UNIT- II

LECT -28

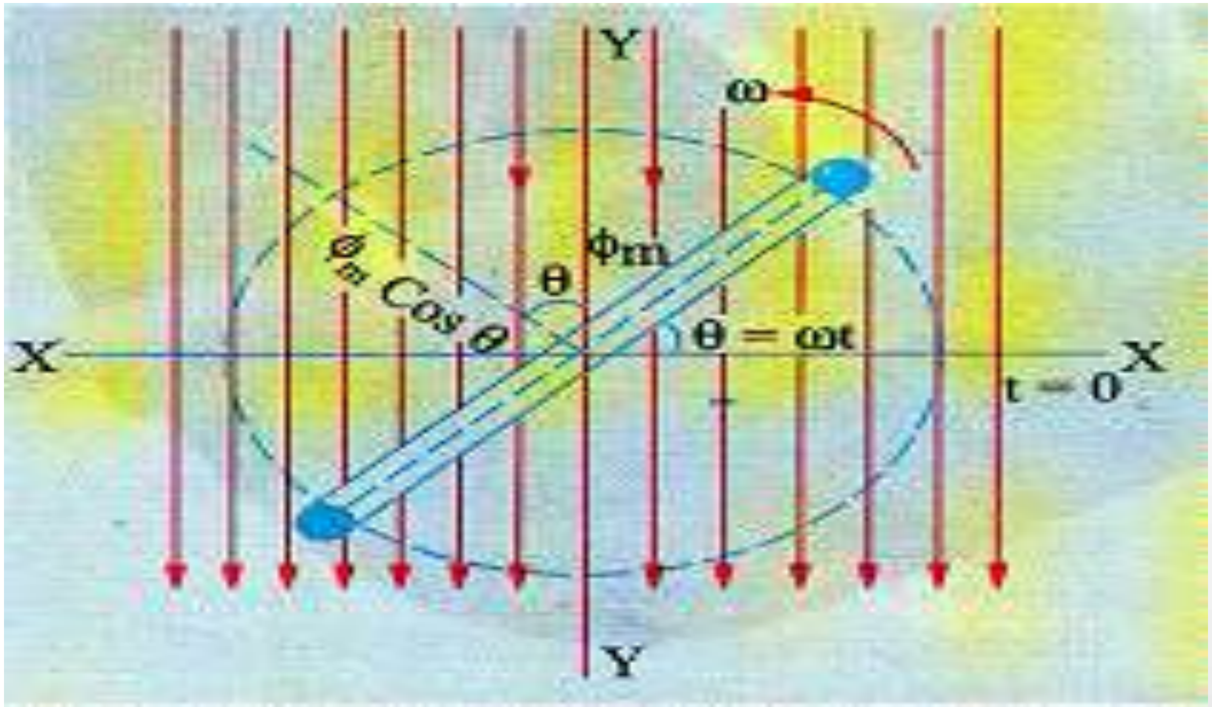
REVIEW
OF
AC FUNDAMENTALS

AC SERIES CIRCUIT

- **1. GENERATION OF ALTERNATING VOLTAGE AND CURRENTS :-**
- **Alternating voltage may be generating by rotating a coil in a magnetic field or by rotating a magnetic field within a stationary coil. The value of the voltage generated depends, in each case, upon the number of turns in the coil, strength of the field and the speed at which the coil or magnetic field rotates**

AC SERIES CIRCUIT

- **2. EQUATIONS OF THE ALTERNATING VOLTAGES AND CURRENTS**
- **Consider a rectangular coil having N turns and rotating in a uniform magnetic field with an angular velocity of ω radian/second as shown in below fig**



EQUATIONS OF THE ALTERNATING VOLTAGES AND CURRENTS

- **Let time be measured from X-axis. Maximum flux ϕ_m is linked with the coil when its plane coincides with the X-axis. In time t seconds ,this coil rotates through an angle $\theta = \omega t$. In this deflected position , the component of the flux which is perpendicular to the plane of coil is**
- $$\phi = \phi_m \cos \omega t .$$
- **Hence , *flux linkages* of the coil at any time are**
- $$N\phi = N\phi_m \cos \omega t.$$
- According to Faraday's Law of Electromagnetic Induction , the emf induced in the coil is given by the rate of change of flux-linkages of the coil.

EQUATIONS OF THE ALTERNATING VOLTAGES AND CURRENTS

- **Hence, the value of the induced emf at this instant (i.e. when $\theta=\omega t$) or the instantaneous value of the induced emf is**
- $e = -d/dt\ (N\phi)$
- $= -N\ d/dt\ (\phi_m \cos \omega t)$ volt
- $= -N \phi_m \omega\ (-\sin \omega t)$ volt
- $= \omega N \phi_m \sin \omega t$ volt
- $= \omega N \phi_m \sin\theta$ volt………………(1)

EQUATIONS OF THE ALTERNATING VOLTAGES AND CURRENTS

- When the coil has turned through 90° i.e. when θ=90° then sinθ=1, hence e has maximum value say E_m .
- Therefore , from Eq.(1) we get
- $E_m = \phi_m \omega N = B_m A \omega N = 2\pi f N B_m A$ volt
- Where B_m =maximum flux density in Wb/m2 and
- A= area of the coil in m2
- f = frequency of retation of the coil in rev/second or Hz
- Hence alternating Voltage is

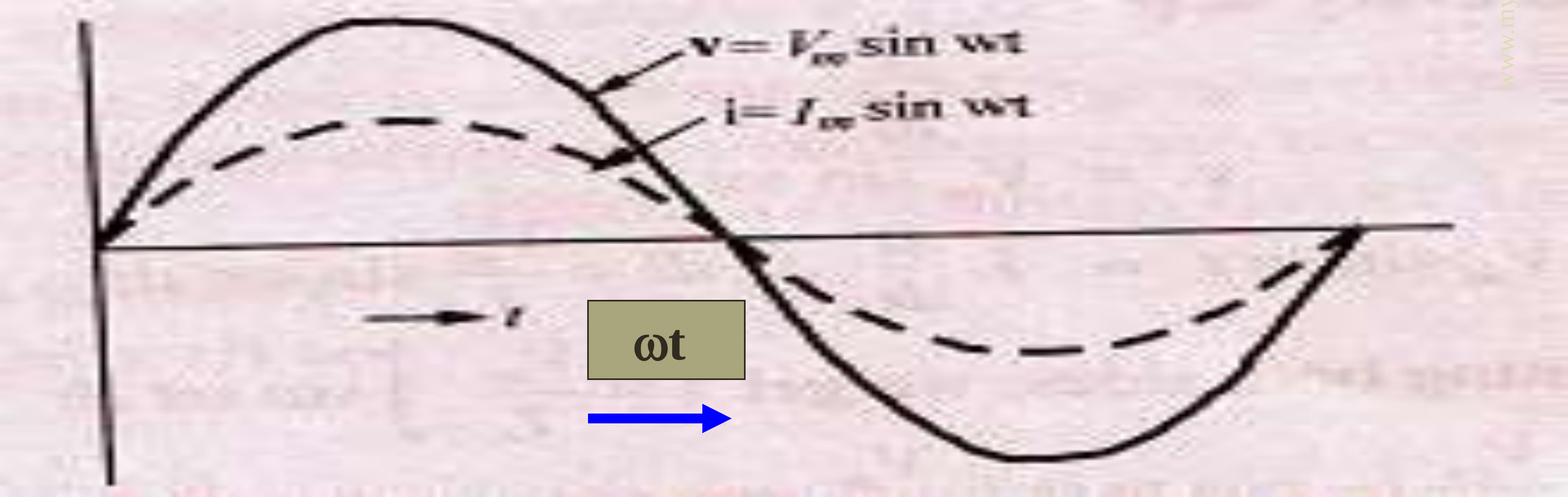
$$e = E_m \sin \omega t \text{ volt}$$

- Hence alternating current is

$$i = I_m \sin \omega t \text{ Amp}$$

EQUATIONS OF THE ALTERNATING VOLTAGES AND CURRENTS

- **The induced emf varies as sine function of the time angle ωt when emf plotted against time , a curve shown in below fig. is obtained. This curve is known sine curve and emf which varies in this manner is known as *sinusoidal emf*.**



IMPORTANT DEFINATIONS OF AN ALTERNATING QUANTITY

- **CYCLE:- One complete set of positive and negative values of alternating quantity is known as cycle.**
- **TIME PERIOD :- The time taken by an alternating quantity to complete one cycle is called its time period T. For example , a 50-Hz alternating current has a time period of 1/50 second.**
- **FREQUENCY :- The number of cycle/second is called the frequency of the alternating quantity. Its unit is Hertz (Hz). The frequency is given by the reciprocal of the time period of the alternating quantity. f = 1/T or T=1/f**
- AMPLITUDE :- The maximum value , positive or negative , of an alternating quantity is known as its amplitude.

ROOT-MEAN-SQUARE(R.M.S.)VALUE

- The rms value of an alternating current is given by **" that steady (d.c.) current which when flowing through a given circuit for a given time produces the same heat as produced by the alternating current when flowing through the same circuit for the same time."**
- It is also known as the *effective or virtual* value of the alternating current

ROOT-MEAN-SQUARE(R.M.S.)VALUE

- The standard form of a sinusoidal alternating current is $i = I_m \sin \omega t$
- The mean of the squares of the instantaneous values of current over one complete cycle is
- $= \int_0^{2\pi} (i^2 /(2\pi-0))\, d\theta$
- The square root of this value is
- $= \sqrt{\int_0^{2\pi} (i^2/2\pi)\, d\theta}$
- Hence, rms value of the alternating current is
- $I = \sqrt{\int_0^{2\pi} (i^2/2\pi)\, d\theta}$

ROOT-MEAN-SQUARE(R.M.S.)VALUE

- $I = \sqrt{\int_o^{2\pi} (i^2/2\pi)\, d\theta}$
- $= \sqrt{\int_o^{2\pi} [\,(I_M \sin\theta)^2 /2\pi)]\, d\theta}$ (put $i = I_m \sin\theta$)

  $= \sqrt{\int_o^{2\pi} (\,I^2_M \sin^2\theta /2\pi)\, d\theta}$
- $= \sqrt{(\,I^2_M / 2\pi\,) \int_o^{2\pi} \sin^2\theta\, d\theta}$
- $= \sqrt{(\,I^2_M / 2\pi\,) \int_o^{2\pi} [(1-\cos 2\theta)/ 2\,]\, d\theta}$
- $= \sqrt{(\,I^2_M / 4\pi\,) \int_o^{2\pi} (1-\cos 2\theta)\, d\theta}$
- $= \sqrt{(\,I^2_M / 4\pi\,)\ (\theta-\sin 2\theta/2)^{2\pi}_{0}}$
- $= \sqrt{(\,I^2_M / 4\pi\,) (2\pi - 0 - \sin 4\pi - 0)}$
- $= \sqrt{(\,I^2_M / 4\pi\,) (2\pi)} = \sqrt{(\,I^2_M / 2\,)} = I_M \sqrt{2}$
- $I = 0.707\, I_m$
- **Rms value of current = 0.707 X max. value of current**

AVERAGE VALUE

- The average value I_a of an alternating current is expressed by " that steady current which transfers across any circuit the same charge as is transferred by that alternating current during the same time".

AVERAGE VALUE

- The average value of the current over one complete cycle is
- $= \int_{o}^{\pi} (i/(\pi-0))\, d\theta$
- $= \int_{o}^{\pi} [\,(I_M \sin\theta)/\pi)]\, d\theta$ (put $i = I_m \sin\theta$)

  $= (I_M/\pi) \int_{o}^{\pi} \sin\theta\, d\theta$
- $= (I_M/\pi)\ (-\cos\theta)^{\pi}_{0}$
- $= -\ (I_M/\pi)\,(-1\ -1)$
- $= (I_M/\pi)\,(2) = 2\, I_M/\pi$
- $I = 0.637\, I_m$
- **Average value of current = 0.637 X maximum value**

FORM FACTOR & PEAK FACTOR

- FORM FACTOR - Form Factor is the ratio of rms value to the Average value.
- K_f = rms value/average value
- = 0.707 I_m / 0.637 I_m = 1.11

Creast or Peak or Amplitude Factor - Peak factor is the ratio of maximum value to the rms value.

- K_a = maximum value/rms value
- = I_m / 0.707 I_m = 1.414

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PROBLEMS
OF
AC FUNDAMENTALS

TUTORIAL PROBLEM 1:

A rectangular coil of size 5 cm X 10 cm has 50 turns and is supported on an axle, the axle of the coil is normal to a large uniform magnetic field in which the flux-density is 0.1 WB/m2 and coil is rotate about the axle at 1000 RPM. Calculate max emf and emf when coil makes an angle 45°.

<u>Solu</u>

$Em = 2\pi \; f \; N \; BA$

A= 5*10 = 50 cm2 =5 * 10-3 m2 ; N= 50; f = 1000/60 =50/3 rps; B = 0.1 WB/m2

$Em = 2\pi * (50/3) * 50 * 0.1*5 * 10^{-3} = 2.62 \text{ V}$

$E = Em \sin\theta = 2.62 \sin 45 = 1.85 \text{ V}$

Max value of alternating current is 120 A at 60Hz frequency. Write down its alternating eq. Find

the instantaneous value after 1/360 sec. (b) the time taken to reach 96A for the first time.

Solu

Instantaneous current eq. Is

$i = 120 \sin 2\pi \; f \; t = 120 \sin 120 \; \pi t$

$t = 1/360$

$i = 120 \sin(120*\pi*1/360) = 120 \sin(120*180*1/360) = 120 \sin 60 = 103.9 \text{ A}$

(b) $96 = 120 \sin(2*180*60* t)$

$96/120 = \sin(2*180*60* t)$

$\sin(2*180*60* t) = 0.8$

$2*180*60* t = \sin^{-1}(0.8) = 53$

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AC SERIES CIRCUIT

AC SERIES CIRCUIT

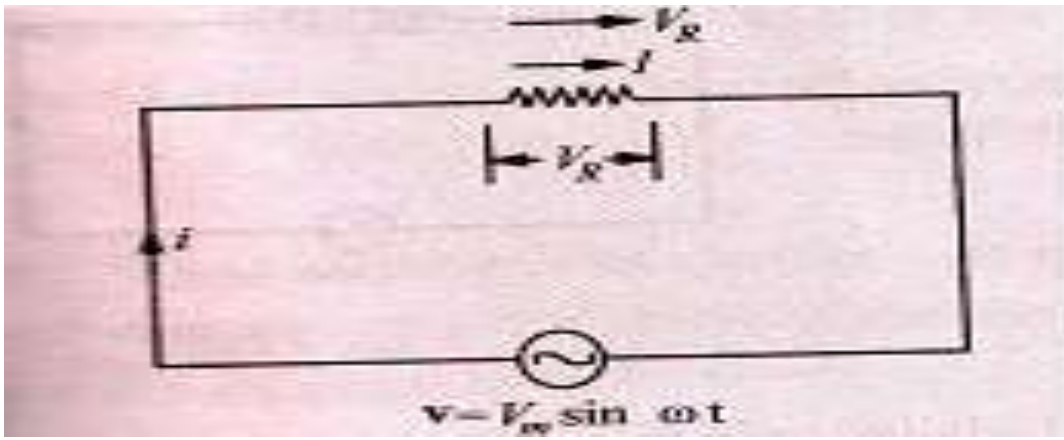
- 1. AC THROUGH PURE RESISTANCE.

  2. AC THROUGH PURE INDUCTANCE

  3. AC THROUGH PURE CAPACITANCE

AC SERIES CIRCUIT

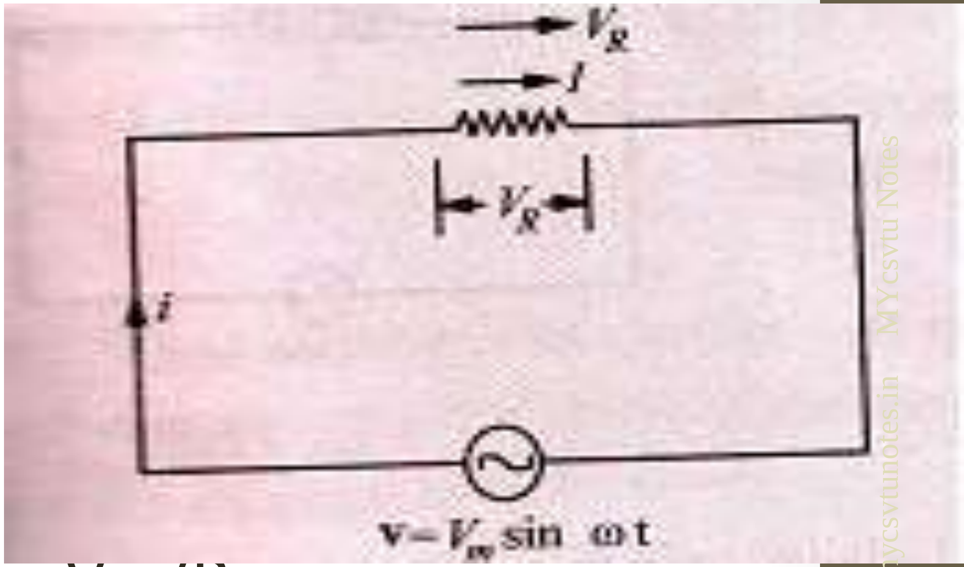
- **AC THROUGH PURE RESISTANCE R**



- **In above fig. Let applied voltage be given by the equation**
- $$v = V_m \sin \omega t \quad ....1$$
- **Let R = ohmic resistance ; i = instantaneous current.**
- **Obviously , the applied voltage has to supply ohmic voltage drop only .**

AC SERIES CIRCUIT

AC THROUGH PURE RESISTANCE R



- Hence, for equilibrium
- $v = Ir$
- **$v = V_m \sin \omega t$ …….1**
- $V_m \sin \omega t = iR$
- $I = (V_m / R) \sin \omega t$
- $I = I_m \sin \omega t$ …………2
- Where $I_m = V_m / R$
- current 'i' is maximum when sin ωt is unity.
- Comparing (1) and (2), we find that the alternating voltage and current are in phase with each other as shown in fig. It is also shown vectorially by vector V_R and I.

AC SERIES CIRCUIT

AC THROUGH PURE RESISTANCE R

POWER THROUGH PURE RESISTANCE :

POWER P = vi

or $P = V_m \sin wt \times I_m \sin wt$

$= V_m I_m \sin^2 wt$

$= (V_m I_m/2)(2\sin^2 wt)$

$= (V_m I_m/2)(1 - \cos 2wt)$

$= VI - VI \cos 2wt$ ....(3)

where RMS Value of Voltage

$V = V_m/\sqrt{2}$

and Current $I = I_m/\sqrt{2}$

AC SERIES CIRCUIT

AC THROUGH PURE RESISTANCE R

Power P = VI – VI cos2wt Consists two components

- (1) Constant term VI.
- (2) Fluctuating component VI cos2wt its average value for a complete AC cycle is zero.

Hence pure Resistance Consumed Power P = VI

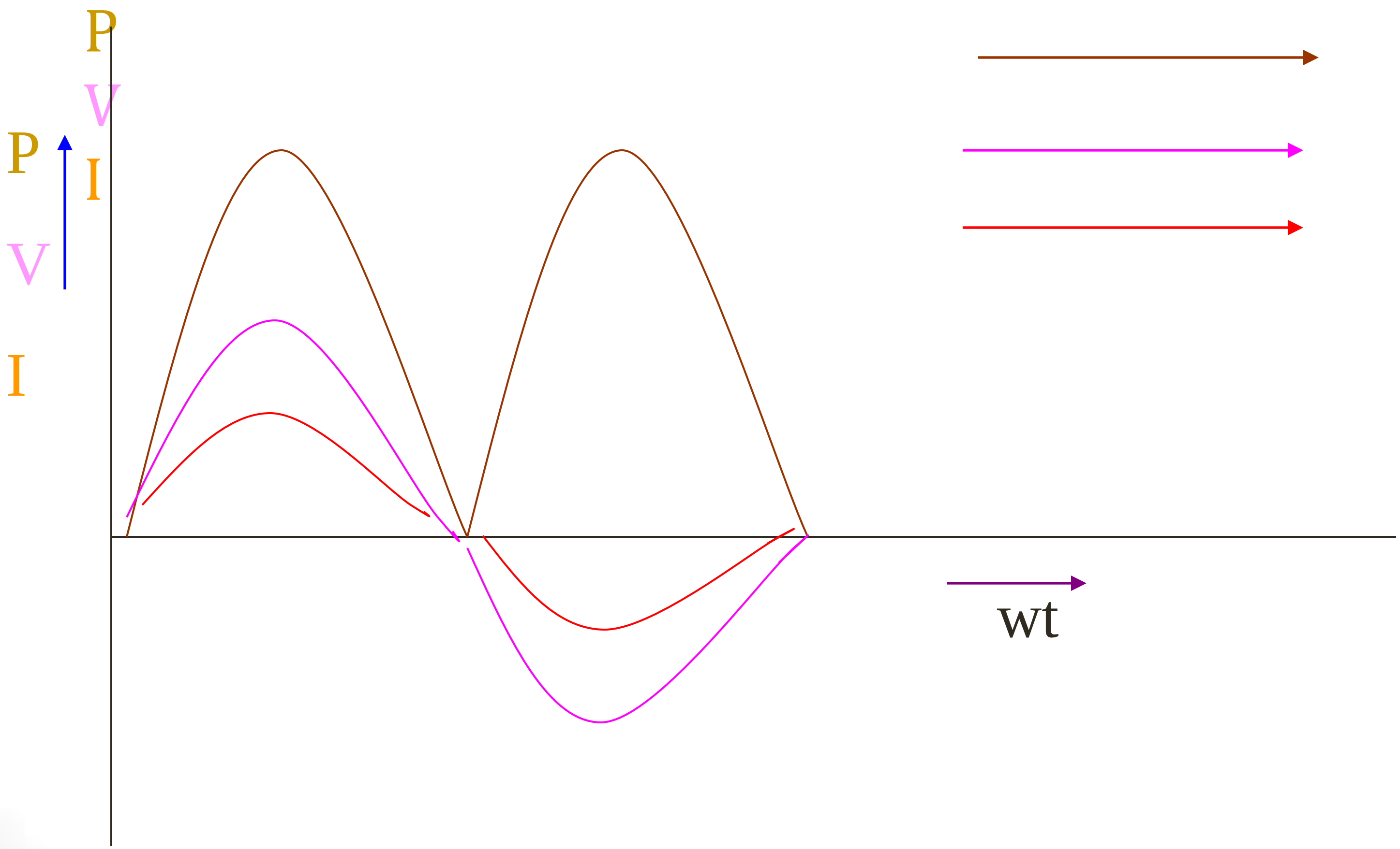
AC SERIES CIRCUIT

AC THROUGH PURE RESISTANCE R

So, In summery

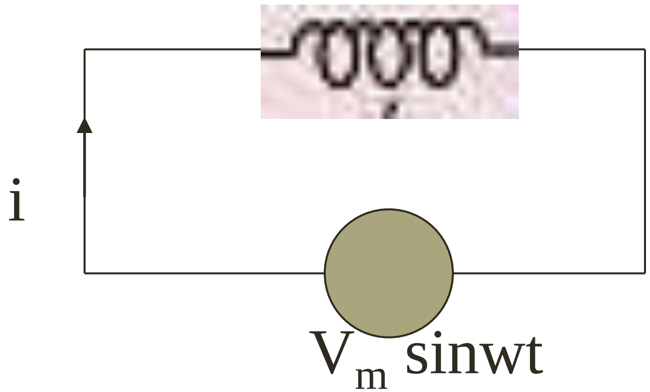
- **When AC voltage $v = V_m$ sinwt applied to pure resistance**
- **Current $I = I_m$ sinwt I.e. I and V are in same phase**
- **Power P = VI**

WAVE FORM WHEN AC THROUGH PURE RESISTANCE



AC SERIES CIRCUIT

AC THROUGH PURE INDUCTANCE L



When AC Voltage v = V_m sinwt …(1)

Applied to Pure inductance L ,then, a back emf is produced due to the self-inductance . This back emf is equal to supply voltage and given that

v = - L di/dt

AC SERIES CIRCUIT

AC THROUGH PURE INDUCTANCE L

Or di/dt = $(V_m \sin wt)/L$

$= (V_m /L) \sin wt$

or di = $(V_m /L) \sin wt \, dt$

$I = V_m /L \int \sin \omega t \, dt$

$i = V_m /\omega L \, (-\cos \omega t)$

$= - V_m /\omega L * \cos \omega t$

The term ωL play the part of 'resistance'. It is called *inductive reactance* X_L of the coil and it unit is ohm .

Max. value of i is $I_m = V_m / X_L$

$i = - I_m * \cos \omega t$……(2)

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

$i = I_m \sin (\omega t - 90)$…….(3)

AC SERIES CIRCUIT

AC THROUGH PURE INDUCTANCE L

From equation (1) & (3) the current leg applied voltage by 90 in other words when voltage is maximum current is zero.

POWER THROUGH PURE INDUCTANCE :

Power $P = vi = V_m \sin\omega t * I_m \sin(\omega t - 90)$

$P = V_m \sin\omega t * I_m (-\cos\omega t)$

$P = -V_m I_m /2 * \sin 2\omega t$

Power for whole cycle is

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

So, average demand of power from the supply for a complete cycle is zero.

Hence Power consumed across pure Inductance is zero.

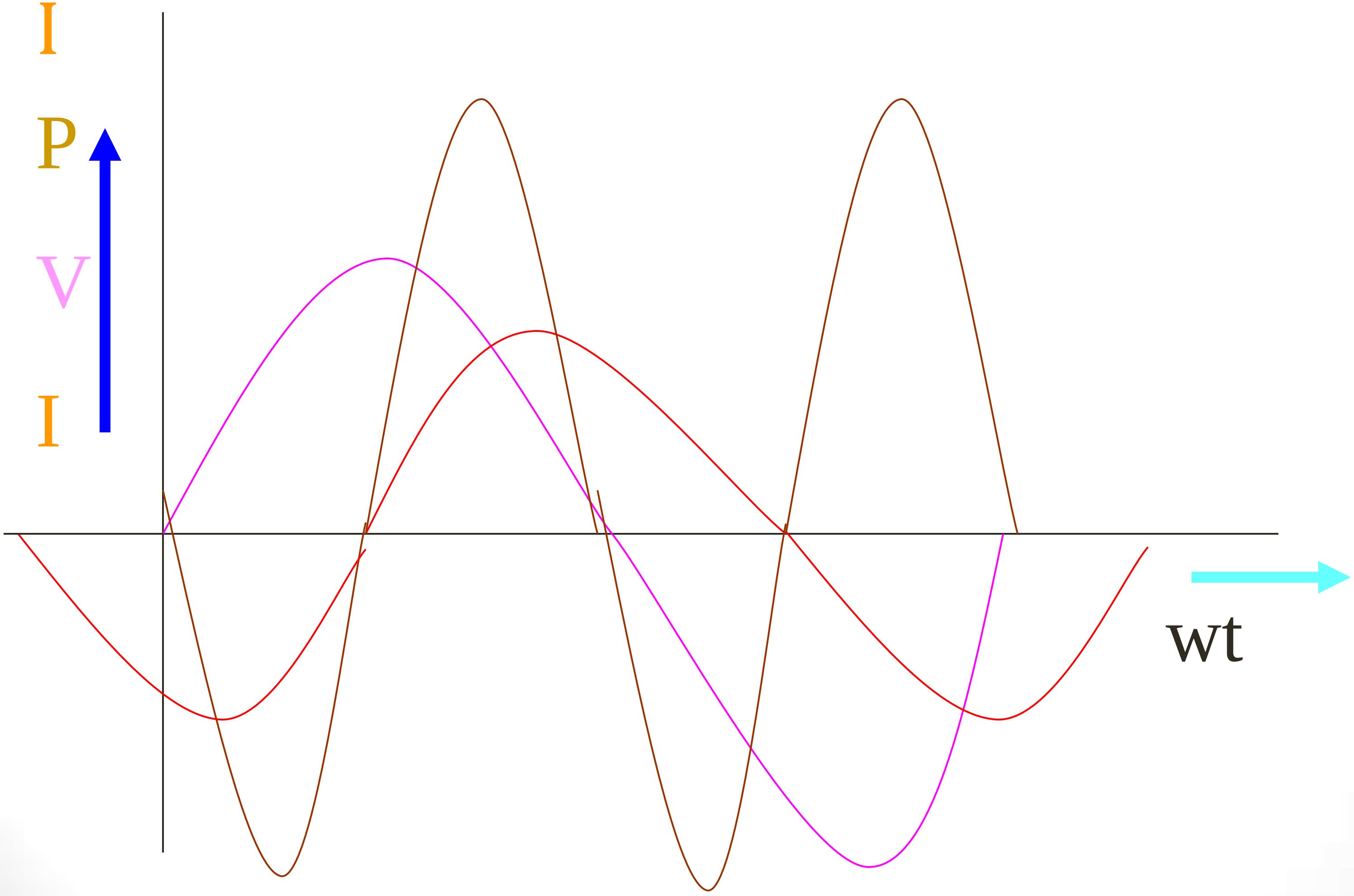
AC SERIES CIRCUIT

AC THROUGH PURE INDUCTANCE L

- So, In summery
  When AC voltage v = V_m sinwt applied to pure inductance
  1. Current I = I_m sin(wt – 90) I.e. I lags V by 90
  2. Power P = - VI $\sin^2$wt.
  3. Power consumed across pure Inductance is zero

INDUCTANCE

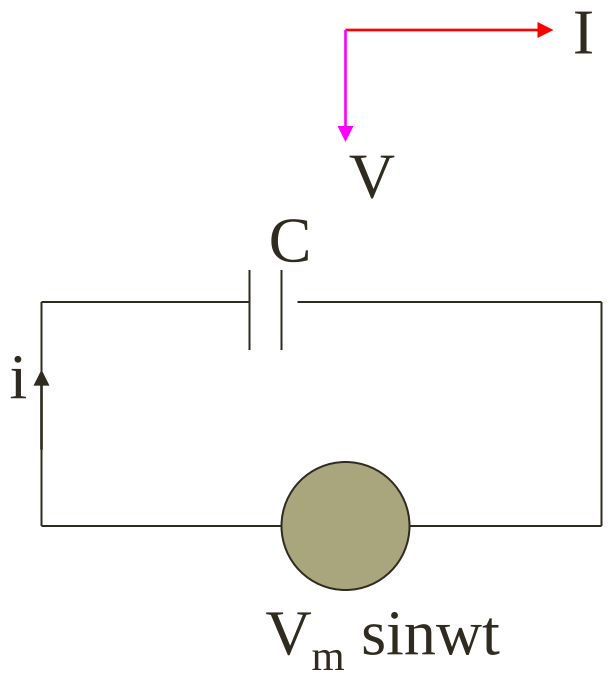
P
V
I



AC SERIES CIRCUIT

AC THROUGH PURE CAPACITANCE

When an alternating voltage is applied to the plates of a capacitor, the capacitance is charged first in one direction and then charge in opposite direction.



AC SERIES CIRCUIT

AC THROUGH PURE CAPACITANCE

Let p.d. developed between plates at any instant.

$v = V_m \sin\omega t$........(1)

If q = charge on plates at that instant.

and C= capacitance

Then $q = Cv$

$= C V_m \sin\omega t$

Now current i is given by the rate of flow of charge.

$i = dq/dt$

$= d/dt\,(CV_m \sin\omega t)$

$= C V_m (\cos\omega t/\omega)$

$= V_m /1/\omega C * \cos\omega t$

AC SERIES CIRCUIT

AC THROUGH PURE CAPACITANCE

- The denominator $1/\omega C$ is known *capacitive reactance* and it is represented by X_C and its unit is in ohm.

  $i = V_m / X_C * \cos\omega t$

  obviously $I_m = V_m / X_C$

  Hence current $I = I_m \cos\omega t$ ....(2)

  $I = I_m \sin(90 + \omega t)$ ..(3)

- **If $v = V_m \sin\omega t$ applied to pury capacitance , then the current is given by $i = I_m \sin(90 + \omega t)$.**
- Hence , we find that the current lead voltage by 90.

POWER THROUGH PURE CAPACITANCE

Power $p = vi = V_m \sin\omega t * I_m \sin(\omega t + 90)$

$p = V_m \sin\omega t * I_m (\cos \omega t)$

$p = -V_m I_m/2 * \sin 2\omega t$

Power for whole cycle is

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

So, average demand of power from the supply for a complete cycle is zero. Hence Power consumed across pure Capacitance is zero.

AC SERIES CIRCUIT

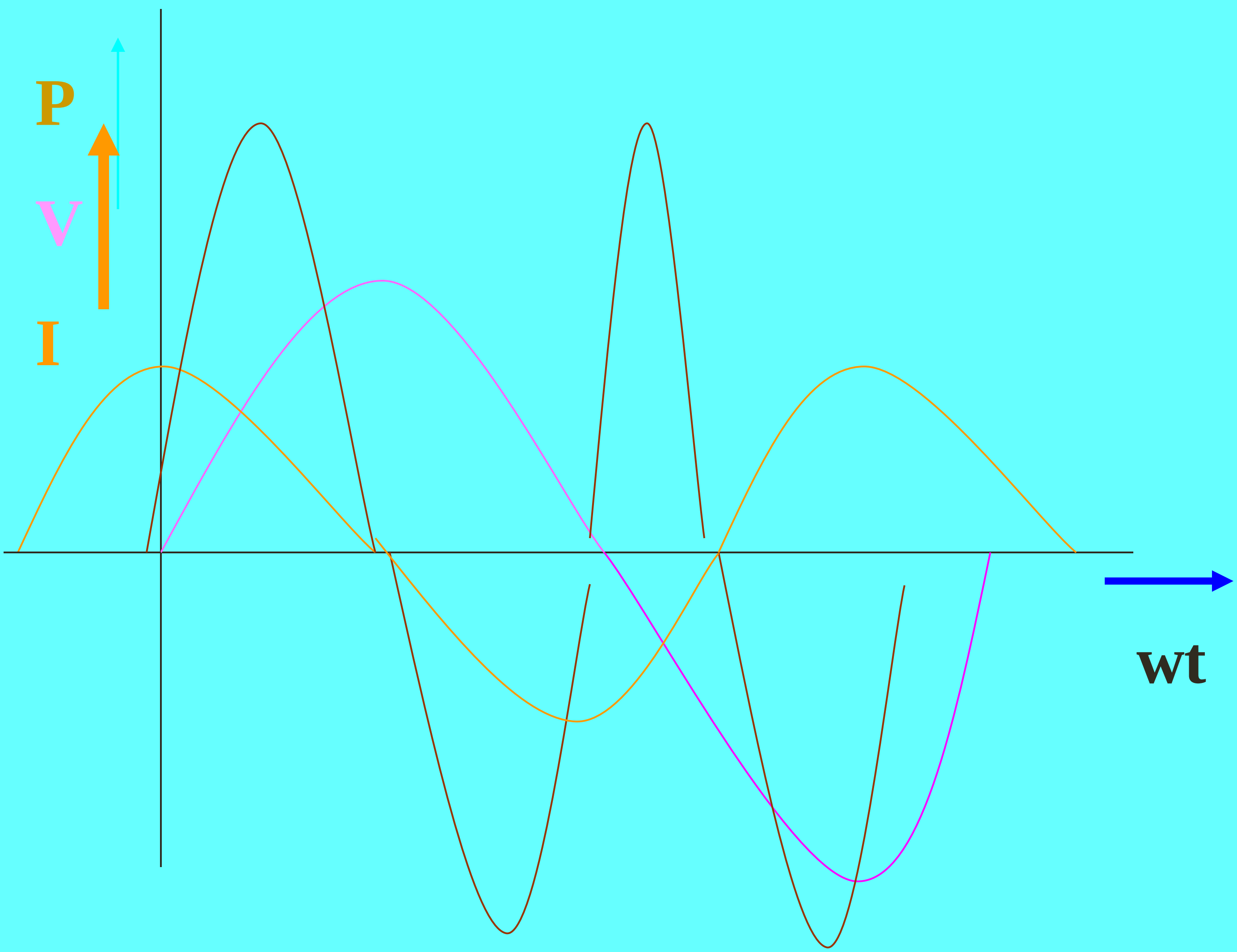
AC THROUGH PURE CAPACITANCE

- So, In summery
  When AC voltage $v = V_m$ sinwt applied to pure capacitance
- 1.Current $I = I_m$ sin(wt + 90) i.e. I leads V by 90
  2. Power P = -VI sin2wt.
- 3 Hence Power consumed across pure Capacitance is zero.

P

V

I



TYPES OF IMPEDANCE	VALUE OF IMPEDANCE	PHASE ANGLE FOR CURRENT	PF
RESISTANCE ONLY	R	0°	1
INDUCTANCE ONLY	ωL	90° LAG	0
CAPACITANCE ONLY	1/ωC	90° LEAD	0

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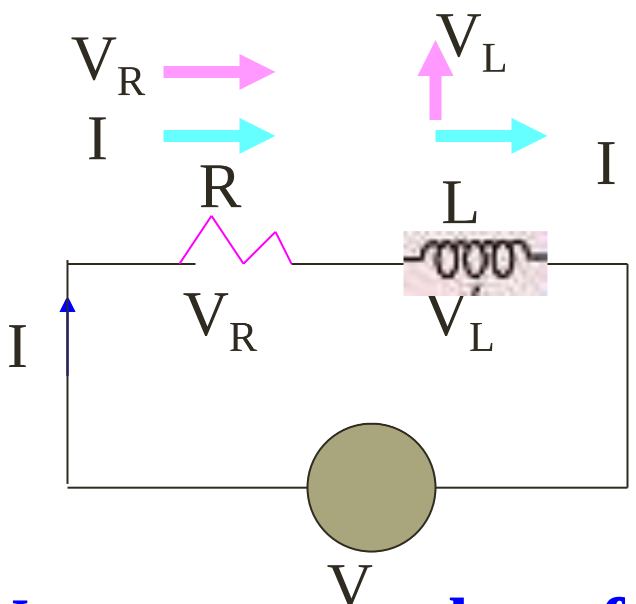
R-L SERIES CIRCUIT

A.C. THROUGH RESISTANCE & INDUCTANCE



A pure resistance R and a pure inductive coil of inductance L are connected in series shown in fig.

Let V = r.m.s. value of the applied voltage

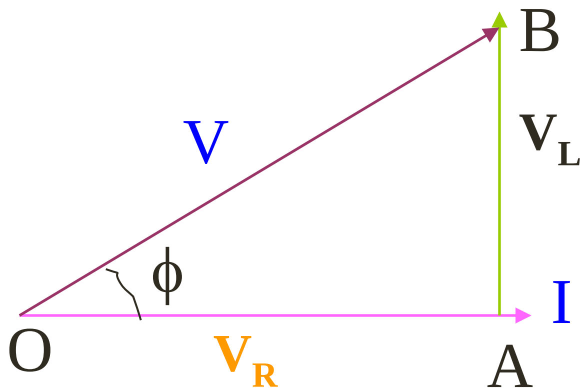
I = r.m.s. value of the resultant current.

V_R = IR - voltage drop across R (in phase with I)

V_L = IX_L - voltage drop across coil (ahead of I by 90°)

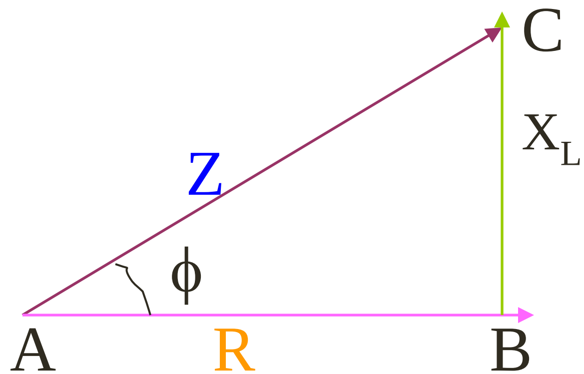
These voltage drops are shown in voltage triangle OAB. Vector OA represent ohmic drop V_R and AB represent inductive drop V_L.

The applied voltage V is represented by OB i.e. vector sum of two.



Voltage triangle OAB

Fig. 1



Impedance triangle ABC

Fig. 2

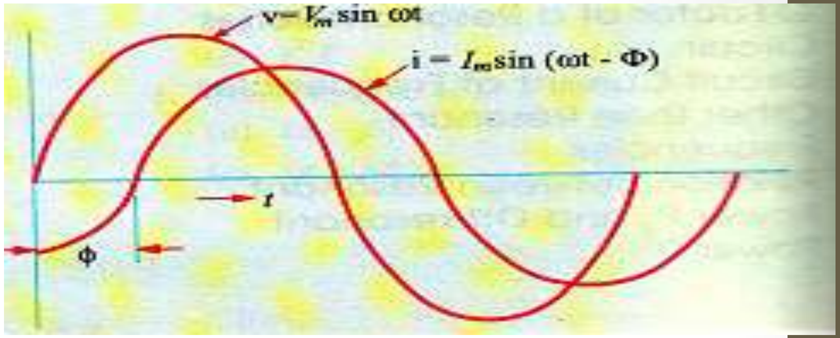
Hence $V = \sqrt{(V_R^2 + V_L^2)} = \sqrt{[(IR)^2 + (IX_L)^2]} = I\sqrt{[R^2 + X_L^2]}$

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

A.C. THROUGH RESISTANCE & INDUCTANCE

- The quantity $\sqrt{[R^2 + X_L^2]}$ is known as the *impedance (Z)* of the circuit .
- As seen from the impedance triangle ABC fig.[2] $Z^2 = R^2 + X_L^2$
- (IMPEDANCE) ^{2}
- = (RESISTANCE) ^{2} +(REACTANCE) ^{2}

From Voltage Phasor diagram (Fig. 1) the current I lags applied voltage V by an angle ϕ such that



$$\tan\phi = V_L / V_R$$
$$= IX_L/IR$$
$$= X_L/R$$
$$= \omega L/R$$
$$= \text{REACTANCE/RESISTANCE}$$

$$\phi = \tan^{-1}(X_L/R)$$

Hence if applied voltage $v = V_m \sin\omega t$

Then current equation is $i = I_m \sin(\omega t - \phi)$

where $I_m = V_m/Z$

and $\phi = \tan^{-1}(X_L/R)$

Power in R-L series circuit :-

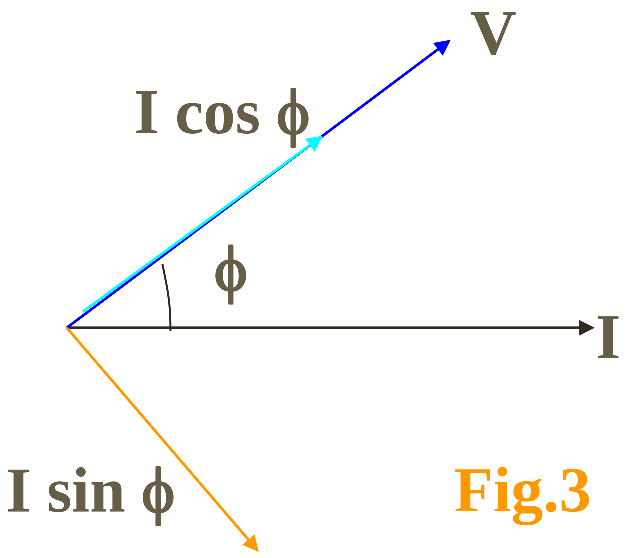


Fig.3

In fig (3) Current I has been resolved into its two mutually perpendicular components ,

1. ACTIVE COMPONENT OF CURRENT(I cos ϕ) : Active component is that which in phase with applied voltage i.e. I cos ϕ. It is also known as "wattful" component.

2. REACTIVE COMPONENT OF CURRENT(I sin ϕ) : Reactive component is that which in quadrate with applied voltage i.e. I sin ϕ. It is also known as "wattless"or "ideal" component.

The mean power consumed by the circuit is given by the product of V
and that component of the current I which is in phase with V.

So $P = V * I \cos\phi$

$= \text{rms value of voltage} * \text{rms value of current} * \cos\phi$

The term 'cosϕ' is called the power factor (pf) of the circuit.

$P = VI \cos\phi$

$= VI * (R/Z)$ [.....$\cos\phi = R/Z$]

$= (V/Z) * I.R$

$= I * IR$

$= I^2R$ WATT [.....$\cos\phi = R/Z$]

Power in terms of instantaneous values

instantaneous power p = vi

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

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

$$= \tfrac{1}{2} * V_m I_m [\cos\phi - \cos(2\omega t - \phi)]$$

Power consists of two parts

(i) a constant part $\tfrac{1}{2} * V_m I_m \cos\phi$ which is to be real power.

(ii) a pulsating part $\tfrac{1}{2} * V_m I_m \cos(2\omega t - \phi)$ which has frequency twice that of the V & I and its average value over a complete cycle is zero.

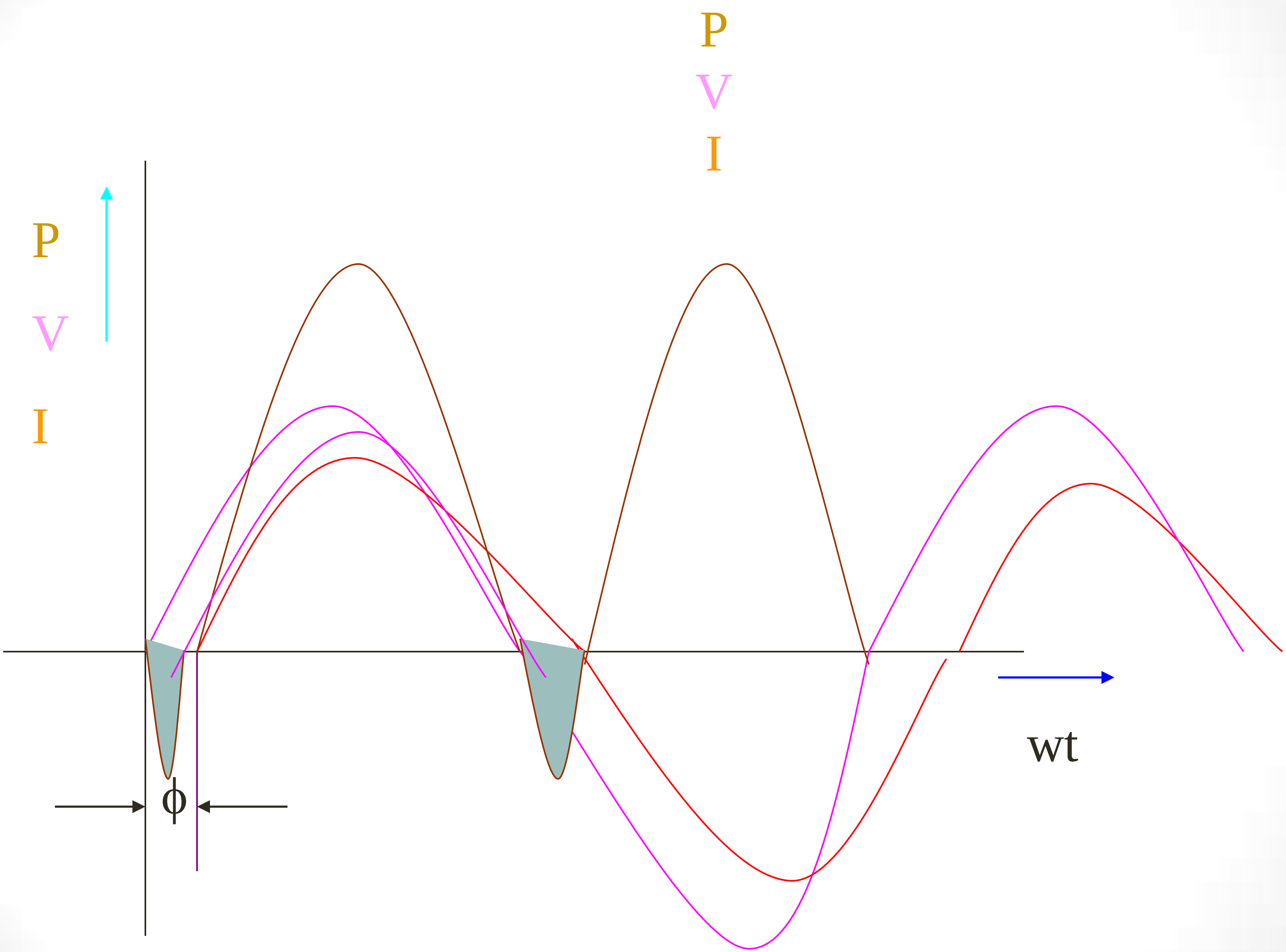
Hence average power consumed in series R-L Circuit is :

$$= \tfrac{1}{2} * V_m I_m \cos\phi = V_m/\sqrt{2} * I_m/\sqrt{2} * \cos\phi$$

$$P = VI \cos\phi \text{ Watt.}$$

Where V & I represent the rms values.

WAVEFORM OF R-L SERIES CIRCUIT



Symbolic Notation of Impedance :

$$Z = R + j X_L$$

Impedance vector has numerical value of $\sqrt{[R^2 + X_L^2]}$

Its phase angle with the reference axis is $\phi = \tan^{-1}(X_L/R)$

It may also be expressed in the polar form as $Z = Z \angle\phi°$

$$I = V/Z$$

$$= V \angle 0° / Z \angle \phi°$$

$$= V/Z \angle -\phi°$$

It shows that I vector is lagging the V vector by $\phi°$ and numerical value of current is V/Z

POWER FACTOR

It may be define as

(i) cosine of the angle of lead or lag.

(ii) It is the ratio of resistance to impedance (R/Z)

(iii) It is the ratio of true power to apparent power

(VI cosϕ / VI)

POWER IN AC CIRCUIT

Let a series R-L circuit draw a current of I when alternating voltage of rms value V is applied to it. Suppose that I lags V by ϕ

There are three types of power in AC circuit

(1) Apparent power (S) : It is product of rms value of applied voltage(V) and circuit current (I)

$$S = V*I$$
$$= (IZ)*I$$
$$= I^2Z \quad \text{VOLT- AMP(VA)}$$

(2) Active power(P) : It is product of rms value of applied voltage(V) and active component of current(I cosϕ). This power is actually dissipated in the circuit.

$$P = V* I \cos\phi$$
$$= IZ*I \ (R/Z)$$
$$= I^2R \text{ WATT}$$

(3) Reactive power (Q) : It is product of rms value of applied voltage(V) and reactive component of Current (I sinϕ)

$$Q = V* I\sin\phi$$
$$= IZ*I(X_L/Z)$$
$$= I^2 X_L \quad \text{VAR(VOLT-AMP-REACTIVE)}$$

These three power are shown in the power triangle in Fig. (4)

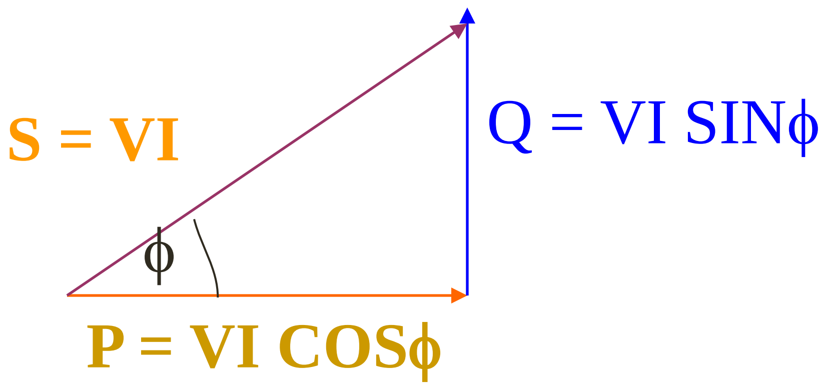


Fig 4

Where $S^2 = P^2 + Q^2$ or $S = \sqrt{(P^2 + Q^2)}$

Q –Factor of a coil : It is define as it is *reciprocal of power factor*

$$Q - \text{Factor} = 1/\cos\phi$$
$$= 1/(R/Z)$$
$$= Z/R$$

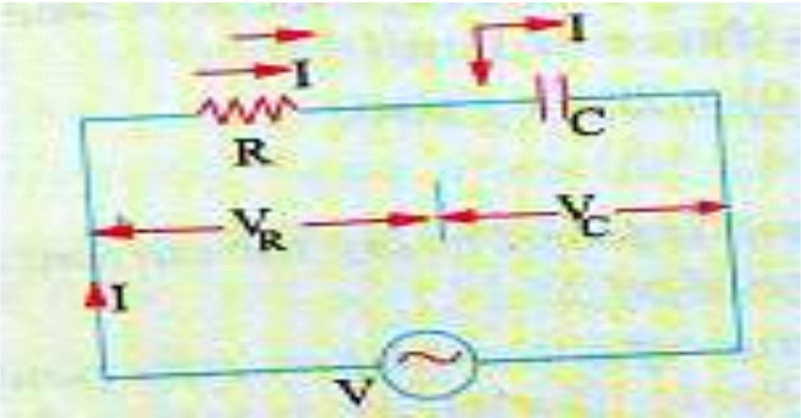
In a coil resistance is small as compared to reactance then

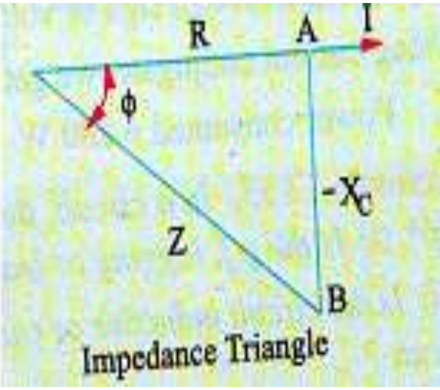
$$Q - \text{Factor} = \omega L/R$$

$Q = 2\pi$ (maximum energy stored / energy dissipated per cycle)

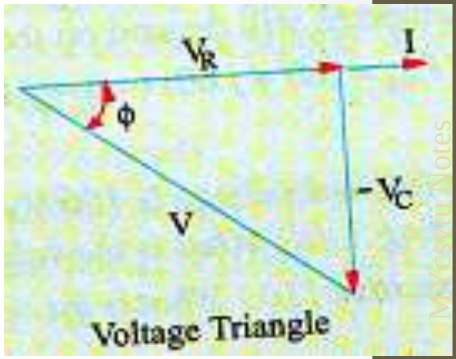
AC SERIES CIRCUIT

A.C. THROUGH RESISTANCE AND CAPACITANCE





Impedance Triangle



Voltage Triangle

- A pure resistance (R) and pure capacitance (C) is connect across supply voltage V.
- Let V=r.m.s. value of the applied voltage
- I=r.m.s. value of the resultant current.
- $V_R = I_R$ - voltage drop across R (in phase with I)
- $V_C = IX_C$ - voltage drop across capacitor (lagging I by 90°)

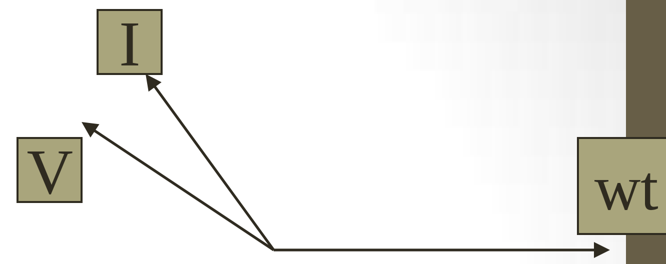
LECT -32

PROBLEMS
OF
R-L SERIES CIRCUIT

AC SERIES CIRCUIT

- **PROBLEM 1**
- **In a series R-L circuit current and voltage are expressed i (t) = 5 sin (314 t + 2π/3)**
- **and v = 15 sin(314 t+ 5π/6)**
- **calculate**
- **(1) impedance (2) Resistance**
- **(3) Inductance L in henery**
- **(4) average power drawn by the circuit**
- **(5) pf**

AC SERIES CIRCUIT



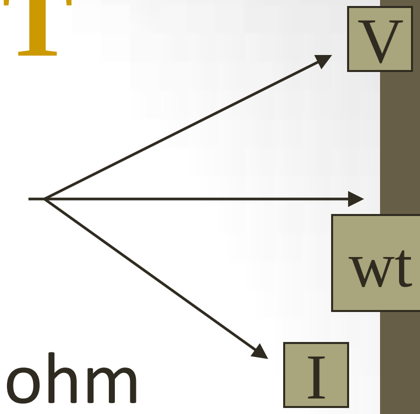
- **solution**

- Calculate phase angle between I and V
- phase angle of I $2\pi/3 = 120$
- and phase angle of V = $5\pi/6 = 150$
- Hence phase angle of V is greater than phase angle of I i.e I lag V by 150-120 =30° i.e. $\Phi = 30$
- $w = 2\pi f = 314$ hence $f = 314/2\pi = 50$ Hz
- (1) Im = 5 and Vm =15 then Z = Vm/Im =15/5 =3 ohms
- (2) cos 30 = R/Z so, R = Z cos30 =3 * cos30
- = 3 * 0.866 = 2.6 ohms
- (3) $X_L = \sqrt{(Z^2 - R^2)} = \sqrt{(3^2 - 2.6^2)} = 1.5$ ohms
- $X_L = wL = 314 * L$, then L = 1.5 /314 = 4.78 mH
- (4)power $P = I^2 R = (Im/\sqrt{2})^2 R = (5/\sqrt{2})^2 * 2.6$
- = 32.5 W
- (5) pf =cos 30 = 0.866

AC SERIES CIRCUIT

- **Prob** (2) in a given R-L circuit R = 3.5 ohm and L = 0.1 h find (i) current through the circuit (ii) pf voltage V = 220 $\angle 30°$ is applied across the circuit at 50 Hz.
- **Solu**
- (i) XL = 2 π f L = 2* 3.14 *50 * 0.1 = 31.42 ohm
- Z = $\sqrt{(R^2 + X^2L)}$ = $\sqrt{(3.5^2 + 31.42^2)}$ = 31.6 ohms
- Z in polar form **Z** = $Z\angle\theta$ where $\theta = \tan^{-1}$ (XL/R)
- = $\tan^{-1}$ (31.42/3.5)= $\angle 83.65°$
- Hence **Z** = 31.6 $\angle 83.65°$
- **I = V/Z** = $200\angle 30°/31.6\angle 83.65°$= 6.96 $\angle -53.65°$
- (ii) angle between voltage and current from vector diagram is 53.65°+30° =83.65° with current lagging
- hance pf = cos83.65 = 0.11
-

AC SERIES CIRCUIT



- **Solu**
- (i) $X_L = 2 \pi f L = 2 * 3.14 * 50 * 0.1 = 31.42$ ohm
- $Z = \sqrt{(R^2 + X_L^2)} = \sqrt{(3.5^2 + 31.42^2)} = 31.6$ ohms
- Z in polar form $\mathbf{Z} = Z\angle\theta$ where $\theta = \tan^{-1}(X_L/R)$
- $= \tan^{-1}(31.42/3.5) = \angle 83.65°$
- Hence $\mathbf{Z} = 31.6 \angle 83.65°$
- $\mathbf{I = V/Z} = 200\angle 30°/31.6\angle 83.65° = 6.96 \angle -53.65°$
- (ii) angle between voltage and current from vector diagram is $53.65° + 30° = 83.65°$ with current lagging
- hance pf = cos83.65 = 0.11
-

AC SERIES CIRCUIT

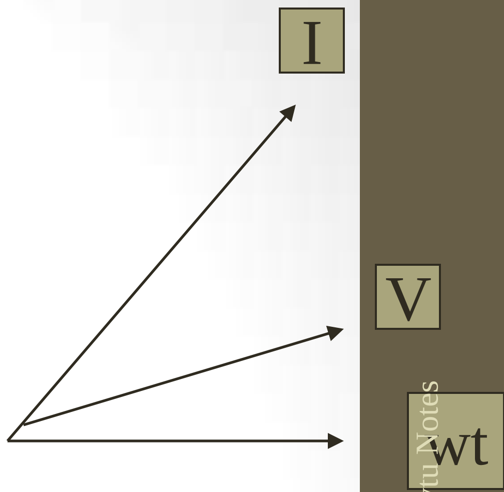
- Prob 3. In an alternating circuit, V= (100-j50) and
- I = (3- j4). Calculate real and reactive power, Z,R and reactance X also indicate X is inductive or capacitive.
  - Solu
- Power P = VI* = P + jQ = (100-j50)(3+j4)
- =(111.80 ∠-26.56°) * (5 ∠53.65°)
- =559∠27° = 500+ j250
- Hence reactive power P = 500 watt and Q =250 VAR
- Z = R + j X = V/I = (111.80∠-26.56°)/5∠-53.65°
- = 22.36 ∠27° = 19.92 + j 10.15
- Hence R = 3.81 ohms and reactance is in positive so circuit consist inductance therefore inductive reactance
- X = 10.15 ohms.

AC SERIES CIRCUIT

- **Prob 4.**
- **A series circuit is connected across an ac source**
- **$e = 200\sqrt{2} \sin(wt + 20)$**
- **and $i = 10\sqrt{2} \cos(314t - 25)$.**
- **Determine parameters of the circuit.**

- **Solu**

- Current $i = 10\sqrt{2}\cos(314t - 25)$
- $= 10\sqrt{2}\sin(90+314t - 25)$
- $= 10\sqrt{2}\sin(314t + 65)$
- And voltage $v = 200\sqrt{2}\sin(wt + 20)$
- $= 200\sqrt{2}\sin(314t + 20)$
- And angle between V and ref is 20 and I and ref is 65 , hence current I lead V by (65-20) 45°
- Hence pf =cos45= 0.707(leading) and given circuit is R-C series circuit.
- $V_m = 200\sqrt{2}$ and $I_m = 10\sqrt{2}$,therefore
- $Z = V_m/I_m = 200\sqrt{2}/10\sqrt{2} = 20$ ohms
- $R = Z\cos 45 = 20 * 0.707 = 14.14$ ohms
- $X = \sqrt{(Z^2 - R^2)} = \sqrt{(20^2 - 14.14^2)} = 14.14$ ohms
- $X_c = 1/2\pi f C = 1/ 2 * 3.14 * 50 * C = 14.14$
- $C = 1/ 2 * 3.14 * 50 * 14.14 = 226\mu F$



AC SERIES CIRCUIT

- **Prob 5.**

- **When voltage of 100V at 50Hz is applied to a coil A, the current taken is 8A and the power is 120W. when applied to a coil B, the current is 10A and power is 500W. what current and power will be taken when 100V is applied to two coil connected in series?**

AC SERIES CIRCUIT

- Solu

- $Z_1 = 100/8 = 12.5$ ohms, $P = I^2R_1$
- hence $R_1 = P/I^2 = 120/(8)^2 = 1.875$ ohms
- $X_1 = \sqrt{(Z^2_1 - R^2_1)} = \sqrt{[(12.5)^2 - (1.875)^2]} = 12.36$ ohms
- similarly $Z_2{}^2 = 100/10 = 10$ ohms, $P = I^2R_2$
- hence $R_2 = P/I^2 = 500/(10)^2 = 5$ ohms
- $X_2{}^2 = \sqrt{(Z_2{}^2 - R^2_2)} = \sqrt{[(10)^2 - (5)^2]} = 8.66$ ohms
- $R = R_1 + R_2 = 1.875 + 5 = 6.875$ ohms
- and $X = X_1 + X_2 = 12.36 + 8.66 = 21.02$ ohms
- $Z = \sqrt{(R^2 + X^2)} = \sqrt{[(6.875)^2 + (21.02)^2]} = 22.1$ ohms
- $I = V/Z = 100/22.1 = 4.52$
- $P = I^2 R = (4.52)^2 * 6.875 = 140$ W

- Prob 6.
- A coil takes a current of 6 A when connected to a 24 V DC supply. To obtained the same current with a 50 Hz ac supply, the voltage required was 30 V. calculate inductance, power.
- Solu
- coil offers only resistance to dc supply because frequency zero in dc so inductive reactance is zero whereas it offers impedance to ac supply.
- So for dc R = 24/6 = 4 ohm
- and for ac Z= 30/6 = 5 ohms
- $X = \sqrt{(Z^2 - R^2)} = \sqrt{(5^2 - 4^2)} = 3$ ohms,
- wL = 2*3.14*50 *L = 3 therefore L = 9.5 mH
- $P = I^2 R = 6^2*4 = 144W$

AC SERIES CIRCUIT

- **Example 7**

- ***The potential difference measured across a coil is 4.5 V when it carries current of 9 A. The same coil when carries an alternating current of 9 A at 25 Hz the potential difference is 24 V.***
- ***Find the current, the power and the power factor when it is supplied 50 Hz supply.***

AC SERIES CIRCUIT

Example 8

In a particular R-L series circuit a voltage of 10 V at 50 Hz produces a current 700 mA while the same voltage at 75 Hz produces 500 mA. What are the values of R and L in the.

AC SERIES CIRCUIT

- **Solution.**
- **(i) $Z = \sqrt{[R^2 + (2nx50L)^2]} = \sqrt{[R^2 2 + 98696L^2]}$**
- **V=1Z or 10 = 700x10-3$\sqrt{[R^2 + 98696L^2]}$**
- **$\sqrt{[R^2 + 98696L^2]} = 10 / 700 \times 10\text{-}^3$**
- **or $R^2 + 98696\ L^2 = 10000/49$ ...(i)**
- **In the second case $Z = \sqrt{[R^2 + (2nx75L)^2]}$**
- **$= \sqrt{[R^2 2 + 222066\ L^2]}$**
- **V=1Z or 10 = $500 \times 10^{-3} \sqrt{[R^2 + 222066\ L^2]}$**
- **$\sqrt{[R^2 + 222066\ L^2]} = 10 / 500 \times 10\text{-}^3$**
- **or $R^2 + 222066\ L^2 = 20$**
- **or $R^2 + 222066L^2 = 400$ (ii)**
- **subtracting Eq. (i) from (ii), we get**
- **L = 0.0398 H = 40 mH and R = 6.9 Ω.**

AC SERIES CIRCUIT

- **Example 9**

- **A series circuit consists of a resistance of 6 Ω and an inductive reactance of 8 Ω potential difference of 141.4 V (rm.s.) is applied to it. At a certain instant the applied voltage is +100 V and is increasing. Calculate at this current, (i) the current (ii) the voltage drop across the resistance and (iii) voltage drop across inductive reactance.**

AC SERIES CIRCUIT

- **Solution.**
- **Z= R + jX = 6 +j8 = 10 ∠53.10**
- **Current lags behind the applied voltage by 53.1°. Let V be taken as the reference**
- **Then, v = (141.4 x √2) sin wt = 200 sin wt**
- **i = (Vm/Z) sin (wt – 53.1°) = 20 sin (wt - 53.1°).**
- **When the voltage is + 100 V and increasing**
- **100 = 200 sin wt ; sin wt = 0.5 ; w t = 30°**
- **At this instant, the current is given by**
- **i = 20 sin (30° - 53.1°) = - 20 sin 23.1° = - 7.847 A.**
- **Drop across resistor = iR = - 7.847 x 6 = - 47 V.**

AC SERIES CIRCUIT

- (iii) Let us first find the equation of the voltage drop V_L across the inductive reactance.
- Max. of the voltage drop = ImX_L= 20 x 8 = 160 V. It leads the current by 90°. Since current itself lags the applied voltage by 53.1 °, the reactive voltage drop across the applied voltage by (90° -53.1) = 36.9
- Hence, the equation of this voltage drop at the instant when wt = 30° is
- V_L = 160 sin (30° + 36.9°) = 160 sin 66.9°
- = 147.2 V.

AC SERIES CIRCUIT

- **Example 10**

- **A 60 Hz sinusoidal voltage v = 141 sin wt is applied to a series R-L circuit. The resistance and the inductance are 3Ω and 0.0106 H respectively.**
- **Compute the value of the current in the circuit and its phase angle with respect to the voltage.**
- **write the expression for the instantaneous current in the circuit.**
- **Compute the r.m.s value and the phase of the voltages appearing across the resistance and inductance.**
- **Find the average power dissipated by the circuit.**
- **Calculate the pf of the circuit.**

AC SERIES CIRCUIT

- **Example 11**

- **A series circuit consists of a resistance of 6 Ω and an inductive reactance of 8 Ω. Poential difference of 141.4 V (rm.s.) is applied to it. At a certain instant the applied voltage is + V and is increasing. Calculate at this current, (i) the current (ii) the voltage drop across the sz,:.nre and (iii) voltage drop across inductive reactance**.

AC SERIES CIRCUIT

- solution.
- Vm= 141 V; V= 141/√2 = 100V or V= 100+j0
- X_L = 2πx60x0.0106= 4 Ω Z=3+j4 = 5∠53.1°
- I = V / Z = 100 ∠ 0°/ 5 ∠ 53.1 = 20 ∠- 53.1°
- Since angle is minus,the current lags behind the voltage by ∠ 53.1
- Im = √2 x 20 = 28,28 ; .. i = 28.28 sin (w t - 53.1 °)
- V_R = IR = (20 ∠- 53.1°)x3 = 60∠- 53.1° volt.
- V_L = jIX_L = (1 ∠90°)(4)(20 ∠- 53.1°) = 80 ∠36.9°
- P = VI cos ϕ = 100 x 20 x cos 53.10 = 1200 W.
- Pf = cos ϕ =cos 53.1°=0.6.

AC SERIES CIRCUIT

Example 12

- *In a given R-L circuit, R = 3.5 Ω and L = 0.1 H. Find (i) the current through the circuit and (ii) power factor if a 50Hz voltage V = 220 $\angle 30^\circ$ is applied across the circuit.*

AC SERIES CIRCUIT

Solution.

- *XL* = 2πfL=2π x 50 x 0.1=31.42Ω
- Z= √(R2+XL2) = √(3.52 +31.422) = 31.6Ω
- ∴ Z= 31.6∠tan-1(31.42/3.5) =31.6∠83.65°
- *(i)* I=V/Z= (220∠30°/ 31.6∠83.65°)
- I= 6.96 ∠-53.65°
- *(ii)* Phase angle between voltage current is
- I= 53.65° + 30° = 83.65° with current lagging.
- p.f. = cos 83.65° = 0.11 (lag).

AC SERIES CIRCUIT

- ***Example 13***
- *An inductive circuit draws 10 A and 1 kW from a 200-V, 50 Hz a.c. supply. Deteremine (1) impedanee in Cartesian from (a + jb) (ii) the impedance in polar from (iii)The pf (iv) the active and the reactive power (v) the apparent power.*
- .

AC SERIES CIRCUIT

- ***Example*** *14.*

- *When a voltage of 100 Vat 50 Hz is applied to a choking coil A, the current is 8 A and power* is *120 W. When applied to a coil B, the current is 10 A and the power is 500 W. what current and power will be taken when 100 V is applied to the two coils connected in series.*

AC SERIES CIRCUIT

- ***Example 15***

- *A resistance of 20 ohm, inductance of 0.2 H and capacitance of I50uF are connected in series and are fed by a 230 V, 50 Hz supply. Find XL, Xce, Z, Y, p f, active power and reactive power*

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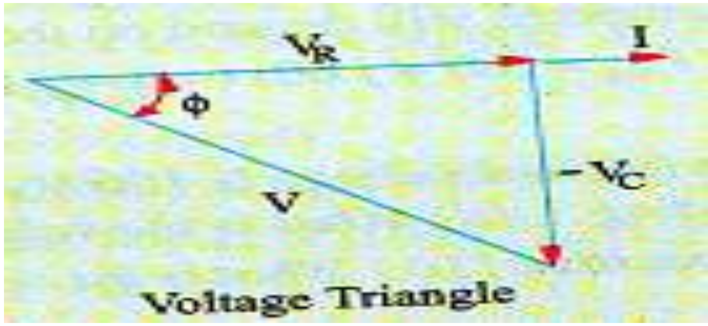
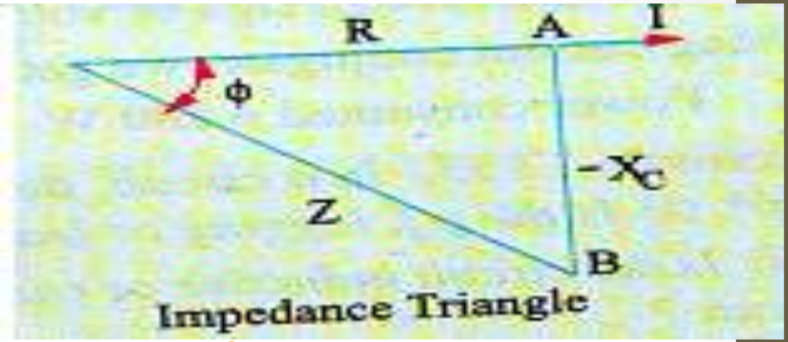
R-C & R-L-C SERIES CIRCUIT

AC SERIES CIRCUIT

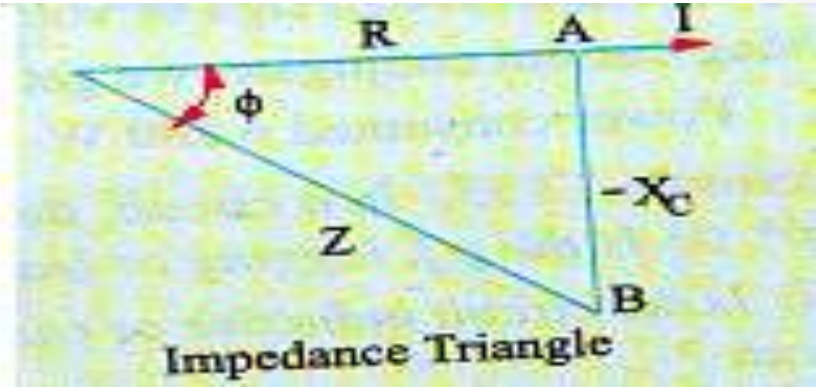
A.C. THROUGH RESISTANCE AND CAPACITANCE





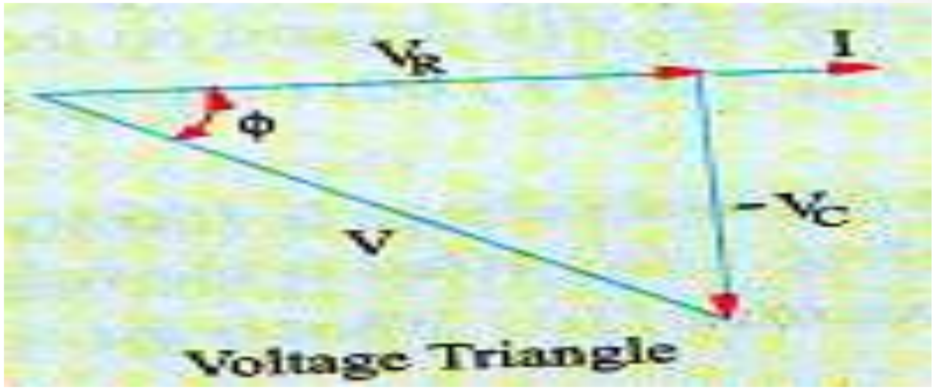
- These voltage drops are shown in voltage triangle OAB. Vector OA represent ohmic drop V_R and AB represent capacitive drop Vc .The applied voltage V is represented by OB i.e. vector sum of two.
- Hence $V = \sqrt{[(V_R)^2 + (-Vc)^2]} = \sqrt{[(IR)^2 + (-IXc)^2]}$
- $= I \sqrt{[R^2 + Xc^2]}$
- $I = V / \sqrt{[R^2 + X^2c]} = V/Z$

AC SERIES CIRCUIT



- **The quantity √[R^2 +X^2c] is known as the *impedance (Z)* of the circuit .As seen from the impedance triangle ABC fig.[c]**
- **$Z^2 = R^2 + X^2c$**
- **(IMPEDANCE) ^{2} =(RESISTANCE) ^{2} +(REACTANCE) ^{2}**

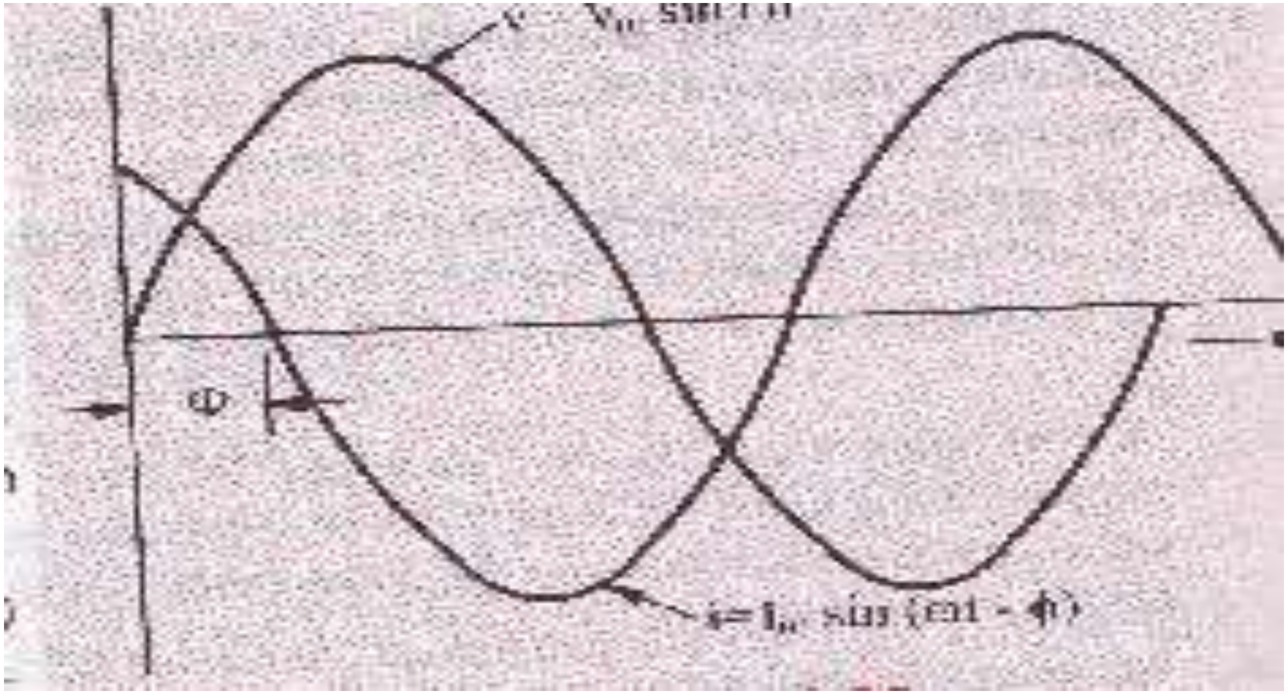
AC SERIES CIRCUIT



- From above vector diagram (b) the current I leads applied voltage V by an angle ϕ such that
- $\tan\phi = -V_c / V_r = -IX_c/IR = -X_c/R$.
- $\phi = \tan^{-1}(-X_c/R)$
- Hence if applied voltage $v = V_m \sin\omega t$ then current equation is $i = I_m \sin(\omega t + \phi)$ where $I_m = V_m/Z$ and
- $\phi = \tan^{-1}(-X_c/R)$
- waveform fo R-C series circuit is shown in fig(d).

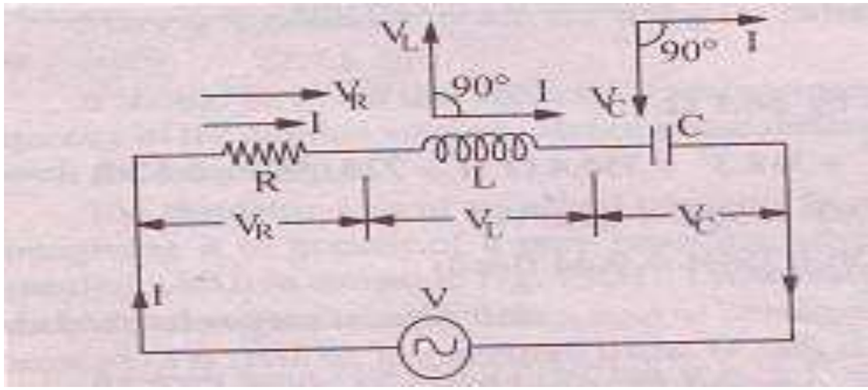
AC SERIES CIRCUIT

- **WAVEFORM OF R-C SERIES CIRCUIT**



AC SERIES CIRCUIT

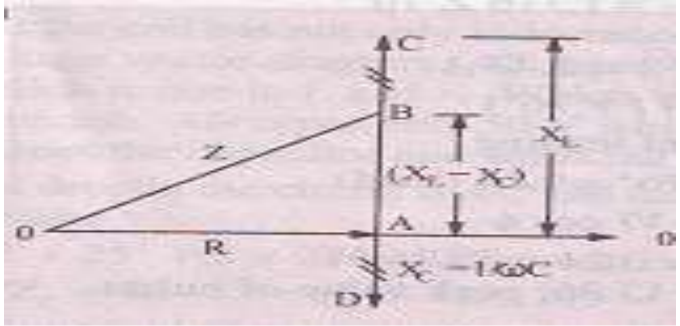
A.C. THROUGH RESISTANCE, INDUCTANCE AND CAPACITANCE

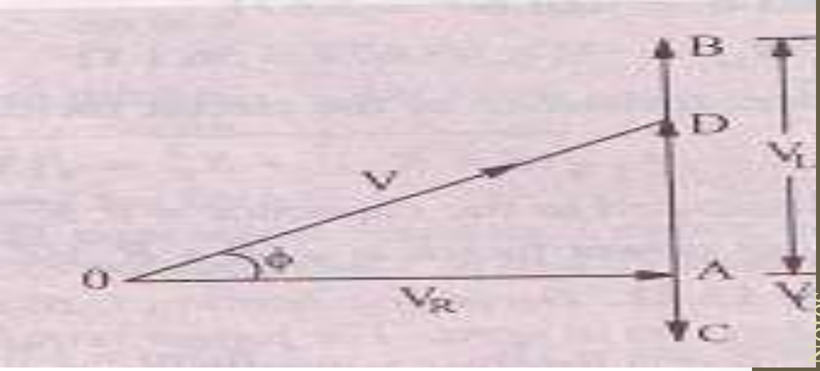


- A pure resistance(R), A pure inductance (L) and

  A pure capacitance(C) is connect across supply voltage V.
- V_R = IR - voltage drop across R (in phase with I)
- $V_L = IX_L$ - voltage drop across capacitor (lagging I by 90°)
- $V_C = IX_C$ - voltage drop across capacitor (leading I by 90°)

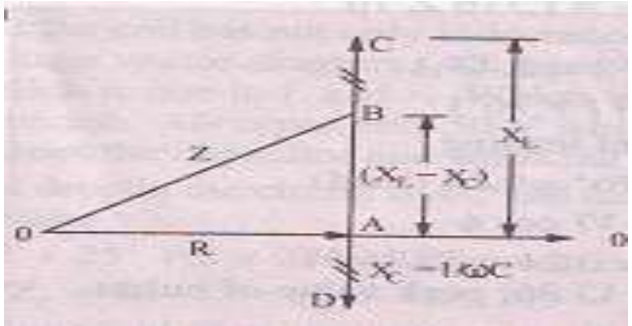
AC SERIES CIRCUIT

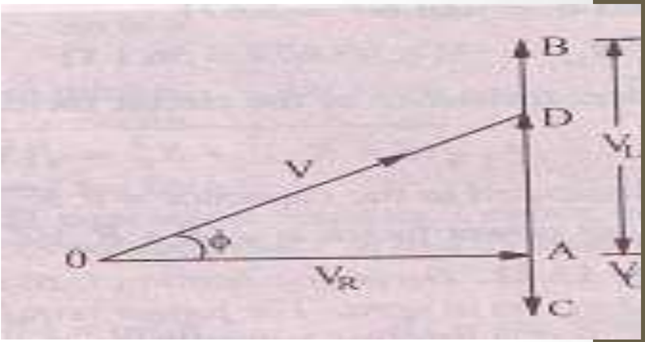




- These voltage drops are shown in voltage triangle OAB. Vector OA represent ohmic drop V_R and AB represent inductive drop V_L and AC represent capacitive drop V_c .It will be seen that V_L and V_c are 180° out of phase with each other i.e. they are direct phase opposition to each other.
- Subtracting BD (=AC) from AB, we get net reactive drop AD = $I(X_L - X_c)$. The applied voltage V is represented by OD i.e. vector sum of OA and AD.

AC SERIES CIRCUIT





- Hence OD = $\sqrt{[(OA)^2 + (AD)^2]}$
- $V = \sqrt{[(IR)^2 + (IX_L - IXc)^2]}$
- $= I\sqrt{[(R)^2 + (X_L - Xc)^2]} = I\sqrt{[R^2 + X^2]}$
- Where *NET REACTANCE* $X = X_L - Xc$
- Hence $I = V/\sqrt{[R^2 + X^2]} = V/Z$
- The quantity $\sqrt{[R^2 + (X_L - Xc)^2]}$ is known as the *impedance (Z)* of the circui
- t .As seen from the impedance triangle fig.[c]
- $Z^2 = R^2 + X^2$
- $(IMPEDANCE)^2 = (RESISTANCE)^2 + (NET\ REACTANCE)^2$

AC SERIES CIRCUIT

- Phase angle ϕ is given by $\tan\phi = (X_L - X_c)/R$
- $= X/R$ = net reactance / resistance
- And pf is given by
- $\cos\phi = R / Z = R / \sqrt{[R^2 + (X_L - X_c)^2]}$
- Hence if applied voltage $v = V_m \sin\omega t$ then current equation in R-L-C series circuit is $i = I_m \sin(\omega t \pm \phi)$
- where $I_m = V_m/Z$.
- The + ve sign to be used when current leads i.e. ($X_c > X_L$) and – ve sign to be used when current lags
- i.e. ($X_L > X_c$)

AC SERIES CIRCUIT

TYPES OF IMPEDANCE	VALUE OF IMPEDANCE	PHASE ANGLE	PF
RESISTANCE ONLY	R	0°	1
INDUCTANCE ONLY	ωL	90° LAG	0
CAPACITANCE ONLY	$1/\omega C$	90° LEAD	0
R-L ONLY	$\sqrt{[R^2 + (\omega L)^2]}$	$0° < \phi < 90°$ LAG	1>PF>0 LAG
R-C ONLY	$\sqrt{[R^2 + (-1/\omega C)^2]}$	$0° < \phi < 90°$ LEAD	1>PF>0 LEAD
R-L-C	$\sqrt{[R^2 + (\omega L \sim 1/\omega C)^2]}$	BETWEEN 0° AND 90° LAG OR LEAD	BETWEEN 0 AND UNITY LAG OR LEAD

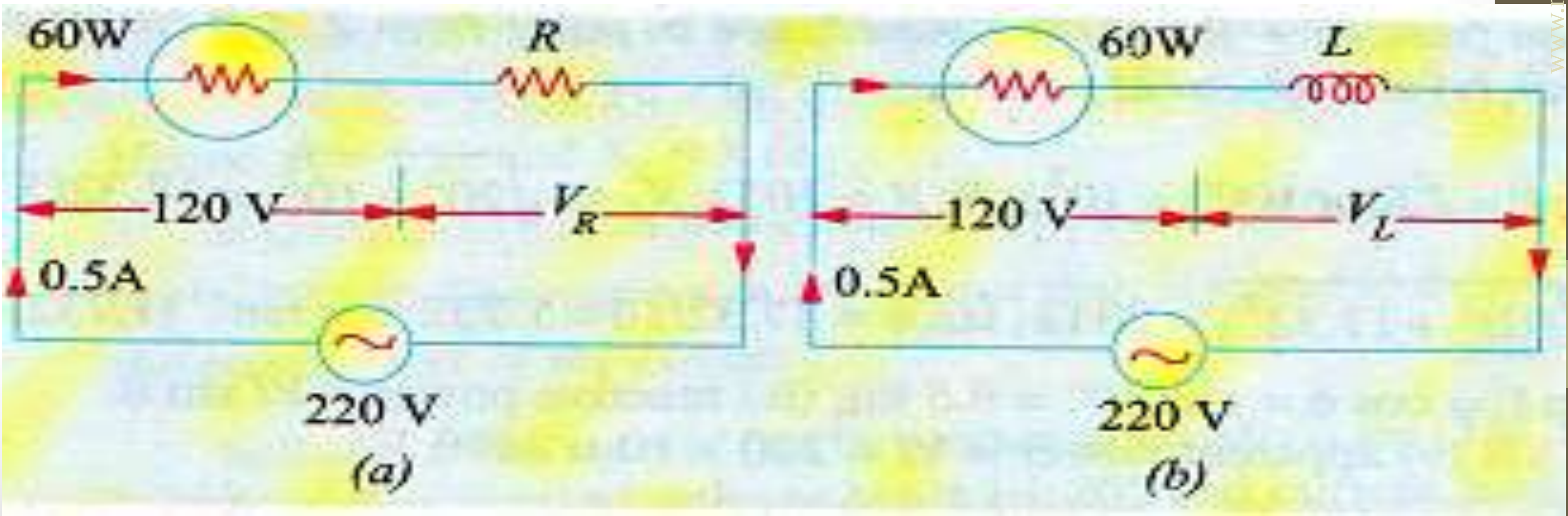
LECT -34

PROBLEMS
OF
R-L-C SERIES CIRCUIT

AC SERIES CIRCUIT

- ***Example 16***

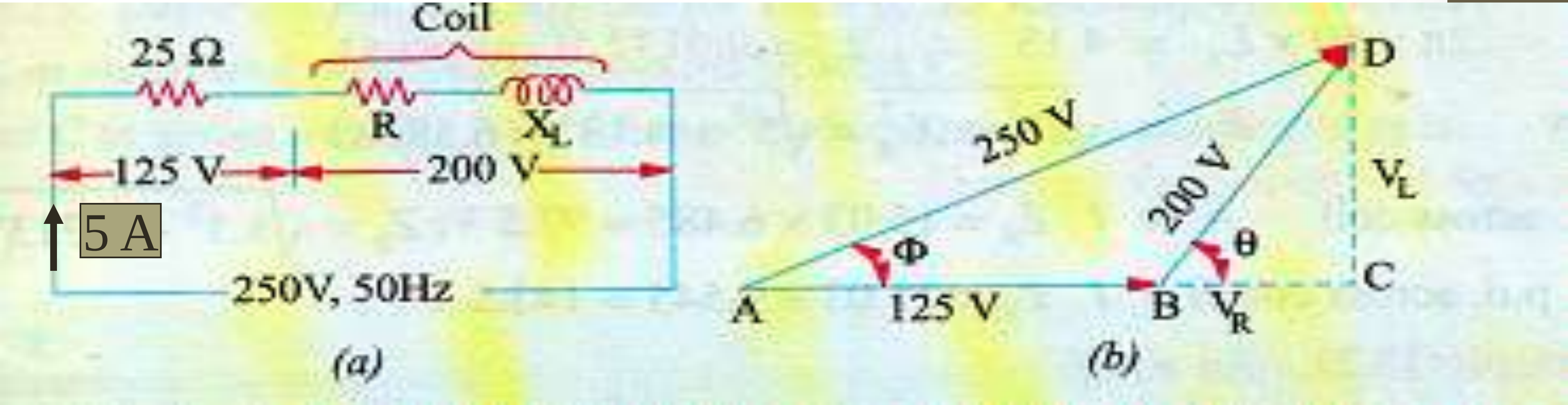
- ***A 120-V, 60-W lamp is io be operated on 220-V, 50-Hz supply mains. Calculate what value of (a) non-inductive resistance (b) pure inductance would be required in order lamp is run on correct voltage. Which method is preferable and why ?***



AC SERIES CIRCUIT

- **Example 17**

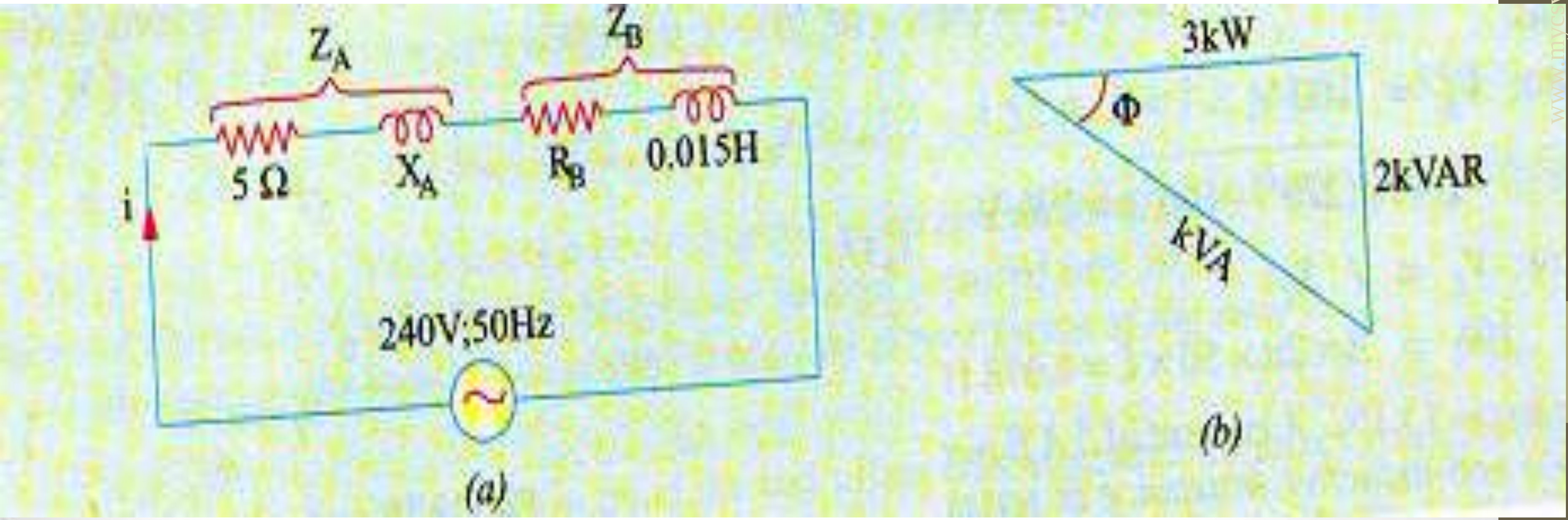
- ***A current of 5 A flows through a non-inductive resistance in series choking coil when supplied at 250-V 50-Hz. If the voltage across the resistance is 125 V and and across the coil 200 V,***
- ***calculate (a) impedance, reactance and resistance of the coil (b) the power absorbed by the coil and (c) Total power. Draw the vector diagram.***



AC SERIES CIRCUIT

- **Example 18**

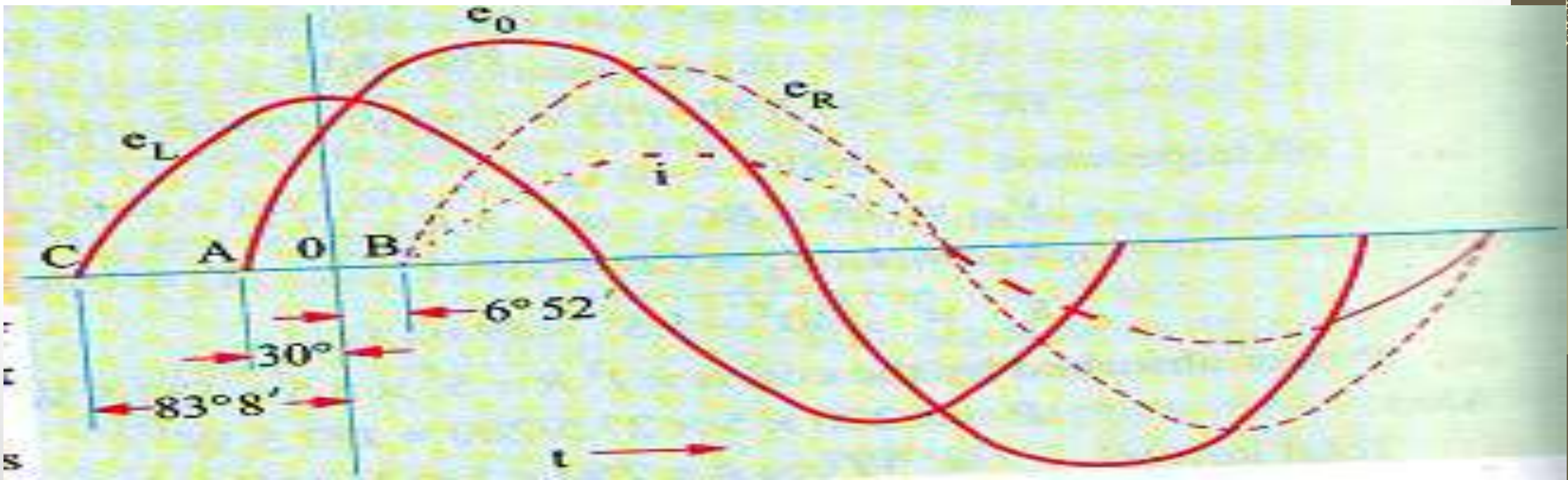
- **Two coils A and B are connected in series across a 240-V, 50-Hz supply. The Resistance of A is 5 ohm and the inductance of B is 0.015 H. If the input from the supply is 3 kW and 2 KVAR of A and the resistance of B. Find Resistance of B and the inductance of A. Calculate the voltage across each coil.**



AC SERIES CIRCUIT

- **Example 19**

- ***An e.m f. eo = 141.4 sin (377 t + 30) is impressed on the impedance coil having a resistance of 4 Ω and an inductive reactance of 1.25 Ω measured at 25 Hz. What is the equation of the current ? Sketch the waves for i, e_R, e_L and e_o.***



AC SERIES CIRCUIT

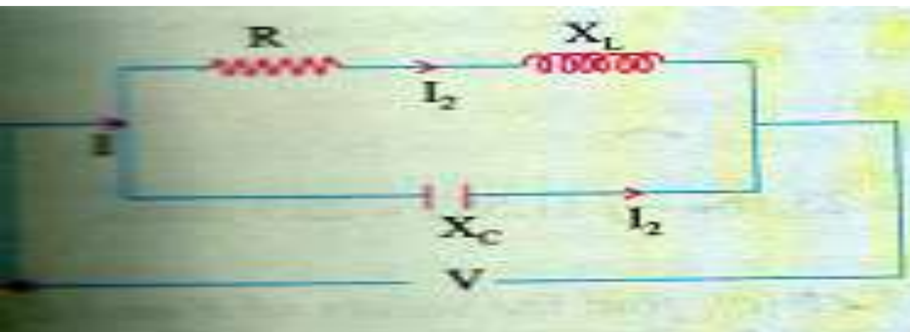
- **Example 20**

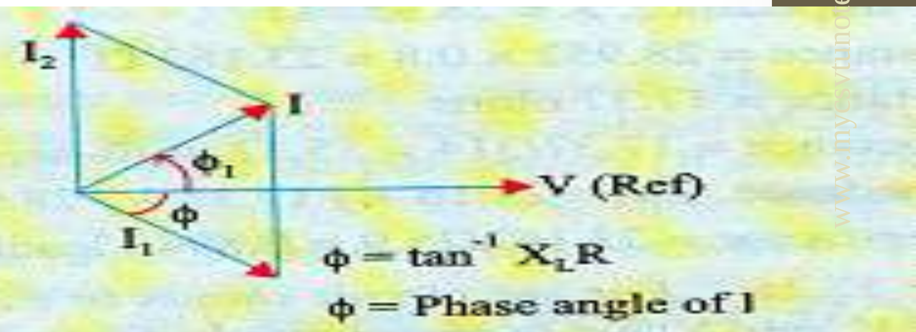
- ***A single phase, 7.46 kW motor is supplied from a 400V, 50-Hz a. c. mains. If its effciency is 85% and power factor 0.8 lagging, calculate (a) the kVA input (b) the reactive component of input current and (c) KVAR.***

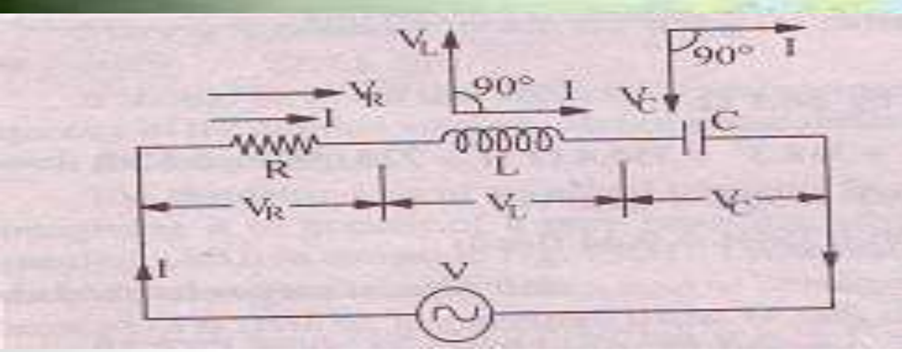
AC SERIES CIRCUIT

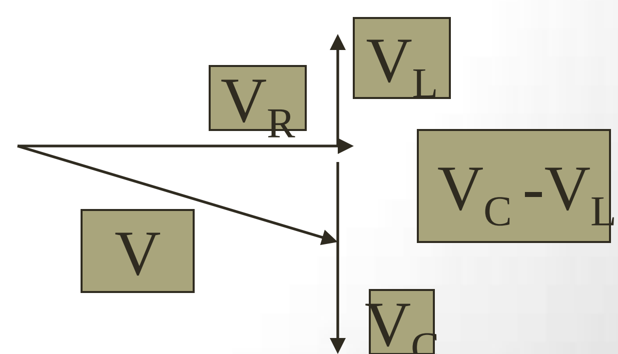
- **Example 21**

- ***Draw the phasor diagram for each of the following combinations (i) R and L in series and combination in parallel with C.***
- ***(ii) R, L and C in series with XC > XL when ac voltage source is connected to it.***



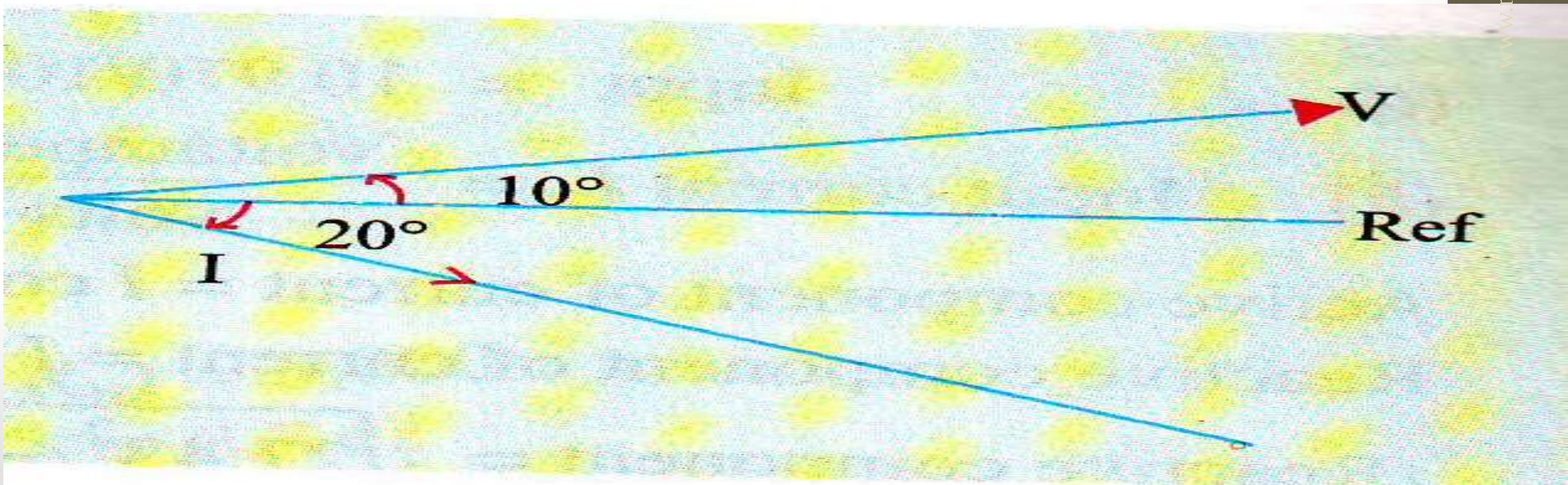






AC SERIES CIRCUIT

- **Example 22**
- ***A voltage v (t) = 141.4 sin (314 t + 10°) is applied to a circuit and the steady current is given by***
- ***i = 14.14 sin (314 t - 20°) is found to flow through it Determine***
- ***(i) The p .f. of the circuit***
- ***(ii) The power delivered to the circuit***
- ***(iii) Draw the phasor diagram***

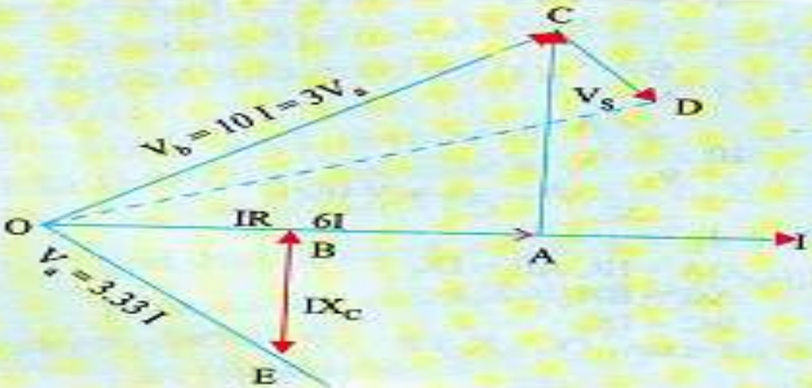


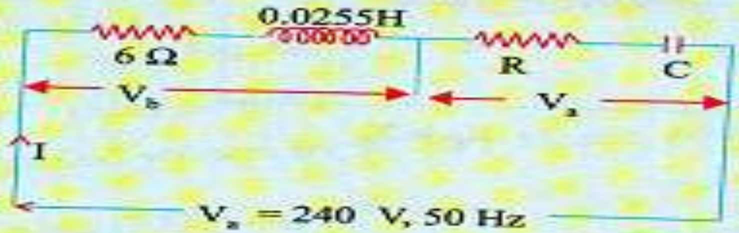
- **Example**. 23

- **A coil of 0.8 p f. is connected in series with 110 micro farad capacitor Supply frequency is 50 Hz. The potential difference across the coil is found to be equal to that across the capacitor. Calculate the resistance and the inductance of the coil. Calculate the net power factor**
- **Solution.**
- **X_C = 1/(3.14 x C) = 28.952 ohms**
- **Voltage across capacitance = Voltage across coil.**
- **Therefore Coil Impedance, Z = 28.952 Ω**
- **Coil resistance = 28.952 x 0.8 = 23.162Ω**
- **Coil reactance = 17.37 ohms**
- **Coil-inductance = 17.37/314 = 55.32 milli-henrys**
- **Total impedance, Z = 23.16 + j 17.37 - j 28.952**
- **= 23.162 - j 11.582 = 25.9 ohms**
- **Net power-factor = 23.162/25.9 = 0.8943 leading**

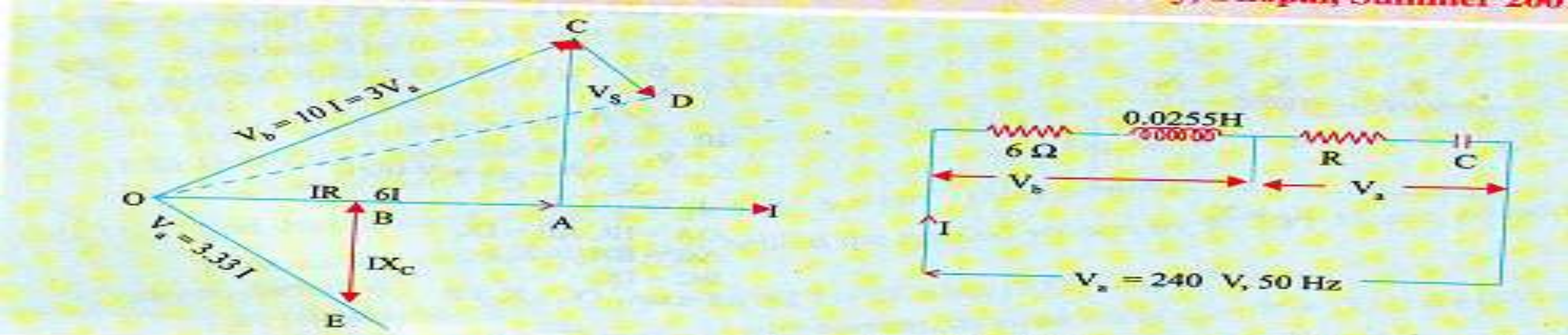
AC SERIES CIRCUIT

- **Example 24**
- ***For the circuit shown in Fig. find the values of R and C so that Vb = 3Va, and Vb and Va are in phase quadrature. Find also the phase relationships between Va and Vb,***
- ***and Vb and I.***



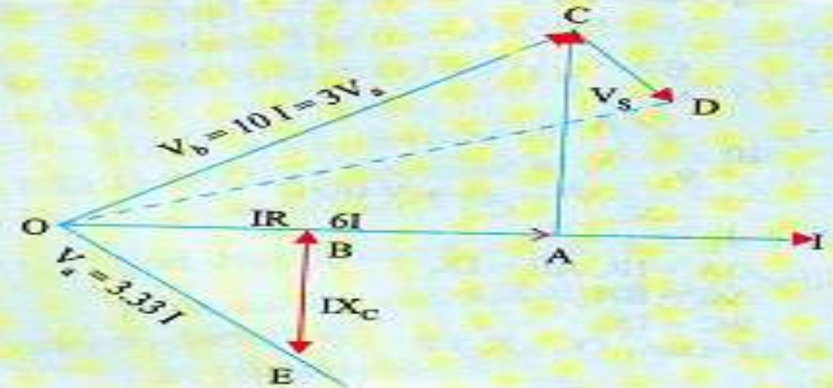


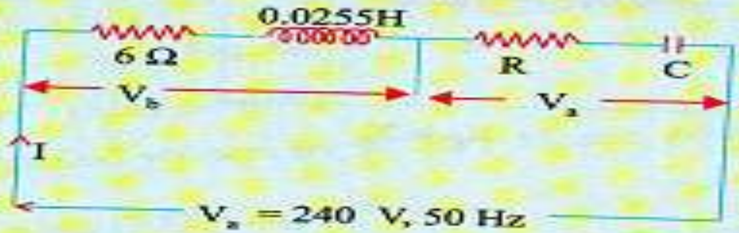
- Solution.
- $\angle COA = 0 = 53.13°$
- $\angle BOE = 90° - 53.13° = 36.87°$
- $\angle DOA = 34.7°$ Angle between V and *I* _
- angle between V_a and $V_b = 18.43°$
- $X_L = 314 \times 0.0255 = 8$ ohms
- $Z_b = 6 + j8 = 10 \angle 53.13°$ ohms
- $V_b = 10\,I = 3\,V_a$, and hence $V_a = 3.33\,I$



quadrant. Hence Va must be in the fourth quadrant, since Za consists of *R* and X_c Angle between Va and I is then 36.87°. Since Za, and Zb in series, V is represented by the phasor *OD* which is at angle of 34.7°.

- I V I =√10 V*a*=10.53I



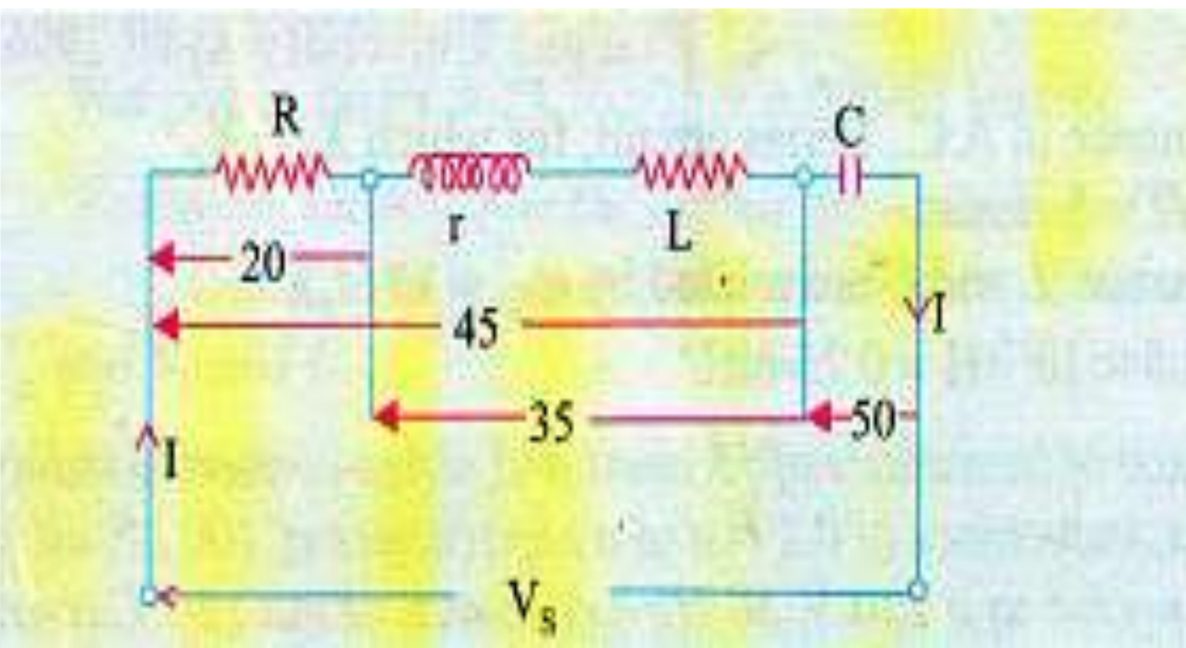


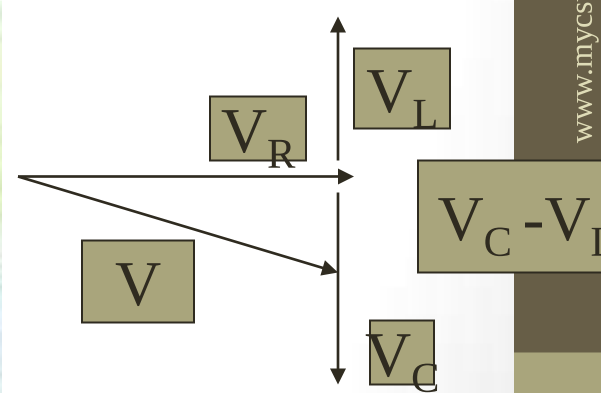
- Thus the circuit has a total effective impedance of 10.53 ohms. In the phasor diagram, *OA = 6 I , AC = 8 1,*
- *OC =* 10 I *= Vb = 3 Va*
- *Va = 0E=3.331,*
- _*BOE* = 36.87°, OB - *RI = OE* x cos 36.87° = 3.33 x 0.8 x I = 2.66 1. ***R*** = 2.66
- *BE = OE* sin36.87° = 3.33x0.6 x I = 2 I
- Xc = 2 ohms. For X, = 2 ohms, C = 1/(314 x 2) = 1592 µF
- Horizontal component of *OD = OB +* OA = 8.66 *I*
- Vertical component of *OD =* AC - *BE = 6 1*
- *OD* = 10.54 *I = V*
- the total impedance = 10.54 ohms = *8.66 + j* 6 ohms
- Angle between Vs and *I* = ∠ *DOA* = tan^{-1} (6/866) = 34.7°

- **Example 25**
- ***A coil is connected in series with a pure capacitor. The combination is fed from 10 V supply of 10,000 Hz. It was observed that the maximum current of 2 Amp flows in the circuit when the capacitor is of value 1 microfarad. Find the parameters (R and L) of the coil.***
- **Solution.**
- **This is the situation of resonance in A.C. Series circuit, for which *XL = XC   Z = R = V/1=* 10/2 = 5 ohms**
- **Wc angular frequency, at resonance, *L* and C are related by $W^2o = 1/(LC)$,**
- **$L = 1/(W^2o\ C) = 2.5 \times 10^{-4}$ H = 0.25 mH**

- Example 26

- *Resistor (= R), choke-coil (r, L), and a capacitor of 25.2 μF are connect in series. When supplied from an A. C. source, in takes 0.4 A. If the voltage across the resistor is 20 V , voltage across the resistor and choke is 45 volts, voltage across the choke is 35 volts, and across the capacitor is 50 V Find : (a) The values of r, L (b) Applied voltage and its frequency, (e) P.F of the total circuit active power consumed. Draw the phasor diagram.*





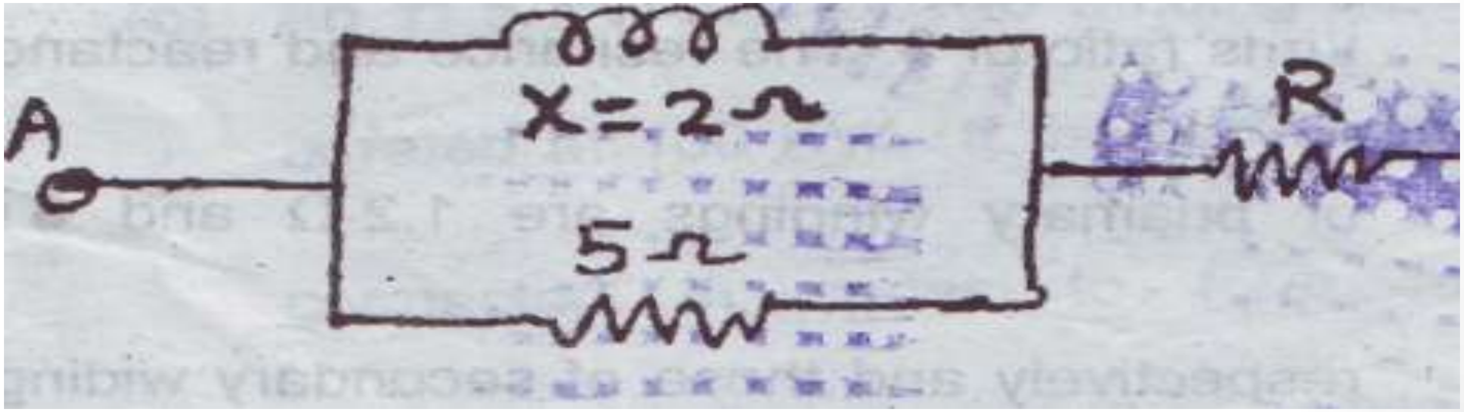
- *Example 27*

- ***An iron-cored choking coil takes 5 A when connected to a 20-V d. c. supply and takes 5A at 100 V a.c. and consumes 250 W. Determine (a) impedance (b) the power factor (c) inductance of the coil.***
- **(a)** $Z = 100/5 = 20\ \Omega$
- $P = VI \cos\phi$ or $250 = 100 \times 5 \times \cos\phi$
- $\cos\phi = 250/500 = 0.5$
- **Total loss = loss in resistance + iron loss**
- **.•. 250 = 20 x 5 + Pi**
- **Pi = 250 - 100 =150 W**
- **Effective resistance of the choke is P / I^2 = 250/25 =10 Ω**
- $X_L = \sqrt{(Z^{2} - R^2)}$ _ = (400 -100) = 17.32 Ω

LECT -35

PARALEL
R-L-C CIRCUIT

PRB 1. A voltage of 100V is applied across AB produce 40 A current. Find Value of R and power factor of circuit.



Prob 2 :

Two impedancs given by
Z1 = (10 + ,j5) and
Z2 = (8 + j6), are connected in parallel and connected across a voltage of v = (200 + j0).
Calculate the circuit current, its phase and branch currents.
Draw the vector diagram

LECT -36

STAR CONNECTION
IN
THREE PHASE CIRCUIT

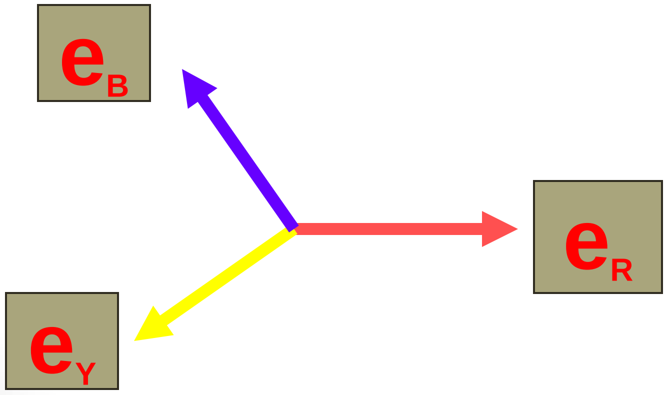
POLYPHASE CIRCUIT

Three coils have three emfs induced in them which are similar in all respect except they are 120° out of time phase with one another and each voltage wave is assumed to be sinsoidal and having maximum value Em. As the three circuits are exactly similar but are 120 electrical apart, the emf waves generated in them are displaced from each other by 120°.Their equation are

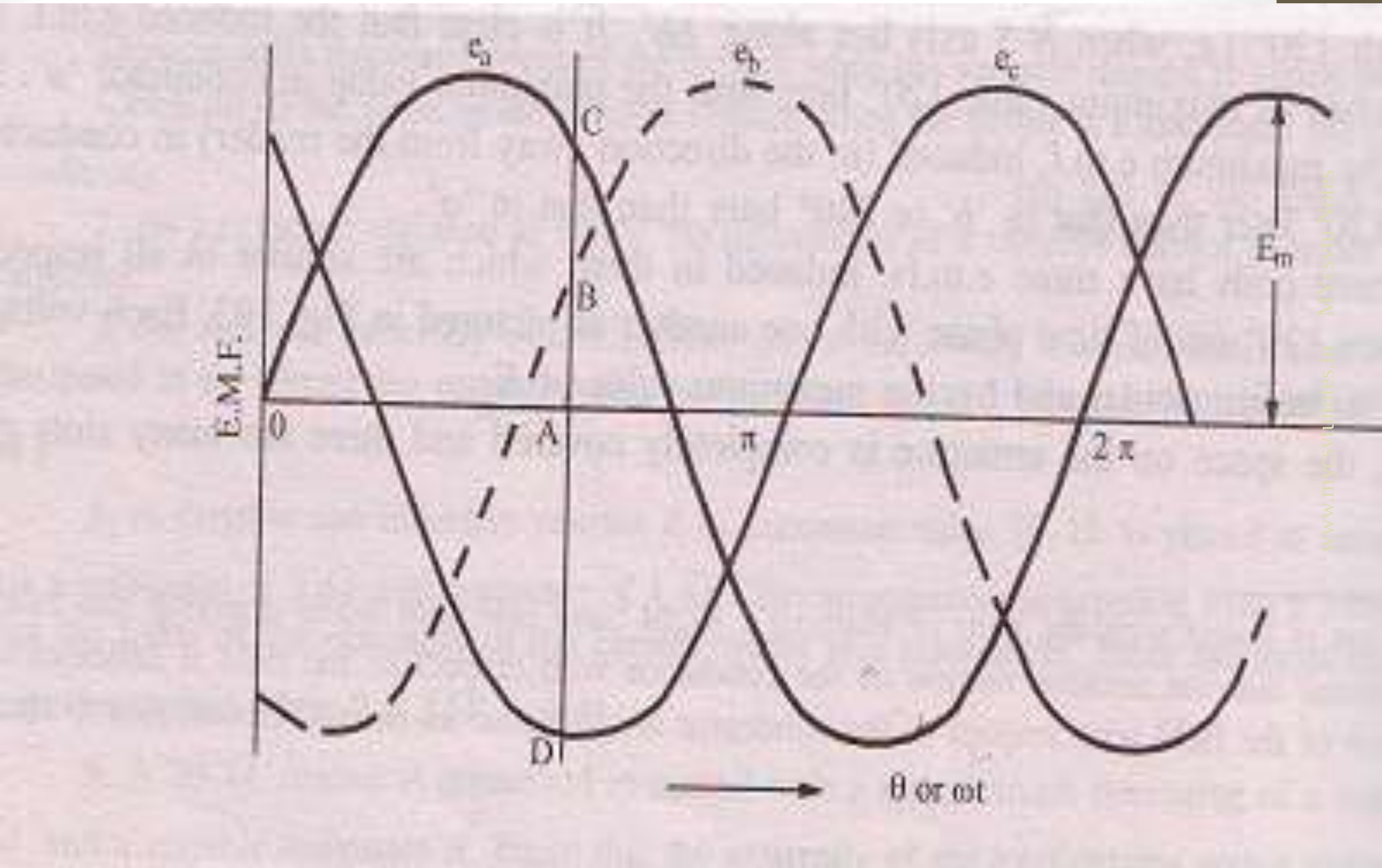
$$e_R = E_m \sin wt$$

$$e_Y = E_m \sin (wt - 120)$$

$$e_B = E_m \sin(wt - 240)$$



POLYPHASE CIRCUIT



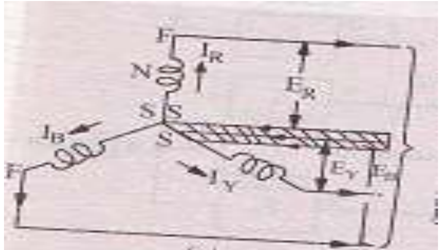
POLYPHASE CIRCUIT

- The sum of the above three eq is zero
- Resultant emf
- $e_R + e_Y + e_B$
- $= E_m \sin wt + E_m \sin(wt - 120) + E_m \sin(wt - 240)$
- $= E_m[\sin wt + \sin(wt - 120) + \sin(wt - 240)]$
- $= E_m[\sin wt + 2 \sin(wt - 180) \cos 60]$
- $= 0$

POLYPHASE CIRCUIT

- Voltage and Current in Y-Connection

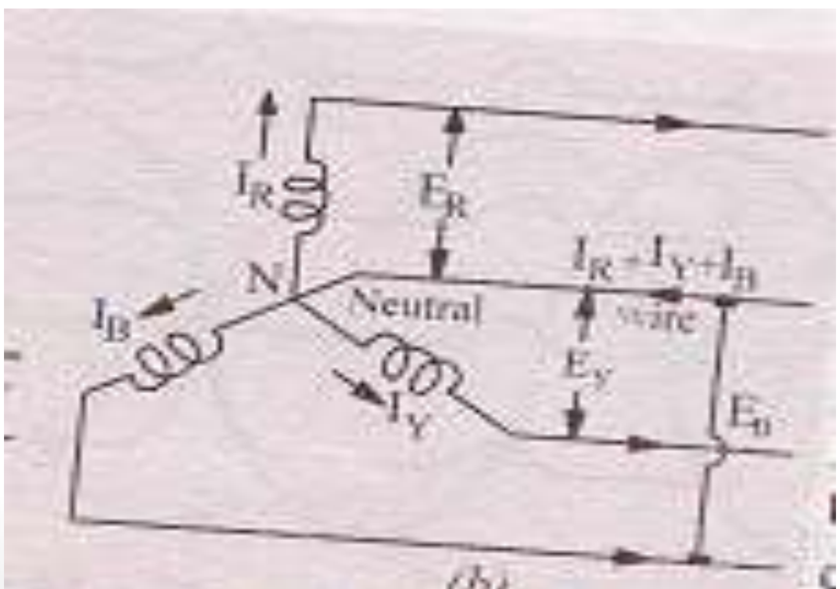
- The voltage induced in each winding is called the *phase* voltage. However, the voltage available between any pair of terminals (or outers) is called *line* voltage(V_L) and the current flowing in each line current (I_L).
- In this from of interconnection, there are two phase windings between each pair of terminals but since their *similar* ends have been joined together.
- Potential difference between any two terminals p.d. is given by the *vector difference* of the two phase e.m.fs.

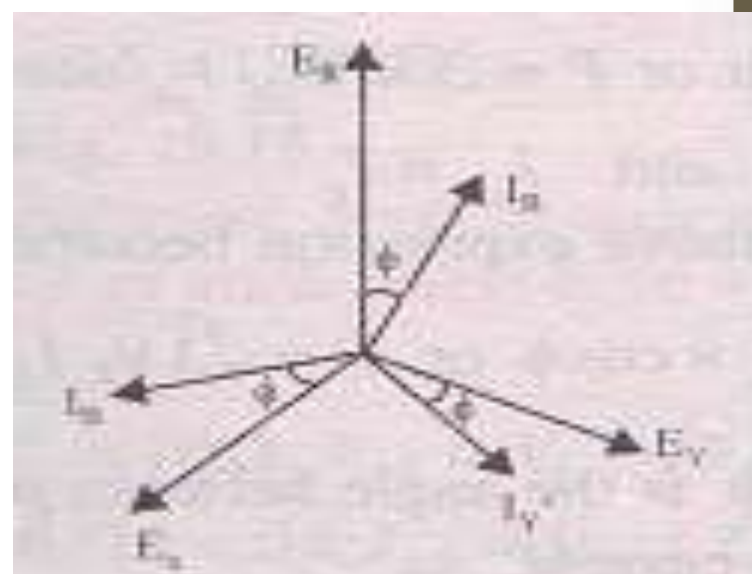


(a)

POLYPHASE CIRCUIT

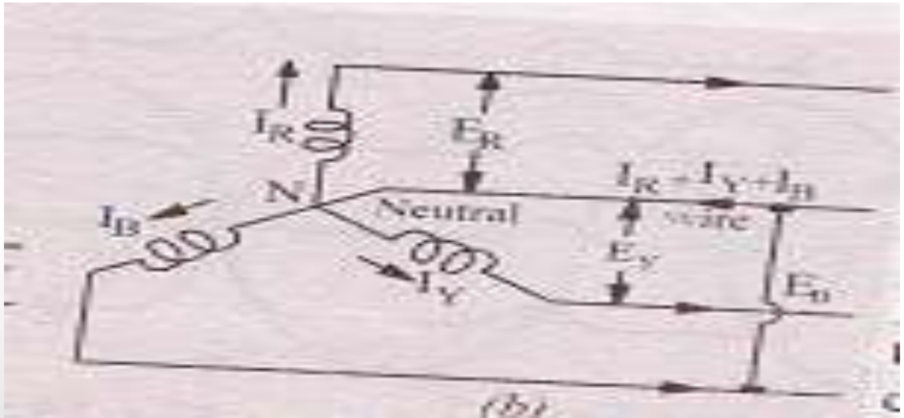
- **The vector diagram for phase voltages and currents in a star connection is shown in fig. where a balanced system has been assumed.**
- **It means that $V_R = V_Y = V_B = V_{ph}$ (phase Voltage.).**
-

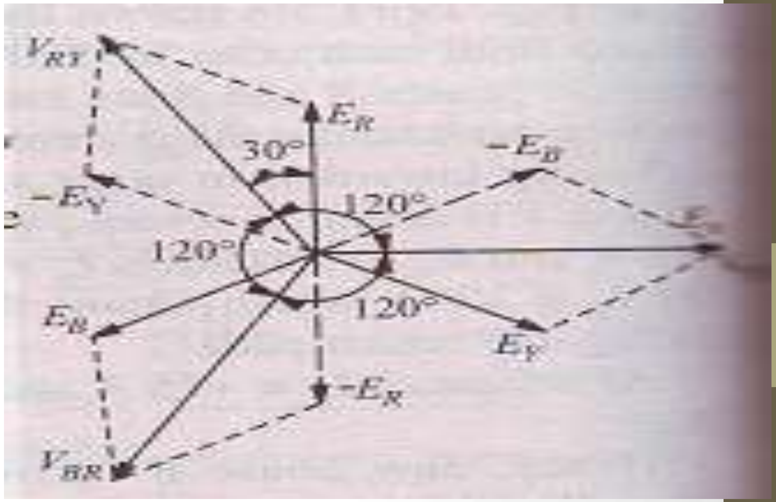




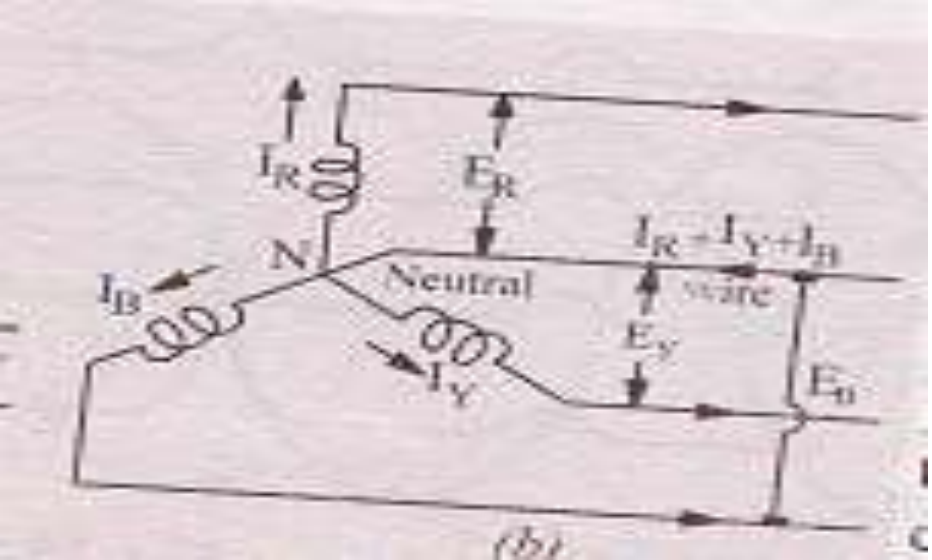
POLYPHASE CIRCUIT

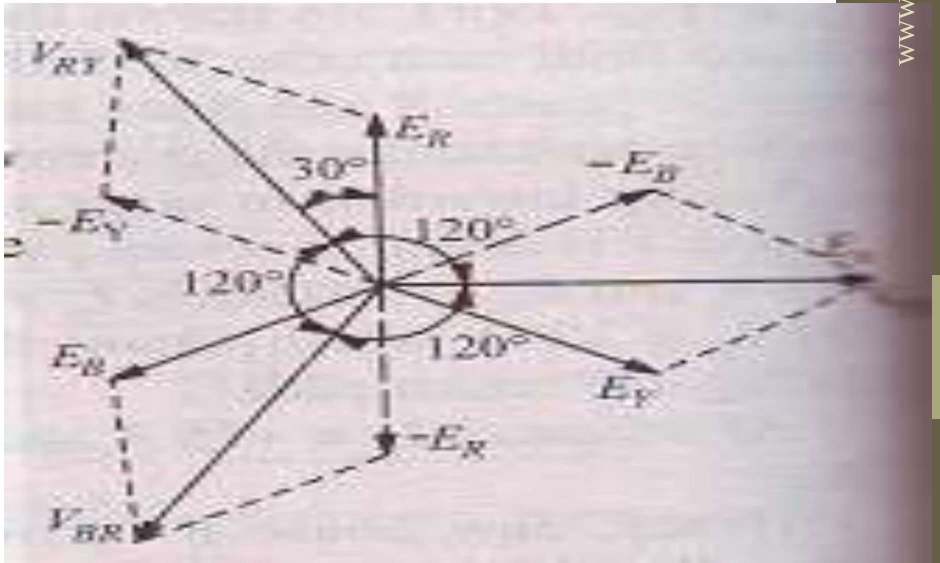
- Line voltage V_{RY} is voltage between line 1 and line 2 and it the is the vector difference between of V_R and V_Y. I.e. $V_{RY} = V_R - V_Y$
- Line voltage V_{YB} is voltage between line 2 and line 3 and it the is the vector difference between of V_Y and V_B. I.e. $V_{YB} = V_Y - V_B$
- Line voltage V_{BR} is voltage between line 3 and line 1 and it the is the vector difference between of V_B and V_R. I.e. $V_{BR} = V_B - V_R$





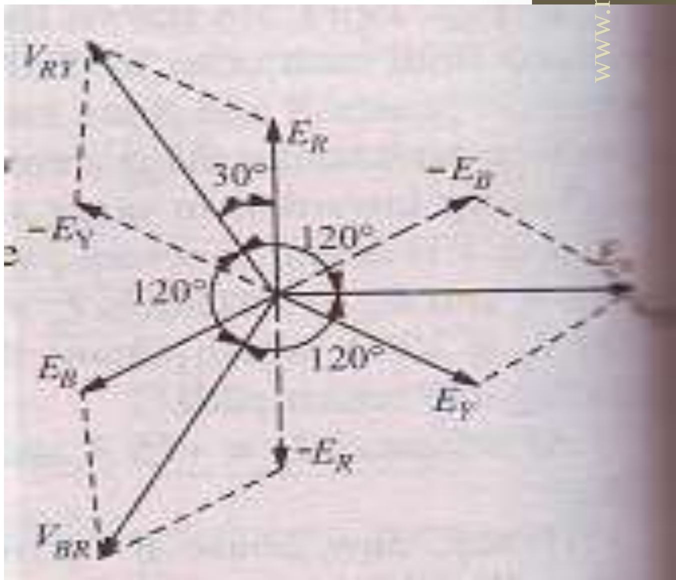
- Relation between Line Voltage and Phase Voltage
- Line voltage V_{RY} is voltage between line 1 and line 2 and it the is the vector difference between of V_R and V_Y. I.e. $V_{RY} = V_R - V_Y$
- Hence, V_{RY} is found by compounding V_R and V_Y reserved and its value is given by the diagonal of the parallelogram of fig. Obviusly, the angle between V_R and V_Y reversed is 60.
- Hence if $V_R = V_Y = V_B = V_{ph}$
- then $V_{RY} = 2 \text{ X } V_{ph} x\cos(60/2) = 2 \text{ X } V_{ph} x\cos 30$
- $= 2 \text{ X } V_{ph} \text{ x } \sqrt{3}/2 = \sqrt{3}\, V_{ph}$.





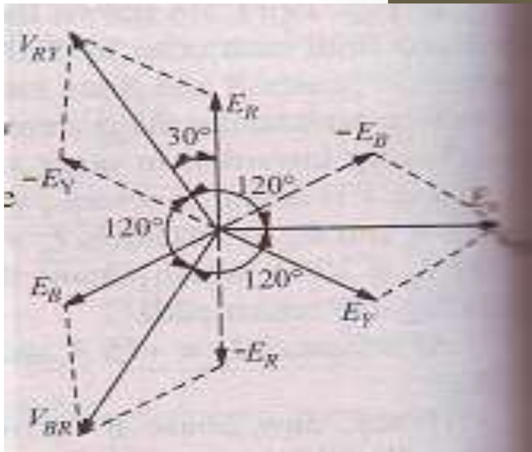
POLYPHASE CIRCUIT

- $V_{RY} = V_R - V_Y = \sqrt{3}\, V_{ph}$.
- Similarly, $V_{YB} = V_Y - V_B = \sqrt{3}\, V_{ph}$.
- And $V_{BR} = V_B - V_R = \sqrt{3}\, V_{ph}$.
- Now $V_{RY} = V_{YB} = V_{BR}$ = line voltage,say, V_L
- Hence, in star connection $V_L=\sqrt{3}.\ V_{ph}$
- **Line Voltage = √3 (Phase Voltage)**
- It will be noted from fig. that
- Line voltages are 120° apart



POLYPHASE CIRCUIT

- Relation between Line Current and phase currents
- **It is seen from fig that each line is in series with its individual phase winding, hence the line current in each line is the same as the current in the phase winding to which the line is connected Current in line 1 = I_R**
- **current in line 2 = I_Y**
- **current in line 3 = I_B**
- **Since $I_R = I_B = I_Y = I_{ph}$ (phase current)**
- **∴ In star connection**
- **line current $I_L = I_{PH}$**
- In star connection
- Line current = phase currents



POLYPHASE CIRCUIT

- Power
- The total active or true power in the circuit is the sum of three phase powers hence,
- Total active power=3x phase power or
- $P = 3 \times V_{ph} I_{ph} \cos\phi$
- now $V_{ph} = V_L/\sqrt{3}$ and $I_{ph} = I_L$
- hence, in terms of line values, the above expression becomes
- $P = 3(V_L/\sqrt{3})\, I_L \cos\phi = \sqrt{3} \times V_L I_L \cos\phi$ WATT
- It should be particularly noted that ϕ is the angle between Line voltage and line current.
- Similarly, total reactive power is given by
- $Q = \sqrt{3} V_L I_L \sin\phi$ VAR
- The total apparent power of the three phases is
- $S = \sqrt{3}\, V_L I_L$ VA
- $S = \sqrt{(P^2 + Q^2)}$

POLYPHASE CIRCUIT

- **STAR CONNECTION**

- **Line Voltage = √3 (Phase Voltage)**
- **Line current = Phase currents**
- **Active power P = $\sqrt{3} \times V_L I_L \cos\phi$ WATT**
- **Reactive power Q = $\sqrt{3} V_L I_L \sin\phi$ VAR**
- **Apparent power S = $\sqrt{3} V_L I_L$ VA**
- **Star connection is four wire three – phase systems.**
- **In Star connection neutral point is available.**

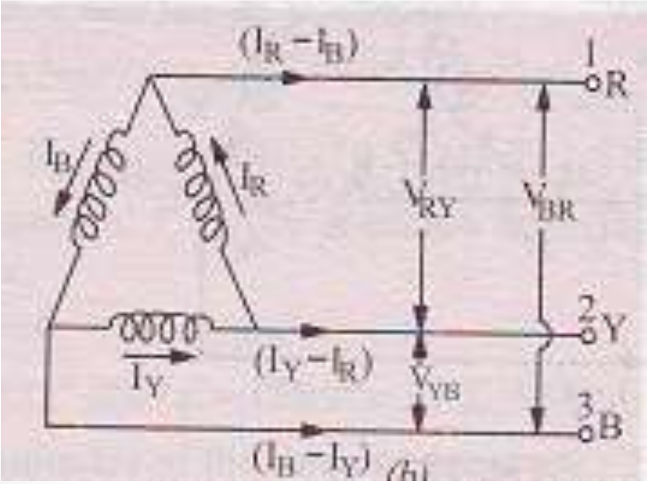
LECT -37

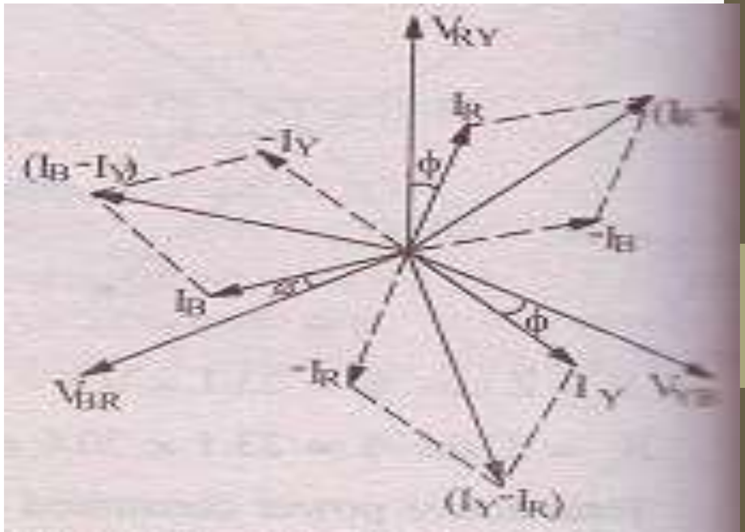
DELTA CONNECTION
IN
THREE PHASE CIRCUIT

POLYPHASE CIRCUIT

- **Delta(∇) or Mesh Connection**

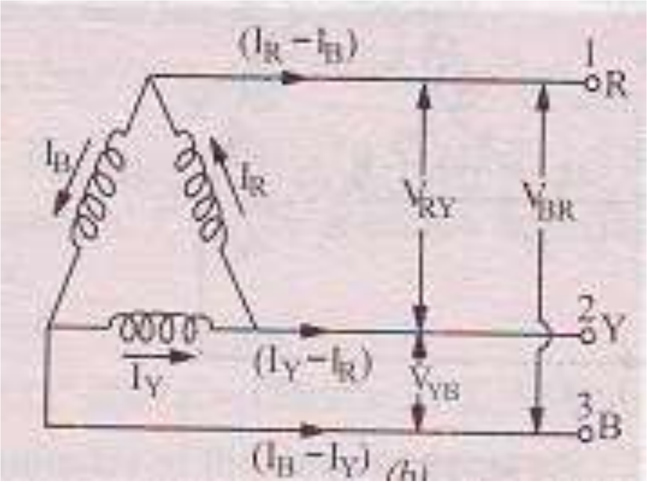
- **In this from of interconnection the dissimilar ends of the three phase windings are joined together i.e. the 'starting' end of one phase is joined to the 'finishing' end of the other phase and so on as shown in fig in other words, the three windings are joined in series to from a closed mesh as shown in fig.**

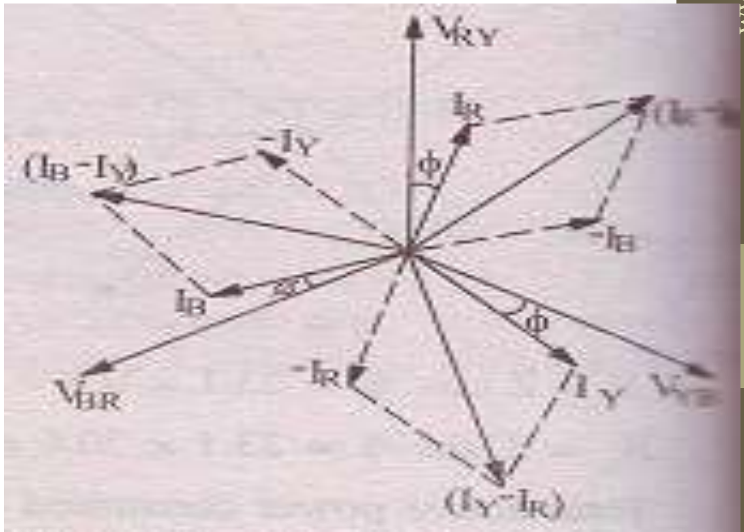




POLYPHASE CIRCUIT

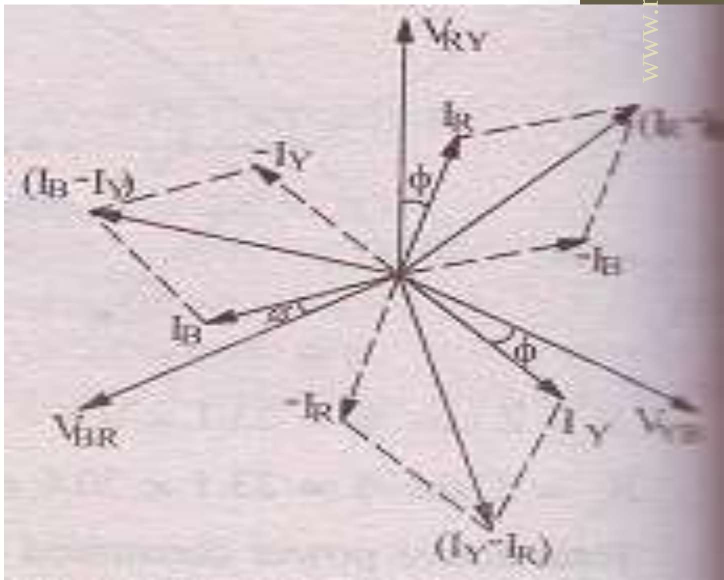
- Three leads are taken out from the three junctions as shown in fig.
- It might look as if this sort of interconnection result in short circuiting the three windings. However, if the system is blanced then sum of the three voltages round the closed mesh is zero, hence no current of fundamental frequency can flow around the mesh when the terminals are open.





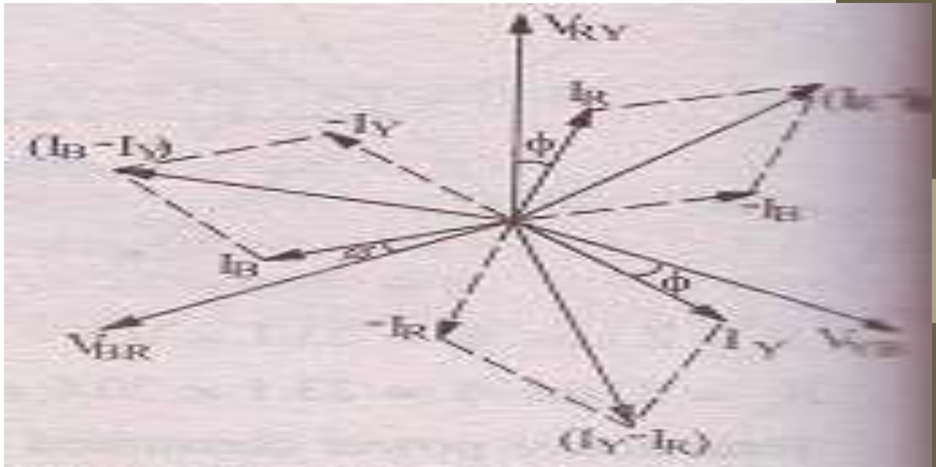
POLYPHASE CIRCUIT

- **Relation between Line Current and phase currents**
- **It will be seen from fig (b) that current in each line is the vector difference of the two phase currents flowing trough that line. For example**
- **Current line 1 is $I_1 = I_R - I_B$ vector difference**
- **Current line 2 is $I_2 = I_Y - I_R$ vector difference**
- **Current line 3 is $I_3 = I_B - I_Y$ vector difference**
- **Current in line no1 is found by compounding I_R and I_B reversed and its value is given by the diagonal of the parallelogram.The angle between I_R and I_B reversed (i.e $-I_B$) is 60.**
- **If $I_R = I_B$ = Phase current I_{ph} (say),**
- **then Current in line no1 is**
- **$I_1 = 2 I_{ph} \cos(60/2) = 2 I_{ph} \cos 30$**
- **$= \sqrt{3}\ I_{ph}$**



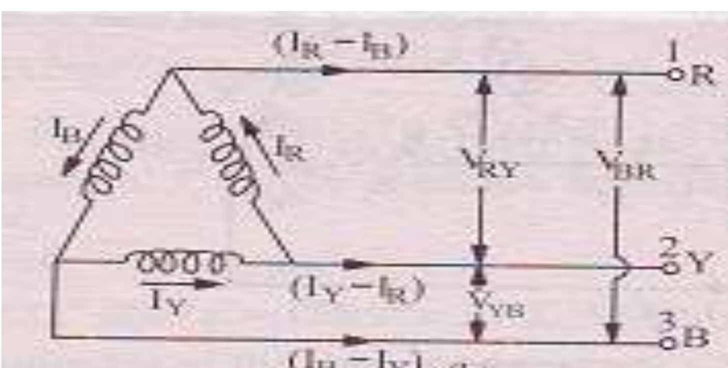
POLYPHASE CIRCUIT

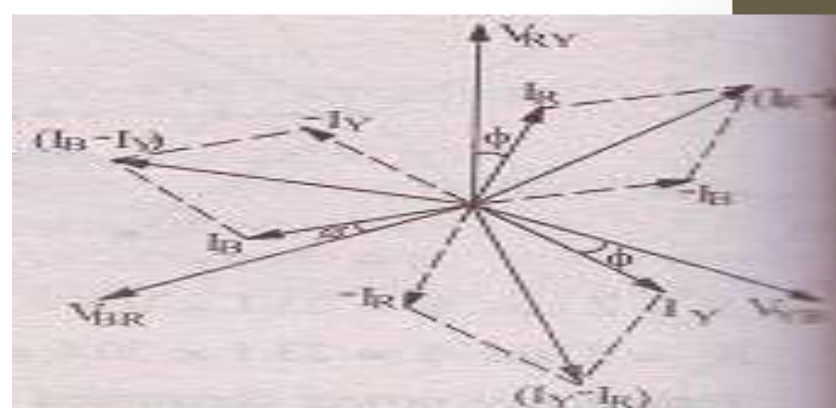
- Current line 2 is $I_2 = I_Y - I_R = \sqrt{3}\ I_{ph}$
- Current line 3 is $I_3 = I_B - I_Y = \sqrt{3}\ I_{ph}$
- Since all the line currents are equal in magnitude i.e.
- $I_1 = I_2 = I_3 = I_L$ = Line Current
- $I_L = \sqrt{3}\ I_{ph}$
- Line current = √3 Phase Current
- With reference to Fig , it should be noted that line currents are 120° apart



POLYPHASE CIRCUIT

- **Relation between Line Voltage and Phase Voltage**
- **The vector diagram for voltages and currents in a delta connection is shown in fig. where a balanced system has been assumed. The line voltage is applied to each phase components.**
- **It means that**
- **$V_R = V_Y = V_B = V_{ph}$ (phase Voltage.) = V_L (Line Voltage.).**
-





POLYPHASE CIRCUIT

- Power
- The total active or true power in the circuit is the sum of three phase powers hence,
- Total active power = 3x phase power
- $P = 3 \times V_{ph} I_{ph} \cos\phi$
- now $V_{ph} = V_L$ and $I_{ph} = I_L / \sqrt{3}$
- Hence, in terms of line values, the above expression becomes
- $P = 3V_L (I_L / \sqrt{3}) \cos\phi = \sqrt{3} \ X \ V_L I_L \cos\phi$ WATT
- It should be particularly noted that ϕ is the angle between line voltage and line current.
- Similarly, total reactive power is given by
- $Q = \sqrt{3} V_L I_L \sin\phi$ VAR
- The total apparent power of the three phases is
- $S = \sqrt{3} \ V_L I_L$ VA
- $S = \sqrt{(P^2 + Q^2)}$

POLYPHASE CIRCUIT

- **DELTA CONNECTION**

- Line Voltage = √3 (Phase Voltage)
- Line current = Phase currents
- Active power P = $\sqrt{3} \times V_L I_L \cos\phi$ WATT
- Reactive power Q = $\sqrt{3} V_L I_L \sin\phi$ VAR
- Apparent power S = $\sqrt{3}\, V_L I_L$ VA
- Delta connection is Three wire three – phase systems.
- In Delta connection neutral point is not available

LECT -38

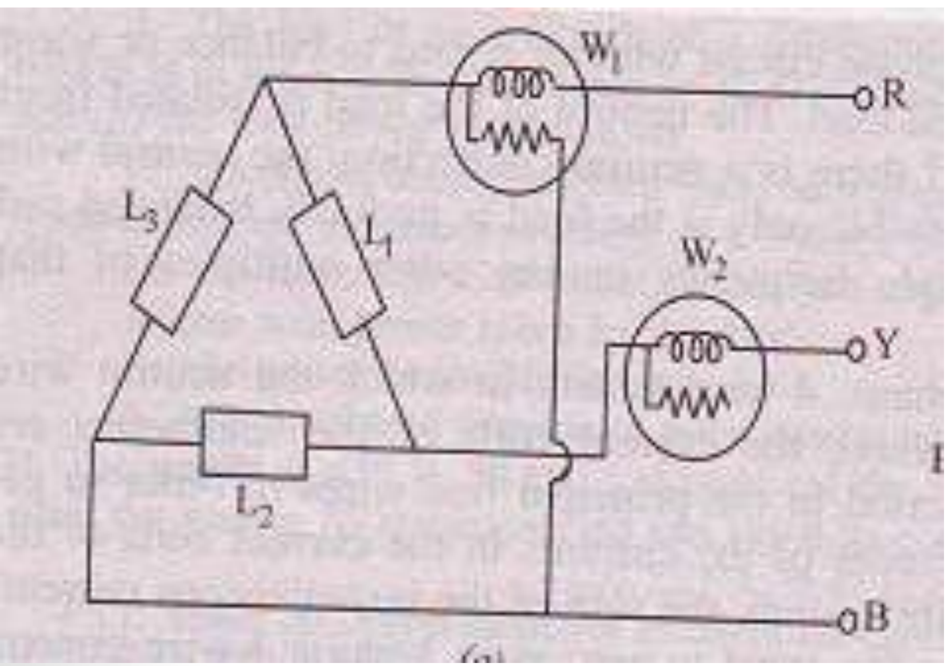
POWER MEASUREMENT
IN
THREE PHASE CIRCUIT

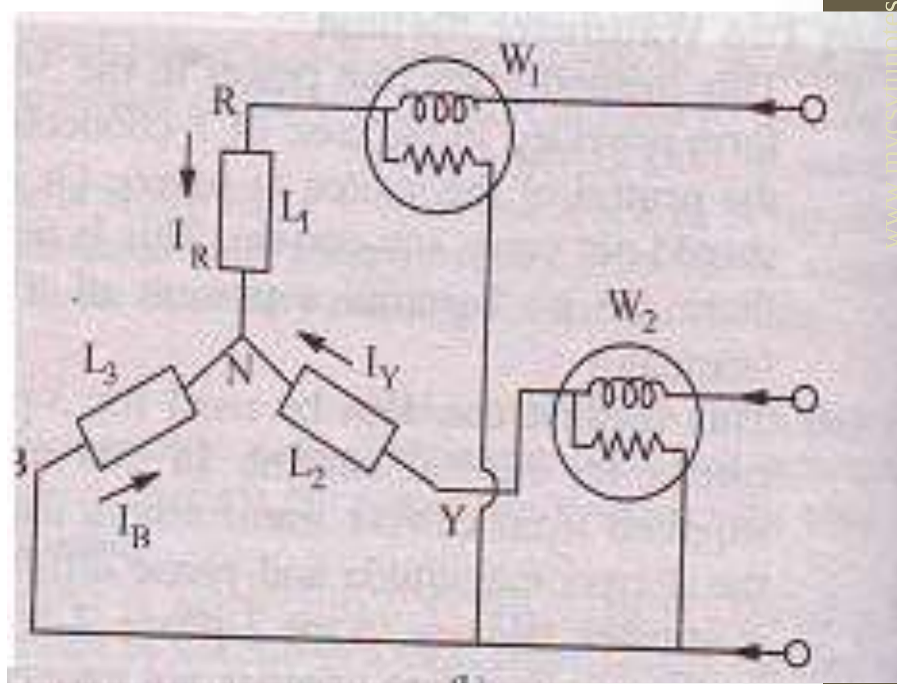
POLYPHASE CIRCUIT

- POWER MEASUREMENT IN 3-PHASE CIRCUIT :
- Following methods are available for measuring power in a 3-phase load :
- Three wattmeter method.
- Two wattmeter method.
- One wattmeter method.

POLYPHASE CIRCUIT

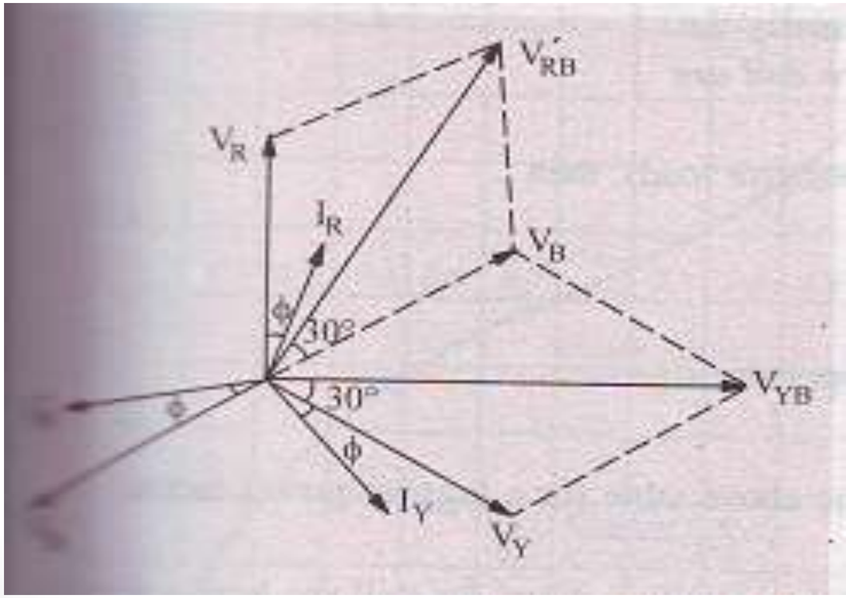
- Two Wattmeter Method-Balanced Load
- If the load is balanced , then power factor of the load can also be found from the two wattmeter readings. The Y & connected load in fig. will be assumed inductive. The vector diagram for such a balanced Y-connected load is shown in fig. we will now consider.





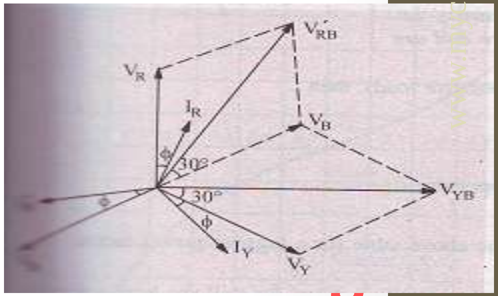
POLYPHASE CIRCUIT

- Let V_R,V_Y and V_B be the r.m.s. values of the three phase voltages and I_R,I_Y and I_B the r.m.s. values of the currents. Assume the currents lagging behind their respective phase voltages by ∅.



POLYPHASE CIRCUIT

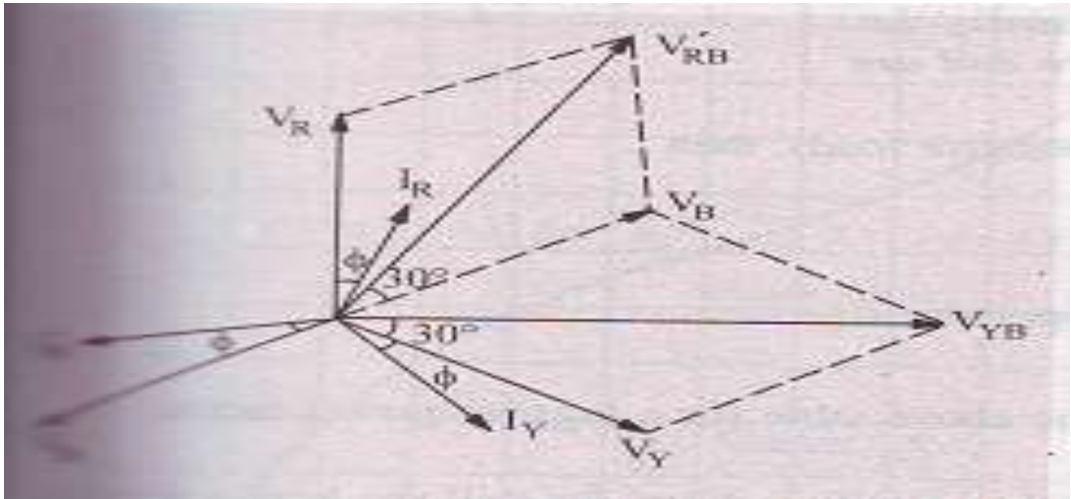
- Since wattmeter measure power in the circuit. Then reading of W_1 is
- = { Current through wattmeter W_1 X P.D. across voltage coil of W_1 X Phase angle}
- Current through wattmeter W_1 is I_RThis V_{RB} is found by compounding V_R and V_B reserved as shown in fig. it is seen that phase difference between V_{RB} and I_R = $(30-\phi)$.
- $\therefore$ Reading of $W_1 = I_R V_{RB} \cos(30-\phi)$
- Similarly, The reading of W_2 is
- = { Current through wattmeter W_2 X P.D. a



coil of W_2 X Phase angle}

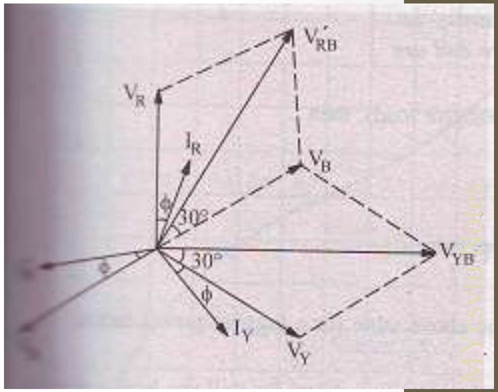
POLYPHASE CIRCUIT

- Then reading of W_2 is
- = { Current through wattmeter W_2 X P.D. across voltage coil of W_2 X Phase angle}
- Current through wattmeter W_2 is I_YThis V_{YB} is found by compounding V_Y and V_B reserved as shown in fig. it is seen that phase difference between V_{YB} and I_Y = (30+ϕ).
- $\therefore$ Reading of W_2 = I_Y V_{YB} cos (30+ϕ)



POLYPHASE CIRCUIT

- Since load is balanced , and in star connection
- $I_R = I_B = I_Y = I_{ph} = I_L$ Line current
- $V_{RY} = V_{YB} = V_{BR} = V_L$ = line voltage
- $W_1 = V_L I_L \cos(30-\phi)$ and
- $W_2 = V_L I_L \cos(30+\phi)$
- $W_1 + W_2 = V_L I_L \cos(30-\phi) + V_L I_L \cos(30+\phi)$
- $= V_L I_L [\cos(30-\phi) + \cos(30+\phi)]$
- $= V_L I_L [\cos 30 \cos\phi + \sin 30 \sin\phi + \cos 30 \cos\phi - \sin 30 \sin\phi]$
- $= V_L I_L (2\cos 30 \cos\phi) = \sqrt{3} V_L I_L \cos\phi$
- = Total power in the 3-phase load.
- Hence Total power in the 3-phase balanced load is measured by two wattmeter.



POLYPHASE CIRCUIT

- Variations in Wattmeter Readings
- It has been shown above that for a lagging power factor
- $W_1 = V_L I_L \cos(30-\phi)$ and
- $W_2 = V_L I_L \cos(30+\phi)$
- From that it is clear that individual readings of the wattmeters not only depend *on the load but upon its power factor also.* We will consider the following cases:
- when $\phi=0$ i.e. power factor is unity (i.e. resistive load) then,
- $W_1 = W_2 = V_L I_L \cos 30$
- Both wattmeters indicate equal and positive readings

POLYPHASE CIRCUIT

- **when ϕ=60 i.e. power factor =0.5(langing)**
- **then W_2= V_L I_L cos(30+60) =0.**
- **Hence, the power is measured by W1 alone.**
- **when 90>ϕ>60 i.e.0.5>p.f.>0,**
- **then W_1 is still positive but reading of W_2 is reversed because the phase angle between the current and voltage is more then 90. For getting the total power, the reading of W_2 is to be subtracted from that of W_1. Under this condition, W_2 will read 'down-scale'i.e. backwards. Hence, to obtain a reading on W_2,it is necessary to reverse either its pressure coil or current coil, usually the former.** ***All readings taken after reversal of pressure coil are to be taken as negative.***

POLYPHASE CIRCUIT

- When ϕ=90 (i.e. pure inuctive or capacitive load), then
- $W_1 = V_L I_L \cos(30-\phi) = V_L I_L \cos(30 - 90)$
- $= V_L I_L \cos 60 = 0.5 V_L I_L$
- And $W_2 = V_L I_L \cos(30 + 60)$
- $= V_L I_L \cos 120 = - 0.5 V_L I_L$
- As seen the two readings are equal but opposite sign.
- W1+W2=0

POLYPHASE CIRCUIT

- Power Factor-Balanced load
- In case the load is balanced (and currents and voltage are sinusoidal) and for a *lagging* power factor:
- $W_1+W_2 = V_L I_L [\cos(30-\phi) + \cos(30+\phi)] = \sqrt{3} V_L I_L \cos\phi$ ......(1)
- Similarly
- $W_1 - W_2 = V_L I_L [\cos(30-\phi) - \cos(30+\phi)] = - V_L I_L \sin\phi$ ....(2)
- dividing(ii) by (I), we have
- $\tan\phi = -\sqrt{3}\,[(w1—W2) / (W1+W2)]$ ....(A)
  Balanced load-Leading power factor
- in this case, as seen from fig.
- $W_1 = V_L I_L \cos(30+\phi)$ and $W_2 = V_L I_L \cos(30-\phi)$
- W1=VlIl cos(30+ϕ) and W2=VlIl cos(30-ϕ)
- $W_1+W_2 = V_L I_L [\cos(30+\phi) + \cos(30-\phi)] = \sqrt{3} V_L I_L \cos\phi$ ......(1)
- Similarly
- $W_1 - W_2 = V_L I_L [\cos(30+\phi) - \cos(30-\phi)] = \sqrt{3} V_L I_L \sin\phi$ ....(2)
- ∴ $\tan\phi = \sqrt{3}\,[(w1—W2) / (W1+W2)]$ ....(B)

POLYPHASE CIRCUIT

ϕ	0	60	90
$\cos\phi$	1	0.5	0
W_1	+VE	+VE	+VE
W_2	+VE $W_1 = W_2$	0	-VE $W_1 = W_2$

LECT -39

PROBLEMS OF POWER MEASUREMENT IN THREE PHASE CIRCUIT

POLYPHASE CIRCUIT

- **Example 1.** A blanced star connected load of (8+j6)Ω per phase is connected to a blanced 3-phase 400-V supply. Find the line current, power factor,power and total volt amperes.

POLYPHASE CIRCUIT

- **Solution.**
- Zph=√8+6=10Ω
- Vph=400/√3=231V
- Iph=Vph/Zph=231/10=23.1A
- Il=Iph=**23.1V**
- P.f.= cosϕ=Rph/Zph=8/10=**0.8(lag)**
- Power P=√3VlIl cosϕ
- = √3x400x23.1x0.8=**12,800 W**
- also, P=3Iph Rph=3(23.1)x8=12,800 W
- total volt amperes, S=√3VlIl
- =√3x400x23.1=**16,000 V**

POLYPHASE CIRCUIT

- **Example 2.** given a balanced 3-ϕ,3-wire system with Y-connected load for which line voltage is 230 V and Impedance of each phase is (6+j8) ohm. Find the line current and power observed by each phase.
- **Solution.** Zph=√6+8=10Ω; Vph =Vl/√3=230/√3=133V
- cosϕ=R/Z=6/10=0.6;Iph=Vph/Zph=133/10=13.3A
- Il=Iph=**13.3*A**
- Power observed by each phase=I2ph Rph=(13.3) 2x6=**1067 W**

POLYPHASE CIRCUIT

- **Example 3** Three impedances each of magnitude (15-j20) ohms are connected in mesh across a 3-phase, 400 - volt a. c. supply. Determine is the phase current, line current , active power and reactive power drawn from the supply.
- **Solution .**The circuit is similar to that showen in Fig .17.21 below.
- VPh = VL= 400 V, ZPh=√15+20= 25Ω, cos ϕ =R/Z =15/25=0.6(lead)
- IPh = VPh= 400/25 =**16A**; Il =√3.Iph =√3x16 =**27.7A**
- Active power P =√3VLIL cos ϕ =√3x400x27.7x0.06=**11,514W**
- rective power Q =√3VLIL sin ϕ =√3x400x27.7x0.08=**15,352VAR**

POLYPHASE CIRCUIT

- **Example 4** A220-v, 3-ϕ voltage is applied to a balanced delta-connected 3-ϕ load of phase impedance (15+j20) Ω
- Find the phasor current in each line.
- What is the power consumed per phase ?
- What is the phasor sum of the three line current ? Why dose it have this value?
- **Solution .** The circuit is shown in Fig.17.21.
- VPh = VL= 220 V, ZPh=$\sqrt{}$15+20= 25Ω, I p h= V P h / Z ph 220/25=8.8A
- (a) IL ==$\sqrt{3}$ I p h==$\sqrt{3}$x8.8= **15.24A** (b) P= I p h R p h =8.8x15=**462W**
- (C)Phasor sum would be zero because the three currents are equal in magnitude and have a mutual phase diferance of 120