I B-Tech I-Semester End Examinations (Regular) – Dec-2025

Basic Electrical Engineering

R25

Key paper (R25EE103ES)

PART–A

① ⓐ Passive Elements: Passive Elements are the Elements which either store Energy or dissipate Energy in the form of heat. Resistor, Inductor and Capacitor are the three basic passive elements.

ⓑ Current relationship: $\bar{I}_{ph} = \bar{I}_L$

Voltage relationship: $\bar{V}_L = \sqrt{3}\,\bar{V}_{ph}$

ⓒ Voltage regulation:

$$\text{Vol. reg.} = \frac{E_2 - V_2}{V_2} \times 100$$

E_2 = secondary terminal vol. on no load.

V_2 = Secondary terminal vol. on given load.

ⓓ Significance of Back Emf:

Back Emf in DC motors is the voltage induced in the armature that opposes the supply voltage, acting as a self-regulating mechanism. It limits armature current to safe levels, controls motor speed based on load, improves energy efficiency, and ensures torque adjusts to mechanical demands.

ⓔ $f = 50\,Hz$, $s = 4\%$

$$f_r = sf$$
$$= 0.04 \times 50$$
$$= 2\ Hz.$$

The polarity of this voltage drop always depends on direction of the current. The current always flows from higher potential to lower potential.

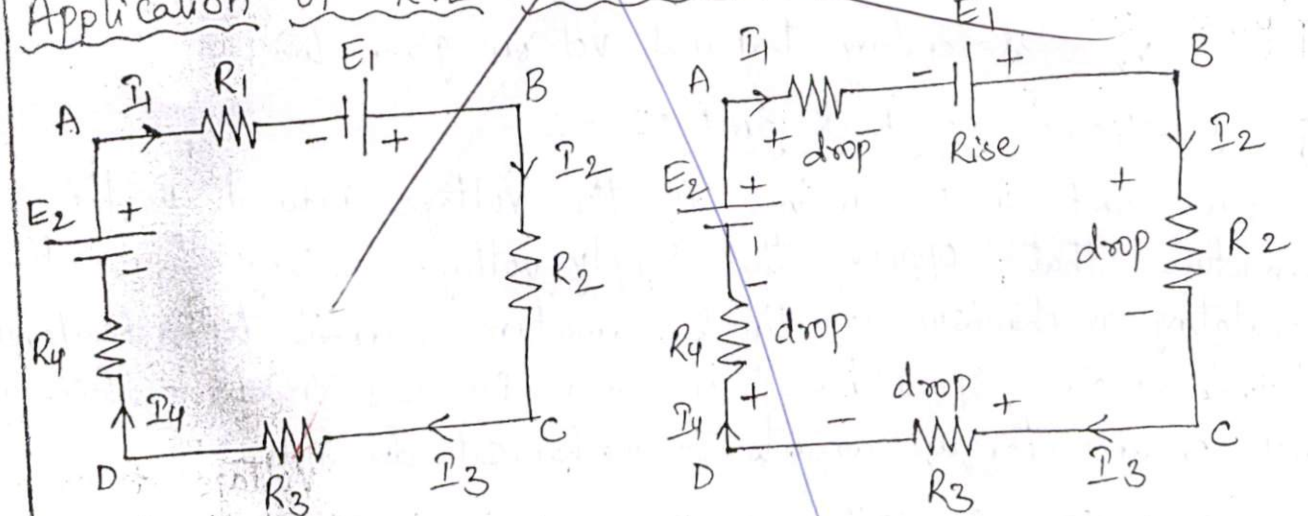
In fig@, current I is flowing from right to left, hence point B is at higher potential than point A.

In fig ⓑ, current I is flowing from left to right, hence point A is at higher potential than point B.

→ while tracing a closed path, if we go from -ve marked terminal to +ve marked terminal, that voltage must be taken as +ve. This is called potential rise.

→ while tracing a closed path, if we go from +ve marked terminal to -ve marked terminal, that voltage must be taken as -ve. This is called potential drop.

Application of KVL to a closed path:



Equation by using KVL around closed path as,

$$-I_1R_1 + E_1 - I_2R_2 - I_3R_3 - I_4R_4 + E_2 = 0 \longrightarrow \text{KVL Equat}$$

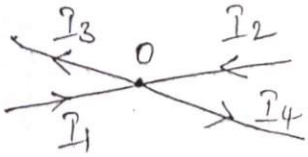
i.e., $E_1 + E_2 = I_1R_1 + I_2R_2 + I_3R_3 + I_4R_4$

PART-B

(2)(a) Kirchhoff's Laws :

Kirchhoff's Current Law (KCL) :

The total current flowing towards a junction point is equal to the total current flowing away from that junction point.



$$I_1 + I_2 = I_3 + I_4$$

The algebraic sum of all the current meeting at a junction point is always zero.

$$\Sigma I \text{ at junction point} = 0$$

Sign Convention :

Currents flowing towards a junction point are assumed to be +ve while currents flowing away from a junction point assumed to be −ve.

Applying KCL,

$$\Sigma I \text{ at junction } O = 0$$

$$I_1 + I_2 - I_3 - I_4 = 0$$

$$\text{i.e., } I_1 + I_2 = I_3 + I_4$$

Kirchhoff's voltage Law (KVL) :

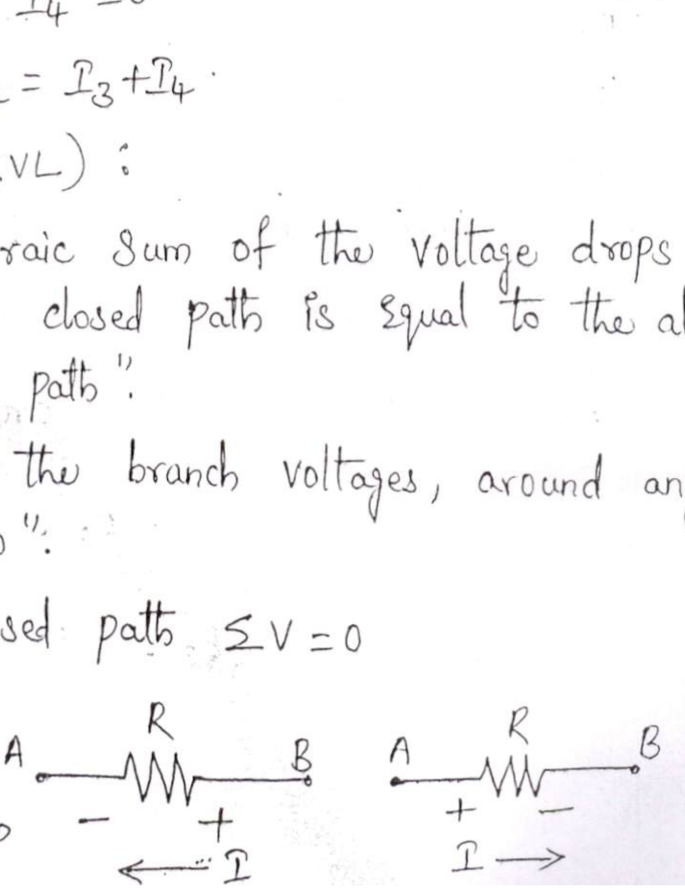
"In any network, the algebraic sum of the voltage drops across the circuit elements of any closed path is equal to the algebraic sum of the emf's in the path".

"The algebraic sum of all the branch voltages, around any closed loop is always zero".

$$\text{Around a closed path } \Sigma V = 0$$

Sign Conventions :

When current flows through a resistance, the voltage drop occurs across the resista…



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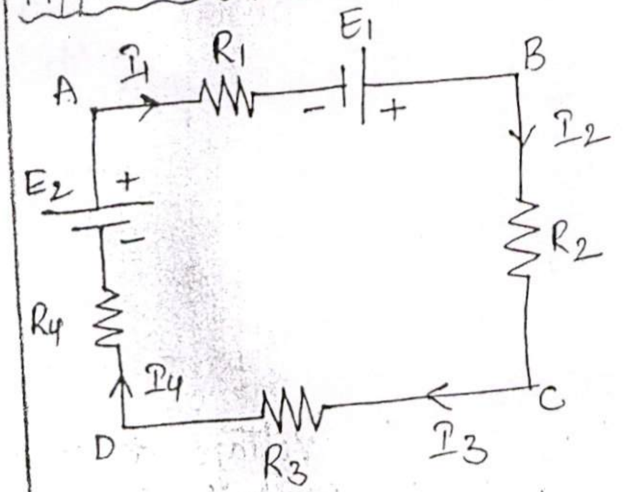
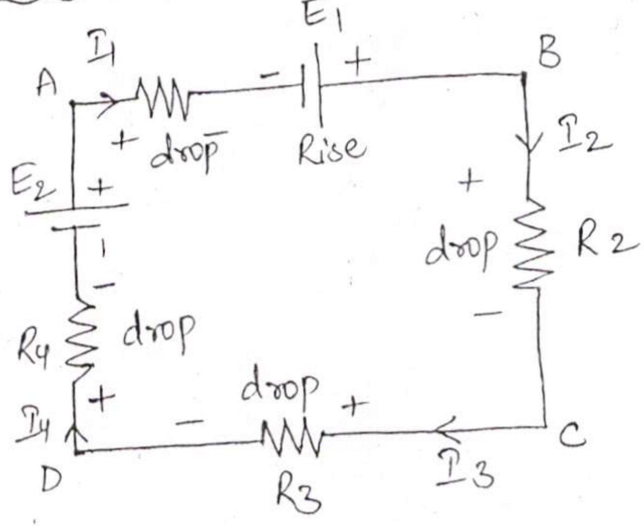


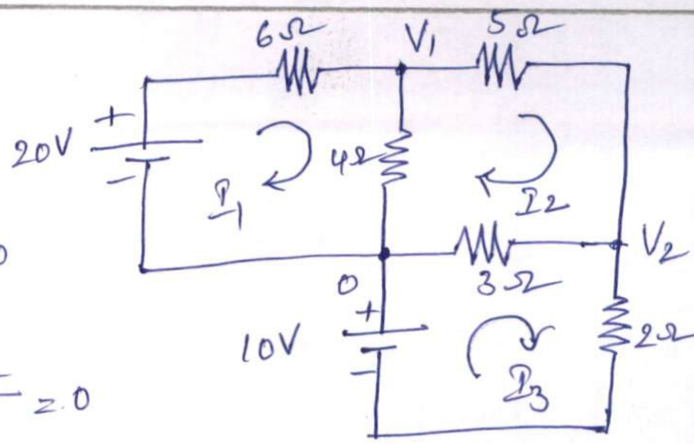


Equation by using KVL around closed path as,

$$-I_1 R_1 + E_1 - I_2 R_2 - I_3 R_3 - I_4 R_4 + E_2 = 0 \quad \rightarrow \text{KVL Equat}$$

i.e., $E_1 + E_2 = I_1 R_1 + I_2 R_2 + I_3 R_3 + I_4 R_4$

② ⓑ Using Nodal analysis



At node 1,

$$\frac{V_1-20}{6}+\frac{V_1}{4}+\frac{V_1-V_2}{5}=0$$

$$\frac{10V_1-200+15V_1+12V_1-12V_2}{60}=0$$

$$37V_1-12V_2=200 \quad \text{—} ①$$

At node 2,

$$\frac{V_2}{3}+\frac{V_2+10}{2}+\frac{V_2-V_1}{5}=0$$

$$-6V_1+31V_2+150=0$$

$$6V_1-31V_2=150 \quad \text{—} ②$$

Solving eq's ① & ②

$$V_1=4.09V, \quad V_2=-4.05V$$

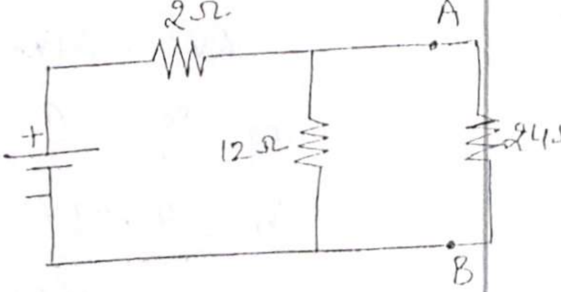
$$I_1=\frac{20-4.09}{6}=2.65A, \quad I_2=\frac{4.09+4.05}{5}=1.63A$$

$$I_3=\frac{-4.05+10}{2}=2.97A.$$

(3)(a) Thevenin's theorem :

Statement : Thevenin's Theorem states that any two terminal linear network having a number of voltage, current sources & resistances can be replaced by a simple equivalent circuit consisting of a single voltage source in series with a resistance, where the value of the voltage source is equal to the open circuit voltage across the two terminals of the network, and resistance is equal to the equivalent resistance measured between the terminals with all the energy sources are replaced by their internal resistances.

In the circuit, if the load resistance 24Ω is connected to Thevenin's equivalent circuit, it will have the same current through it and the same voltage across its terminals as in the original circuit.



→ To verify, let us find the current passing through the 24Ω resistance due to the original circuit

$$I_{24} = I_T \times \frac{12}{12+24}$$

where $$I_T = \frac{10}{2+(12 \| 24)} = \frac{10}{10} = 1A$$

$$\therefore I_{24\Omega} = 1 \times \frac{12}{12+24} = \underline{0.33A}$$

The voltage across the 24Ω resistor $= 0.33 \times 24 = 7.92$ V

Now let us find Thevenin's Equivalent circuit (open circuit)

→ The Thevenin voltage is Equal to the output voltage across the terminals 'AB', i.e. the voltage across the 12Ω resistor. when the load resistance is disconnected from the circuit, the thevenin voltage

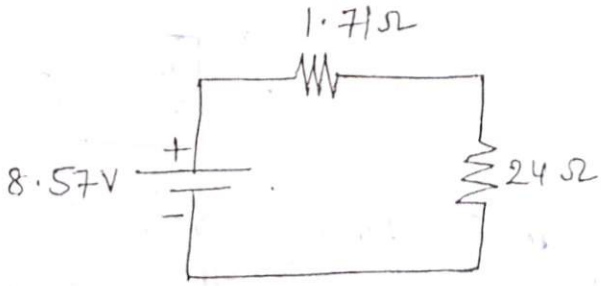
$$V_{th} = 10 \times \frac{12}{14} = \underline{8.57\,V}$$

→ The resistance into the open circuit terminals is Equal to the thevenin resistance

$$R_{th} = \frac{12 \times 2}{12+2} = \underline{1.71\,\Omega}.$$

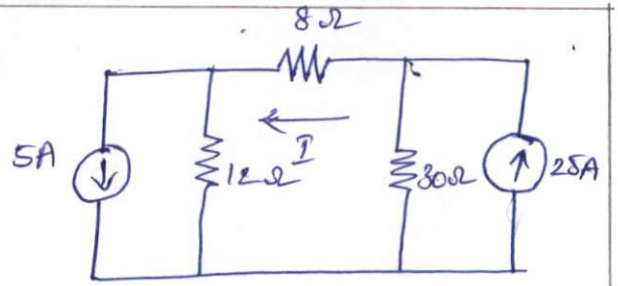
→ Thevenin's Equivalent circuit is as shown

Now let us find the current passing through 24Ω resistance and voltage across it due to thevenin's Equivalent circuit.

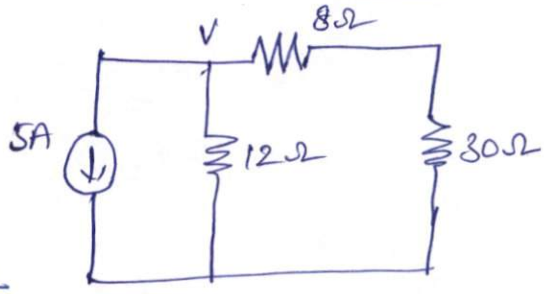


$$I_{24} = \frac{8.57}{24 + 1.71} = \underline{0.33A}$$

③ ⓑ Case 1 : 5A Source acting alone



$$5 + \frac{V}{12} + \frac{V}{38} = 0$$



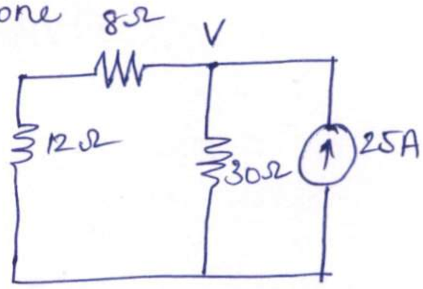
$$38V + 12V = -2280$$

$$V = -45.6V$$

$$I'_{8\Omega} = \frac{V}{38} = \frac{-45.6}{38}$$

$$= -1.2A$$

Case 2 : 25A Source acting alone



$$-25 + \frac{V}{30} + \frac{V}{20} = 0$$

$$V = 300V$$

$$I''_{8\Omega} = \frac{V}{20} = 15A$$

$$\therefore I = I' + I'' = -1.2 + 15 = 13.8\,A$$

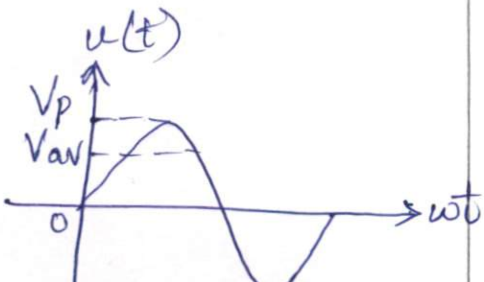
$$\therefore \boxed{I = 13.8\ A}$$

④ ⓐ Average value :

In general the average value of any function $v(t)$, with period T is given by

$$V_{av} = \frac{1}{T}\int_0^T v(t)\,dt$$

The average value of a Sinewave over one Complete cycle is always zero.



The average value of a sinewave $v(t) = V_p \sin\omega t$ is given by

$$V_{av} = \frac{1}{\pi}\int_0^{\pi} V_p \sin\omega t \, d(\omega t)$$

$$= \frac{1}{\pi}\left[-V_p \cos\omega t\right]_0^{\pi} = \frac{2V_p}{\pi}$$

$$\therefore \boxed{V_{av} = 0.637\, V_p}$$

RMS value :

The rms value of any function with period T has an rms value given by,

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^{T} v(t)^2 \, dt}$$

Consider $v(t) = V_p \sin\omega t$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^{T} (V_p \sin\omega t)^2 \, d(\omega t)}$$

$$= \sqrt{\frac{1}{T}\int_0^{2\pi} V_p^2 \left[\frac{1-\cos 2\omega t}{2}\right] d(\omega t)}$$

$$= \frac{V_p}{2\sqrt{\pi}}\sqrt{\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{2\pi}}$$

$$= \frac{V_p}{2\sqrt{\pi}} \times \sqrt{2\pi} = \frac{V_p}{\sqrt{2}}$$

$$\therefore \boxed{V_{rms} = 0.707\, V_p}$$

4 (b) $i(t) = 250 \sin(314t)$

(i) $V_m = 250V$

(ii) $V_{rms} = 0.707 V_m = 0.707 \times 250 = 176.75V$

(iii) $V_{avg} = 0.638 V_m = 0.638 \times 250 = 159.5V$

(iv) Form factor $= \frac{V_{rms}}{V_{avg}} = \frac{176.75}{159.5} = 1.11$

(v) peak factor $= \frac{V_m}{V_{rms}} = \frac{250}{176.75} = 1.414.$

5 (a) Resonant frequency:

The frequency at which the imaginary part of the impedance of the circuit becomes zero, or the angle of the impedance becomes zero is called resonant frequency, f_r.

$$\omega_r L - \frac{1}{\omega_r C} = 0$$

$$\omega_r^2 = \frac{1}{LC} \quad (or) \quad \omega_r = \frac{1}{\sqrt{LC}}$$

$$\therefore \quad 2\pi f_r = \frac{1}{\sqrt{LC}}$$

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

5 b $X_C = 80\,\Omega$

$R = 60\,\Omega$

a $Z = \sqrt{R^2 + X_C^2} = \sqrt{60^2 + 80^2} = 100\,\Omega$

b $I = \frac{V}{Z} = \frac{240}{100} = 2.4\,A$

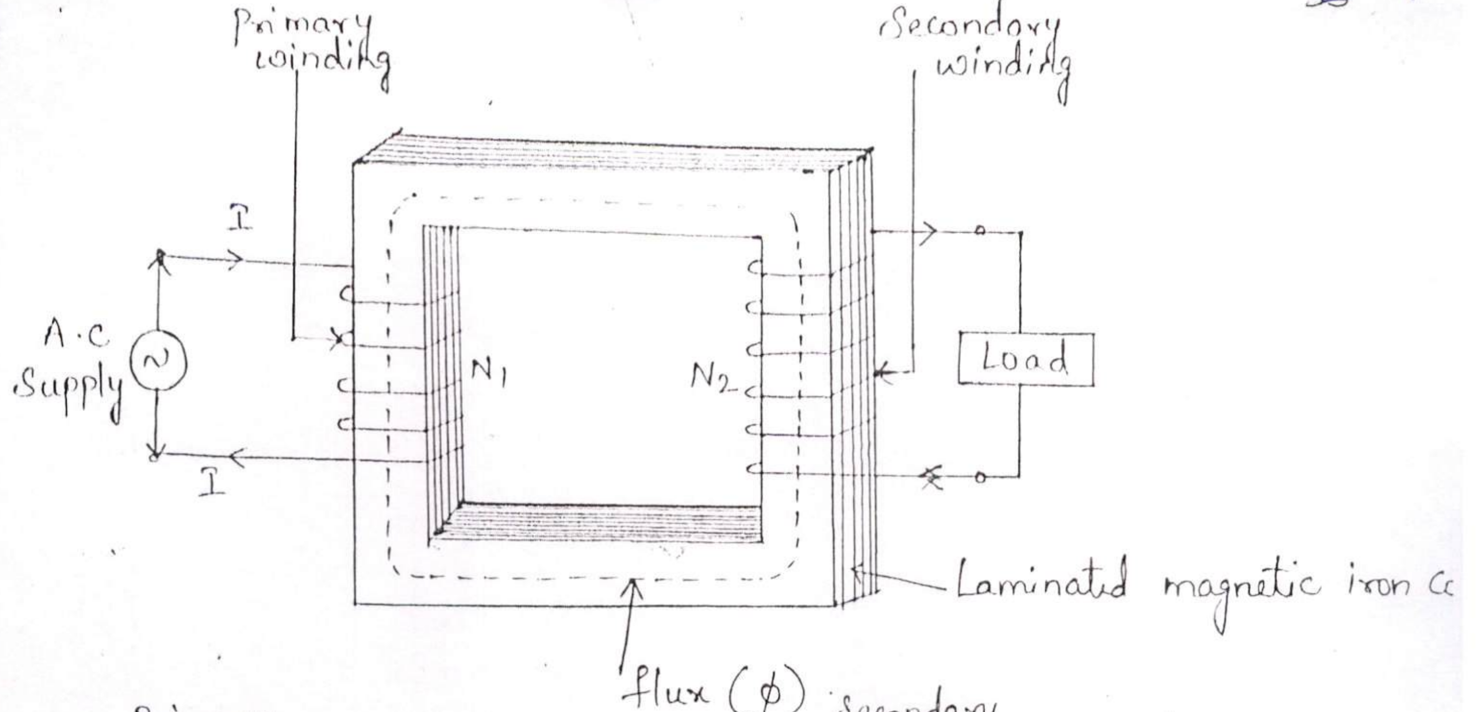
c $\cos\phi = \frac{R}{Z} = \frac{60}{100} = 0.6$

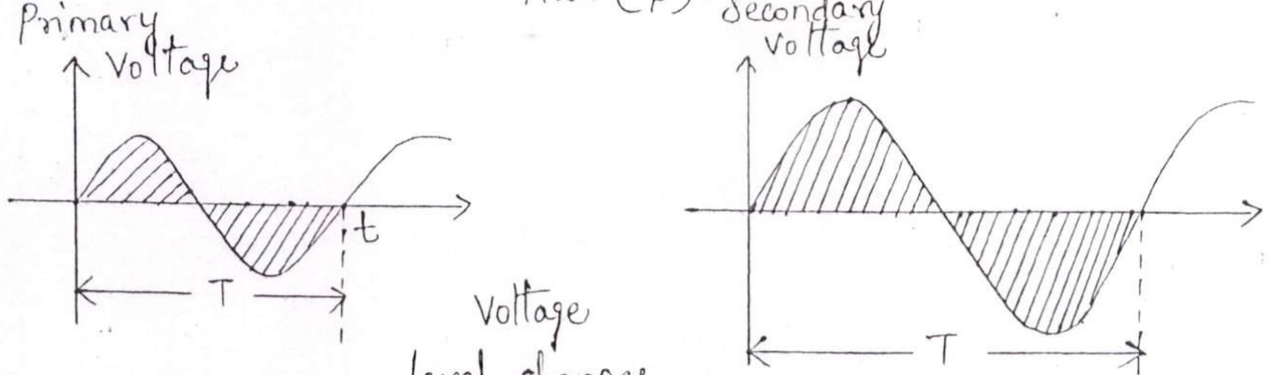
$\phi = \cos^{-1}(0.6) = 53.13^0$

⑥ ⓐ

Principle of working :-
The principle of mutual induction states that when two coils are inductively coupled and if current in one coil is changed uniform then an emf gets induced in the other coil. This emf can drive a current, when a closed path is provided to it. The transfor works on the same principle. It consists of two inductive coils which are electrically seperated but linked through a common magnetic circuit. The two coils have high mutual inductance.

One of the two coils is connected to a source of alternating voltage. This coil in which electrical energy is fed with the help of source is called Primary winding (P). The other winding is connected to load. The electrical energy transformed to this winding is drawn out to the load. This winding is called Secondary winding (S). The primary winding has N_1 no. of turns while the secondary winding has N_2 no. of turns.





Voltage level changes but freq i.e. time period T remains same.

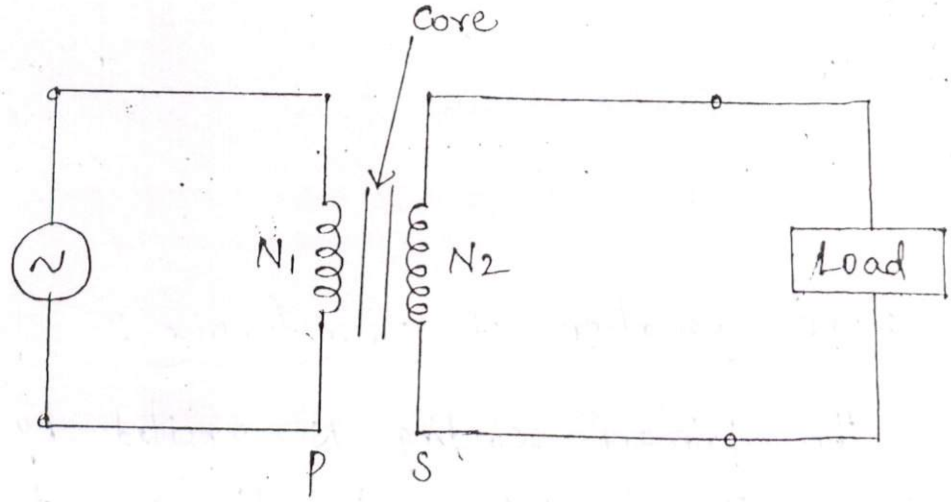


fig: Symbolic representation

when primary winding is excited by an alternating voltage, it circulates an alternating current. This current produces an alternating flux (ϕ) which completes its path through common magnetic core as shown dotted in the fig. Thus an alternating, flux links with the secondary winding. As the flux is alternating, according to Faraday's Law of an electromagnetic induction, mutually induced emf gets developed in the secondary winding. If now load is connected to the secondary winding, this e.m.f drives a current through it.

Thus though there is no electrical contact between the two windings, an electrical energy gets transferred from primary to the secondary.

6 6 EMF equation of transformer :

when the primary winding is excited by an alternating voltage V_1, it circulates alternating current, producing an alternating flux ϕ. The primary winding has N_1 no. of turns. The alternating flux ϕ linking with the primary winding itself induces an emf in it denoted as E_1.

The flux links with secondary winding through the common magnetic core. It produces induced emf E_2 in the secondary winding. This is mutually induced emf. Let us derive the equations for E_1 and E_2.

The primary winding is excited by purely sinusoidal alternating voltage. Hence the flux produced is also sinusoidal in nature having maximum value of ϕ_m as shown.

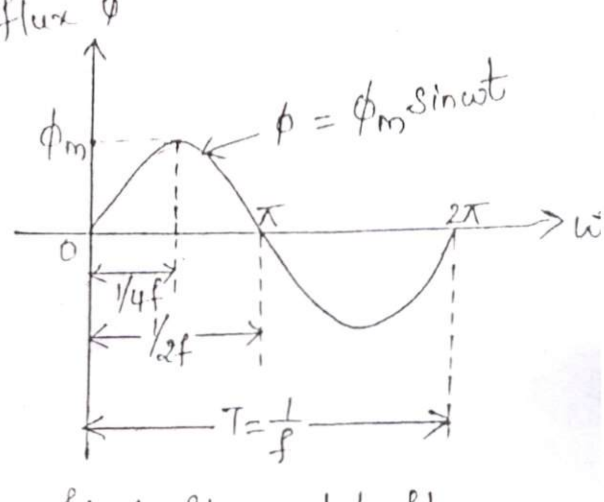


fig : Sinusoidal flux

The various quantities which affect the magnitude of the induced emf are :

ϕ = Flux

ϕ_m = Max. value of flux

N_1 = no. of primary winding turns.

N_2 = no. of secondary winding turns.

f = freq. of the supply voltage.

E_1 = RMS value of the primary induced emf.

E_2 = RMS value of the secondary induced emf.

From Faraday's Law of electromagnetic induction the average emf induced in each turn is proportional to the average rate of change of flux.

$\therefore$ Average emf per turn = Average rate of change of flux.

$$\therefore \text{Average emf per turn} = \frac{d\phi}{dt}$$

Now $$\frac{d\phi}{dt} = \frac{\text{change in flux}}{\text{Time required for change in flux}}$$

Consider the $1/4^{th}$ cycle of the flux as shown. Complete cycle gets completed in $1/f$ seconds. In $1/4^{th}$ time period, the change in flux is from 0 to ϕ_m.

$$\therefore \frac{d\phi}{dt} = \frac{\phi_m - 0}{\left(\frac{1}{4f}\right)}$$ as dt for $1/4^{th}$ time period is $1/4f$ seconds.

$$= 4f\phi_m \text{ wb/sec}$$

$\therefore$ Average Emf per turn $= 4f\phi_m$ volts.

As ϕ is sinusoidal, the induced emf in each turn of both windings is also sinusoidal in nature. For sinusoidal quantity,

$$\text{Form factor} = \frac{\text{RMS value}}{\text{Average value}} = 1.11$$

$\therefore$ RMS value $= 1.11 \times$ Average value

$\therefore$ RMS value of induced emf per turn

$$= 1.11 \times 4f\phi_m = 4.44f\phi_m.$$

There are N_1 no. of primary turns hence the RMS value of induced emf of primary denoted as E_1 is,

$$E_1 = N_1 \times 4.44 f \phi_m \text{ volts.}$$

while as there are N_2 no. of secondary turns the RMS value of induced emf of secondary denoted as E_2 is,

$$E_2 = N_2 \times 4.44 f \phi_m \text{ volts.}$$

The expressions of E_1 and E_2 are called emf equations of a transformer.

$$\boxed{\begin{aligned} E_1 &= 4.44 f \phi_m N_1 \text{ volts} \\ E_2 &= 4.44 f \phi_m N_2 \text{ volts} \end{aligned}}$$

(7) (a) $P_{cu} = 1.2 KW$, $P_i = 0.8 KW$, $25 KVA$

$$\%\eta_{f.L} = \frac{VI\cos\phi}{VI\cos\phi + P_i + P_{cu}} \times 100$$

$$= \frac{25 \times 0.8}{25 \times 0.8 + 1.2 + 0.8} \times 100 = 90.91\%$$

(b) $$\%\eta_{H.L} = \frac{\frac{1}{2}(20)}{\frac{1}{2}(20) + 0.8 + \frac{1}{4}(1.2)} \times 100$$

$$= 90.09\%$$

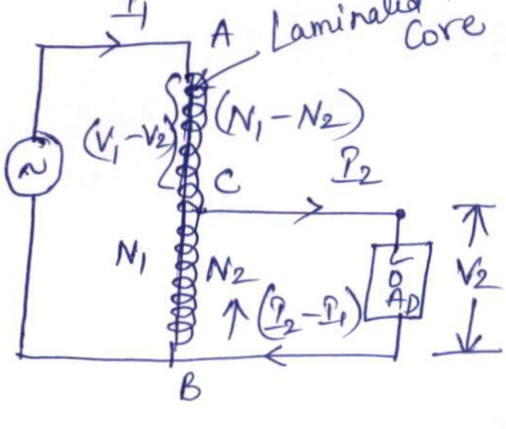
(7) (b) Auto transformer:

→ Auto transformer is special type of transformer in which only one winding is wound on the laminated iron core.

→ The part of winding which is connected to the supply is called as primary winding. The part of winding which connected to the load is called secondary winding.

→ Both windings are linked with electrically & magnetically. whereas in 1-ϕ two winding transformer both primary & secondary winding are seperated and these windings are electrically seperated but magnetically linked.

→ In Auto transformer o/p voltage varied by changing turns in secondary winding so another name for auto transformer is VARIAC.



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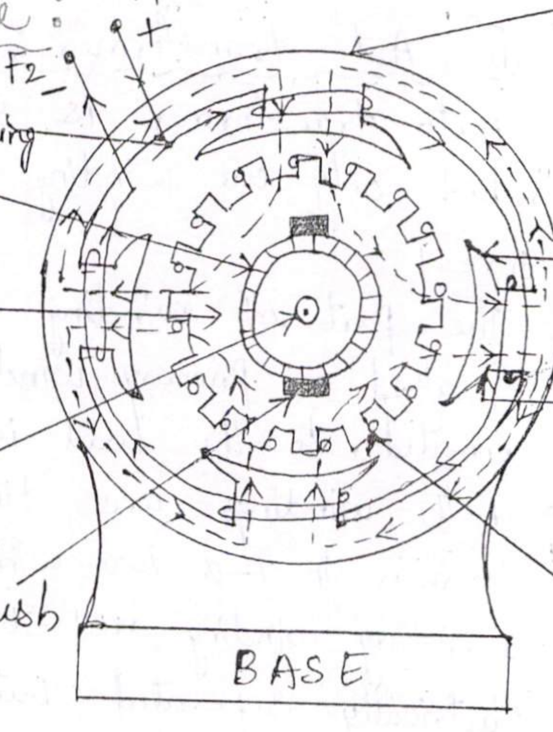
Construction of a DC Machine :

DC Machine has following parts :

1. Yoke
2. Poles
3. Field winding
4. Armature
5. Commutator
6. Brushes
7. Bearing



① **Yoke**: It is outer frame of DC Generator.

Functions:

→ It provides mechanical support to the poles.
→ It provides a path of low reluctance for magnetic flux.
→ It serves of outermost cover of DC machine.

choice of material:

It is made up of cast iron for small machines. For large machines it is made up of cast steel.

② **poles**: Each pole is divided into two parts (i) pole core, (ii) pole shoe.

Functions:

→ pole core carries a field winding which is necessary to produce flux.
→ pole shoes spread out the magnetic flux uniformly in the airgap and reduce the reluctance of the magnetic path.

choice of material:

It is made up of cast iron or cast steel. The pole shoe is always laminated to avoid Eddy current loss.

③ **Field winding**:

The field winding is wound on the pole core.

Function:

It helps in producing the magnetic flux i.e Exciting the pole as an Electromagnet. It is also called as Exciting winding.

choice of material: Copper or aluminium.

④ **Armature**:

It is further divided into two parts (i) Armature core (ii) Armature winding.

(i) Armature Core:

Armature Core is Cylindrical in shape mounted on the shaft. It is buildup of circular laminated sheet. It consists of slots on its Periphery.

Functions :

→ The purpose of armature core is to hold the armature winding.

→ Provides low reluctance path to magnetic flux. obstruction offered by a mag. ckt to the flux

Choice of material :

It is assembled from steel laminations in order to reduce eddy current losses, the laminations are insulated from each other

(ii) Armature winding :

Armature winding is nothing but the interconnection of armature conductors, placed in the slots provided on the armature core.

Functions :

→ Generation of emf takes place in the armature winding in case of generators.

→ To carry the current supplied in case of d.c motors.

Choice of material :

It is made up of conducting material, which is copper.

(5) Commutator :

The nature of emf induced in the armature conductors is alternating. The function of the commutator is to convert the ac voltages induced in the armature conductors to dc voltage in the external circuit in generator operation, whereas in dc motors it produces unidirectional torque.

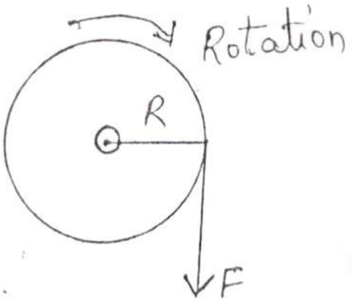
Choice of material :

As it collects current from armature, it is also made up of copper segments. It is made up of high conductivity hard drawn copper.

(6) Brushes :

The rotating armature and external circuit are connected through brushes.

9 (a) Torque Equation of a DC motor :



The turning or twisting force about an axis is called torque. Consider a wheel of radius R metres acted upon by a circumferential force F newtons as shown. The wheel is rotating at a speed of N r.p.m. Then angular speed of the wheel is,

$$\omega = \frac{2\pi N}{60} \text{ rad/sec.}$$

So workdone in one revolution is,

$$W = F \times \text{distance travelled in one revolution.}$$
$$= F \times 2\pi R \text{ joules.}$$

And $P = \text{power developed} = \frac{\text{workdone}}{\text{Time}}$

$$= \frac{F \times 2\pi R}{\text{Time for 1 rev}} = \frac{F \times 2\pi R}{(60/N)} = (F \times R) \times \left(\frac{2\pi N}{60}\right)$$

$$\therefore P = T \times \omega \text{ watts.}$$

where T = Torque in N-m.
ω = Angular speed in rad/sec.

Let T_a be the gross torque developed by the armature of the motor. It is also called armature torque. The gross mechanical power developed in the armature is $E_b I_a$, then

power in armature = Armature torque $\times \omega$

$$\therefore E_b I_a = T_a \times \frac{2\pi N}{60}$$

But E_b in a motor is given by,

$$E_b = \frac{Z P \phi N}{60 A}$$

$$\therefore \frac{Z P \phi N}{60 A} \times I_a = T_a \times \frac{2\pi N}{60}$$

$$T_a = \frac{1}{2\pi} \phi I_a \times \frac{P Z}{A}$$

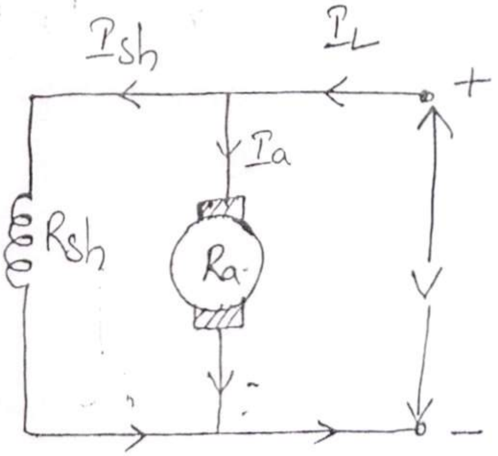
$$\boxed{T_a = 0.159 \phi I_a \cdot \frac{P Z}{A} \quad N\text{-}m}$$

9 b

Types of DC Motors :

DC Motors
- Seperately Excited
- Self-Excited
  - Series
  - Shunt
  - Compound
    - Long Shunt
    - Short Shunt

(i) shunt-wound motor :

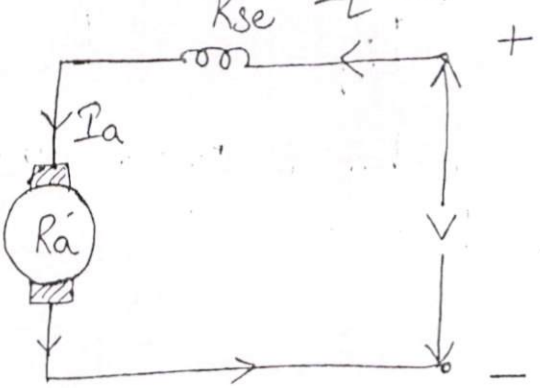


Shunt-wound motor in which the field winding is connected in parallel with the armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary mmf by means of a relatively large no. of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current.

$$I_L = I_a + I_{sh}$$
$$I_{sh} = V/R_{sh}$$
and $V = E_b + I_a R_a + V_{brush}$ $\boxed{\phi \propto I_{sh}}$

(ii) **Series - wound motor :**

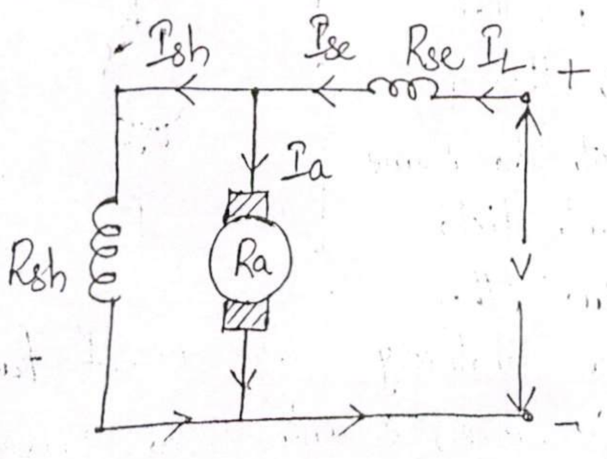
In which the field winding is connected in series with the armature series field winding carries the armature current. Since, current passing through a series field winding is same as the armature current.



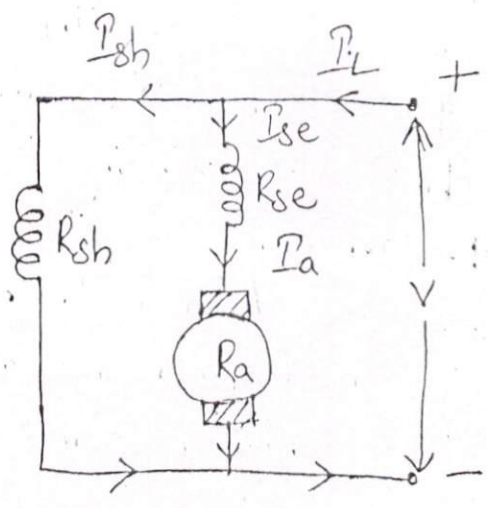
Therefore, a series field winding has a relatively small no. of turns of thick wire and therefore, will possess a low resistance.

$$I_L = I_{se} = I_a$$
and $V = E_b + I_a R_a + I_{se} R_{se} + V_{brush}$
$V = E_b + I_a (R_a + R_{se}) + V_{brush}$ $\boxed{\phi \propto I_{se} \propto I_a}$

(iii) **Compound - wound motor :**



Short - Shunt connection



Long - Shunt connection.

Compound - wound motor which has two field windings ; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections. When the shunt field winding is directly connected across the armature terminals, it is called short-shunt connection. When the shunt winding is so connected that it shunts in series combination of armature and series field, it is called long-shunt connection.

For long shunt compound motor,

$$I_L = I_{se} + I_{sh}$$

But $I_{se} = I_a$

$$\therefore I_L = I_a + I_{sh}$$

and $I_{sh} = \dfrac{V}{R_{sh}}$

and $V = E_b + I_a R_a + I_{se} R_{se} + V_{brush}$

$$= E_b + I_a (R_a + R_{se}) + V_{brush}$$

For short shunt compound motor,

$$I_L = I_{se}$$

and $I_L = I_a + I_{sh}$

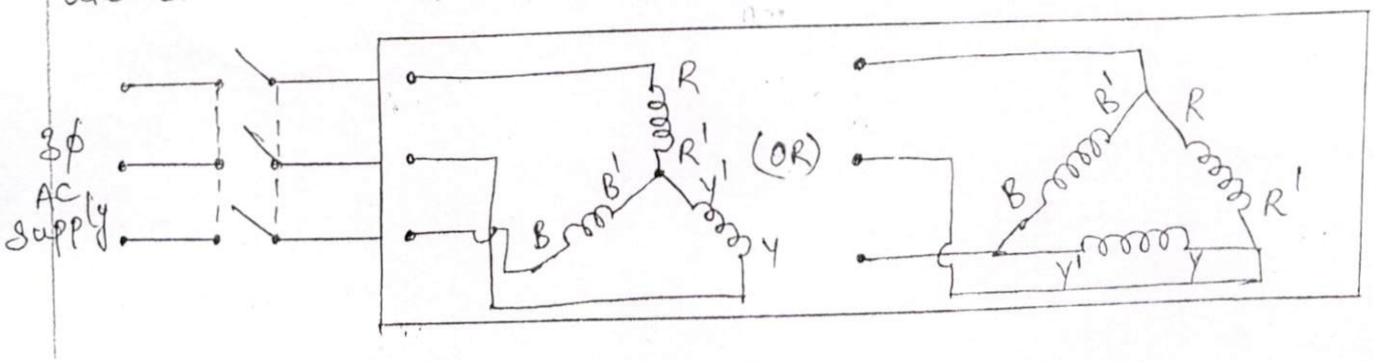
$$V = E_b + I_{se} R_{se} + I_a R_a + V_{brush}$$

$$= E_b + I_L R_{se} + I_a R_a + V_{brush}$$

(1.10).

Generation of Rotating Magnetic field :

A 3-ϕ induction motor consists of 3-ϕ windings as its stationary part called stator. The 3-ϕ windings are displac from each other by 120°. These windings are connected in star(delta and are supplied by a 3-ϕ AC supply. These windings are denoted as $R-R'$, $Y-Y'$ & $B-B'$.



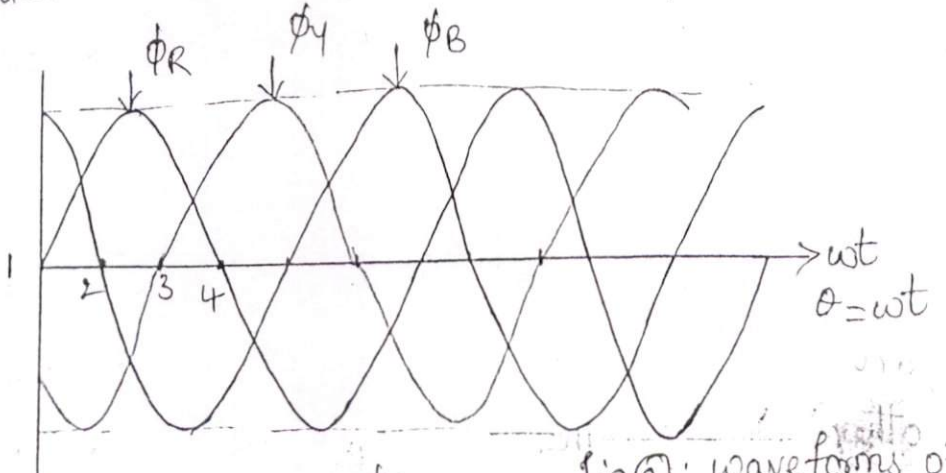
The 3-ϕ currents flow simultaneously through the windings and are displaced from each other by 120° electrically, each alternating phase current produces its own flux which is sinusoidal. All three phases are sinusoidal and are seperated by 120°. If the phase sequence of windings is RYB, the mathematical equations for instantaneous values of three fluxes ϕ_R, ϕ_Y & ϕ_B can be written as,

$$\phi_R = \phi_m \sin\omega t = \phi_m \sin\theta \quad \text{—— (1)}$$

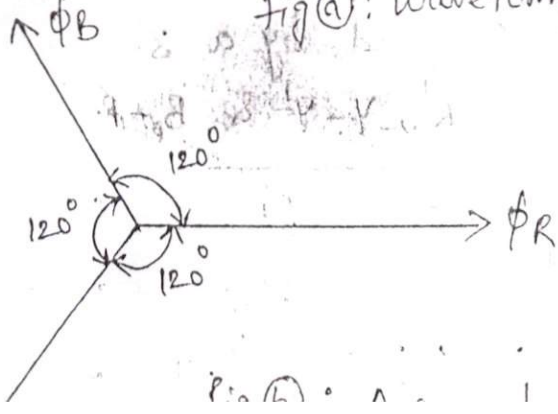
$$\phi_Y = \phi_m \sin(\omega t - 120^\circ) = \phi_m \sin(\theta - 120^\circ) \quad \text{—— (2)}$$

$$\phi_Y = \phi_m \sin(\omega t - 240^\circ) = \phi_m \sin(\theta - 240^\circ) \quad \text{—— (3)}$$

As windings are identical and supply is balanced, the magnitude of each flux is ϕ_m. Due to phase difference sequence R-Y-B, flux ϕ_Y lags behind ϕ_R by 120° & ϕ_B lags ϕ_Y by 120°, ϕ_B lags ϕ_R by 120°. The flux ϕ_R is taken as reference while writing equations.



fig(a): waveforms of 3-fluxes



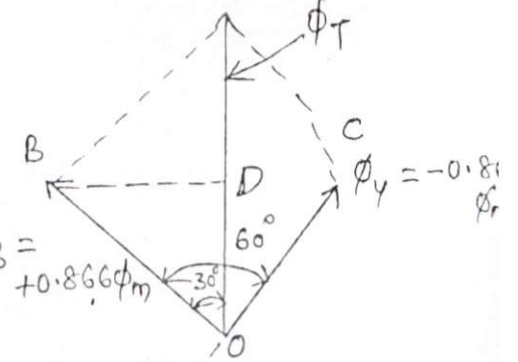
fig(b): ...

The resultant flux ϕ_T is the phasor addition of ϕ_R, ϕ_Y, ϕ_B

$$\overline{\phi_T} = \overline{\phi_R} + \overline{\phi_Y} + \overline{\phi_B}$$

Find ϕ_T at instants 1, 2, 3, 4 as shown which represen the values of θ as 0°, 60°, 120° & 180° respectively.

The phasor addition can be performed by obtaining values of ϕ_R, ϕ_Y & ϕ_B by substituting values of θ in Eq. 1, 2 & 3



Assumed +ve direction of ϕ

fig: Vector diagram for $\theta=$

Case 1 : $\theta = 0^\circ$

$$\phi_R = \phi_m \sin 0 = 0$$

$$\phi_Y = \phi_m \sin(-120^\circ) = -0.866\phi_m$$

$$\phi_B = \phi_m \sin(-240^\circ) = +0.866\phi_m$$

BD is drawn perpendicular from B on ϕ_T. It bisects ϕ_T.

$$OD = DA = \frac{\phi_T}{2}$$

In Δ OBD,

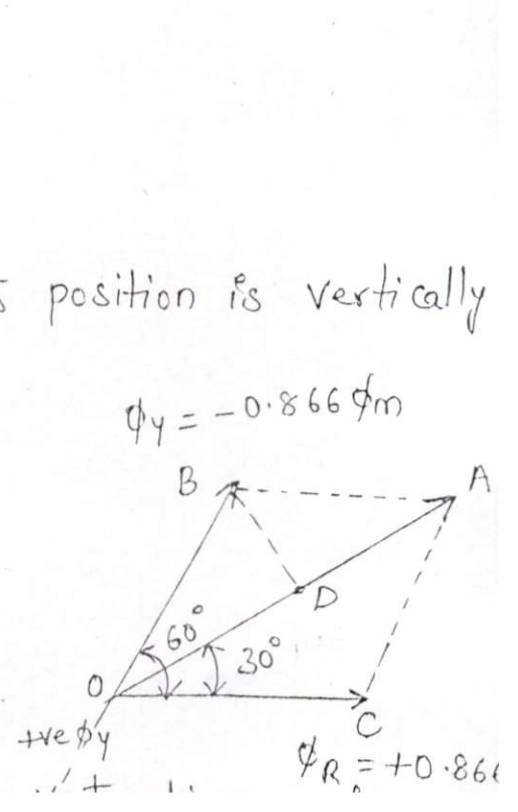
$$\angle BOD = 30^\circ$$

$$\cos 30^\circ = \frac{OD}{OB} = \frac{\phi_T/2}{0.866\phi_m}$$

$$\phi_T = 2 \times 0.866\phi_m \times \cos 30^\circ$$

$$= 1.5\phi_m$$

$\therefore$ magnitude of ϕ_T is $1.5\phi_m$ and its position is vertically upwards at $\theta = 0^\circ$.



Case 2 : $\theta = 60^\circ$

$$\phi_R = \phi_m \sin 60^\circ = +0.866\phi_m$$

$$\phi_Y = \phi_m \sin(-60^\circ) = -0.866\phi_m$$

$$\phi_B = \phi_m \sin(-180^\circ) = 0$$

Doing the same construction, drawing $\perp^{lar}$ from B on ϕ_T we get the same result.

$$\phi_T = 1.5\phi_m$$

But it can be seen that though its magnitude is $1.5\phi_m$ it has rotated through 60° in space, in clockwise direction from its previous position.

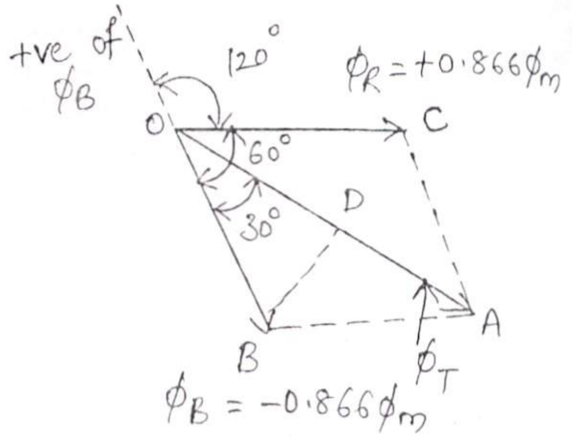


fig: vector diagram for $\phi = 120^\circ$

Case ③ : $\theta = 120^\circ$

$$\phi_R = \phi_m \sin 120^\circ = +0.866\phi_m$$

$$\phi_Y = \phi_m \sin 0 = 0$$

$$\phi_B = \phi_m \sin(-120^\circ) = -0.866\phi_m$$

Similarly drawing $\perp^{lar}$ from B on ϕ_T, we have

$$\phi_T = 1.5\phi_m$$

But the position of ϕ_T is such that it has further rotated through 60° from its previous position in clockwise direction.

Case ④ : $\theta = 180^\circ$

$$\phi_R = \phi_m \sin 180^\circ = 0$$

$$\phi_Y = \phi_m \sin 60^\circ = +0.866\phi_m$$

$$\phi_B = \phi_m \sin(-60^\circ) = -0.866\phi_m$$

Similarly $\phi_T = 1.5\phi_m$

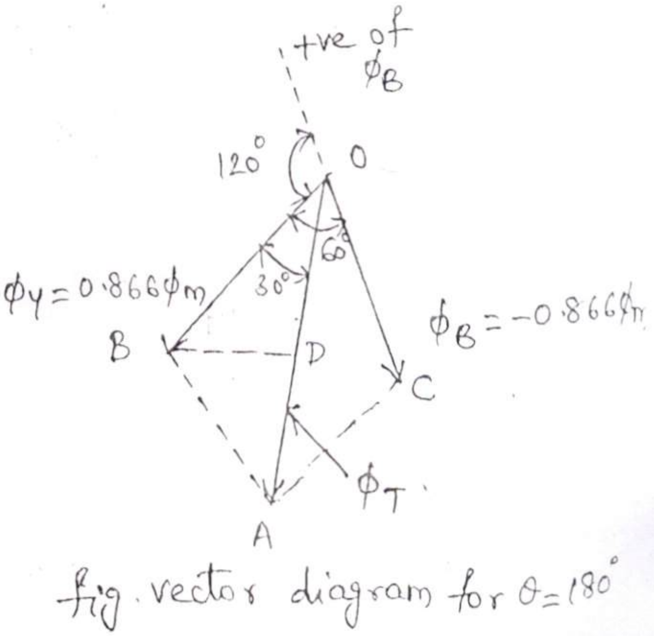


fig. vector diagram for $\theta = 180^\circ$

The magnitude of ϕ_T remains same. But it can be seen that it has further rotated through 60° from its previous position in clockwise direction.

The following conclusions are made :

→ The resultant of the 3 alternating fluxes, seperated from each other by 120°, has a constant amplitude of $1.5\,\phi_m$ where ϕ_m is maximum amplitude of an individual flux due to any phase.

→ The resultant always keeps on rotating with a certain spee in space.

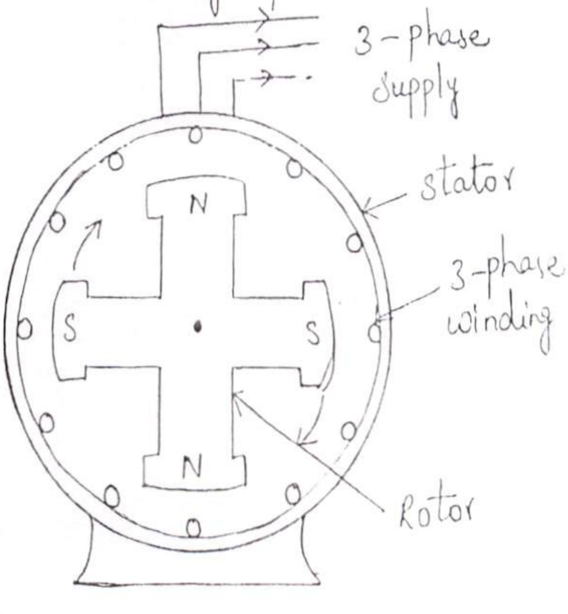
This shows that when a 3-ϕ windings are excited by balanc 3-ϕ ac supply then the resulting field produced is RMF. Though nothing is rotating physically, the field is rotating in space having constant amplitude.

ALTERNATORS

The machine which produces 3-phase power from mechanical power is called an alternator or synchronous generator. Alternators are the primary source of all the electrical energy we consume.
(11) They convert mechanical energy into a.c energy.

Principle :-

3b (An alternator operates on the same fundamental principle of electromagnetic induction as a d.c generator i.e, when the flux linking a conductor changes, an emf is induced in the conductor. Like a d.c generator, an alternator also has an armature winding and a field winding. But there is one important difference between the two. In a d.c generator, the armature winding is placed on the rotor in order to provide a way of converting alternating voltage generated in the winding to a direct voltage at the terminals through the use of a rotating commutator. The field poles are placed on the stationary part of the machine. Since no commutator is required in an alternator, it is usually more convenient and advantageous to place the field winding on the rotating part (i.e., rotor) and armature winding on the stationary part (i.e., stator).



Advantages of stationary armature :-

The field winding of an alternator is placed on the rotor and is connected to d.c supply through two slip rings. The 3-phase armature winding is placed on the stator.

This arrangement has the following advantages :

(i) It is easier to insulate stationary winding for high voltages for which the alternators are usually designed. It is because they are not subjected to centrifugal forces and also extra space is available due to the stationary arrangement of the armature.

(ii) The stationary 3-phase armature can be directly connected to load without going through large, unreliable slip rings & brushes.

(iii) Only two slip rings are required for d.c supply to the field winding on the rotor. Since the exciting current is small, the slip rings and brush gear required are of light construction.

(v) Due to simple and robust construction of the rotor, higher speed of rotating d.c field is possible. This increases the output obtainable from a machine of given dimensions.

3a

Construction of Alternator :-

An alternator has 3-phase winding on the stator and a d.c field winding on the rotor.

1) Stator : It is the stationary part of the machine and is built up of sheet-steel laminations having slots on its inner periphery. A 3-phase winding is placed in these slots and serves as the armature winding of the alternator. The armature winding is always connected in star and the neutral is connected to ground.

2) Rotor :- The rotor carries a field winding which is supplied with direct current through two slip rings by a seperate dc source. This d.c source is generally a small d.c shunt or compound generator mounted on the shaft of the alternator. Rotor construction is of two types, namely ;

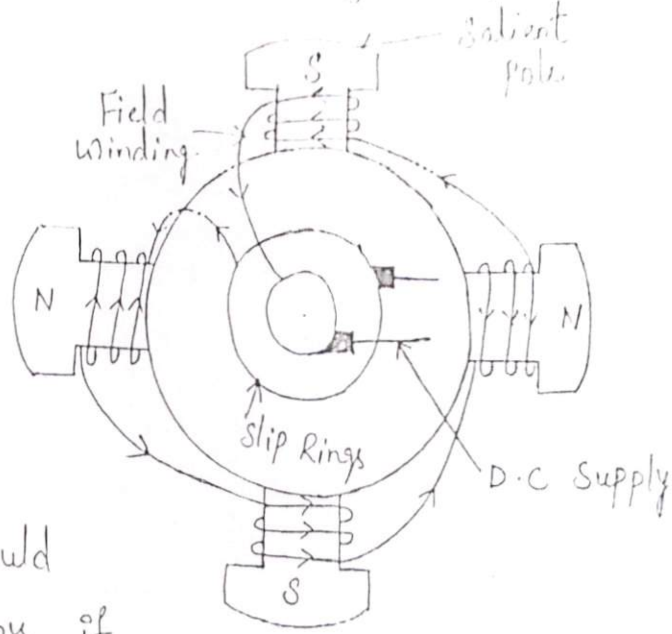
(i) Salient (or projecting) pole type

(ii) Non-Salient (or cylindrical) pole type

(i) Salient pole type :-

In this type, salient or projecting poles are mounted on a large circular steel frame which is fixed to the shaft of the alternator as shown. The individual field pole windings are connected in series in such a way that when the field winding is energised by the d.c exciter, adjacent poles have opposite polarities.

Low and medium - speed alternators (120 - 400 r.p.m) such as those driven by diesel engines or water turbines have salient pole type rotors due to the following reasons:

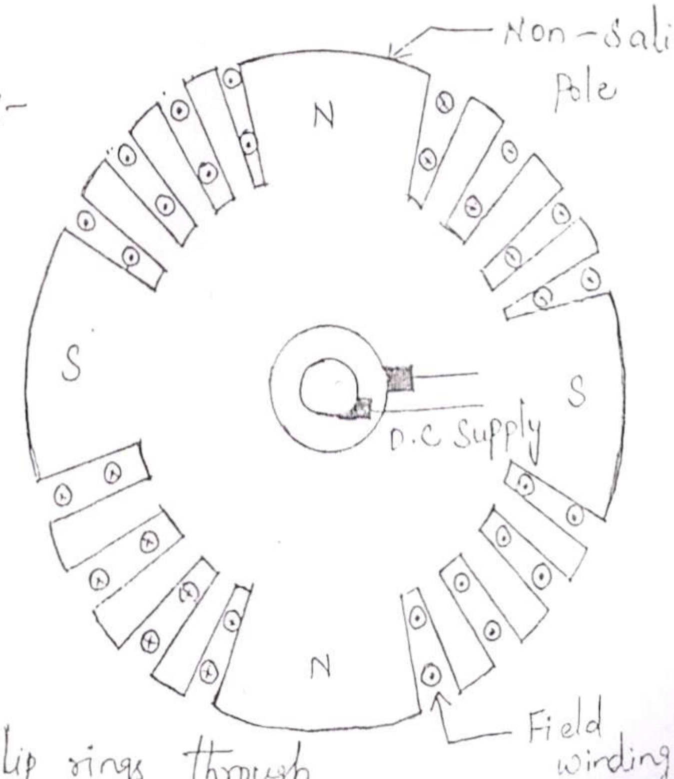


(a) The salient field poles would cause an excessive windage loss if driven at high speed and would tend to provide noise.

(b) Salient - pole construction cannot be made strong enough to withstand the mechanical stress to which they may be subjected at higher speeds.

(ii) Non - salient pole type :-

In this type, the rotor is made of smooth solid forged - steel radial cylinder having a no. of slots along the outer periphery. The field windings are embedded in these slots and are connected in series to the slip rings through



which [illegible] The

regions forming the poles are usually left unslotted as shown. It is clear that the poles formed are non-salient i.e., they do not project out from the rotor surface.

High speed alternators (1500 or 3000 rpm) are driven by steam turbines and use non-salient type rotors due to the following reasons :

(a) This type of construction has mechanical robustness & gives noiseless operation at high speeds.

(b) The flux distribution around the periphery is nearly a sine wave and hence a better emf waveform is obtained than in the case of salient-pole type.

Since steam turbines run at high speed and a frequency of 50 Hz is required, we need a small no. of poles on the rotor of high-speed alternators. We can use no less than 2 poles and this fixes the highest possible speed. The next lower speed is 1500 rpm for a 4-pole machine.) 30r

Alternator operation :-

The rotor winding is energised from the d.c exciter and alternate N and S poles are developed on the rotor. When the rotor is rotated in anticlockwise direction by a prime mover, the stator or armature conductors are cut by the magnetic flux of rotor poles. Consequently, emf is induced in the armature conductors due to electromagnetic induction. The induced emf is alternating since N and S poles of rotor alternately pass the armature conductors. The direction of induced emf can be found by Fleming's right hand rule and frequency is given by:

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

where N = speed of rotor in rpm
P = no. of rotor poles

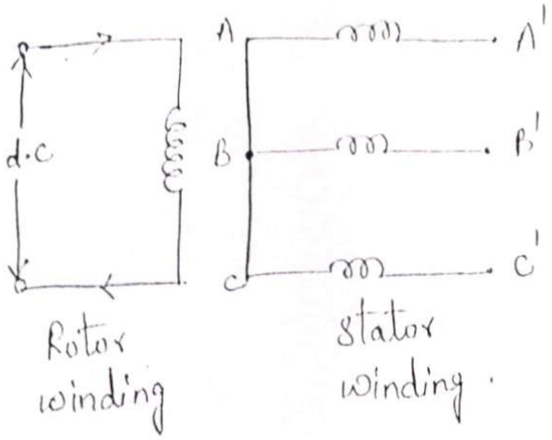


fig (i)

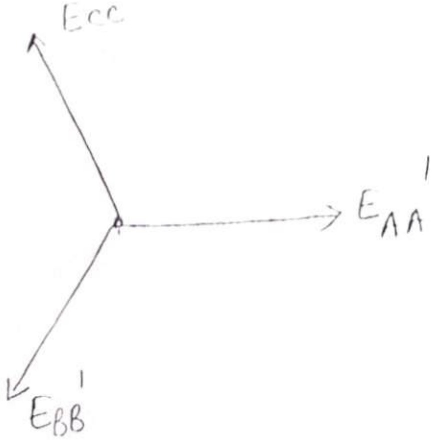


fig (ii)

Fig (i) shows star – connected armature winding and d.c field winding. When the rotor is rotated, a 3 - phase voltage is induced in the armature winding. The magnitude of induced emf depends upon the speed of rotation and the d.c. exciting current. The magnitude of emf in each phase of the armature winding is the same. However, they differ in phase by 120° electrical as shown in the phasor diagram in fig : (ii).

Frequency :-

The frequency of induced emf in the armature conductor depends upon speed and the number of poles.

Let N = rotor speed in rpm

P = no. of rotor poles

f = freq. of emf in HZ

I B.Tech I-Semester End Exams (Regular) - Dec-2025

R25

Basic Electrical Engineering

Scheme of Evaluation (R25EE103ES)

PART-A

1. (a) Definition of passive elements - 2M
   (b) Relation of voltage & current of 3 ϕ balanced star-connected system - 2M.
   (c) voltage regulation definition - 2M
   (d) Significance of back emf - 2M
   (e) Calculation of rotor frequency - 2M.

PART-B

2. (a) statement of KVL & KCL - 2M, Explanation - 2M } 4M
   (b) Calculation of I_1 - 2M, Calculation of I_2 - 2M, Calculation of I_3 - 2M } 6M

3. (a) Thevenin's Theorem statement - 1M, Explanation - 3M } 4M
   (b) Calculation of I' - 2M, Calculation of I'' - 2M, Calculation of I - 2M } 6M

4. (a) Average value Expression - 2.5M, RMS value Expression - 2.5M } 5M
   (b) Maximum value - 1M
   RMS value - 1M

Average value — 1M
Form factor — 1M
peak factor — 1M
} 5M.

(5) (a) Expression for resonant freq. — 5M

(b) calculation of Z — 1M
calculation of I — 2M
calculation of p.f — 2M
} 5M

(6) (a) working principle of transformer with diagram — 5M

(b) EMF Eq. of 1-ϕ transformer — 5M

(7) (a) $\eta_{F.L} = 2.5M$
$\eta_{H.L} = 2.5M$
} 5M

(b) Construction of Auto transformer with diagram — 5M

(8) Construction of DC machine with diagram — 10M

(9) (a) Torque Eq. of DC motor — 5M

(b) Types of DC motors — 5M

(10) Production of RMF by Considering 4 Cases — 10M

(11) Construction of Synchronous generator — 8M
working — 2M