a) S of air gap.

$$S_{ag} = \frac{1}{\mu_0} \times \frac{l_g}{a}$$

$$= \frac{10^{-4}}{0.001 \times 4\pi \times 10^{-7}}$$

$S_{ag} = 79618$ AT Wb^{-1}

b) S of section a of ring.

$$S_a = \frac{l_a}{\mu_0 \mu_{r_a} a} = \frac{0.3}{2\pi}$$

$S_a = 47770$ AT Wb^{-1}

c) $$S_b = \frac{l_b}{\mu_0 \mu_{r_2} a} = \frac{0.2}{4\pi \times 10^{-7} \times 0.001 \times 1000}$$

$S_b = 159154$ AT Wb^{-1}

d) $$S_c = \frac{l_c}{\mu_0 \mu_{r_c} a} = \frac{0.1}{0.001 \times 4\pi \times 10^{-7} \times 10000}$$

$$= \frac{0.1 \times 10^6}{4\pi}$$

$$= 0.079577 \times 10^5$$

$$= 7957.7 \text{ AT } Wb^{-1}$$

Total $S = S_{ag} + S_b + S_c + S_d$

$= 79618 + 47770 + 159154 + 7957.7$

$\therefore$ $S = 294,499.7$

Magnet and Magnetism

Any body which possesses the power to attract of iron is called magnet.

The property by virtue of which it takes place is called magnetism.

MAGNETS
- Natural
- Artificial

Natural magnet
- comparatively weaker
- do not find any physical application

Artificial magnet
- made artificially from iron, steel or alloy material. It can be prepared by either rubbing iron bars with a mag-net or by passing an electric current through the wire ~~and~~ wound around an iron piece.
- magnets prepared the electricity way are called electromagnets. The phenomenon is called ~~electromagnetism~~. electromagnetism.
- magnets used in electrical machines and equipment are of artificial types and generally are horse-shoe or U-shaped, as they can retain thier magnetism for very long time

- artificial magnets
  → permanent
  → temporary

- Permanent magnets – prepared from hardened steel and contain certain alloys of nickel and cobalt, which retain the magnetism unaltered for long durations even after removal of magnetising force

- Temporary magnets – ~~prepared by methods like~~ artificial magnets that lose their magnetic properties after the removal of magnetising force.

Magnetic Effect of Electric Current

- when an electric current flows through a conductor, magnetic field is set up all along the length of the conductor.

- Magnetic lines of force are in the form of concentric circles around the conductor.

- magnetic lines are stronger near the conductor and gets weaker at the point further away from the conductor.

- the direction of lines of force in the form of concentric circles depends upon the direction of current and determined by right hand rule.

Right Hand Rule

Hold the conductor in the right hand with the thumb pointing in the direction of current, then the fingers will point at the direction of magnetic field around conductor.

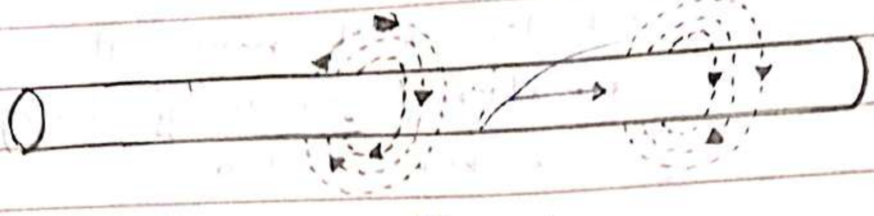


Fig.: 1

Cross and Dot convention

- current flowing through a conductor produces mag-netic field around it. ~~The~~

- direction of current in the conductor is indicated by dot and cross convention.

- represents the direction of current ⊥ 2-D surface has been ~~repere~~ represented upon (board, paper, sc etc.)

$\otimes$ Cross　　　　$\odot$ Dot

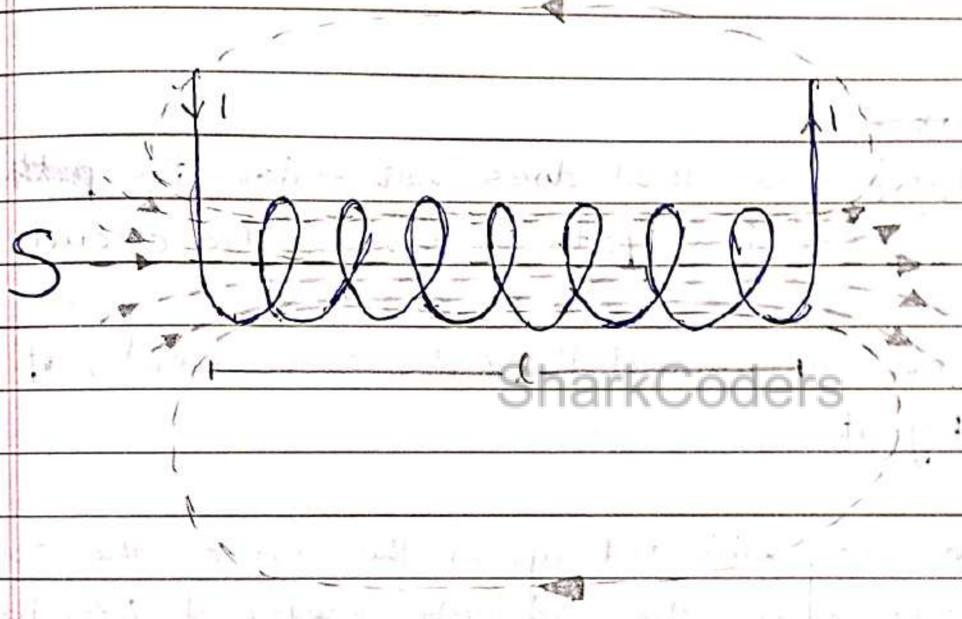
- cross - current flowing away from the observer. and into the plane of the paper.

- dot - current flowing towards the observer carr ~~the~~ current out of the plane. ~~of paper~~

Magnetic field of solenoid

When a long conductor is wound with a large number of turns.

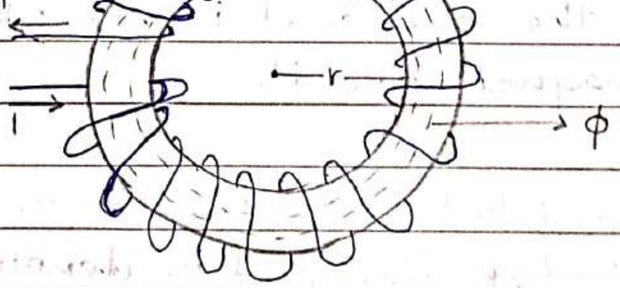
- its axial length is much greater than its diameter
- core is either air cored or wound on a long tubular core of magnetic or non-magnetic material.



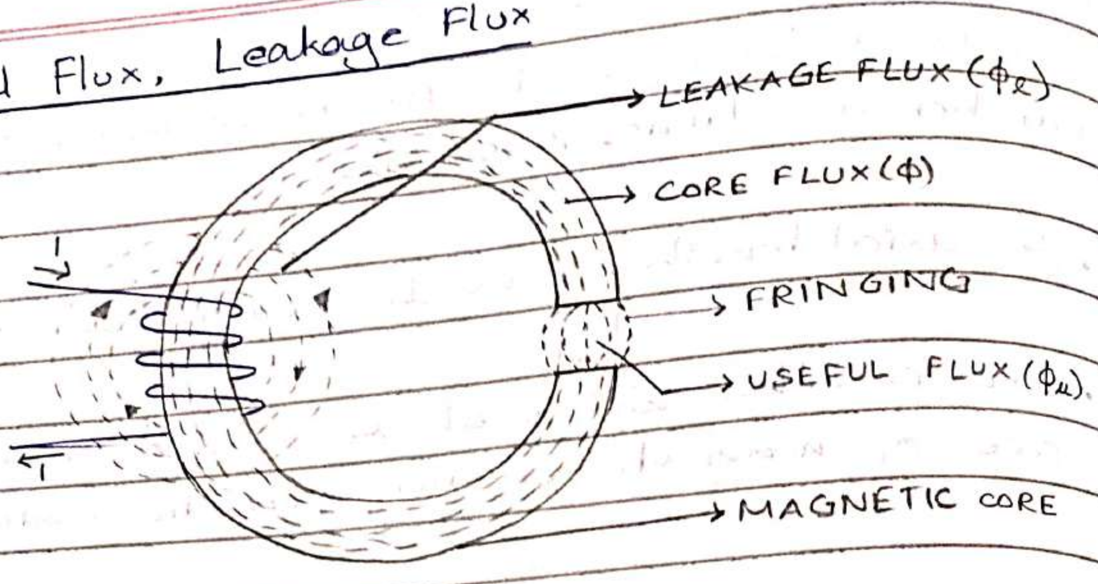
Magnetic field of Toroid

Formed when solenoid is bend in a circular and the are joined. All the loops of a wire which makes up a toroid contribute magnetic field inside the toroid in the same direction in the form of concentric rings.

- magnetic field inside and outside the toroid is zero.



Useful Flux, Leakage Flux



~~Leaked flux~~

- leakage flux - flux that does not follow the ~~path~~ desired path in a magnetic circuit

- when current is passed through a solenoid, ϕ is produced by it.

- most of the flux will set up in the core of the solen and passes through the magnetic material. i.e. iron core and remaining part of the flux pass through the circuit

- useful flux - flux in the air gap.
  → can be utilized for various useful applications and is denoted by ϕ_u.

- useful flux leaks through the air ~~area~~ surroundi the core of the coil and is not utilized for any work in magnet circuit.

- Type of flux which is not used for any useful ~~w~~ is called leakage flux and is denoted by ϕ_l

Leakage coefficient

The ratio of the total flux produced to the useful flux set up in the air gap of the magnetic circuit.

- a.k.a. leakage factor

- denoted by λ

$$\lambda = \frac{\phi \text{ (total flux)}}{\phi_u \text{ (useful flux)}}$$

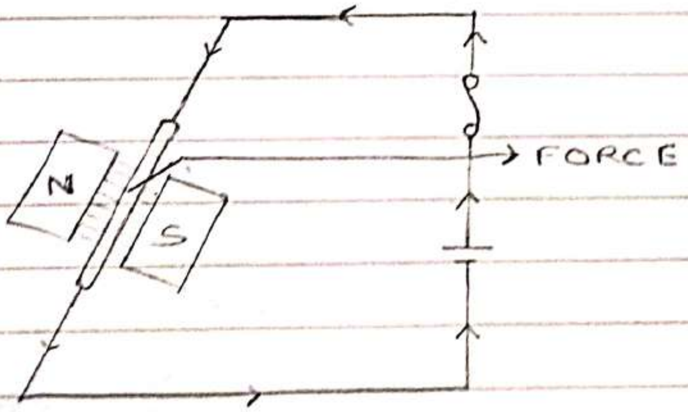
Fringing

ϕ_u that sets up in the air gap tends to buldge outward as lines of force repel each other when passing through non-magnetic material. This effect is fringing.

- tendency of ϕ to spread out at the edges of the air gap is magnetic fringing

Force on current carrying conductor placed in magnetic field

If a current carrying conductor is placed $\perp$ direction of magnetic field between the poles, it experiences a force which is $\perp$ both ~~perp~~ β direction of current and the magnetic field.



• when an electric current is passed through wire, the wire, if lifted upwards showing that upward force is acted on a current carrying cond on reversing the direction of the current, the wire moves downwards indicating the foree downwards.

• direction of force can be determined by fleming's left hand rule.

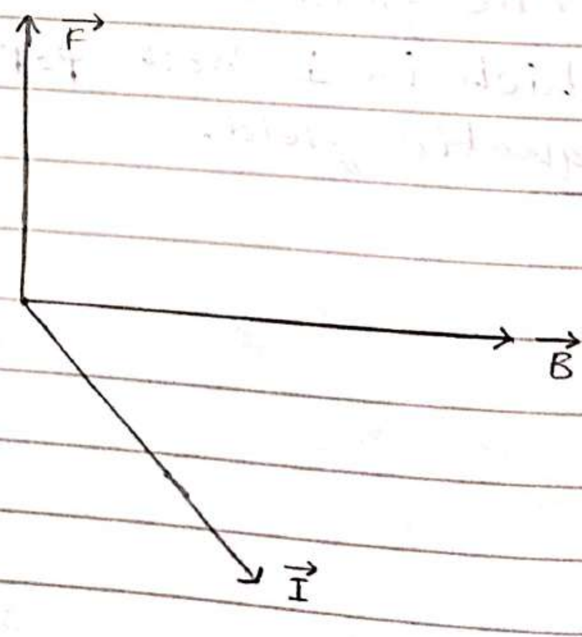
Fleming's Left Hand Rule

Stretch out the first finger, second finger and thumb of your left hand so that they are at right angles to each other.

• the first finger points to the direction of ma field i.e. N to S

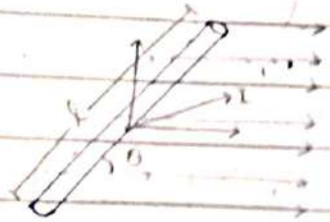
• the second finger i.e. middle finger points towards direction of current.

• thumb will point in the direction of motion of condu



• conductor lies at an angle θ with the ϕ, then the force experienced on the current carrying conductor is :

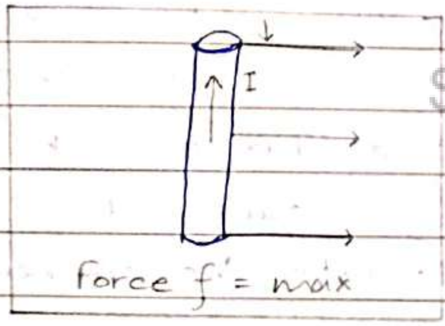
$F = BIl \sin\theta$

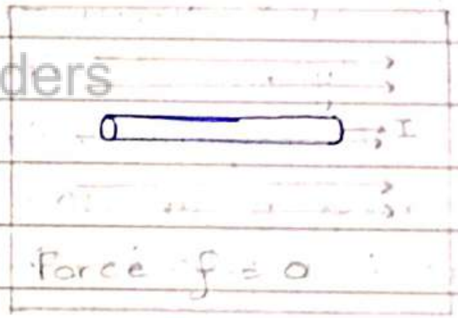


• force is max when $I \perp$ magnetic field ~~and ze~~

• force is zero when $I \parallel$ magnetic field

• θ = angle between I and magnetic field





Numericals

1. A flux density of 1T is required in the 2mm air gap radially cut in an iron ring of mean circumference of 100.2 cm. Calculate the mmf required assuming μ_r = 1000.

Ans. <u>Given</u>

$B = 1T$

length of air gap $= 2mm = 2 \times 10^{-3}$
$= 2 \times 10^{-3}$

length of ring $= 100.2$ cm $= 100.2 \times 10^{-2}$ m

mmf = ?

$$mmf = \frac{B}{\mu_0}\left(\frac{L_i}{\mu_r} + L_g\right)$$

$$= \frac{1}{4\pi \times 10^{-7}}\left(\frac{100.2 \times 10^{-2}}{10^{+3}} + 2\times 10^{-3}\right)$$

$$= \frac{1}{4\pi \times 10^{-7}}\left(100.2 \times 10^{-5} + 2\times 10^{-3}\right)$$

$$= \frac{100.2 \times 10^{-5} + 2\times 10^{-3}}{4\pi \times 10^{-7}}$$

$$= \frac{200.4 \times 10^{-8}}{4\pi \times 10^{-7}} = \frac{\cancel{200.4\times}\ 20.04}{4\pi}$$

$mmf = \cancel{1000}\ 2388.9$ AT.

Q. An iron ring has circular cross section of 4 cm in radius and circumference of 100 cm. The ring is uniformly wound with a coil of 700 turns. Calculate current required to produce a flux of 2 m Wb in the ring if $\mu_r = 900$ for iron. If a saw cut of 1 mm wide is made in the ring, calculate the current that will give same flux as in

1. 2m Wb

Ans. Given.

$R = 4\,cm = 4 \times 10^{-2}$

~~$\ell = 100\,cm = 1m$~~

$N = 700$

$A = \pi R^2 = 3.14 \times 16 = 50.24$

$l_i = 100\,cm = 1m$

$\phi = 2m\,Wb = 2\times 10^{-3}\,Wb$

$\mu_r = 900$

air gap length $l_g = 1\,mm = 0.001m$

$$NI = Hl = \frac{\phi}{\mu_0 \mu_r A}$$

$$700\,I = \frac{2\times10^{-3}}{4\pi\times10^{-7}\times900\times50.26\times10^{-4}}$$

$$I = 0.5025\ A$$

ii) $l_g = 0.001\ m$

$l_i = 1 - 0.001\ m$

$= 0.999\ m$

$\phi = 2m\ Wb$

$$NI = \frac{B}{\mu_0}\left[\frac{l_i}{\mu_r} + l_g\right]$$

$$700\,I = \frac{0.39}{4\pi\times10^{-7}}\left[\frac{0.999}{900} + 0.001\right]$$

$$I = \frac{0.39 \times 0.00211}{4\pi\times10^{-7}\times700}$$

$$I = 0.9359\ A$$

Electromagnetic Induction

Magnetic induction of an electromotive force (i.e. voltage) across an electrical conductor in changing magnetic field.

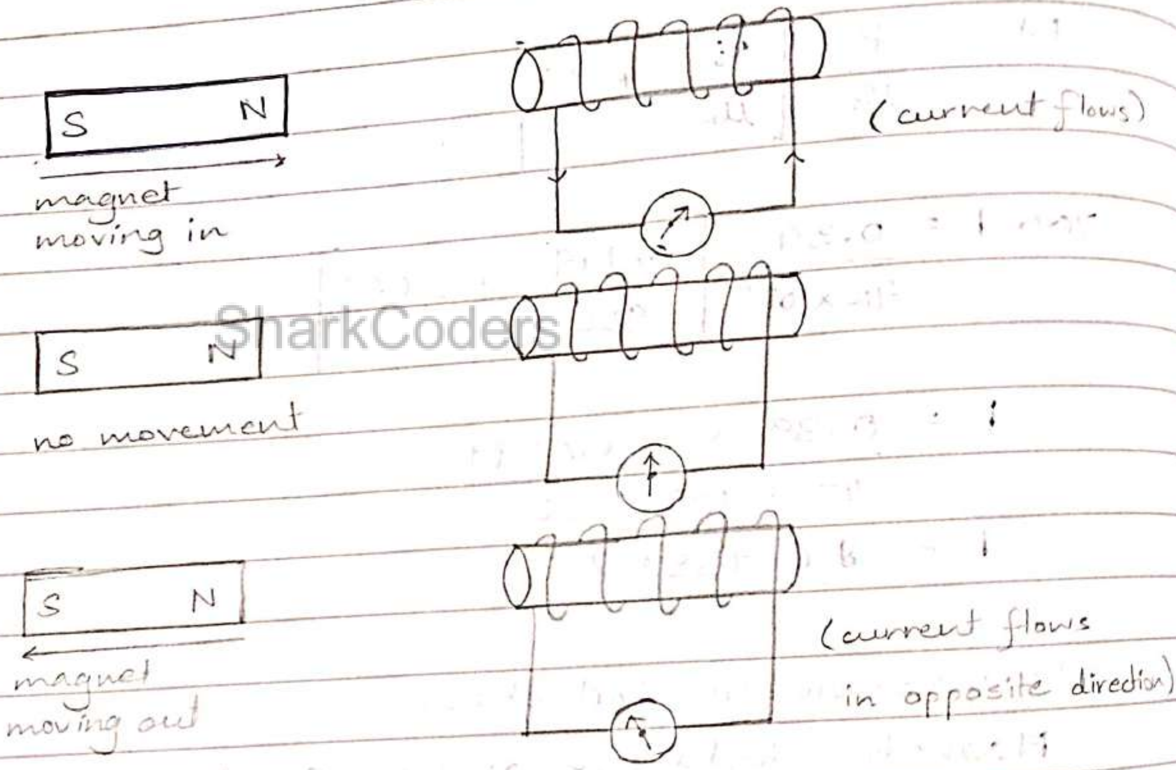
ELECTROMAGNETIC INDUCTION GENERATION :

- Static conductor in moving magnetic field
- Moving conductor in static magnetic field

- If the conductor forms a complete loop or circuit, current will flow in it.

- the emf and hence current in the conductor or cu will persist so long this change is taking place

- phenomenon of electromagnetic induction was first discovered by Micheal Faraday in 1831 when he moved a bar magnet through an electric coil.



Faraday's Laws of Electromagnetic Induction

1. First Law
   - states that whenever the ϕ linking a conductor or the coil changes, an emf is induced in it.

   - such an emf lasts as long as this change is taking place

2. Second Law

- magnitude of emf induced in a conductor or coil is directly proportional to the rate of change of flux ~~of~~ linkages where flux linkages = flux × no. of turns of coil

- induced emf e = rate of change of flux linkages

→ ϕ_1 = initial value of flux linked with coil
→ ϕ_2 = final value of flux linked with coil

- change in flux linkages = $N\phi_2 - N\phi_1$

- rate of change of flux induced = $\dfrac{\text{change in flux linkages}}{t}$

$$= \frac{N\phi_2 - N\phi_1}{t}$$

$$e \propto \frac{(N\phi_2 - N\phi_1)}{t}$$

$$e = k\frac{(N\phi_2 - N\phi_1)}{t}$$

$\because$ K = 1 in SI units

$$\Rightarrow e = \frac{N\phi_2 - N\phi_1}{t}$$

In differential form,

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

Direction of induced emf and current

The direction of induced emf and current in a closed circuit can be determined by
i. Lenz's Law
ii. Fleming's Right Hand Rule.

Lenz's Law

The direction of current induced in a conductor by changing magnetic field is such that the magnetic field created by the induced emf current opposses the initial changing magnetic field

- The emf ~~indued~~ induced in the conductor or coil is:

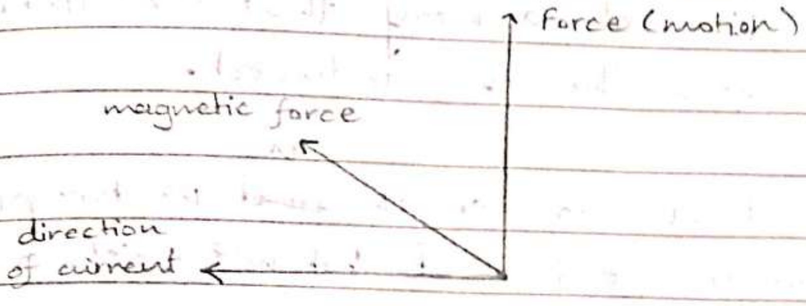
$$e = -N\frac{d\phi}{dt}$$

The -ve sign indicates that the induced emf opposes the cause producing it.

Fleming's Right Hand Rule

It is to find out the direction of induced current in a conductor which is moving $\perp$ the magnetic field

- the thumb, the fore finger, and middle finger are held so that they are at right angles to each other
- thumb shows the direction of motion of conductor
- fore finger shows the direction of magnetic field.
- middle finger shows the direction of induced current



• Application

→ direction of induced current within an electric generator is determined

<u>Statically / Dynamically induced emf</u>

An emf (electromotive force) is said to be induced when a flox linking with a conductor or coil changes.

Induced emf
- Statically induced
  - Self induced
  - Mutually induced
- Dynamically induced

Dynamically induced emf

Achieved by moving a conductor in stationary magnetic field in such a way that flux linking with conductor changes the emf induced.

Consider a conductor of length ~~and~~ l meters placed uniform magnetic field of B $Wb\,m^{-2}$ with a velocity of V ms^{-1}.

Suppose the conductor moves through a small distance dx in ~~dt~~ dt seconds.

Area swept by the conductor $= l\,dx\ m^2$

Flux cut $d\phi = Bl\,dx$ Wb

emf induced $e = N \dfrac{d\phi}{dt}$

$e = (BlV)$ Volts $\left[\because \dfrac{dx}{dt} = V\right]$

- max ϕ is cut when a conductor moves $\perp$ magnetic field, hence emf induced is max.

- if the conductor moves at an angle θ with respect to the magnetic field, then its velocity component is given by $V\sin\theta$.

  $\therefore$ emf induced $e = (BlV\sin\theta)$ V

- direction of induced emf given by fleming's right hand rule.

Statically induced emf :
Achieved when a conductor is stationary and the field is moving or changing, the emf is induced in the conductor.

Self induced emf :
- emf induced in a coil due to the change of its own flux linked with it.

Mutual emf:
- property of the coil that opposes any change in the amount of current flowing through it.

- $e = N \frac{d\phi}{dt} = \frac{d(N\phi)}{dt}$

As $\phi \propto I$ hence $N\phi \propto I$

$$e \propto \frac{di}{dt}$$

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

- magnitude of self induced emf $\propto$ rate of change of current in the coil

- L = constant of proportionality
  = self-inductance
  = coefficient of self-inductance
  = inductance of coil

- $e = L\left(\frac{dI}{dt}\right) = \frac{d.LI}{dt}$ ——— (1)

$e = N\left(\frac{d\phi}{dt}\right) = \frac{d(N\phi)}{dt}$ ——— (2)

From (1) and (2),

$LI = N\phi$

$L = \frac{N\phi}{I}$ Henry

OR

As $\phi = \frac{mmf}{S} = \frac{NI}{S}$

$L = \left(\frac{N}{I}\right)\left(\frac{NI}{S}\right)$

$= \frac{N^2}{S} = N^2 P$ $\left[S = \frac{l}{\mu_0 \mu_r a}\right]$ [P = permeance

$L = \frac{N^2 \mu_0 \mu_r a}{l}$

[N = turns

l = length of conductor

I = current

S = reluctance

a = area of coil]

- self-inductance (L) can also be expressed as

→ $L = \frac{e\,di}{dt}$ and $L = \frac{N\phi}{I}$

→ $L = \frac{N^2 a \mu_0 \mu_r}{l}$

~~Mu~~ Mutually induced emf:

- emf in the coil due to the change of ϕ produced by another neighboring coil thinking to it.

- e_m = rate of change of flux linking with the coil B

  $\frac{dI_1}{dt}$ = rate of change of current in coil A

$$e_m \propto \frac{dI_1}{dt}$$

$$e_m = M\frac{dI_1}{dt} \Rightarrow M = \frac{e_m}{\frac{dI_1}{dt}} \quad \text{--- (1)}$$

- M = mutual inductance between 2 coils. (Henry)

  $e_m = 1V$

  $\frac{dI_1}{dt} = 1\,As^{-1}$

- $$e_m = \frac{d(MI_1)}{dt} \quad \text{--- (2)}$$

$$\cancel{e_m = \frac{d(N_2\phi)}{dt}}_2 \quad e_m = \frac{d(N_2\phi_{12})}{dt} \quad \text{--- (3)}$$

Equating (2) and (3),

$$MI_1 = N_2\phi_{12}$$

OR

$$M = \frac{N_2\phi_{12}}{I_1}\ H \quad \text{--- (4)}$$

where ϕ_{12} = ϕ linked to coil B due to change of current in the coil A.

- value of mutual inductance (M) depends upon
  - → no. of turns in secondary/neighboring coil.
  - → cross-sectional area
  - → closeness of the two coils

$$\phi_{12} = \frac{mmf}{S}$$

$$= \frac{NI}{\frac{l}{\mu_0 \mu_r a}}$$

Substituting (4),

$$M = \frac{N_1 N_2}{\frac{l}{\mu_0 \mu_r a}} \quad \text{--- (5)}$$

- mutual inductance $\propto \frac{1}{S}$

Coefficient of coupling

The fraction of ~~magnet~~ ϕ produced by the cur in one coil that links with the other coil.

- done between two coils.

- denoted by k. i.e. gives the information of flu which is linked with the 2 coils.

- when $k=1$, the ϕ produced by one coil is compl linked with the other coil; it is magnetically tig coupled.

- when $k=0$, ϕ produced by the coil does not l at all, with the other coil i.e. magnetically 130(a

- value of k varies between 0 and 1.

- consider 2 magnetic coils 1 and 2 having N_1 and N_2 turns respectively, current I_1 flows through coil 1 ϕ ~~tike~~ link with coil 1. If coefficient of coupling between the two coil is K, then the ϕ linked with coil 2 is $K\phi_1$.

$$L_1 = \frac{N_1 \phi_1}{I_1} \quad \text{and} \quad M_{12} = \frac{N_2 \phi_{12}}{I_1}$$

$$M_{12} = \frac{N_2 K \phi_1}{I_1} \qquad [\phi_{12} = K\phi_1]$$

- consider coil 2 in which current I_2 produces ϕ_2. As k is the coefficient of coupling between two coils. The flux linked with coil 1 will be $K\phi_2$.

$$L_2 = \frac{N_2 \phi_2}{I_2} \quad \text{and} \quad M_{21} = \frac{N_1 K \phi_2}{I_2}$$

$$M_{12} = M_{21} = M$$

Multiplying the mutual inductance between 2 coils

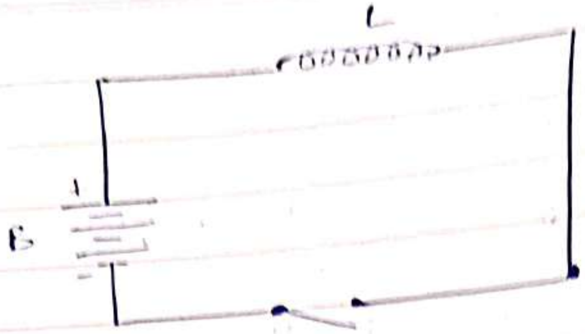
$$M \times M = \left(\frac{K^2 \phi_1 N_1}{I_1}\right)\left(\frac{\phi_2 N_2}{I_2}\right)$$

$$M^2 = K^2 L_1 L_2$$

$$\Rightarrow K = \frac{M}{\sqrt{L_1 L_2}}$$

Energy stored in a magnetic field

Consider an inductor connected to a DC source. The inductor is equivalent to inductance L in series with a small resistance R.



When the switch S is on, the current flowing in the circuit ~~a~~ rises gradually from zero to its final value, and the magnetic field is established. During this rise of current, an emf is induced across the conductor due to change in flux linkages. The self induced emf induced across L is:

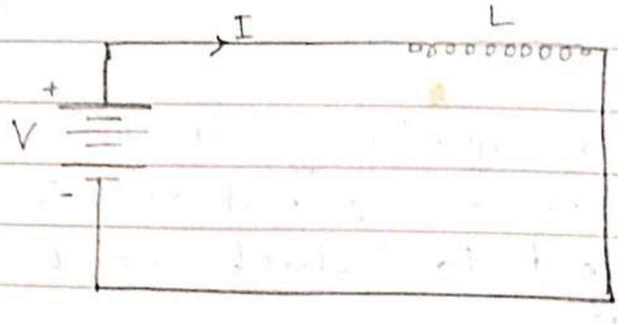
$$E = L\frac{dI}{dt}$$

- After the magnetic field is established and current has reached its maximum value any further energy given to it is dissipated as heat.

- induced voltage across L opposes the applied V.

- electrical energy must be supplied to overcome this ~~problem~~ position.

- supplied energy is stored in the magnetic field.



• The energy supplied to the circuit is spent in two ways.

1. A part of supplied energy is utilized to meet I^2R loss that can't be ~~removed~~ ~~removed~~ recovered.

2. The remaining part is stored in magnetic field, when the field collapses due to the decrease in current, the stored energy is returned to the circuit.

instantaneous power $= p = ei$

$$p = Li \frac{dI}{dt}$$

∴ work done to overcome the opposition for a short time interval of time dt is stored in magnetic field

$$dW = P \cdot dt = Li\left(\frac{dI}{dt}\right) \cdot dt = Li\, dt$$

• total energy stored in magnetic field from the time the current is zero to its maximum steady value of I amperes is

$$W = \int_0^I LI \cdot dt$$

• energy stored in the magnetic field $E = \frac{LI^2}{2}$ J

Energy stored per Unit

• Energy stored $= E = \frac{LI^2}{2}$

Substituting $L = \frac{N\phi}{I}$ in the above eq^n,

$$E = \left(\frac{1}{2}\right)\frac{N\phi I^2}{I} = \frac{N\phi I}{2}$$

$$N \cdot I = mmf = Hl \qquad [\because \phi = B \times A]$$

$$E = \frac{1}{2} H l B \cdot a$$

- $l \times a$ = volume of magnetic field in (m^3).

$\therefore$ energy stored per unit volume.

- $E = \dfrac{HB}{2} \quad J\,m^{-3}$

$E = \dfrac{\mu H^2}{2} \quad J\,m^{-3} \qquad [\because B = \mu H]$

$E = \left(\dfrac{1}{2}\right)\dfrac{B^2}{\mu} \quad J\,m^{-3}$ ...in a medium

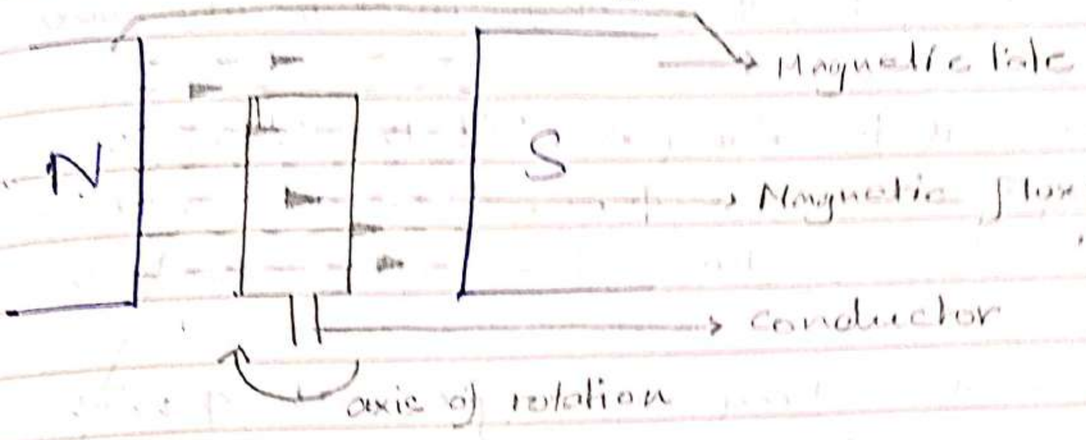
$\mu = \mu_0 \mu_r \qquad [\mu_r = 1 \text{ for air}]$

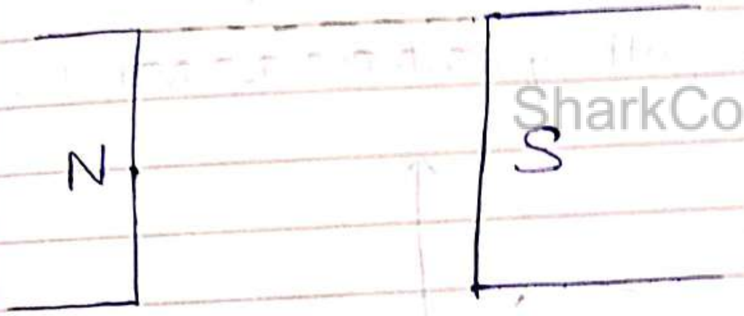
$E = \dfrac{B^2}{2\mu_0} \quad J\,m^{-3}$ ...for air

UNIT IV

AC Fundamentals

Generation of AC supply





AC Generator

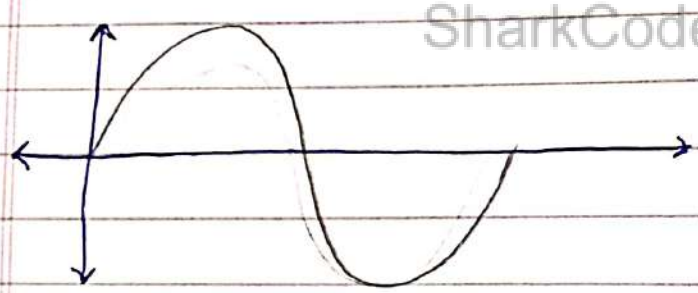
An AC generator uses the principal of the ~~electr~~ ~~-agnetic induction~~ electromagnetic induction. It st that when a current carrying conductor cuts the magnetic field, then 'emf.' used in the conductor.

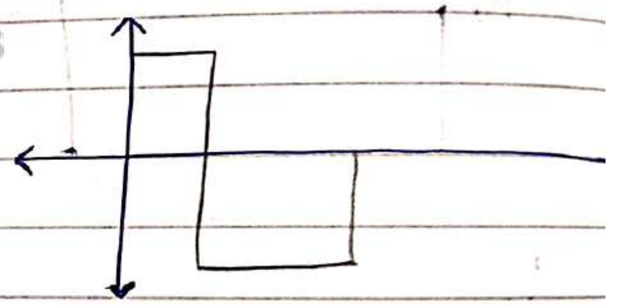
When coil is along ~~x~~ XX' ($\perp$ the line of flux), flux linking with coil = ϕ_m. When coil is along YY' ($\parallel$ the line of flux) flux linking with coil = 0

When coil making an angle ~~with~~ ϕ with x-ax XX', flux linking with coil = $\phi = \phi_m \cos \omega t$ [

Wave form

~~#~~ A graph between alt. quantities against time





Istantaneous value

The valoe of an alternating quantity at a particular instant of a given time.

- generally denoted by small letters

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

- . .

Average of all instantaneous values of alternating quantities over a half-cycle.

Peak value / amplitude / max value

Maximum value (either +ve or -ve) attained by an alternating quantity in one cycle generally denoted by capital letters.

Root Mean Square Value (rms value)

Equivalent DC current which when flowing through a given circuit for a given time produces same amount of field. as produced by an AC when flowing through same circuit for the same time.

Frequency

The number of cycles per second.

- ~~f~~ unit is in Hz.

- denoted by f

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

Time period (T)

Time taken to complete one cycle.

- denoted by T.

- unit in secs.

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

Peak Factor (kp)

The ratio of maximum value to rms value

- $kp = \frac{I_m}{I_m/\sqrt{2}} = 1.414$

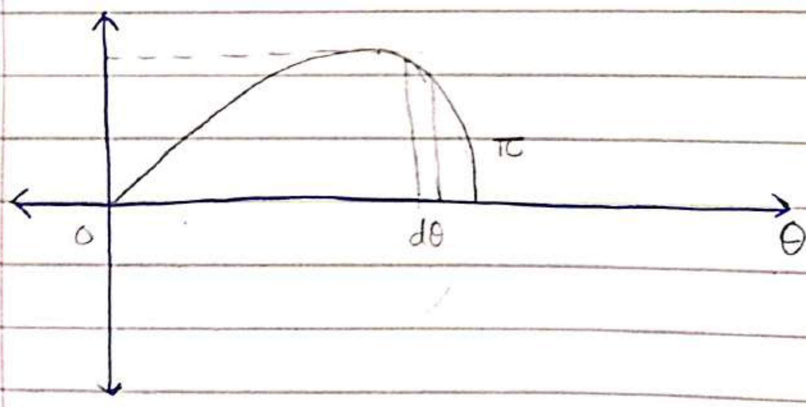
Form Factor (kf)

The ratio of rms value to average value.

- $kf = \frac{\text{rms value}}{\text{avg value}} = \frac{I_m/\sqrt{2}}{2 \cdot I_m/\pi}$

- $kf = 1.11$

Derivation of Average Value (5 m)



$I = I_m \cdot \sin\theta$

$I_{avg} = \int_0^\pi \frac{I\, d\theta}{d\theta}$

$= \frac{\int_0^\pi I_m \sin\theta\, d\theta}{\int_0^\pi d\theta}$

$$= \frac{\int_0^{\pi} I_m \sin\theta \, d\theta}{\pi - 0}$$

$$I_{avg} = \frac{I_m}{\pi} \int_0^{\pi} \sin\theta \, d\theta$$

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

$$= \frac{I_m}{\pi} \left[-\cos\pi - (-\cos 0)\right]$$

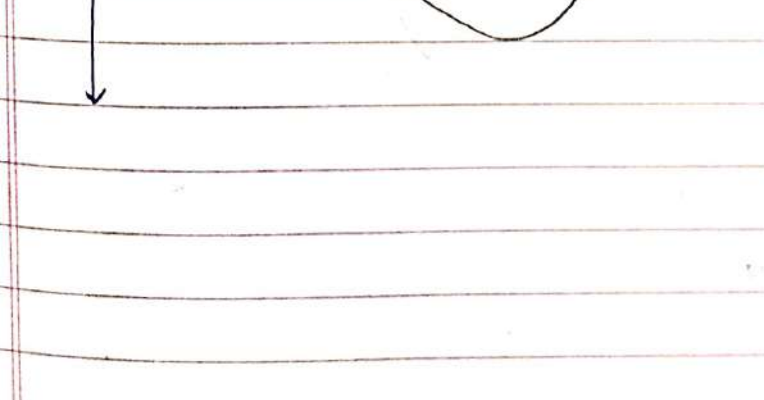
$$= \frac{I_m}{\pi} \left[+1 - (-1)\right]$$

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

$I_{avg} = 0.637 \, I_m$

average value = 0.637 × max value

Derivation of rms value



$I = I_m \sin\theta$

mean of the square of the instantaneous values of current over complete cycle is

$$= \int_0^{2\pi} \frac{I^2 \cdot d\theta}{d\theta}$$

$$I_{rms} = \sqrt{\int_0^{2\pi} \frac{I^2 \cdot d\theta}{d\theta}}$$

$$I_{rms} = \sqrt{\frac{\int_0^{2\pi} I_m^2 \cdot \sin^2\theta \cdot d\theta}{\int_0^{2\pi} d\theta}}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{2\pi} \sin^2\theta \cdot d\theta}$$

~~cos 2θ =~~ We know that:

$$\cos 2\theta = 1 - 2\sin^2\theta$$

$$\sin^2\theta = \frac{1-\cos 2\theta}{2}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{4\pi}\int_0^{2\pi} \frac{1 \cdot \cos 2\theta}{1}}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left(\theta - \frac{\sin 2\theta}{2}\right)_0^{2\pi}}$$

$$= \sqrt{\frac{I_m^2 (2\pi)}{4\pi}}$$

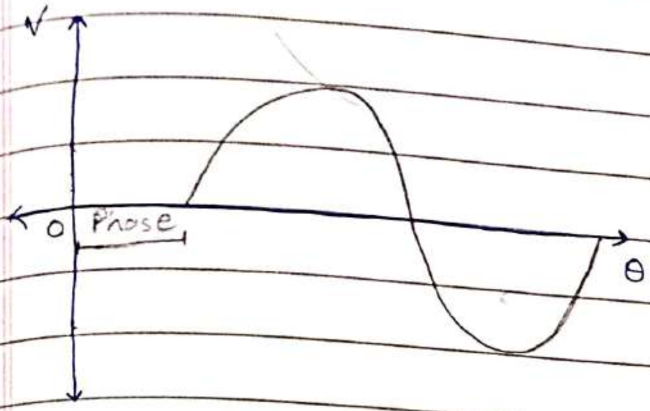
$$= \sqrt{\frac{I_m^2}{2}}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$I_{rms} = 0.707\ I_m$ OR

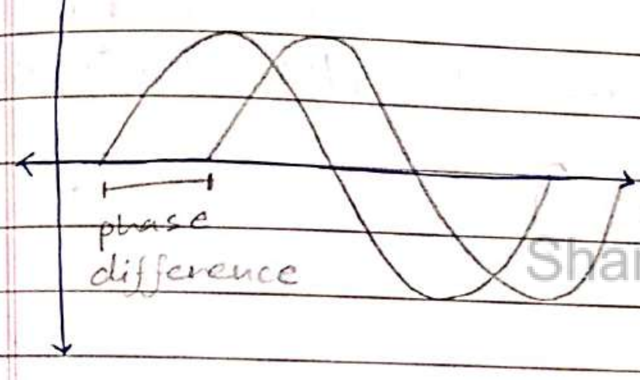
$V_{rms} = 0.707\ V_m$

Phase



- phase tells about position and direction of alternating quantities.

Phase difference



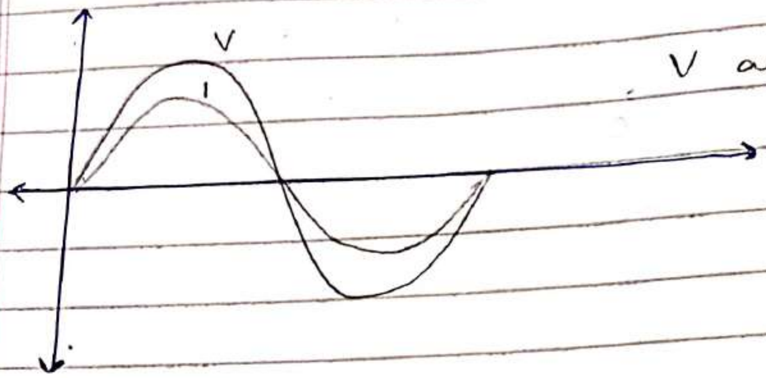
- the difference between the ~~plas~~ phases of 2 alternating quantities.
- angular displacement (θ) between ~~two~~ 2 zero values / 2 max. values of 2 alternating quantities having same wavelength (λ).

Phasor Diagram

- graphical representation of phasor ~~is known a~~
- angle between 2 phases is phase angle.

In phase quantities

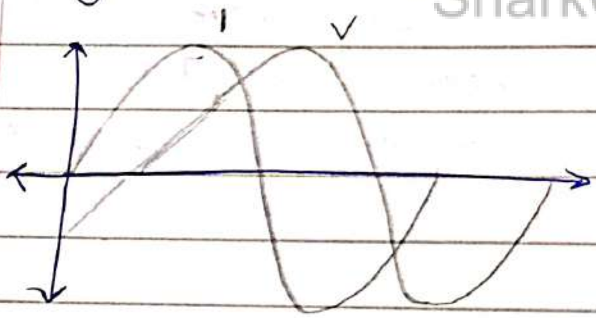
- when 2 alternating quantities have same phase angle, they are said to be in-phase with each other.
- 2 waveforms are said to be in phase when they begin and end simultaneously.



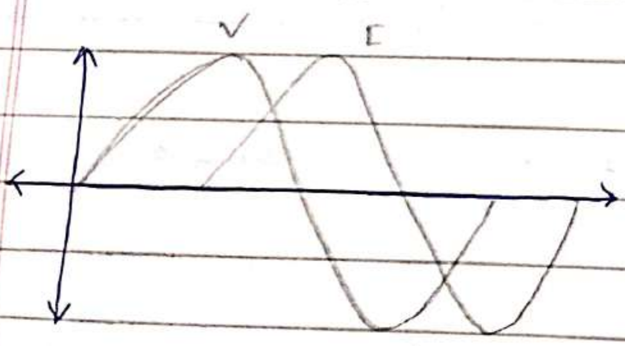
V and I are in phase

- the term lead and lag —— are used to describe the relative positions in time of 2 sinusoidal alternative quality that are not in phase the one is that is ahead in time

Lag and Lead Quantities



I is leading
V is lagging



I is

classmate

Date
Page

Q. A coil of 100 turns is rotated at 1000 RPM in a uniform field having density 4000 T. The axis of rotation is at right angle to the direction of field, the area per turn is 200 mm². Calculate :

i) frequency

ii) T

iii) max value of generated emf

iv) value of generated emf when the coil is rotated by 50°

Ans. Given

$N = 100$

no. of revs = 1000

$B = 4000\ T$

$a = 200\ mm^2$

$= 200 \times 10^{-6}\ m^2$

i) frequency $= \frac{\text{no. of revs}}{60} = \frac{1000}{60} = 16.67\ Hz$

ii) time period $= T = \frac{1}{f} = \frac{1}{16.67} = 0.06$

iii) $E_m = N \cdot B \times a \times 2\pi f$

$= 100 \times 4000 \times 200 \times 10^{-6} \times 2\pi \times 16.67$

$= 16\pi \times 16.67 \times 10^{7-6}$

$= 837.5008 \times 10$

$= 8375.008$

iv) $e = e_m \sin\theta$

$= 8375.008 \sin\theta$

$= 4189.627$

Q. Find the amplitude, then phase, then time period and frequency of the given eqⁿ.

$v(t) = 15 \sin(50t + 20^\circ)$

Ans. $v(t) = V_m \sin(\omega t + \theta)$

amplitude = 15

phase = 20

Time period $= \frac{2\pi}{\omega} = \frac{2 \times 3.14}{50} = 0.1256$

Frequency $= \nu = \frac{1}{T} = \frac{1}{0.1256} = 7.91$ Hz.

Q. A certain waveform has a form factor of 1.2 and peak factor 1.5. If the max value is 100, find the rms value and the average value.

Ans. Given

$k_f = 1.2$

$k_p = 1.5$

max value = 100

Solⁿ

$k_f = \frac{\text{max value}}{\text{rms value}}$

$1.2 = \frac{100}{\text{rms value}}$

rms value $= \frac{100}{1.5} = 66.67$

$k_f = \frac{\text{rms value}}{\text{avg value}}$

$$k_p = \frac{\text{max value}}{\text{rms value}}$$

$$\text{rms value} = \frac{\text{max value}}{k_p}$$

$$k_f = \frac{\text{rms value}}{\text{avg. value}}$$

k

$$\text{avg value} = \frac{\text{rms value}}{k_f}$$

$$= \frac{66.66}{1.2}$$

Q. A volt is represented by sine wave and has max value of 100V. Calculate its rms value and average value.

~~Given~~

Q. A sinosidal alternating current has a max value of 10 A. Find the instantaneous value at.

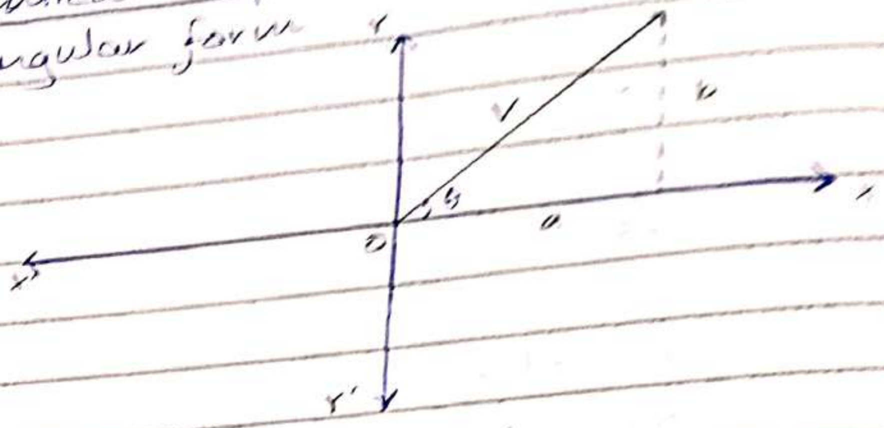
a) 1/12 cycle.
b) 1/6 cycle
c) 1/2 cycle
d) 5/8 cycle
e) 3/4 cycle

Q. An AC is given by $I = \cancel{14} \; 14.14 \sin 377t$. Find
i) rms value of current
ii)
iii) instantaneous value of current when T is 3 msecs

NOTE :- $2\pi f$

Mathematical Representation of phasors

1. Rectangular form



- $V = a + jb$

  OR

  $A = a + jb$

- magnitude of phasor = $V = \sqrt{a^2 + b^2}$

- $\tan\theta = \dfrac{b}{a}$

  $\theta = \tan^{-1}\left(\dfrac{b}{a}\right)$

2. Polar Form

- $V = V \angle \theta$

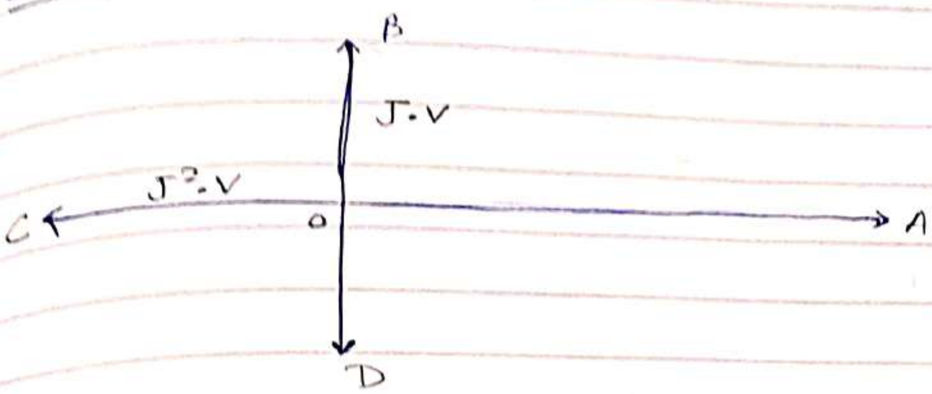
  $A = r \angle \theta$

  $\therefore V = V \angle \pm \theta$ (General form of phasor)

- V - magnitude of phasor

  θ - phasor angle

J-operator



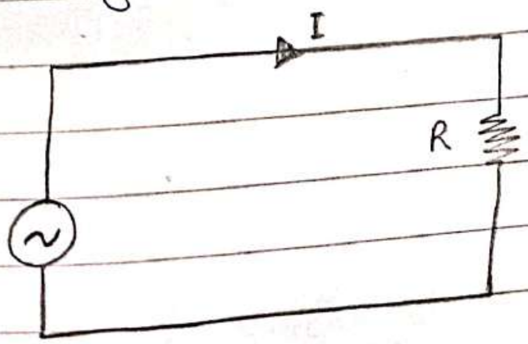
- $OB = J \cdot V$
  $OC = J^2 V$
  $OC = -V$

- $J^2 V = -V$
  $J^2 = -1$
  $J = \sqrt{-1}$

- $J = \sqrt{-1}$
  $J^2 = -1$
  $J^3 = -J$

AC Circuit Analysis

1. AC through pure resistance
   - purely resistive circuit

- 

$V = V_m \sin \omega t$

According to ohm's law,

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

$I = I_m \sin \omega t$ where $I = \frac{V_m}{R}$

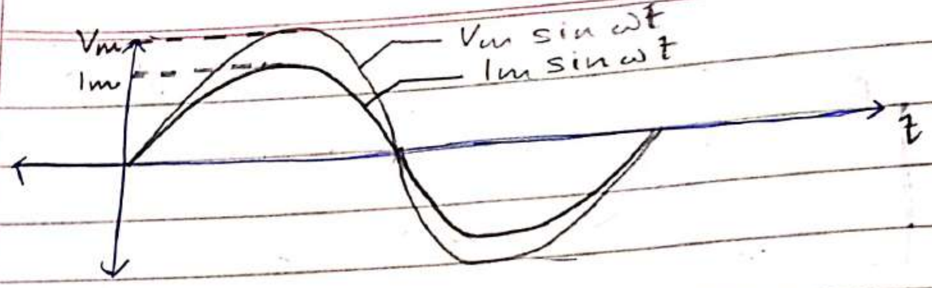


Fig. b

instataneous power $= V \cdot I$

$= V_m I_m \cdot \sin^2 \omega t$

$P = \dfrac{V_m I_m (1 - \cos 2\omega t)}{2}$

Power for whole cycle $= \dfrac{V_m \cdot I_m}{2}$

$= \dfrac{V_m}{\sqrt{2}} \cdot \dfrac{I_m}{\sqrt{2}}$

$= V_{rms} \cdot I_{rms}$

$= V \cdot I$

- V = instantaneous volt
  V_m = maximum value
  V_R = Voltage across resistance.

Fig. c

2. A.C. through pure inductance
- purely inductive circuit

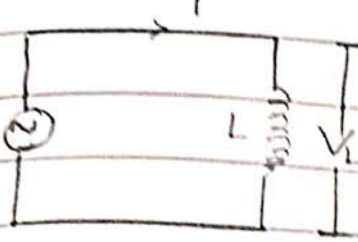


Fig. a : purely inductive c

- The voltage eq^n

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

- $$e_b = -L \frac{di}{dt}$$

$$V = -eb$$

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

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

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

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

On integrating,

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

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

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

$$= \frac{V_m}{\omega L} \cdot \sin(\omega t - \pi/2)$$

$$= \frac{V_m}{X_L}(\sin(\omega t - \pi/2))$$

$$I_m = \frac{V_m}{\omega L}$$

- $\omega L = X_L = I_m \sin(\omega t - 90)$

3. Waveform and phasor diagram

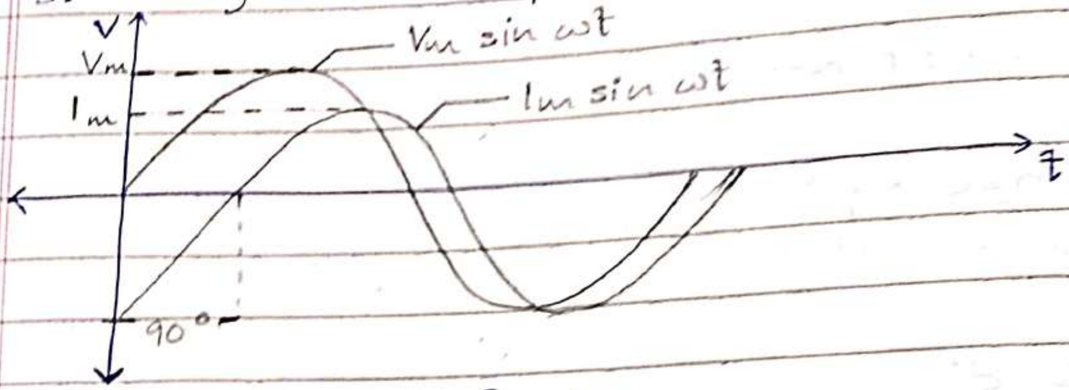


Fig. b

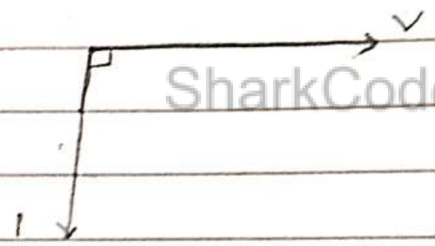
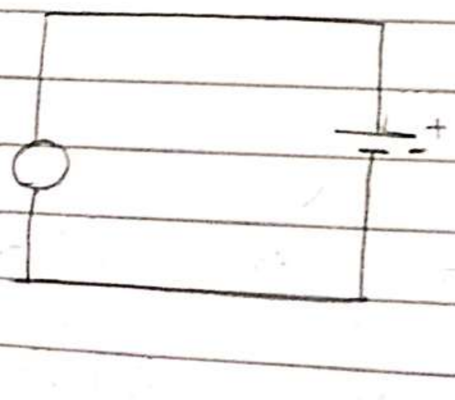
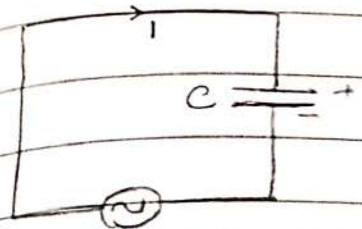


Fig. c

3. AC through capacitor
- purely capacitive circuit



Purely capacitive circuit



$v = \sin \omega t \cdot v_m$

Fig.(a): purely capacitive circuit

$V = V_m \cdot \sin(\omega t)$

$q = C \cdot V$

$= C \cdot V_m \sin \omega t$

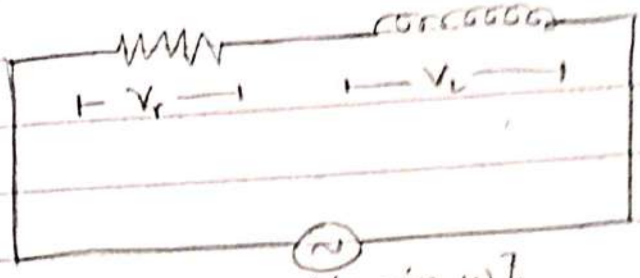
∴ The current is given by capacitor.

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

$=$

Series R-L circuit

$V = V_R + V_L$



$V = V_m \sin \omega t$

Fig. (a):

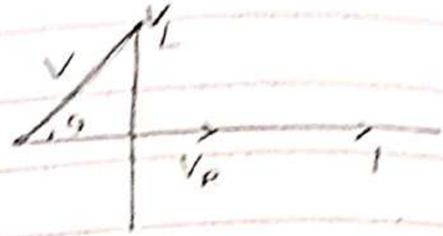


Fig. (c): Phasor Diagram

Consider the circuit containing resistance R and reductance L in series as shown in figure a.

Let V = supply voltage
I = circuit current
V_R = voltage across resistance R
V_L = voltage across conductance L

We know that,
a purely resistive circuit, both V and I, ~~are~~ are in ph
and a purely inductive circuit with current I and
voltage V by 90°

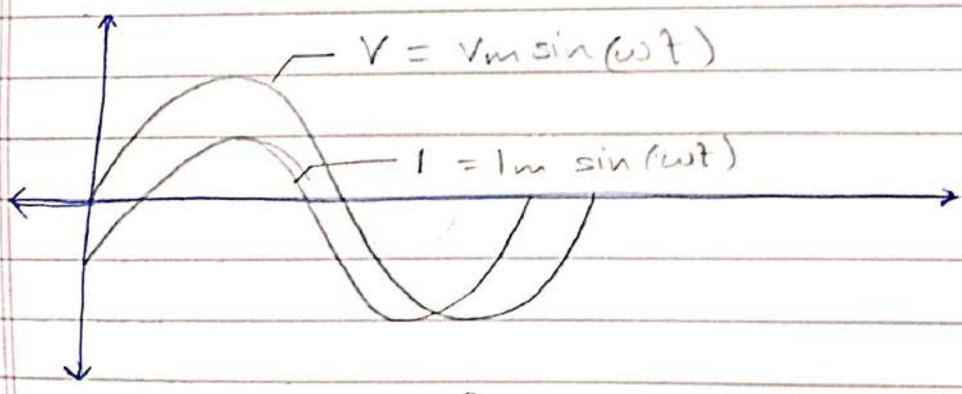
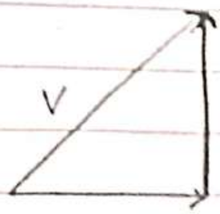


Fig. (b): Wave form

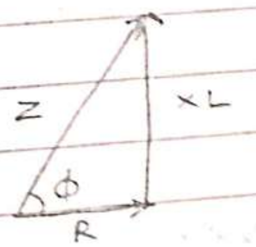
Voltage Triangle



$$V = \sqrt{V_R^2 + V_L^2}$$
$$= \sqrt{(I \cdot R)^2 + (I \cdot XL)^2}$$
$$= I\sqrt{R^2 + XL^2}$$

$$V = I \cdot Z$$
$$Z = \sqrt{R^2 + XL^2}$$

Impedance Triangle



$\cos\phi$ = power factor

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

$$Z = \sqrt{R^2 + XL^2}$$
$$\therefore \tan\phi = \frac{XL}{R}$$

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

co

Active Power

The power that actually is consumed or utilized in an AC circuit.

- a.k.a. real power / true power.
- denoted by E
- measured in ~~Hz, kHz, MHz~~ W, kW, MW
- $P = V \cdot I \cdot \cos\phi$

Reactive Power

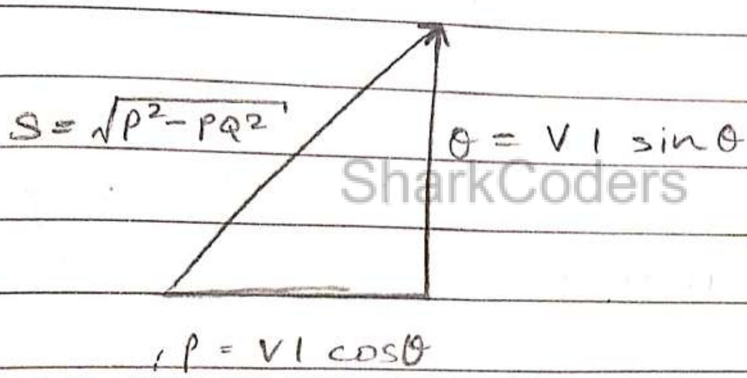
Power which is associated with reactive component (inductance, capacitance).

- denoted by Q
- measured in VAR (Volt, ampere, reactive power), kVAR, MVAR
- $Q = V \cdot I \cdot \sin\phi$

Apparent Power (S)

- $S = \sqrt{P^2 + Q^2}$
- VA, kVA, MVA

Power Triangle


$S = \sqrt{P^2 - PQ^2}$
$Q = VI \sin\theta$
$P = VI \cos\theta$

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UNIT V

Phrase Sequence

The sequence in which the 3 phases reach their max value. Normally phase sequences ~~are~~ R, Y, and

Importance :

- direction of ~~p~~ rotation of 3 phase machine depends on phase sequence. ~~if the~~

- If the phase sequence is changed (e.g.: R-B-Y), the direction of rotation will be reversed.

- therefore, in order to avoid such things, the phase sequence of R-Y-B is always maintained.

Balance load

It is that in which magnitude of all impedences conn-ected in ~~the each~~ load are equal and phase angles of them are also equal and of the same type (~~R~~ resistive, inductive, and capacitive)

Unbalanced Load

If the load doesn't the condition of balance, then it is an unbalanced load.

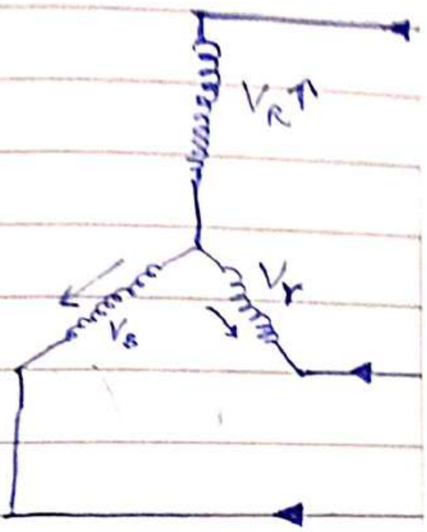
- magnitude and phase angle ~~are~~ differ from each other.

- Balance load ☆
- Unbalanced load
- condition of balance
- 3 phase ??
  3 wire connections
- Neutral node?
- 2 phase
  4 wire
- Earthing vs. neutral

Types of connections

1. Star / Wye (Y)
2. Delta / Mesh (Δ)

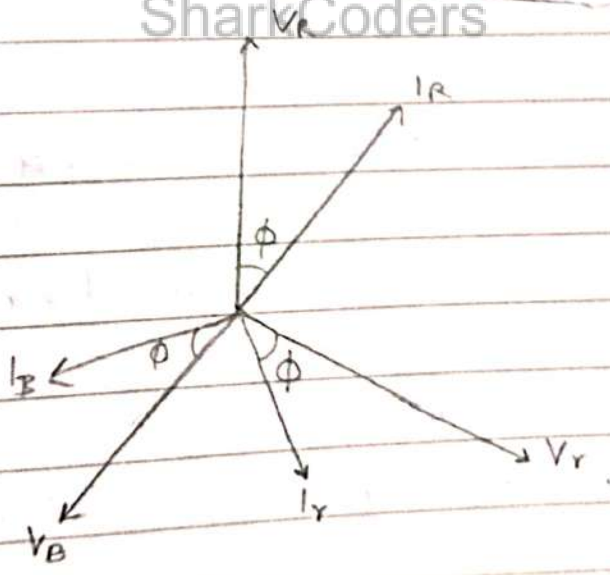
Star connections / Star connected load



IL = Iph

VL and VPH power

generation of 3 phasor



Fig(b) :- Vector diagram.

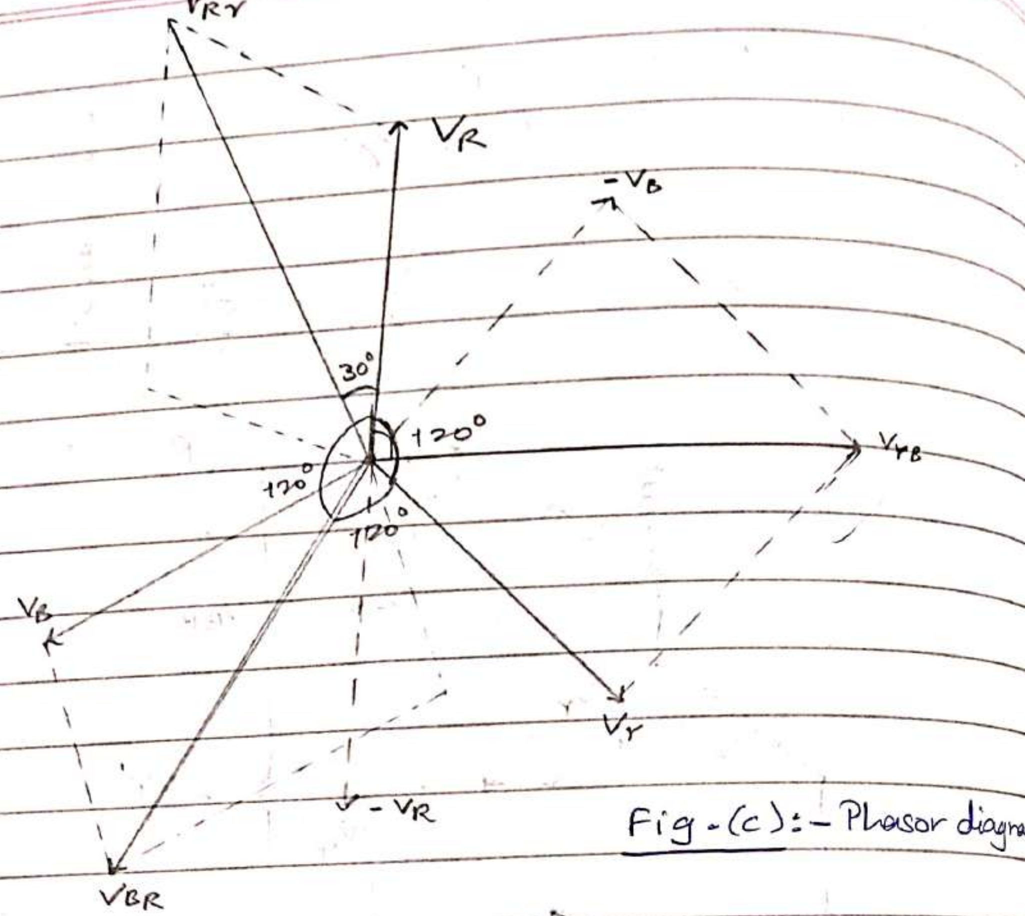


Fig.-(c):- Phasor diagra

- Consider a ~~loop con~~ load connected in star man which consists of 3 phases R, Y, and B.

- Voltage induced in each winding is phase voltage

- Current induced in each winding is phase current

- Voltage induced - V_{ph}
  Current induced - I_{ph}

- The voltage available between any pair of terminals is line voltages

- Current flowing in each line is line current.

- As seen from fig.(a), in this form of interconnections there are 2 phase winding between each pair of terminals but since ~~they are~~ thier similar ends have

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joined together, they are in opposition.

. The rms value of potential difference is given by the vector difference of 2 phase emf and instantaneous value of potential difference is the arithmetic difference of the 2 phase emf.

. Vector diagram for phase voltages and currents in star connections as shown in fig. b.

→ the system is balanced.

~~the system is bal~~

$\therefore V_R = V_Y = V_B = V_{Ph}$ = phase voltage.

. the line voltage V_{RY} between line 1 and 2 is the vector difference of V_R and V_Y.

$V_{RY} = V_R - V_Y$

. the line voltage V_{YB} between line 2 and 3 is the vector difference of V_Y and V_Y.

$V_{YB} = V_Y - V_B$

. the line voltage V_{BR} between line 1 and 3 is the vector difference of V_B and V_R.

$V_{BR} = V_B - V_R$.

Line current and phase current:

It is seen from fig. (a) that each line is in series with its individual phase winding. Hence, line current in each line is the same as the current in phase winding to which the line is connected.

... in line 1 is I_R

... t in

current in line 2 is I_Y

current in line 3 is I_B.

$\Rightarrow I_R = I_Y = I_B = I_{ph}$ = phase current.

$\boxed{\therefore\ I_L = I_{ph}}$

Line voltage and phase voltage

$V_{RY} = V_R - V_Y$

$V_R = V_Y = V_B = V_{ph}$

$V_{RY} = 2\ V_{ph} \cdot \cos(60/2)$

$= 2\ V_{ph} \cos(30)$

$= \cancel{2} \cdot V_{ph} \left(\frac{\sqrt{3}}{\cancel{2}}\right)$

$V_{RY} = \sqrt{3}\ V_{ph}$

$V_{RY} = V_{YB} = V_{BR} = V_L = \sqrt{3}\ V_{ph}$

Power

Total active power = $3 \times$ phase power

$= 3\ V_{ph}\ I_{ph} \cos\theta$

In star connection,

$I_{ph} = I_L$

$V_L = \sqrt{3}\ V_{ph}$

$\therefore V_{ph} = \frac{V_L}{\sqrt{3}}$

$$P = 3 \times \frac{V_L}{\sqrt{3}} \times I_L \cos\phi$$

$$P = \sqrt{3} V_L I_L \cos\phi$$

The potential difference between line 1 and 2 = V_{RY} = $V_R - V_Y$

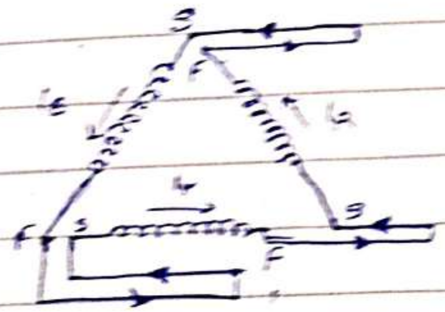
Hence V_{RY} is found by compounding V_R and $-V_Y$ and its value is given by the diagonal of parallelogram of figure C.

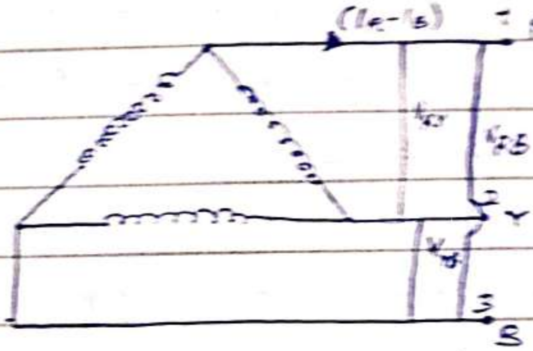
The angle between V_R and $-V_Y$ is 60.
Hence, $V_Y = V_R = V_B = V_{ph}$

- line voltages are $120°$ apart.
- line voltages are $30°$ ahead of thier respective phase voltages.
- angle between line currents and corresponding line voltages is $30 + \phi$ with current lagging.

<u>Power</u>
Total active power or true power in the circuit is the sum of 3 phase power.

Delta connected load





In this form of interconnection the dissimilar ends of 3-phase windings are joined together i.e. the starting end of phase is joined to the finishing end of other phase ~~as~~ and so on as shown in fig A.

~~Vato~~

Line Voltage and Phase voltage

- seen from figure B, there is 3 one phase winding completely included between any pair of terminals
- hence in delta connection the voltage between any pair of line is equals to the phase voltage of phase winding connected between the two line considered.

~~connected between the two~~

- Since phase seq. is RYB, calling the voltage between line 1 and 2 V_{RY} and 2 and B i.e. V_{BY}

- We find that V_{RY} leads V_{YB} by $120°$.

- V_{YB} leads V_{BR} by $120°$ or as shown in fig. C.

$V_{RY} = V_{YB} = V_{BR} = V_L$ (line voltage)

$V_L = V_{ph}$ in Δ connection

Losses in Transformer

1. Core losses (constant losses)

2. Copper losses (variable losses) (I^2R)

$$I_1^2 R_1 + I_2^2 R_2$$

3. Hysterisis loss (W_h)

4. Eddy current (W_e).

Since transformer is a static device, it does ~~~~
It ~~does~~ contain rotation losses. Hence, major losses that occur on load can be divide into 2 groups: Core losses and Cu losses.

1. Core losses

The core flux in a transformer remains practically constant for all loads. Therefore these losses are constant at any load.

- sum of 2 losses, hysteresis loss and eddy current loss.

- losses $\propto$ ~~B~~. B_{max} of core, ν and vol of core (V)

$W_h \propto B_{max}$ and V

$W_h = k \cdot B_{max}^n \cdot \nu \cdot V$ where n = Beiment's constant $= 1.6$

$W_h = k B_{max}^{1.6} \nu V$

- Eddy current loss (W_h)

losses $\propto B_{max}^2 \, \nu^2 \, t^2$ [t = thickness]

2. Copper losses.
It is due to ~~...~~ ohmic resistance of the transformer winding if R_1 and R_2 are the resistors of primary and secondary windings. then the Cu losses of the primary and secondary are $I_1^2 R_1$ and $I_2^2 R_2$.

- total loss = loss of primary + loss of secondary.
  total loss = $I_1^2 R + I_2^2 R_2$

- generally these losses vary as a square of particular current

- a.k.a. variable losses.

Q. Transformer Cu loss is ...
... found to be 50 W at 40 Hz and 86 W at 60 Hz. measured at same t ~~...~~ ϕ. Compute the hysteresis and eddy current loss at 50 Hz.

Ans. Given

Core loss at 40 Hz = 50 W = W_i

Core loss at 60 Hz = 86 W = W_f

Total core loss = $W_i = Af + B \cdot f^2$

$$A + Bf = \frac{W_i}{f}$$

$$A + B \cdot 40 = \frac{50}{40}$$

$$A + 40B = 1.25 \quad \text{—— (1)}$$

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Total core loss = W_i = $Af + Bf^2$

$$\frac{W_i}{f} = A + Bf$$

$$\frac{86}{60} = A + B \cdot 60$$

$1.43 = A + 60B$ ——— (2)

$A = 1.43 + 60B$

From (1) and (2),

$1.25 - 40B = 1.43 - 60B$

1.43
1.25

$60B - 40B = 1.43 - 1.25$

$20B = 0.18$

$B = 9 \times 10^{-3}$

Similarly,

$A = 0.89$

$\therefore$ Total core loss $= W_i = Af + Bf^2$

$= 0.89 \times 40 + 9 \times 10^{-3} \times 1600$

$= 50$

$W_i = Af + Bf^2$

$= 0.89 \times 50 + 0.009 \times 2500$

$= 67$

W_h at 50 Hz $= 44.5\,W$

W_e at 50 Hz $=$ ~~50~~ $22.5\,W$

Q. Transformer connected to a 1100 V, 50 Hz supply. The core loss is 1100 W of which 700 W is the hysteresis loss and 400 W is the eddy current loss, if the applied voltage is raised to 2200 V and frequency 200

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Find the core losses. If the applied voltage are doubled, ~~Given~~ . find the new core losses, i.e. $V = 2200\text{ V}$

~~core losses 1100Wb~~ $f = 100\text{ Hz}$

Here, V and f both are doubled. Therefore B_{max} is constant with

i) 1100 V, 50 Hz

ii) $W = Af$

$$A = \frac{W}{f} = 14$$

$$W_e = Bf^2$$
$$= 0.16.$$

Q. Given

$I_L = 15\ A$

$P = 7.5\ kW$

$= 7.5 \times 10^3\ W$

$S = 10\ kVA$

$= 10^4\ VA$

1) V_L and V_{ph}

2) I_{ph}

3) Z_{ph}

4) $\cos\phi$

5) R_{ph}

6) X_{ph} or X_L

7) $L_{ph} = L = ?$

Sol^n

In Δ connection,

$V_L = V_{ph}$

$I_L = \sqrt{3}\ I_{ph}$

1) $S = \sqrt{3}\ V_L I_L$

$\Rightarrow V_L = \dfrac{S}{\sqrt{3}\ I_L}$

$= \dfrac{10 \times 10^3}{\sqrt{3} \times 15}$

$V_L = 385\,V$

$V_L = V_{ph} = 385\ V$

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2) $I_{ph} = \frac{I_L}{\sqrt{3}}$

$= \frac{15}{\sqrt{3}}$

$I_{ph} = 8.66\ A$

3) $Z_{ph} = \frac{V_{ph}}{I_{ph}}$

$= \frac{385}{8.66}$

$Z_{ph} = 44.4\ \Omega$

4) $\cos\phi$:

$P = \sqrt{3}\, V_L I_L \cos\phi$

$\Rightarrow \cos\phi = \frac{P}{\sqrt{3}\, V_L I_L}$

$\cos\phi = 0.749$

5) $\cos\phi = \frac{R_{ph}}{Z_{ph}}$

$R_{ph} = Z_{ph} \cdot \cos\phi$

$= 33.29\ \Omega$

6) X_{ph} :

$Z = R + jX_L$

$\cos\phi = 0.749$

$\phi = \cos^{-1}(0.749)$

$\phi = \cancel{4.49}\ 41.49$

$Z_{ph} = 44.45 \angle 41.49$

Convert into rectangular form,

$Z_{ph} = 33.29 + j\,29.4$

$X / X_L = 29.4\ \Omega$

$X_L = 2\pi f L$

$L = \frac{X_L}{2\pi f} = 0.094\ H$

An 3 inductive coils, each having resistance of 16 Ω and reactance of 12 Ω, are connected in star across 3 phase 400 V $50Hz.

Calculate :

1) V_L

2) V_{ph}

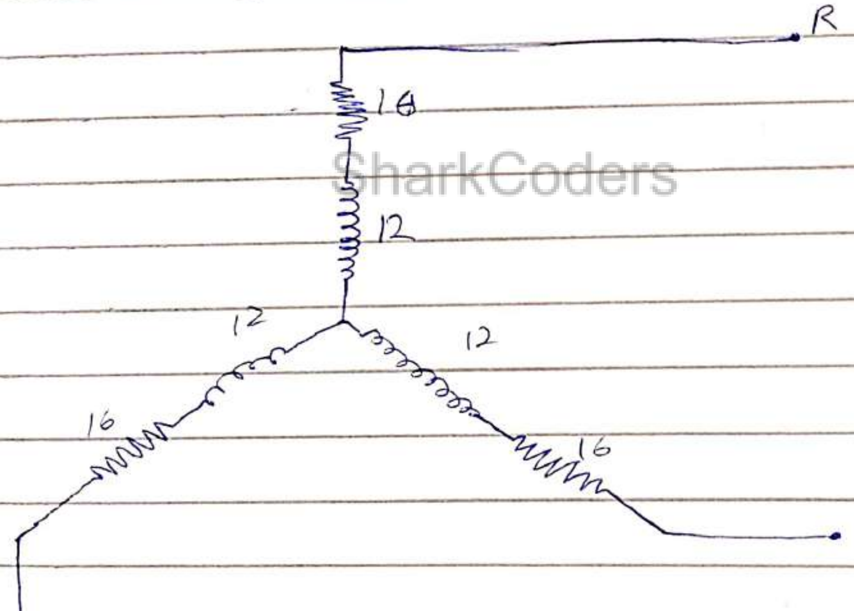
3) I_L

4) I_{ph}

5) P

6) Power absorb

7) phasor diagram



$V_L = 400V$

In star connection

$I_L = I_{ph}$

$V_L = \sqrt{3}\, V_{ph}$

1) $V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94\, V$

$$I_{ph} = \frac{V_{ph}}{Z_{ph}}$$

$$= \frac{230.94 \angle 0}{20 \angle 36.86}$$

$$= 11.5 \angle -36.86$$

$$\boxed{\therefore I_{ph} = 11.55\ A}$$

$$\cos\phi = \cos(-36.86)$$

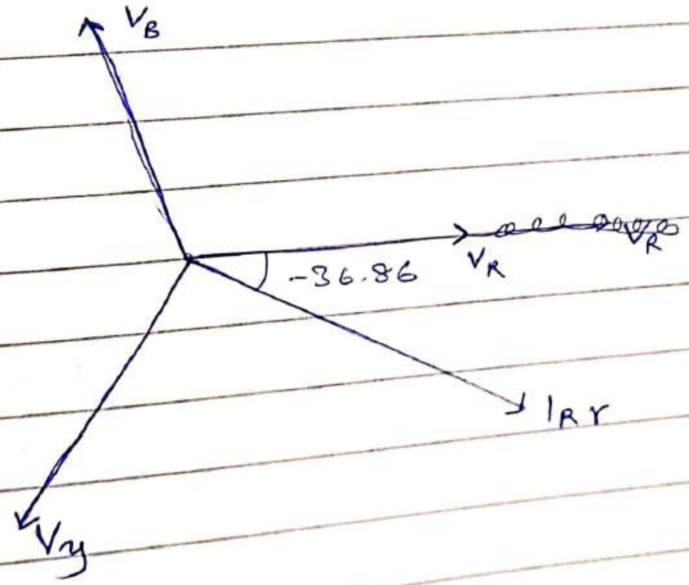
$$= 0.8 \quad \text{(lagging)}$$

$$\text{Power} = \sqrt{3}\, V_L\, I_L \cos\phi$$

$$= \sqrt{3} \times 400 \times 11.55 \times 0.8$$

$$\boxed{\text{Power} = 6.3\ kW}$$

Phasor Diagram



Q. A balanced Δ connected ~~circuit~~ load of impedence $60\angle 30^\circ\ \Omega/\phi$ is connected to 3 ϕ supply of 400 V and ϕ sequence is ABC. Find

1) the ϕ and line values of current
2) the total power and reactive volt ampere
3) the plase angle of line current I_A with respective voltage V_{AB}. Draw the sketch of relevant phasor.

11/12/22.

Given

Q. Transformer rating = 50 kVA

Full load 1'y current I_1 = 260A

Total Resistance referred to 1'y R_{01} = 0.005 Ω

Iron losses W_i = 210 W

F.L. load Cu losses = $I_1^2 R_{01}$

W_{Cu} = 338

∴ Total losses = $W_i + W_{Cu}$

= 210 + 388

= 548 W

1) At unity P.F.

Full load O/P = 50 × 1 kW

= 50 × 10^3 W

% η at unity P.F = $\frac{\text{output}}{(\text{output+losses})} \times 100\%$

= 98.92 %

2) η at 0.8 P.F.

Full load O/P = 50 × 0.8

= 40 kW

% η at 0.8 P.F. = $\frac{\text{output}}{(\text{output + losses})} \times 1$

= 98.64 %

% η .

η at half load

Half load O/P $= \frac{1}{2} \times 50$

$= 25$ KVA

Cu losses at half load $= \left(\frac{I_1^2}{2}\right)^2 \times R_{01}$

$= 84.5$ W

Total losses $= W_i + W_{Cu}$

$= 210 + 84.5$

$= 294.5$ W

η at 0.8 P.F.

O/P $= 25 \times 0.8$

$= 20$ kW

$\% \eta = \frac{\text{output}}{\text{output} + \text{losses}}$

$= \frac{20 \times 10^3}{20 \times 10^3 + 294.5}$

$= 98.55\%$

OP $= 25 \times 1$

$= 25$ kW

$\% \eta = \frac{\text{output}}{\text{output} + \text{losses}}$

$= \frac{25 \times 10^3}{25 \times 10^3 + 294.5}$

$= 98.84\%$

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Q. A transformer 1100/230 V has primary and secondary resistances of ~~0.2~~ ~~0.24~~ 0.4 Ω and 0.03 Ω respectively. If the iron loss amounts 250 W. Determine :
1) the secondary current at which maximum efficiency of
2) max efficiency at ~~0.25~~ 0.8 P.F.

Ans. Given

$V_1 = 1100V$

$V_2 = 230V$

$R_1 = 0.4$

$R_2 = 0.03$

Fe losses = 250W

$$\boxed{\begin{array}{l}\text{for max } \eta, \\ \text{Fe loss} = \text{Cu loss}\end{array}}$$

1) Voltage transformation ratio $k = \frac{V_2}{V_1} = \frac{230}{1100} = 0.2091$

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∴ The resistance referred to IIʳʸ side $R_{02} = R_2 + R_1 k^2$

$= 0.03 + 0.4(0.2091)^2$

$= 0.0475\ \Omega$

Cu losses = Fe loss

$I_2^2 \cdot R_{02} = 250$

$I_2^2 = \frac{250}{R_{02}} = 72.55 A$

2) O/P at max η at 0.8 P.F.,

$O/P = V_2 I_2 \cos\phi$

$= 280 \times 72.55 \times 0.8$

$= 183492\ W$

Total losses $= W_i + W_i$

$= 2W_i = 2 \times 250 = 500 W$

$$x\% = \frac{\text{output}}{\text{output} + \text{losses}} \times 100\%$$

$$= \frac{13349.2}{13349.2 + 500}$$

$$x = 96.39\%$$

Unit VI

DC gen → mechanical ~~⊗~~ to electrical energy:

D.C machines — generator + motor.

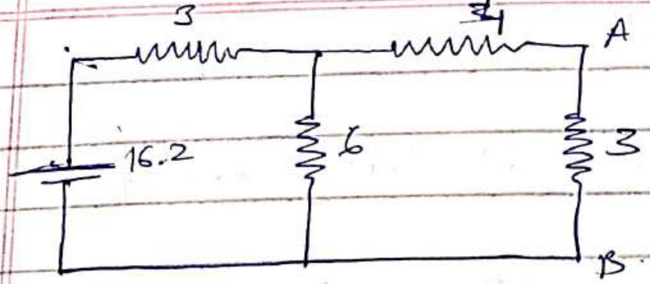
~~DC⊗~~

Norton's Theorem

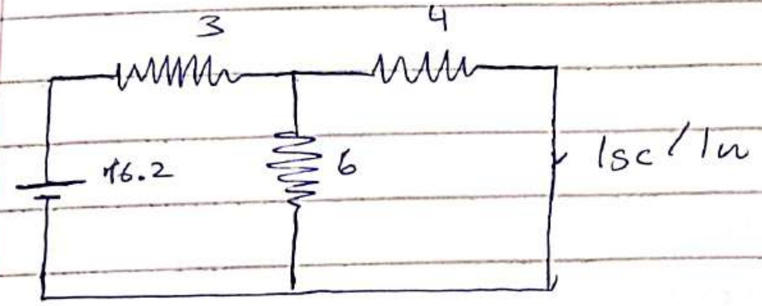
1. Temporarily remove

~~⊗~~

Q.



Ans.



1) $R_T = 3 + 4 \| 6$

$= 3 + \frac{4 \times 6}{4+6}$

$= 3 + \frac{24}{10}$

$= 5.4$

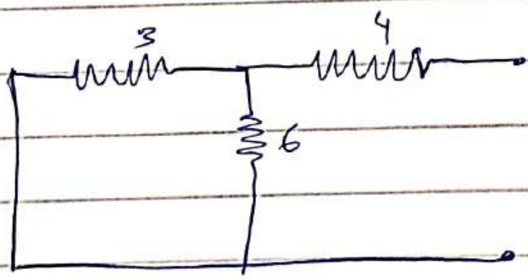
$I_T = \frac{V}{R_T} = \frac{16.2}{5.4}$

$= 3$

$I_N = I_T \times \frac{6}{6+4}$

$= 1.8\ A$

II) R_N

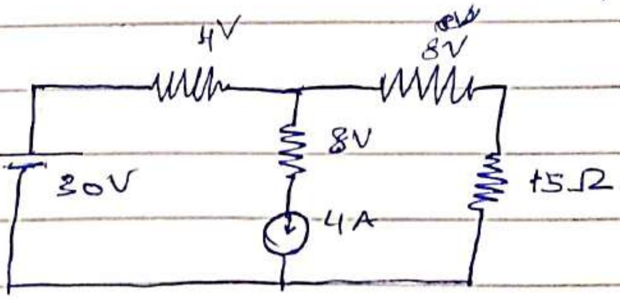


$R_N = (3 \| 6) + 4$

$= \frac{3 \times 6}{3+6} + 4$

$= \frac{18}{9} + 4 = 6$

Q.



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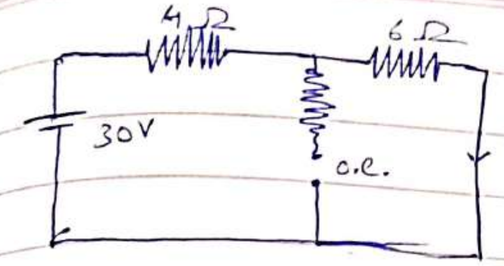
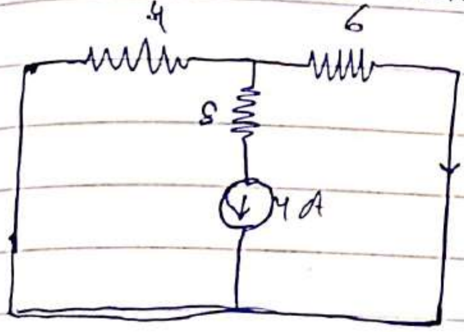


$$I_1 = \frac{V}{R_T} = \frac{30}{4+6} = 3$$

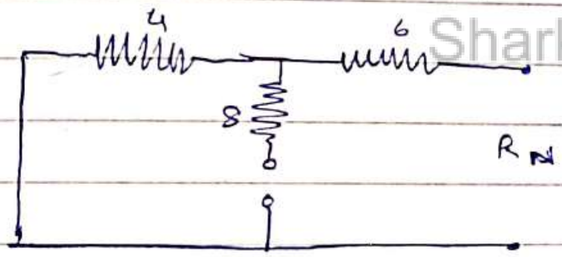
ii) When 4A is acting alone.



$$I_2 = I_T \times \frac{4}{4+6} = 1.6$$

$$I_N = I_1 - I_2.$$
$$= 3 - 1.6 = 1.4$$

iii) Calculate the value of R_N



$$R_N = 4+6 = 10$$

Q. Using Norton's theorem, calculate the current in 5Ω resistor