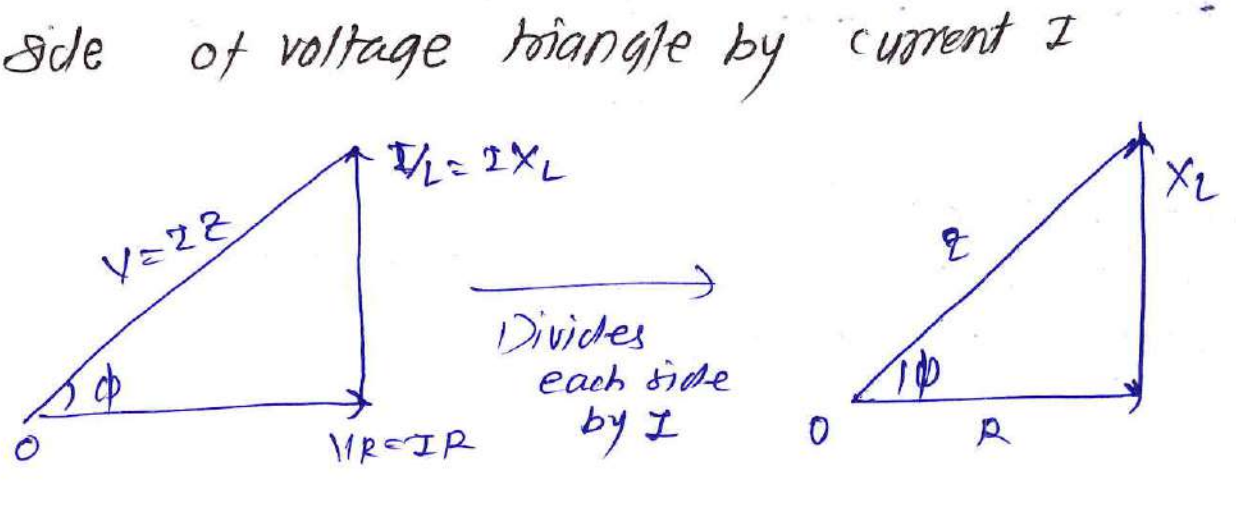
Power factor = cosine angle between voltage & current

$$\cos\phi = \frac{R}{Z}$$

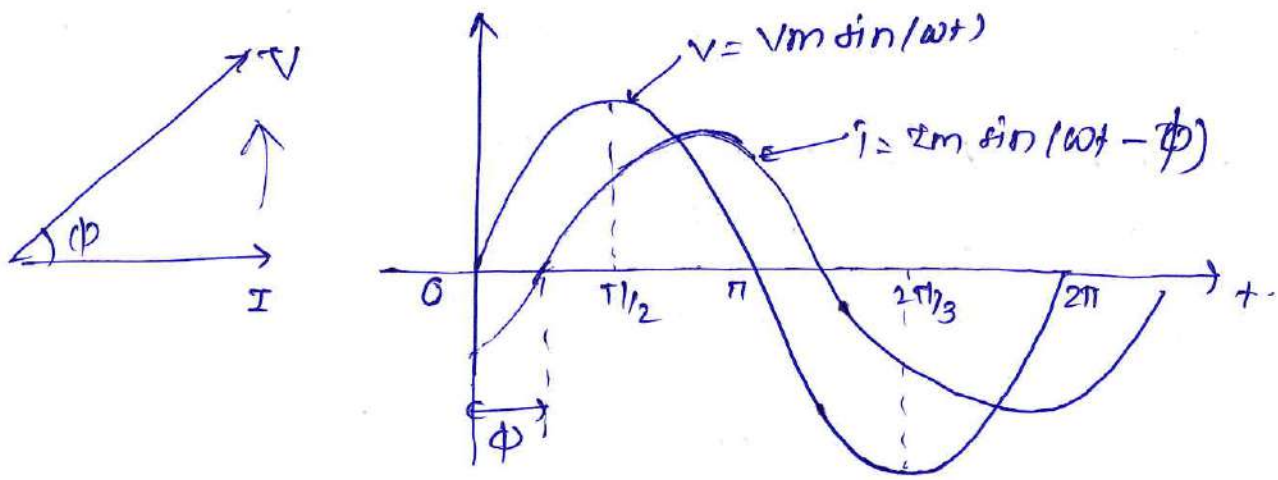
Power factor is lagging for RL series circuit.

Impedance triangle

We obtain impedance triangle, divide each side of voltage triangle by current I



Waveform of voltage & current



Expression of current

$$I = \frac{V(t)}{Z} = \frac{V\angle 0^\circ}{|Z|\angle\phi} = \frac{V}{|Z|}\angle(0^\circ-\phi)$$

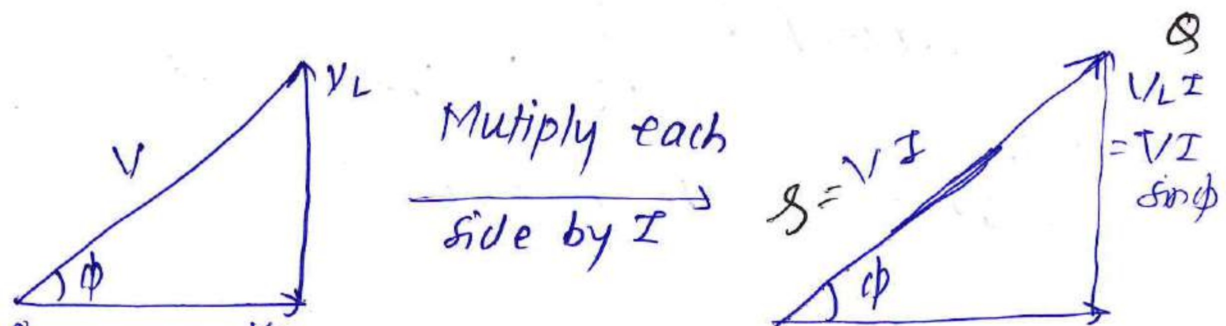
$$\text{Let } \frac{V}{|Z|} = I_m \quad \therefore \; I = I_m \angle -\phi$$

$$\boxed{I = I_m \sin(\omega t - \phi)} \text{ Amp}$$

Current in RL series circuit lags behind applied voltage by an angle ϕ

Power triangle

The power triangle is obtained from voltage triangle by multiplying each side by I



voltage triangle

Power triangle

Active power (P) or True Power OR Real power

Active power is defined as the product of V, I & cosine angle between V & I.

It is denoted by P

$$P = V I \cos\phi$$ watt or KW

SI Unit is watt or kilo watt.

Reactive Power (Q)

Reactive power is defined as the product of V, I & sine angle between V & I.

It is denoted by Q.

$$Q = V I \sin\phi$$ VAR or KVAR

SI Unit is VAR or KVAR.

Apparent power (S)

Apparent power is defined as the product of voltage & current.

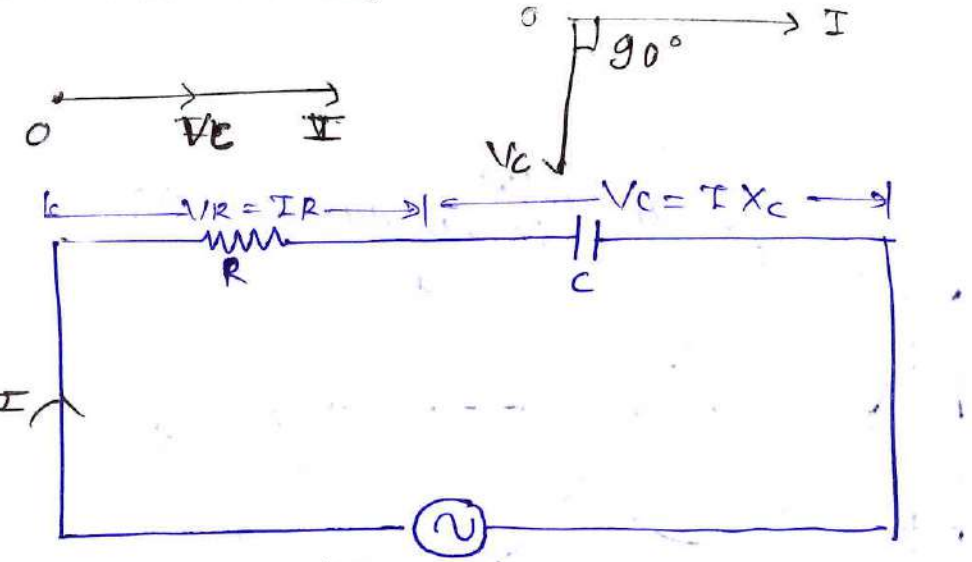
It is denoted by S

$$S = V I$$ VA or KVA

~~SI~~ U.

SI Unit is VA or KVA.

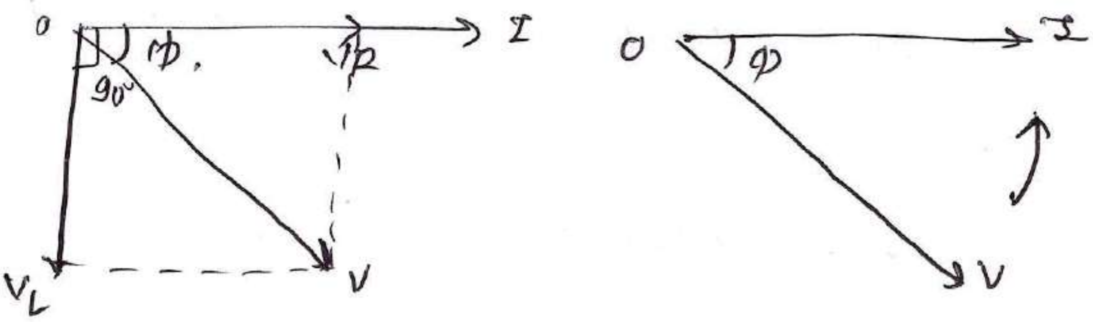
RC Series Circuit



AC voltage source
$V = V_m \sin(\omega t)$

In RC series circuit the voltage source is connected across series combination of RC

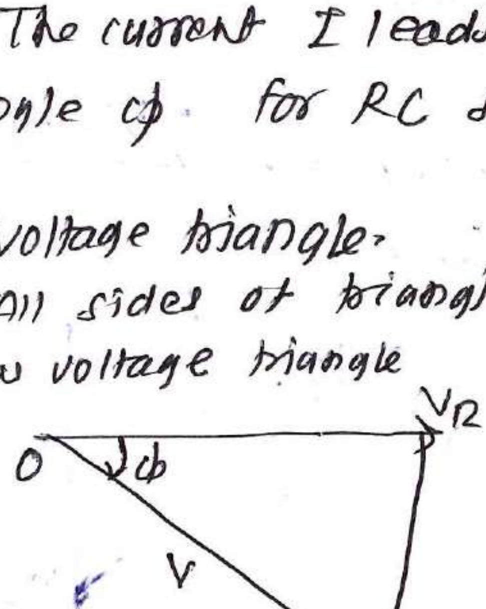
Phasor diagram



The current I leads to voltage V by an angle ϕ for RC series circuit

Voltage triangle.

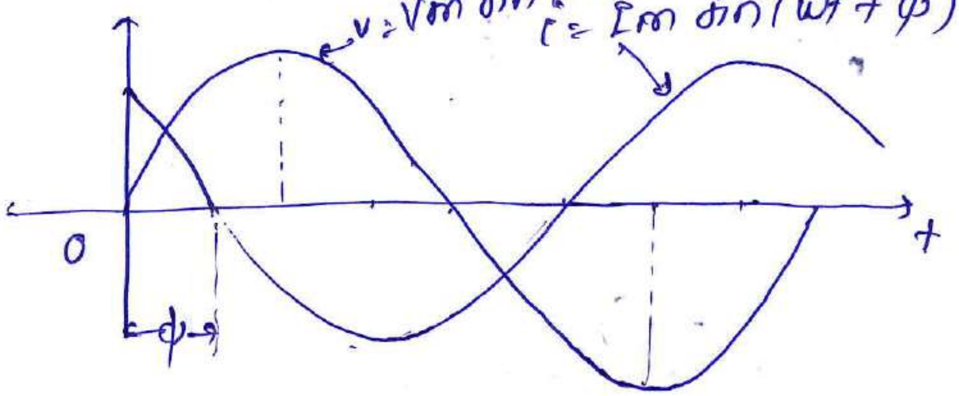
All sides of triangle represent voltages is known as voltage triangle



$$V = \sqrt{(V_R)^2 + (-V_C)^2}$$
$$= \sqrt{(IR)^2 + (-IX_C)^2}$$
$$= \sqrt{I^2R^2 + I^2X_C^2}$$
$$V = I\sqrt{R^2 + X_C^2}$$
$$V = I\,|Z|$$

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

waveform of voltage & current



voltage equation

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

$$i(t) \text{ or } I = \frac{V}{Z} = \frac{V_m \angle 0^\circ}{|Z| \angle -\phi} = \frac{V_m}{|Z|} [0 - (-\phi)]$$

$$= \frac{V_m}{|Z|} \angle \phi$$

But $I_m = \frac{V_m}{|Z|}$ = Maximum or Peak current

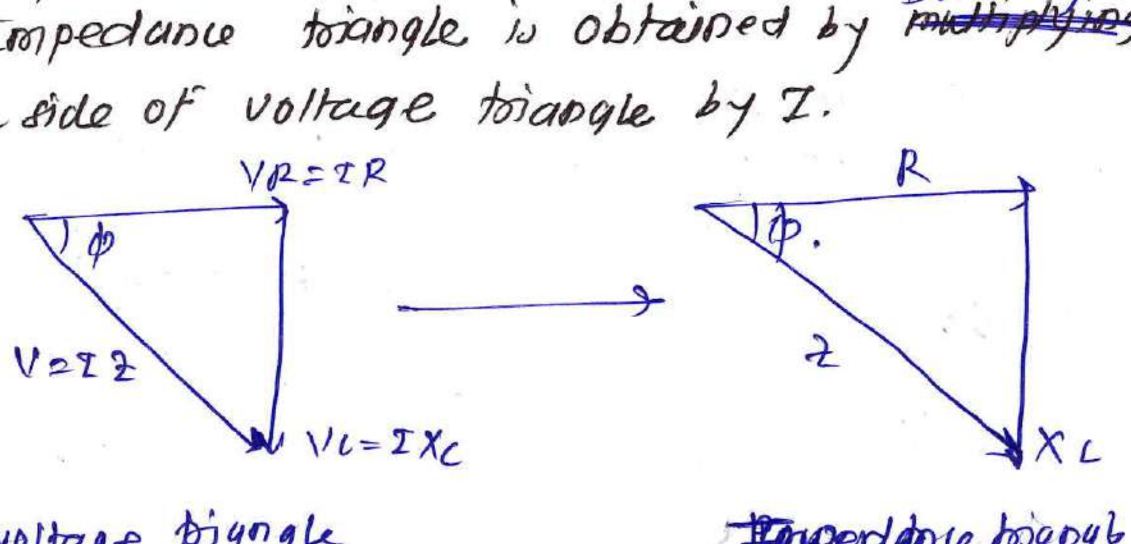
$$I = I_m \angle \phi$$

$$\boxed{I = I_m \sin(\omega t + \phi)} \text{ Amp}$$

Current I leads to voltage V by an angle φ.

Impedance triangle

Impedance triangle is obtained by ~~multiplying~~ Dividing all side of voltage triangle by I.

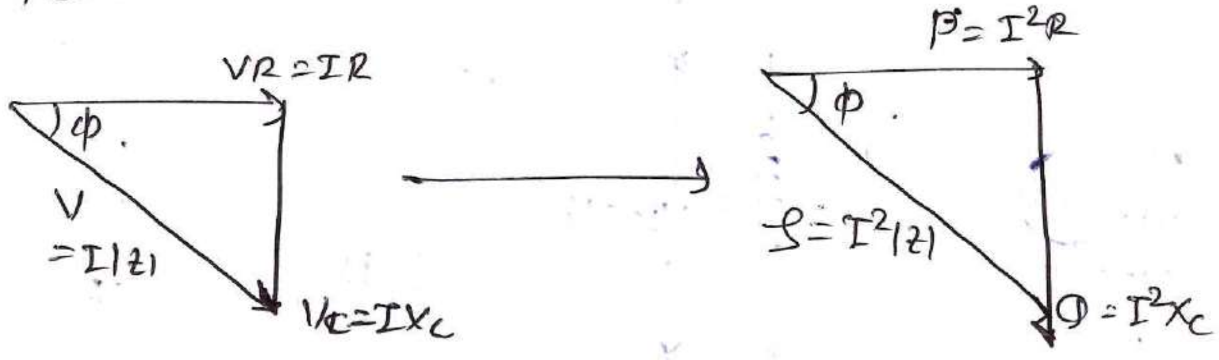


voltage triangle

~~Impedance~~ Impedance triangle

Power triangle

The power triangle for RC circuit can be obtained by multiplying each sides of voltage triangle ~~by~~ by I.



Voltage triangle Power triangle

power factor: It is the cosine angle between voltage & current is known as power factor. It is denoted by $\cos\phi$.

or

It is defined as the ~~app~~ ratio of apparent power to Active power to Apparent power

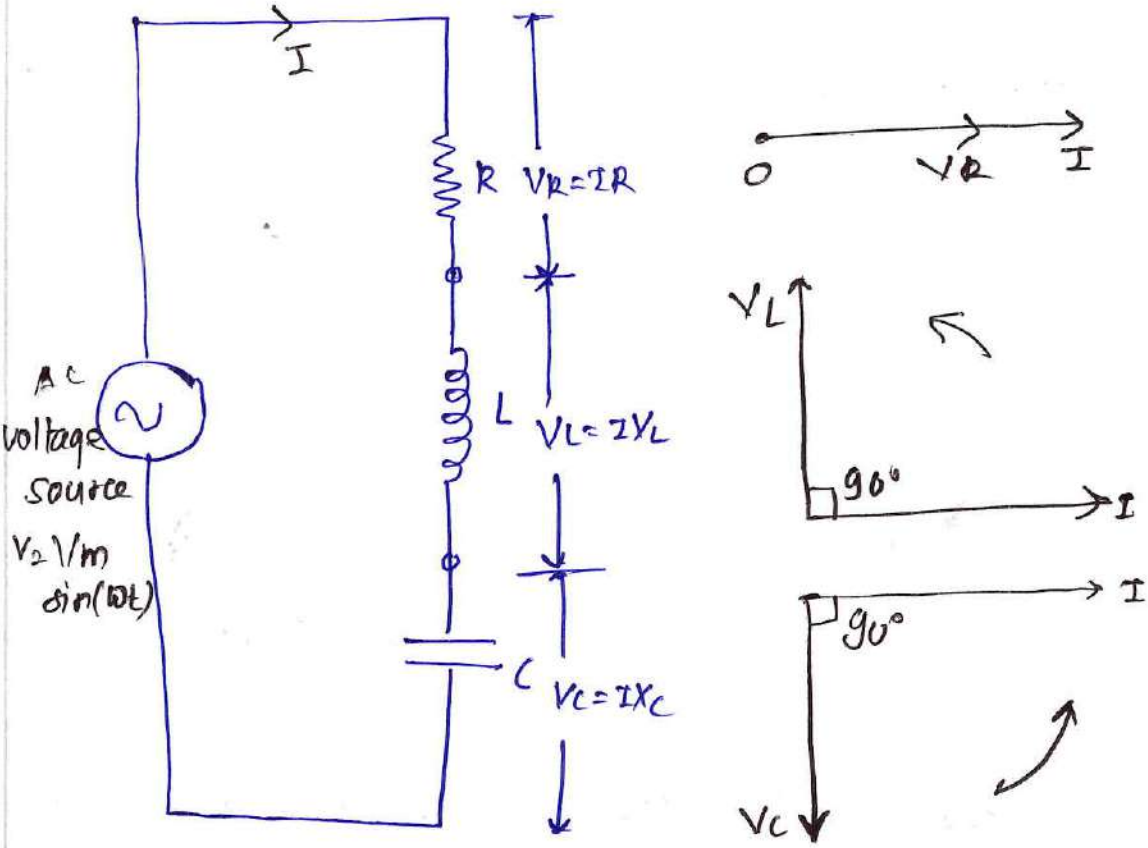
$$p.f = \frac{\text{Active power}}{\text{Apparent power}} = \frac{VI\cos\phi}{VI}$$

$$p.f = \cos\phi.$$

Power factor is leading for RC series circuit.

Active, Reactive, Apparent power is same as RL series circuit.

RLC Series circuit



The voltage source is connected across the combination of Resistance (R), inductance (L) & Capacitance (C). Due voltage source, current I Flowing through the circuit, voltage drop across

1) voltage drop across, R is $V_R = I \cdot R$
2) voltage drop across, L is $V_L = IX_L$
3) voltage drop across, C is $V_C = IX_C$

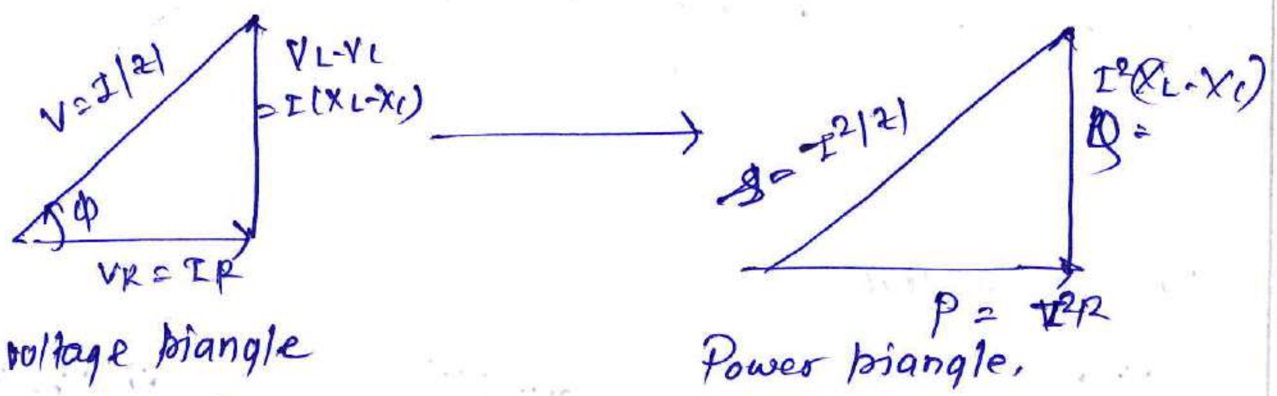
We consider 3 condition for RLC series circuit.

① $X_L > X_C$

X_L is greater than X_C means inductive reactance is greater than capacitive reactance
The voltage across X_L is greater than X_C
Hence $V_L > V_C$.

Power triangle -

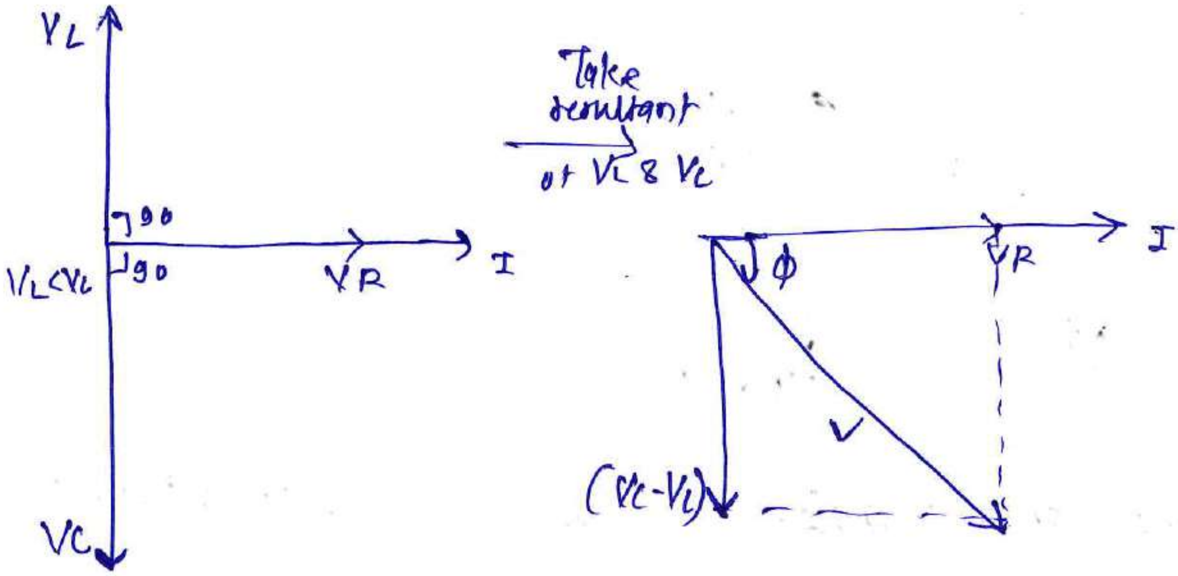
1a) Multiply each side of voltage triangle by I.



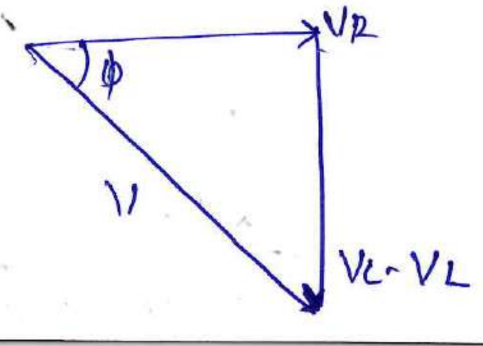
2) $X_L < X_C$ (Inductive Reactance less than Capacitive Reactance)

When $X_L < X_C$ then V_L will be less than V_C. Hence resultant of V_L & V_C i.e $(V_C - V_L)$ will be in the direction of V_C

Phasor diagram



Voltage triangle

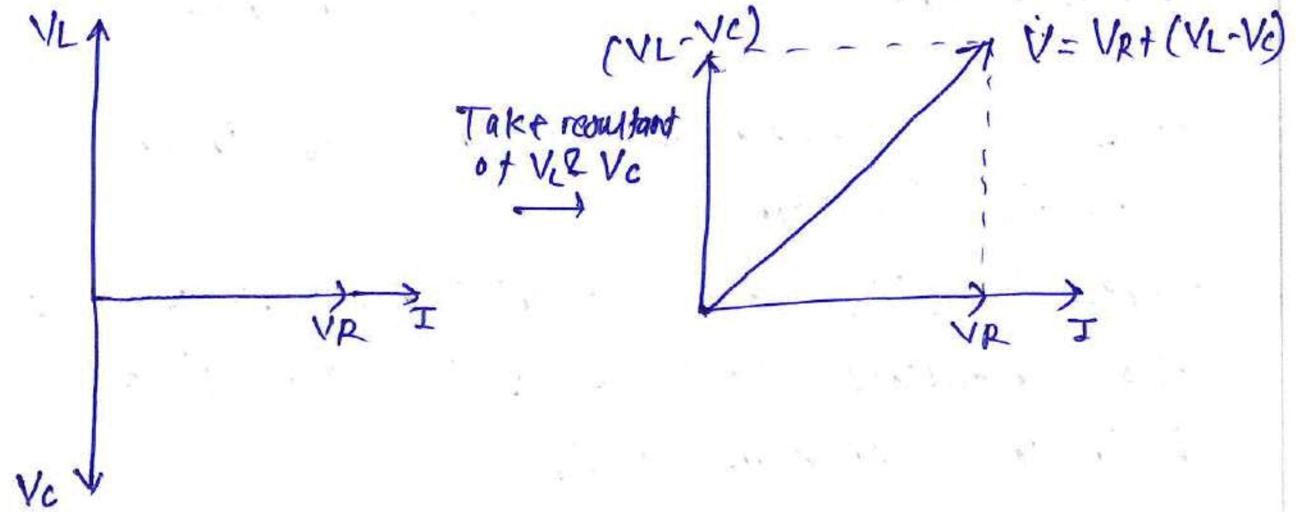


The resultant voltage V is vector addition of V_R, V_L & V_C

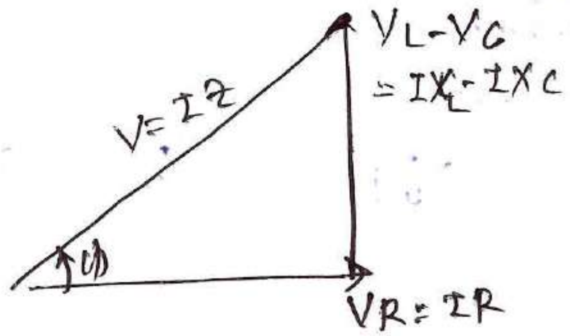
$$\bar{V} = \bar{V_R} + \bar{V_L} + \bar{V_C}$$

As V_L & V_C are in phase opposition
If $V_L > V_C$ their resultant is $V_L - V_C$ i.e simple subtraction of two voltage

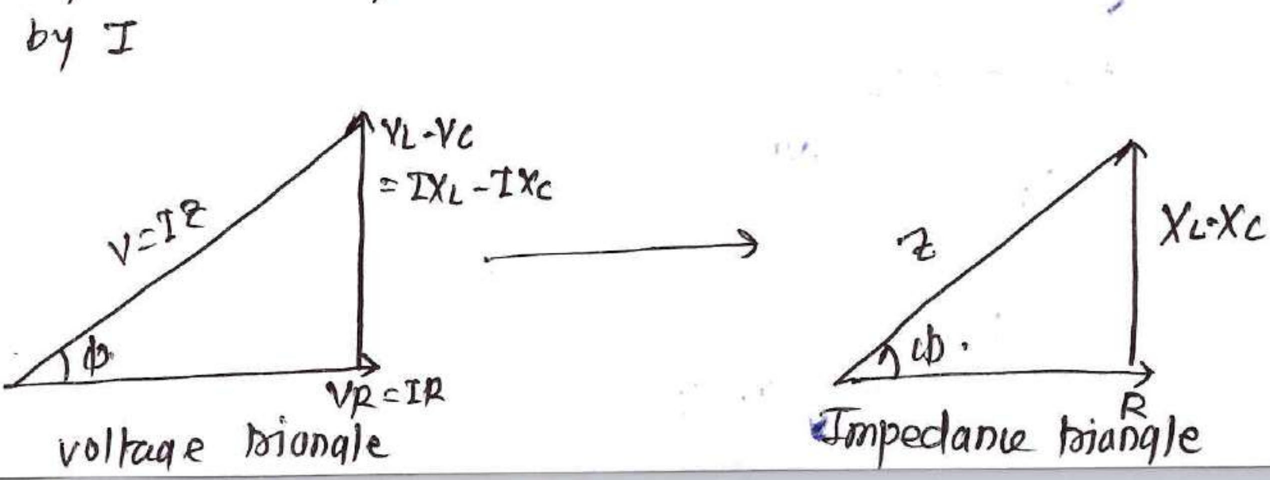
phasor diagram



Voltage triangle.

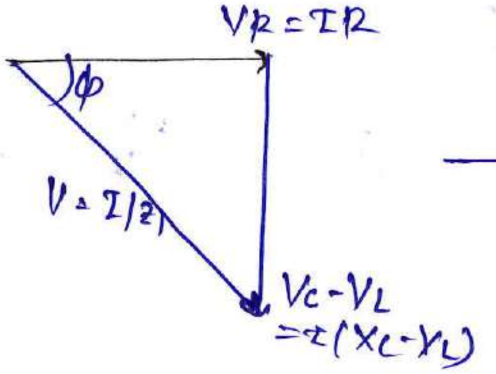


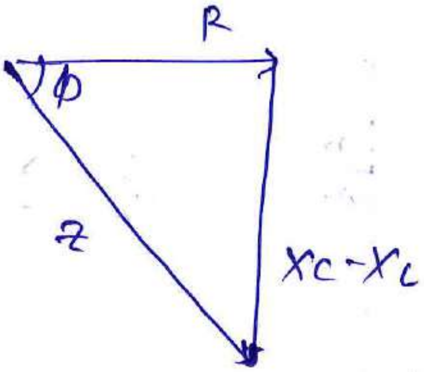
Impedance triangle. :- Divide all sides of voltage triangle by I



Impedance triangle :

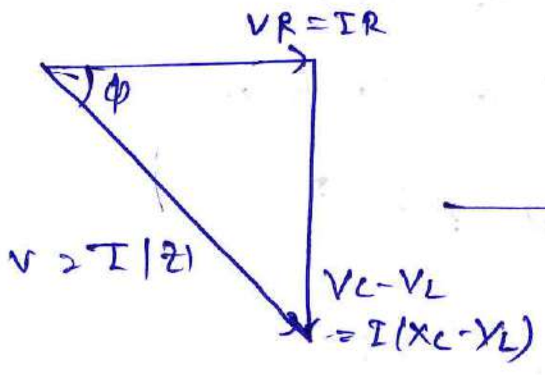
It is obtained by dividing each side of voltage triangle by current I

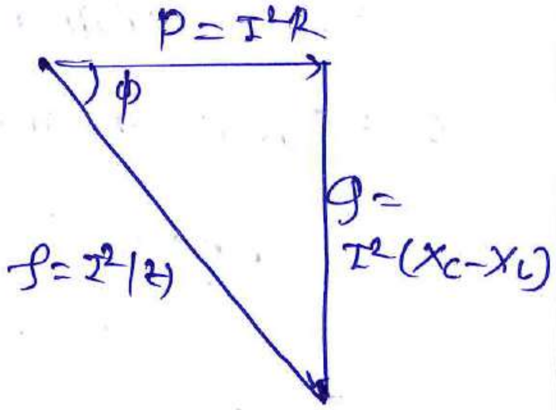




Power triangle.

It is obtained by multiplying each side of voltage triang by current I



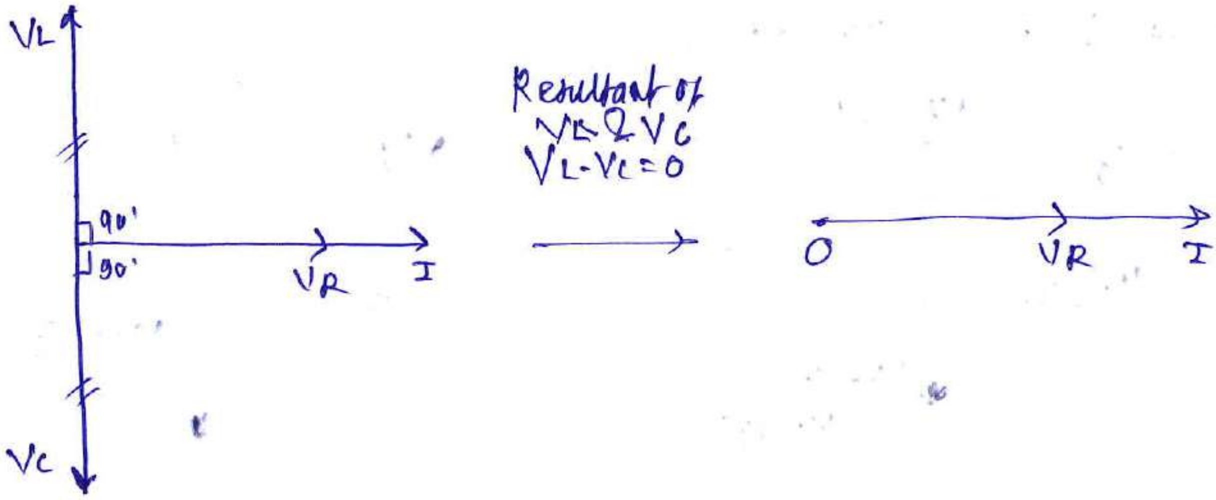


(3) $X_L = X_C$ (Inductive reactance is equal to Capacitive reactance)

when $X_L = X_C$ the V_L will be equal to V_C

Hence V_L & V_C will cancel each other then resultant will zero.

Phasor diagram



Power supplied in RLC series circuit

Average Power = Power consumed in R +

Power consumed by L & Power consumed by C

But Power consumed by L & C are zero

P_{avg} = Power consumed by R.

$= I^2R$

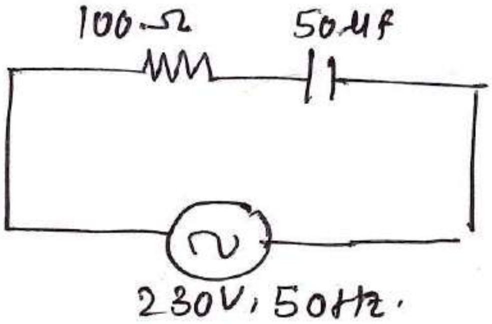
$P = VI\cos\phi$ watt.

Q. A resistance of 100 Ω & 50 μF capacitor are connected in series a 230 V. 50 Hz apply find:-

1. Z
2. I
3. V_R & V_L
4. cos φ & power.

Solution

Given:- R = 100 Ω, C = 50 μF, V = 230 V, f = 50 Hz



$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 50 \times 10^{-6}}$$

$$\boxed{X_C = 63.66\,\Omega}$$

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

$$= \sqrt{(100)^2 + (-63.66)^2} = \sqrt{14052.84}$$

$$Z = 118.54\,\Omega$$

(2) Current

$$I = \frac{V}{Z} = \frac{230\angle 0^\circ}{118.54} = 1.94 \text{ A}$$

(3) Voltage across resistance, V_R

$$V_R = IR = 1.94 \times 100 = 194 \text{ Volt}$$

voltage across capacitor, V_C

$$V_C = I X_C = 1.94 \times 63.66 = 123.50 \text{ Volt}$$

(4) power factor, cos φ.

$$\cos\phi = \frac{R}{Z} = \frac{100}{118.54} = 0.8 \text{ (leading)}$$

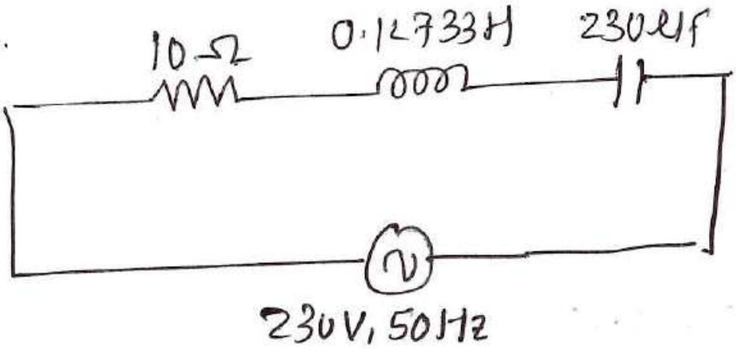
Power (P)

$P = VI\cos\phi = 230 \times 1.94 \times 0.8 = 356.96$ watt.

Q. A coil has resistance of 10 Ω & inductance of 0.12733 H. This coil is connected in series with a capacitor of 230 uf across the supply of 230 V, 50 Hz find:-

1. X_L
2. X_C
3. Voltage across L & C
4. P.F
5. Impedance.
6. Current
7. Angle betn voltage & current

solution:-



1. X_L

$X_L = 2\pi f L = 2\pi \times 50 \times 0.12733 = 40\ \Omega$

2. X_C

$$X_C = \frac{1}{2\pi f C} = \frac{1}{(2\pi \times 50 \times 230 \times 10^{-6})} = 13.83\ \Omega$$

3. P.F, $\cos\phi$.

$$\cos\phi = \frac{R}{Z} = \frac{10}{28} = 0.357 \text{ (leading}$$

4. Impedance Z

$$Z = \sqrt{R^2 + X^2} = \sqrt{(10)^2 + (40-13.83)^2}$$
$$= 28\ \Omega$$

(5) Current, I

$$I = \frac{V}{Z} = \frac{230}{28} = 8.214 \text{ Amp}$$

(6) $V_R = IR = 8.214 \times 10 = 82.14$ Volt

$V_L = IX_L = 8.214 \times 40 = 328.56$ Volt

$V_C = IX_C = 8.214 \times 13.83 = 113.56$ volt

(7) $\phi = \cos^{-1}(0.357) = 69.08^\circ$

Resonance in RLC series circuit

In Series RLC ckt resonance is said to have occured, if inductive reactance is equal to capacitive Reactance.

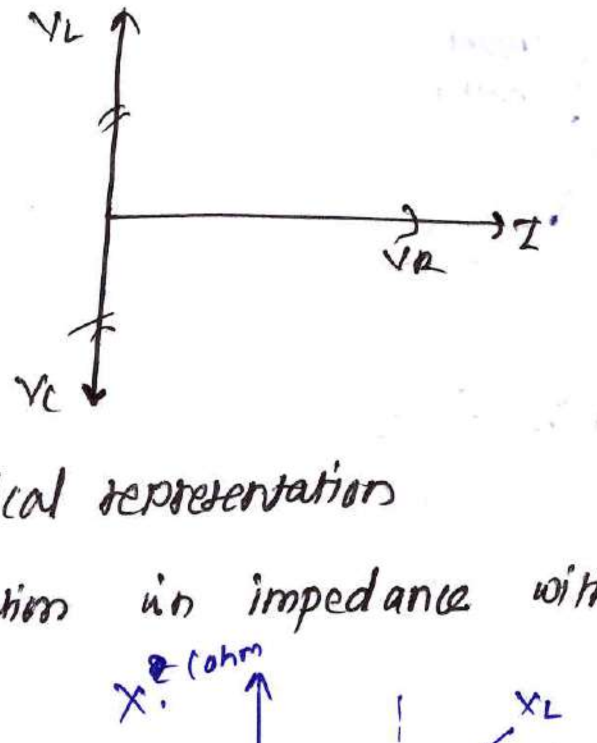
$$X_L = X_C$$

Resonant frequency (f_0)

The frequency at which resonance will occur that frequency is known as Resonant frequency

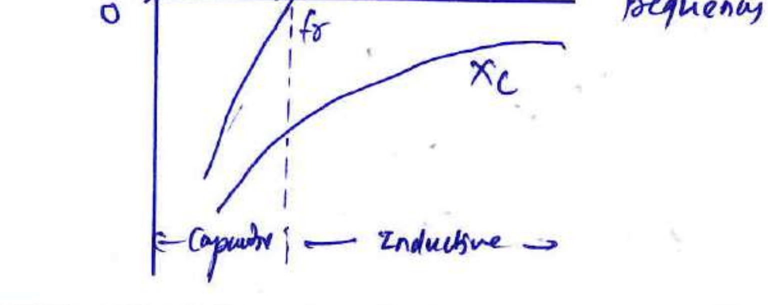
$$f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}$$

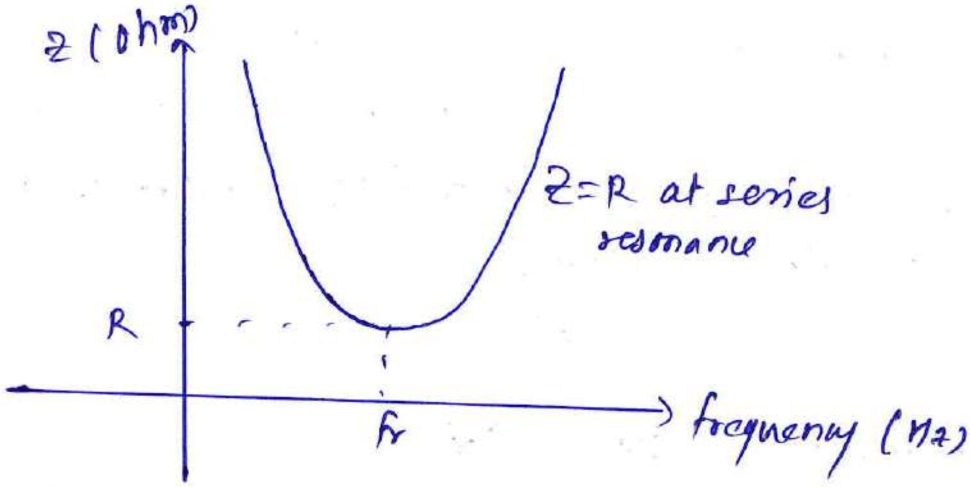
Phasor diagram



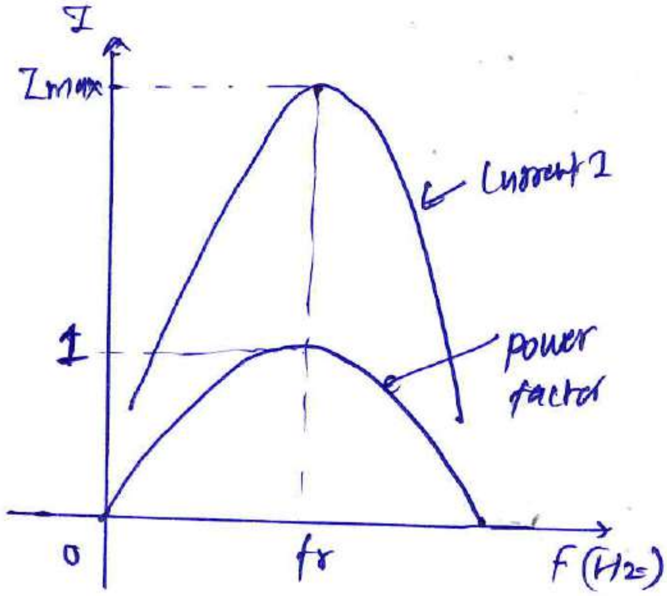
Graphical representation

Variation in impedance with frequency





Variation in current & Power factor



Q factor (Quality factor)

The Q factor is defined as the ratio of energy stored per cycle to the energy lost per cycle

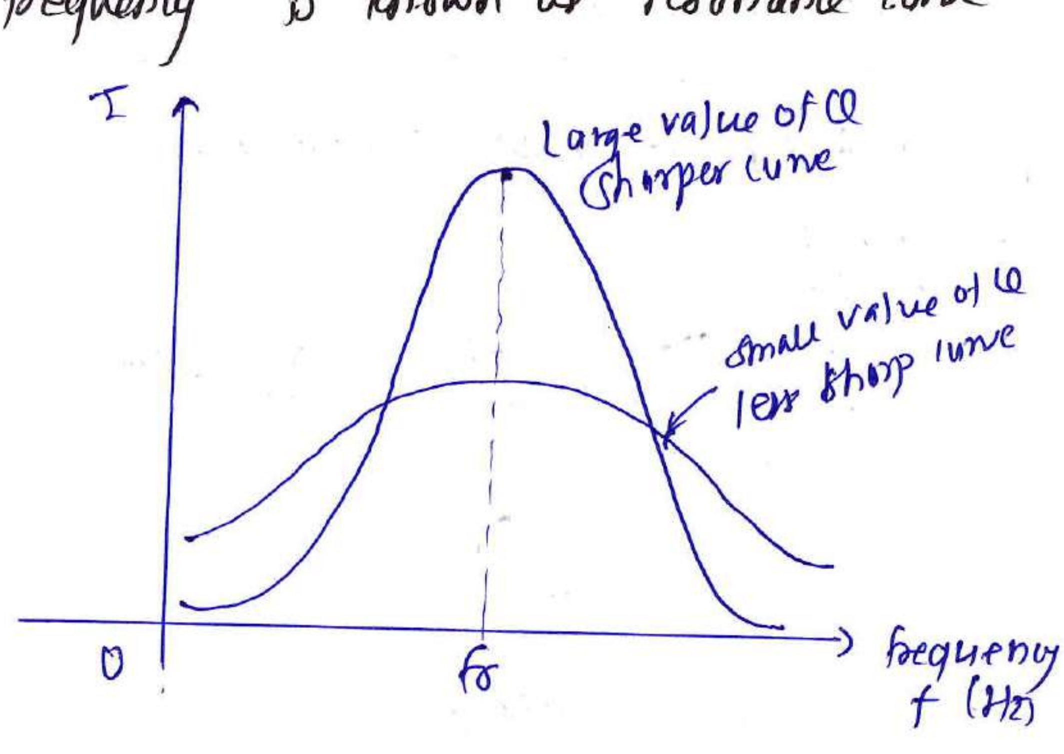
$$Q = 2\pi \frac{\text{Max energy stored per cycle}}{\text{Energy dissipated per cycle}}$$

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

It is Unit less Quantity

Resonance Curve:

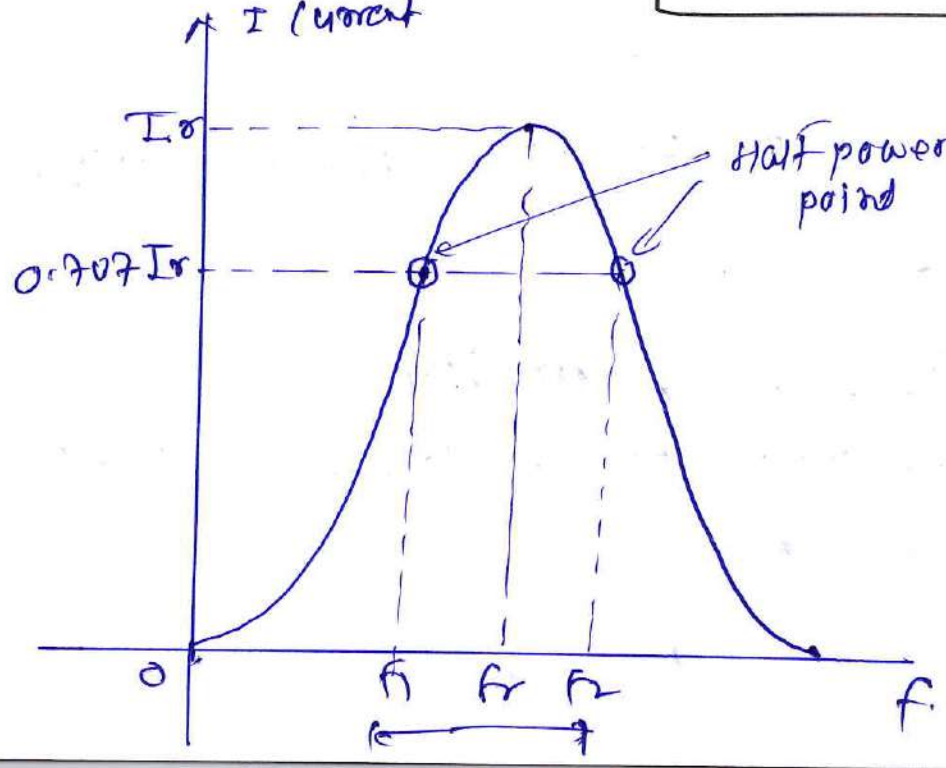
The graph of current (I) plotted against the signal frequency is known as resonance curve



Bandwith

Bandwidth of series resonant ckt is difference betn frequencies at which power reduces to 50% of Maximum power

$$\boxed{B = f_2 - f_1} \text{ Hz} \qquad \boxed{BW = f_r / Q}$$

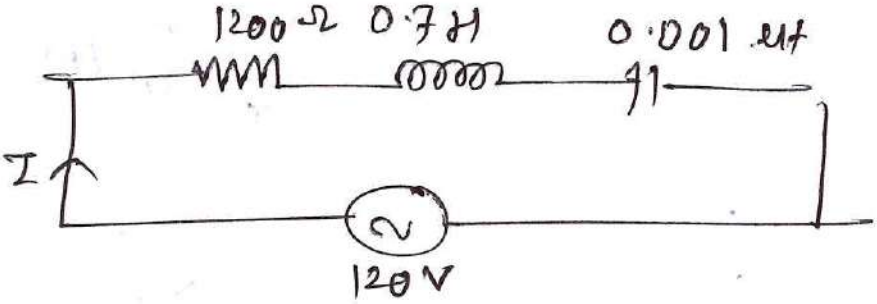


Q.1 A 1200 Ω resistor, 0.7 H coil & 0.001 μF capacitor are in series across 120 V source. Determine

1. Resonant frequency
2. Vtg across capacitor at resonance
3. Q Factor of circuit at resonance

Solution:-

Ckt diagram:



1. Resonant frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.7\times 0.001\times 10^{-6}}}$$

$$\boxed{f_r = 6015.5\ Hz}$$

2. Q factor

$$Q = \frac{1}{\omega_r RC} = \frac{1}{2\pi f_r RC}$$

$$= \frac{1}{(2\pi\times 6015.5\times 1200\times 0.001\times 10^{-6})}$$

$$\boxed{Q = 22.04}$$

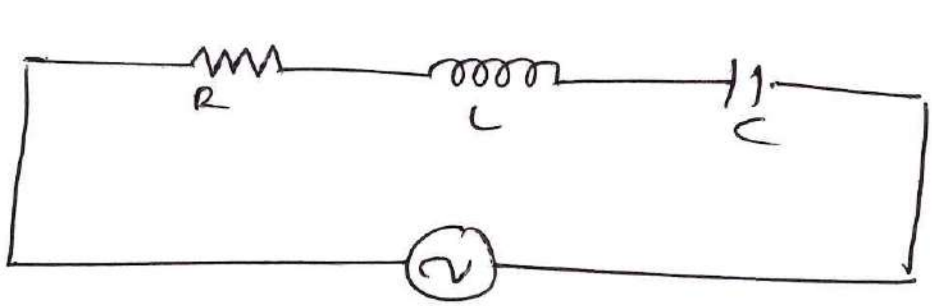
3. Voltage across capacitor

$V_C = QV = 22.04 \times 120 = 2645.75$ volt

Q. A series ckt has following parameter
$R = 10\,\Omega$, $L = \frac{100}{\pi}$ mH, $C = \frac{500}{\pi}$ μF find.
(1) The current flowing when applied voltage is 100 V at 50Hz
(2) p.f of circuit
(3) what value of supply frequency would produces series resonance ?

Solution:-
Given:- $R = 10\,\Omega$, $L = \frac{100}{\pi}$ mH, $C = \frac{500}{\pi}$ μF.

Find:- I, $\cos\phi$, f_r.



(1) current

$$X_L = 2\pi f L = 2\pi \times 50 \times \frac{100}{\pi} \times 10^{-3} = 10\,\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times \frac{500}{\pi} \times 10^{-6}} = 20\,\Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{10^2 + (10-20)^2}$$

$$Z = 14.14\,\Omega.$$

$$I = \frac{V}{Z} = \frac{100}{14.14} = 7.07 \text{ Amp.}$$

(2) Power factor

$$\cos\phi = \frac{R}{Z} = 0.707 \text{ (leading)}$$

(3) Resonance frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{\frac{100}{\pi}\times 10^{-3}\times\frac{500}{\pi}\times 10^{-6}}}$$

$$f_r = 70.71\ Hz$$

Subject Teacher

19.05.2026
HOD.

Principal

UNIT 1 :Single phase AC series circuit

1. Draw impedance triangle and phasor diagram for R-C series circuit. 2marks
2. Draw vector diagram for R–L series circuit and write the equations of instantaneous voltage and current for same circuit. 2marks
3. Define Active power and Reactive power for RLC series circuit. 2marks
4. State the term "Phase" and "Phase difference" in case of alternating qualities. 2 marks
5. Draw voltage and current responses for a pure inductive circuit. 2marks

6. For series R-L-C circuit, draw neat circuit diagram. State the three conditions for R-L-C series circuit. Draw voltage triangle and impedance triangle for XL >Xc. 4 marks
7. A series R-L-C circuit has R = 5W, L = 10 mH and C = 15mF. Calculate : i) Resonant frequencyii) Q-factor of the circuit iii)Bandwidth iv) Voltage Magnification. 4 marks
8. With neat diagram explain phasor representation of sinusoidal quantities. 4marks
9. Explain with neat circuit diagram RC series circuit. Draw impedance triangle and power triangle for same circuit. 4marks
10. Two impedances Z1 = (15 + j 12.56) Ω Z2 = (10 + j31.4) Ω are connected in series with a capacitance of 100 mf and supplied through 230V, 50Hz A.C. source. Find current drawn and voltage across each impedance. 4 marks
11. A capacitor and resistor are connected in series to an A.C. supply of 50V, 50Hz. The current is 2A and the power dissipated in the circuit is 80W. Calculate the values of resistance and capacitance. 4 marks
12. Explain Graphical Representation of Resonance in R–L–C series circuit. 4 marks
13. For a series R-L-C circuit consisting of R = 5W, L = 0.01 H and C = 10 mF supplied with 230 V, 50 Hz supply, Determine : i) ii) iii) iv) v) vi) Circuit impedance Circuit current Circuit power factor Active power Reactive power Apparent power. 6 marks
14. Explain Graphical Representation of Resonance in R-L-C series circuit. 6 marks
15. Draw graphical representation of series resonance and state meaning each term marked on graph. 6 marks

20/5/26
Subject Teacher

20.5.2026
HOD EE

21/5/26
principal