Waves :- when there is a disturbance in a medium, there is a transfer of energy and momentum by waves.

Types of Waves :-

- → Mechanical Waves (medium is requ. for prop.)
  - → Sound Waves
  - → water waves
  - → wave in string
- → E.M. Waves (don't require medium)

cosmic γ

⇒ Definitions, S.I. units, formula.

Physics

Electrical Engineering

Q1 → Define the following terms
(i) Electricity (ii) Electric Potential
(iii) Electric Current (iv) Resistance
(v) Resistivity (vi) Specific Resistance
(vii) Conductance (viii) Conductivity (ix) E.M.F.
(x) Ohm's Law (xi) Electrical Energy
(xii) Electrical Power (xiii) Series & ‖el circuits

Q2 → (i) Linear and Non-Linear elements.
(xii) Bilateral and Unilateral elements.
Resistor ← ↳ diode.

Qn 2 →

R	V	I	E	P
R	$V = IR$	$I = \frac{V}{R}$	I^2Rt	I^2R
L	$V = L\frac{di}{dt}$		$\frac{1}{2}Li^2$	
C	$V = \frac{Q}{C}$		$\frac{1}{2}CV^2$	

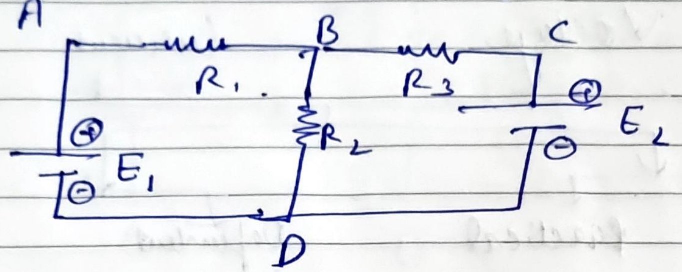
Q3 → Solve any 10 questions on KVL & KCL.?
Q4 → Solve any 10 questions using mesh analysis.
Q5 → " " " " using Nodal analysis.
Q6 → " " " " " Thevenin Theorem.

2 E IRC4

Unit - 2

D C - Circuits

(*) **Network Terminology:**



① **Active elements:** Those elements ~~in the~~ which supplies energy to the circuit, E1 & E2 (here) are active elements.

② **Passive elements:** Those elements which consumes or receives energy. Resistor, Capacitor,

③ **Node:** A point in a network where, two or more elements, join. "A, B, C, D"

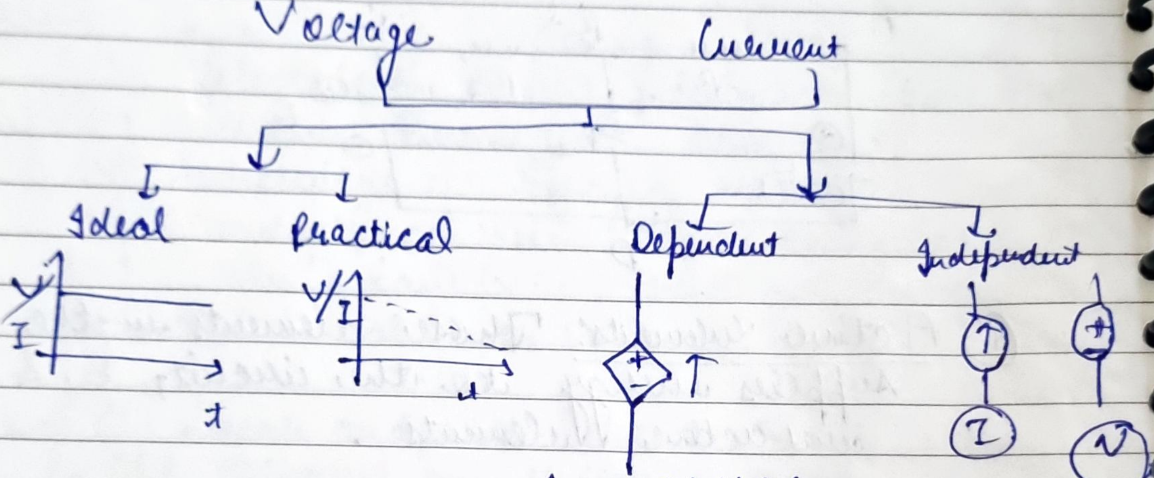
④ **Junction:** A point in a network where, three or more elements join. "B and D"

⑤ **Loop:** The closed path of a network is called loop. ABDA, BCDB, ABCDA.

⑥ **Mesh:** The most elementary form of a loop, which can't be further divided.

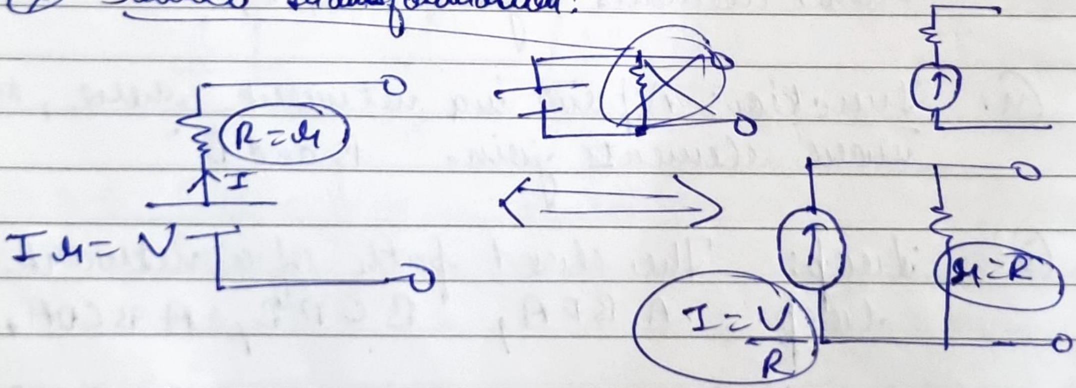
⑦ Branch: The part of a network which lies between two junction points. BCD, BAD.

⊛ Sources :



(i) Vol. Dep. Vol. Sou.
(ii) C. D. V. S.
(iii) V. D. C. S.
(iv) C. D. C. S.

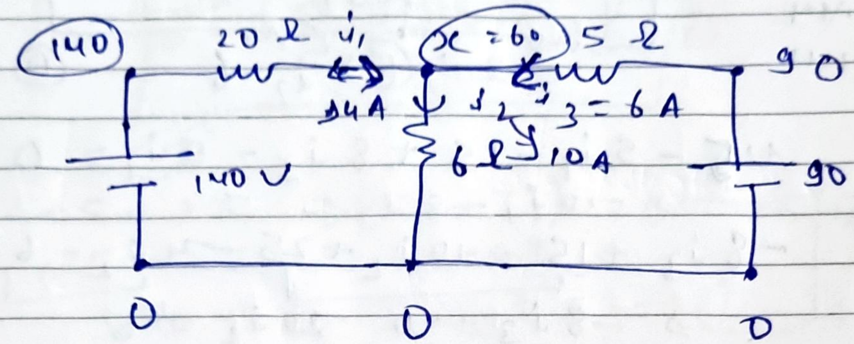
⊛ Source Transformation:



Kirchoff's Law:

(i) KCL (ii) KVL

Q



$$\frac{x-140}{20} + \frac{x-0}{6} + \frac{x-90}{5} = 0$$

$$\Rightarrow \frac{3(x-140) + 10x + 12(x-90)}{60} = 0$$

$$\Rightarrow 3x - 420 + 10x + 12x - 1080 = 0$$

$$\Rightarrow 25x = 150\cancel{0}0$$

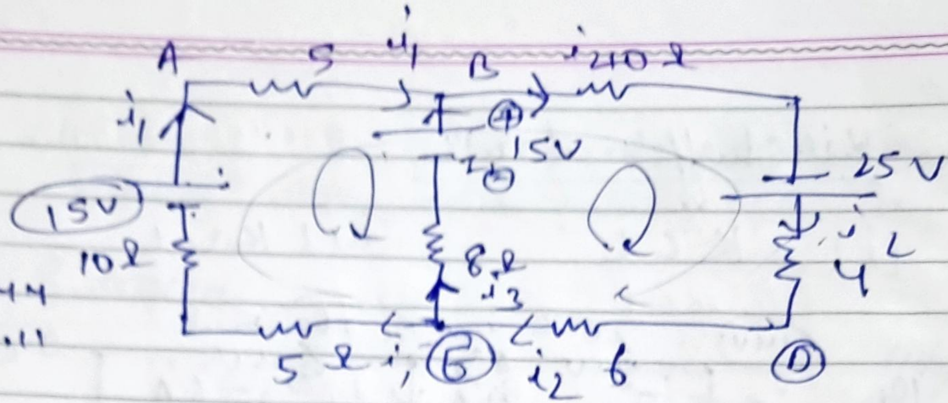
$$\Rightarrow x = 60$$

$i_1 = \frac{140-60}{20}$	$i_2 = \frac{60}{6}$	$i_3 = \frac{30}{5}$
$= 4A$	$= 10A$	$= 6A$

Power $= I^2R$

$= 100 \times 6 = 600W$

Q1



$I_1 \Rightarrow 0.44$

$I_2 \Rightarrow 1.11$ middle branch

$+15 - 5i_1 - 15 + 8i_3 - 5i_1 = 0 \rightarrow (i)$

$\Rightarrow -10i_1 + 8i_3 = 5$

$-8i_3 + \underbrace{15 - 10i_2}_{} + 25 - \underbrace{4i_2 - 6i_2}_{} = 0 \rightarrow (ii)$

$\Rightarrow -8i_3 + 40 - 20i_2 = 0$

$\Rightarrow -8[i_2 - i_1] + 40 - 20i_2 = 0$

$\Rightarrow -8i_2 + 8i_1 + 40 - 20i_2 = 0$

$\Rightarrow 8i_1 - 28i_2 = -40$

$\Rightarrow 2i_1 - 7i_2 = -10$

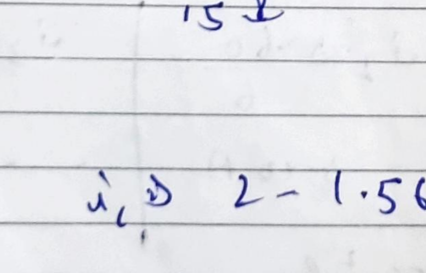
$i_1 + i_3 = i_2$ ~~$+5i_1$~~

$i_3 = i_2 - i_1$

$15 - 5i_1 - 10i_2 + 25 - 4i_2 - 6i_2 - 5i_1 - 10i_1 = 0$

$\Rightarrow 40 - 20i_1 - 20i_2 = 0$

$\Rightarrow i_1 + i_2 = 2 \rightarrow ①$



$2i_1 + 2i_2 = 4$

$2i_1 - 7i_2 = -10$

$-\quad + \quad +$

$9i_2 = 14$

$i_2 = \frac{14}{9}$

$i_1 \Rightarrow 2 - 1.56 \Rightarrow 0.44A \Rightarrow \boxed{1.56A}$

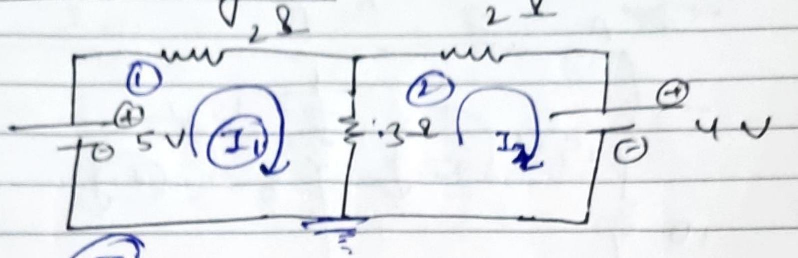
$i_3 \Rightarrow 1.55$

$-\ 0.44$

$1.11A$

⊛ Mesh Analysis :

Q1



Ⓘ

Sol → $+5 - 2I_1 - 3(I_1 - I_2) = 0$ → (i)

$\Rightarrow 5 - 2I_1 - 3I_1 + 3I_2$

$\Rightarrow 5I_1 - 3I_2 = 5 \rightarrow (i)$

Ⅱ $-2I_2 - 4 - 3(I_2 - I_1) = 0$

$\Rightarrow -2I_2 - 4 - 3I_2 + 3I_1 = 0$

$\Rightarrow 3I_1 - 5I_2 = 4 \rightarrow (ii)$

$15I_1 - 9I_2 = 15$

$-\ 15I_1 - 25I_2 = 20$

$\quad\quad\ \ + \quad\quad\quad -$

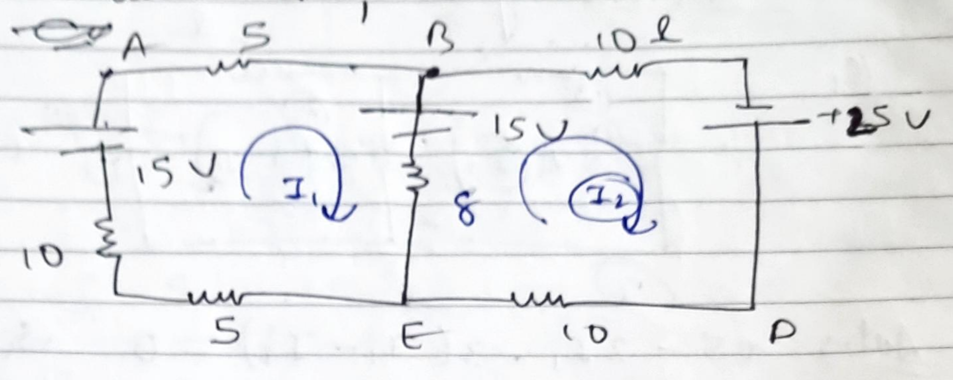
$16I_2 = 25 - 5$

$I_2 \Rightarrow \cancel{\frac{35}{16}} \quad \frac{-5}{16} \Rightarrow -0.3125$

$\Rightarrow 2.18A$

$5I_1 \pm 5 - 0.9375$ 0.9375

Q1 Find current in



Sol → $\cancel{15} - 5I_1 - \cancel{15} - 8(I_1 - I_2) - 5I_1 - 10I_1 = 0$ → ①

$\Rightarrow -5I_1 - 8I_1 + 8I_2 - 15I_1 = 0$

$\Rightarrow -28I_1 + 8I_2 = 0$

$\Rightarrow -7I_1 + 2I_2 = 0 \rightarrow (i)$

$I_1 \Rightarrow 0.44A$

$I_2 \Rightarrow 1.$

$-10I_2 + 25 - 10I_2 - 8(I_2 - I_1) + 15 = 0$

$\Rightarrow$ ~~$-10I_2 + 2$~~

$\Rightarrow -20I_2 + 25 - 8I_2 + 8I_1 + 15 = 0$

$\Rightarrow 40 - 28I_2 + 8I_1 = 0$

$\Rightarrow -8I_1 + 28I_2 = 40 \rightarrow (ii)$

$\Rightarrow 4I_2 - 2I_1 = 10$

$\Rightarrow 2I_2 - I_1 = 5$

~~$-56I_1 + 16I_2 = 0$~~

~~$-56I_1 + 161I_2 = 280$~~

$+ \cancel{145}^{29} I_2 = + \cancel{280}^{56}$

$I_2 \Rightarrow \frac{56}{29}$

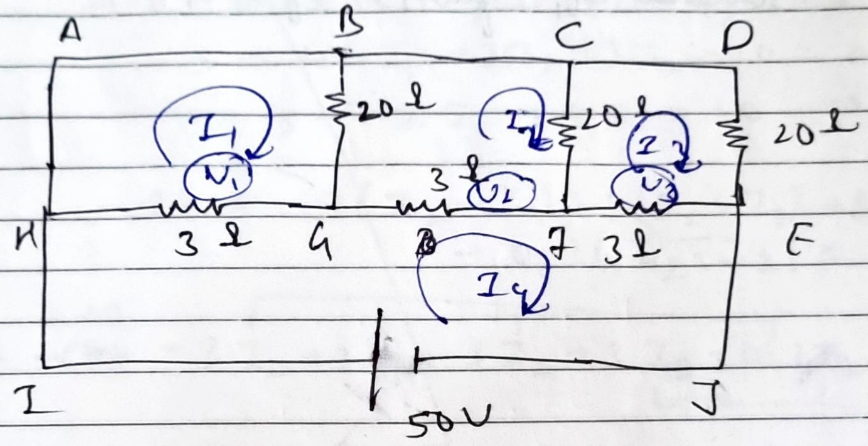
$\Rightarrow I_1 = \frac{2 \times 56^{8}}{29}$

$I_1 \Rightarrow \frac{16}{29}$

$$-7I_1 + \cancel{2I_2} = 0$$
$$\underset{+}{-}I_1 \underset{-}{+} \cancel{2I_2} = \underset{-}{5}$$

$$\cancel{-}6I_1 = -5$$
$$\Rightarrow I_1 \Rightarrow \frac{5}{6} \Rightarrow 0.8$$

Q



Ans →

$$-20(I_1 - I_2) - 3(I_1 - I_4) = 0$$
$$\Rightarrow -20I_1 + 20I_2 - 3I_1 + 3I_4 = 0$$
$$\Rightarrow -23I_1 + 20I_2 + 3I_4 = 0 \rightarrow (i)$$

$$-20(I_2 - I_3) - 3(I_2 - I_4) - 20(I_2 - I_1) = 0$$
$$\Rightarrow -20\underbrace{I_2 + 20I_3 - 3I_2 + 3I_4 - 20I_2}_{} + 20I_1 = 0$$

$$\Rightarrow 20I_1 - 43I_3 + 20I_3 + 3I_4 = 0 \Rightarrow (ii)$$

$$-20I_3 - 3(I_3 - I_4) - 20(I_3 - I_2) = 0$$
$$\Rightarrow -20\underbrace{I_3 - 3I_3 + 3I_4 - 20I_3}_{} + 20I_2 = 0$$

$$\Rightarrow 20I_2 - 43I_3 + 3I_4 = 0 \rightarrow (iii)$$

$I_1 \Rightarrow 4.67A$, $I_2 \Rightarrow 4A$ $I_4 \Rightarrow 9.27A$

$I_3 \Rightarrow 2.5A$

$V_1 = 13.82V$; $V_2 \Rightarrow 15.83V$

$V_3 \Rightarrow 20.35V$

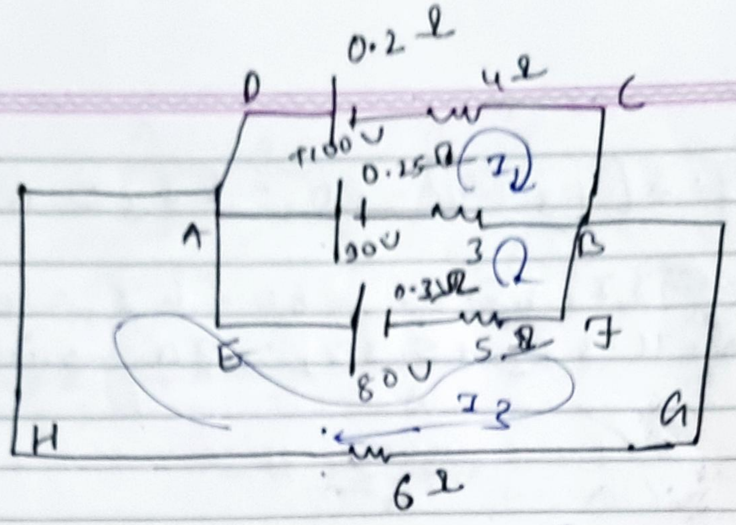
$$\Rightarrow -3(I_4 - I_1) - 3(I_4 - I_2) - 3(I_4 - I_3) + 50 = 0$$

$$\Rightarrow -3I_4 + 3I_1 - 3I_4 + 3I_2 - 3I_4 + 3I_3 + 50 = 0$$

$$\Rightarrow -9I_4 + 3I_1 + 3I_2 + 3I_3 + 50 = 0$$

Substract eqn 2 from 3, 3 from 4

Q1



$I_1 \Rightarrow 6.21$
$I_2 \Rightarrow 11.16$
$I_2 \Rightarrow 12.34$

Current in 3 Ω & 6 Ω.

Sol →

~~$-100 - 0.2I_1 - 4I_1 - \overset{0.25}{3}(I_1 - I_2) + 90 = 0$~~
~~$\Rightarrow -4.2I_1 - 0.25I_1 + 3I_2 - 10 = 0$~~
~~$\Rightarrow -7.2I_1 + 3I_2 = 10 \rightarrow (i)$~~

~~$-90 - 3(I_2 - I_1) - 3(I_2 - I_3) + 80 - 0.3(I_2 - I_3) = 0$~~

~~$\Rightarrow \overset{-10}{-90} - 3I_2 + 3I_1 - 3I_2 + 3I_3 - 0.3I_2 + 0.3I_3 = 0$~~

~~$\Rightarrow 3I_1 - 6.3I_2 + 3.3I_3 = 10 \rightarrow (ii)$~~

~~$-6I_3 - 80 - 5.3(I_3 - I_1) = 0$~~

~~$\Rightarrow -6I_3 - 80 - 5.3I_3 + 5.3I_1 = 0$~~

~~$\Rightarrow 5.3I_1 - 11.3I_3 = 80 \rightarrow (iii)$~~

$-100 - 4.2I_1 - 3.25(I_1 - I_2) + 90 = 0$
$\Rightarrow -7.45I_1 + 3.25I_2 = 10 \rightarrow (i)$

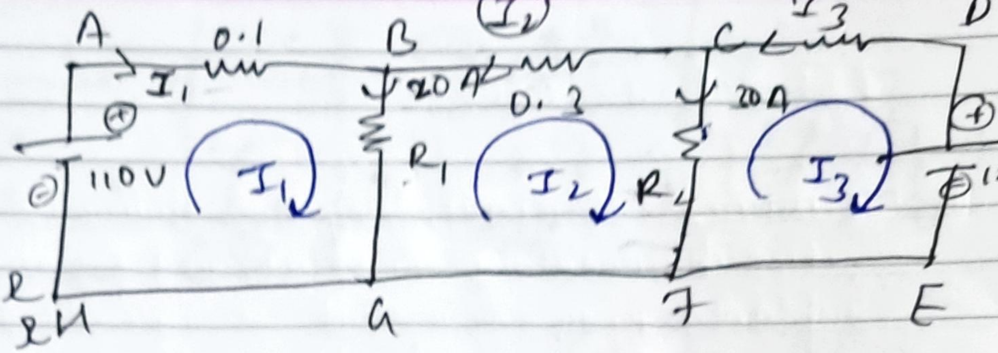
$-90 - 3.25(I_2 - I_1) - 5.3(I_2 - I_3) + 80 = 0$
$\Rightarrow -3.25I_2 + 3.25I_1 - 5.3I_2 + 5.3I_3 = 10$
$\Rightarrow -8.55I_2 + 3.25I_1 + 5.3I_3 = 10$

$-5.3(I_3 - I_2) - 80 - 6I_3 = 0$

$\Rightarrow -5.3I_3 + 5.3I_2 - 80 - 6I_3 = 0$

$\Rightarrow -11.3I_3 + 5.3I_2 = 80 \rightarrow (iii)$

Q1



$R_1 \to 5.45\,\Omega$

$R_2 \to 3.73\,\Omega$

Find R_1 & R_2.

$\{ I_1 \to 10A, \quad I_2 \to 10A, \quad I_3 \to 40A \}$

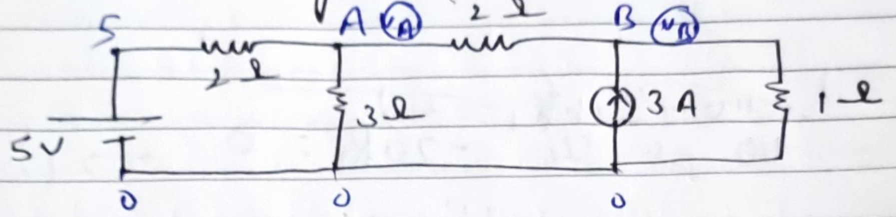
Sol → ~~$+110 - 0.1(I_1 - I_2)$~~

$110 - 0.1 I_1 - 20R_1 = 0 \quad \to (i)$

~~200×0.1~~ $+ 0.3 I_2 - 30R_2 +$

~~e.g.:~~ Nodal Analysis:

~~e.g.:~~



K.C.L. at node A

$$\frac{V_A-5}{2} + \frac{V_A-0}{3} + \frac{V_A-V_B}{2} = 0$$

$\Rightarrow$ $8V_A - 3V_B = 15 \rightarrow (i)$

→ Towards the node current → ⊖ ve

→ Away from " " " → ⊕ ve

$$\frac{V_B-V_A}{2} + \frac{V_B-0}{1} - 3 = 0$$

$\Rightarrow$ $3V_B - V_A = 6 \rightarrow (ii)$

By solving, $7V_A = 21$

$V_A = 3V$; $V_B = 3V$

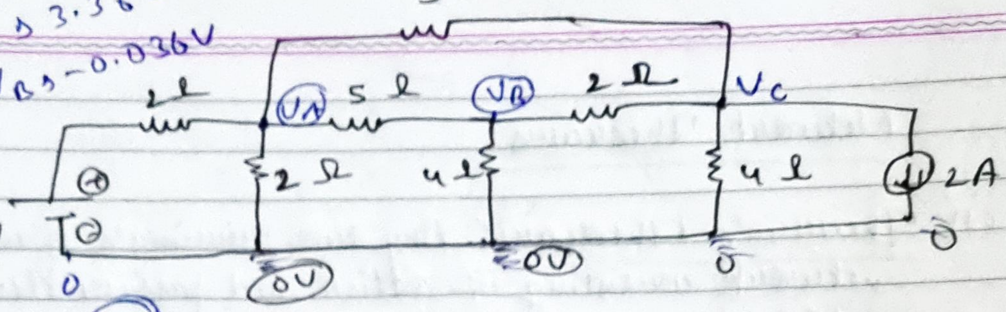
Calculator ⇒ Casio 999 use
FS

$V_C \Rightarrow -1.416$

$V_A \Rightarrow 3.36V$

$V_B \Rightarrow -0.036V$

e.g.



Sol ⇒

Ⓐ

$$\frac{V_A-10}{2}+\frac{V_A-0}{2}+\frac{V_A-V_B}{5}+\frac{V_A-V_C}{5}=0$$

$$\Rightarrow 7V_A-V_B-V_C=25 \rightarrow (i)$$

Ⓑ

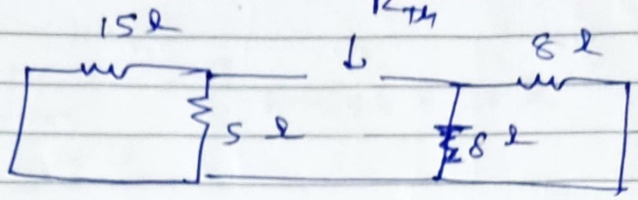
$$\frac{V_B-V_A}{5}+\frac{V_B-0}{4}+\frac{V_B-V_C}{2}=0$$

$$\Rightarrow 19V_B-4V_A-10V_C=0 \rightarrow (ii)$$

Ⓒ

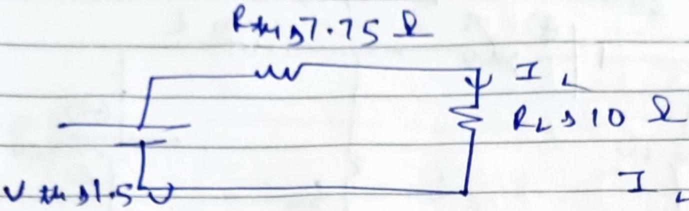
$$\frac{V_C-V_B}{2}+\frac{V_C-V_A}{5}+\frac{V_C-0}{4}+2=0$$

$$\Rightarrow -4V_A-10V_B+19V_C=-14 \rightarrow (iii)$$

⇒


$R_{th} = (15\|5) + (8\|8) = \frac{15\times 8}{20\ 4} + \frac{8\times 8}{16\ 2} = 4$

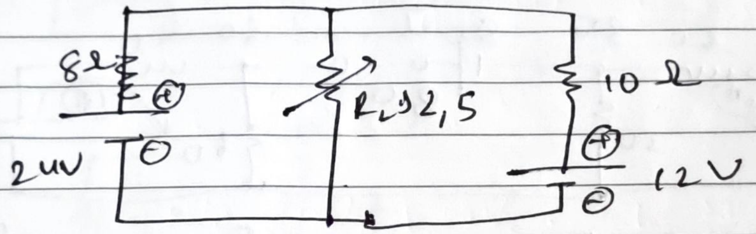
$= 7.75\ \Omega$



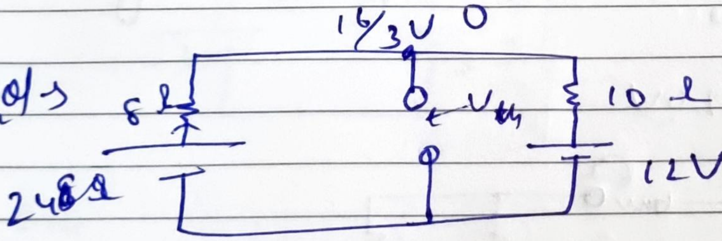
$I_L = \frac{1.5}{17.75} = 0.084\ A$

Ans

e.g.



Δ0/ ⇒

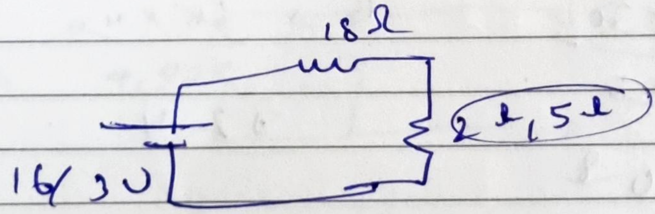


$I = \frac{V}{R}$

$= \frac{24-12}{8+10}$

$= \frac{12}{18} = \frac{2}{3}\ A$

$V = \frac{2}{3} \times 8 = \frac{16}{3}\ V$



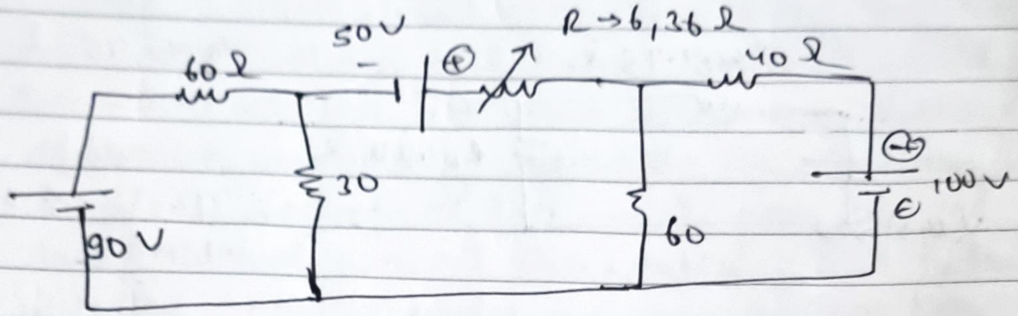
$I = \frac{\cancel{16}\ 8}{3 \times \cancel{20+10}\ 5}$

$= \frac{4}{15}$

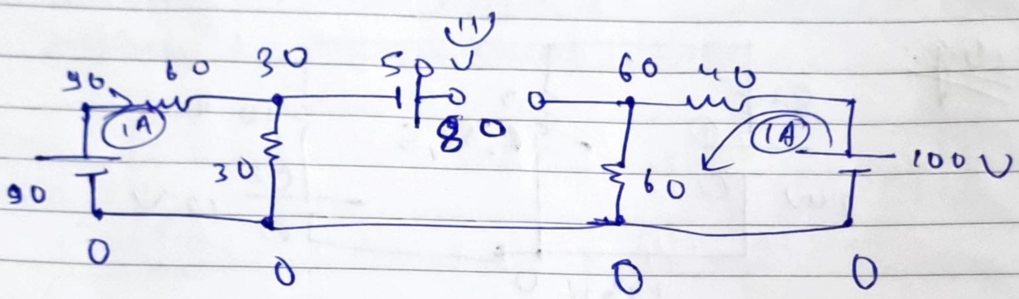
$I = \frac{16}{3\times 23}$

~~R_th = 4.441~~

e.g.

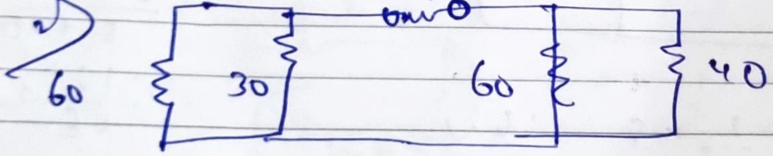


Ans→



$V_{th} \to 20V$

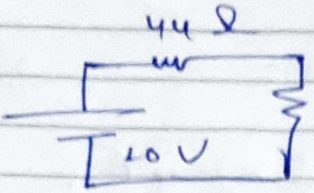
Rth →



$R_{th} \to \frac{60 \times 30}{90} \to 20\,\Omega$

$R \to \frac{60 \times 40}{100} \to 24$

$R_{th} \to 20 + 24 \to 44\,\Omega$



$R_{th} = 6\,\Omega, 36\,\Omega$

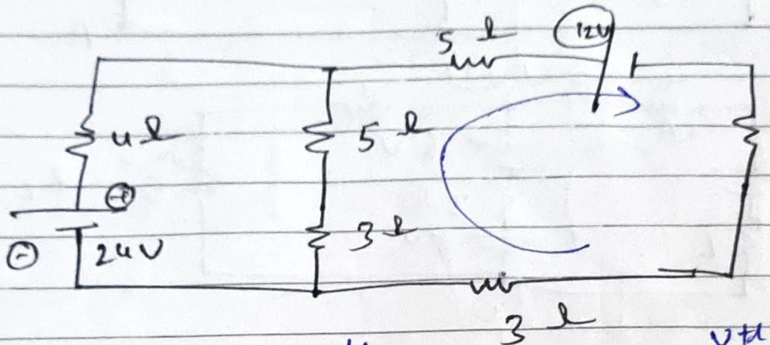
$I_{6\Omega} = \frac{20}{50}$

$= 0.4\,A$

$I_{36\Omega} = \frac{20}{80}$

$= 0.25\,A$

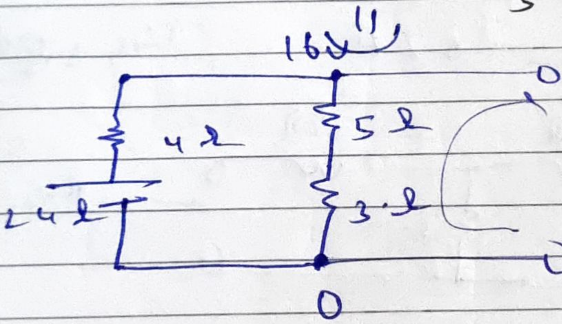
e.g.



$V_{th} = 0 + 16 + 0 - 12$

$\boxed{= 4V}$

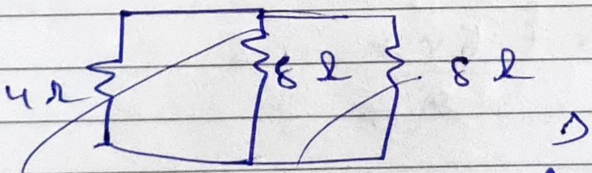
Sol^n =



$I = \frac{24}{12}$

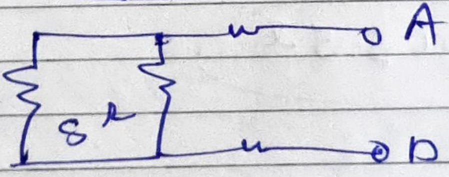
$= 2A$

R_th



$R_{th} = \boxed{2\,\Omega}$

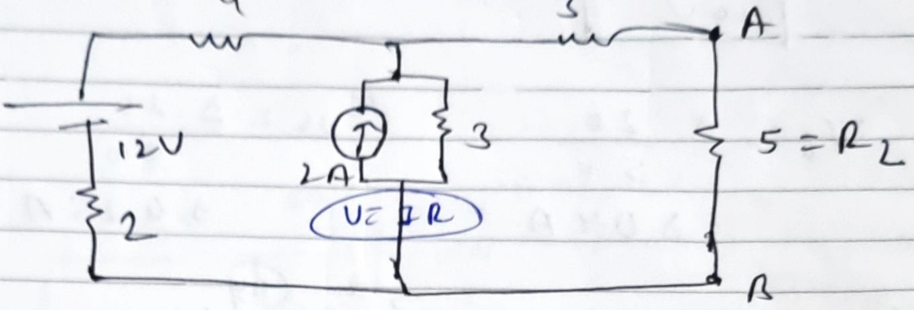
V_th

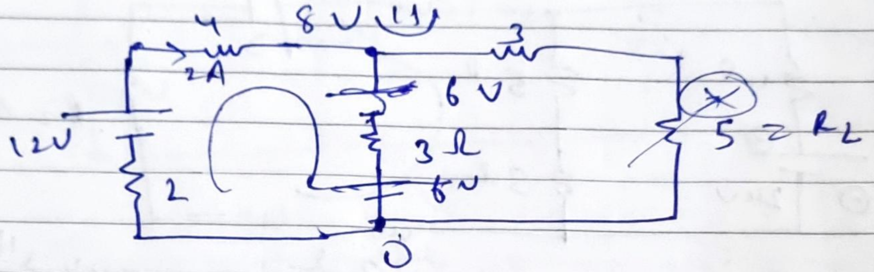


$\frac{\cancel{4}\times 8}{\cancel{12}\,3} + 5 + 3 = \frac{8}{3} + 8 = \frac{32}{3}$

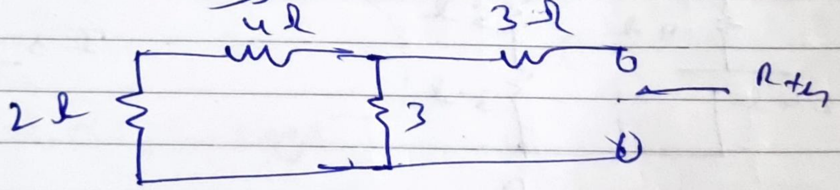
$R_{th} = 10.67\,\Omega$

~~e.g~~





$I = \frac{18}{9} = 2A$, $V_{Th} = 8\,V$

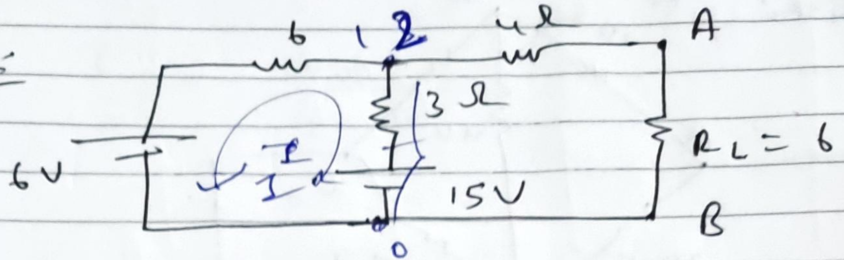


$6 + \frac{\cancel{6}^{2} \times 3}{\cancel{9}_{3}} + 3$

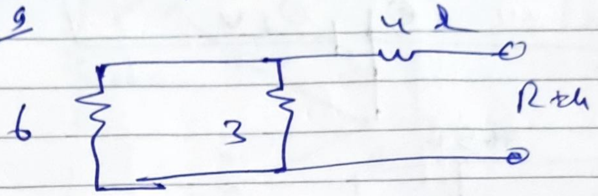
$\frac{6 \times 3}{9}$ 3

$\boxed{R_{th} = 5\,\Omega}$

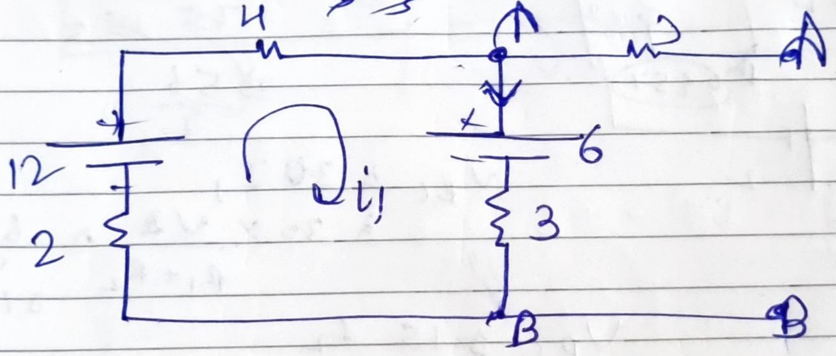
e.g.:



Sol: $I = \frac{9}{9} = 1A$



$R_{th} = \frac{6\times\cancel{3}^{2}}{\cancel{9}_{3}} + 4 = \boxed{6\,\Omega}$



$+12 - 4i_1 - 6 - 3i_1 - 2i_1 = 0$

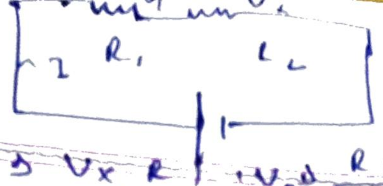
$6 - 9i_1 = 0$

$\underline{i}$ $\quad i_1 = \frac{6}{9} = \frac{2}{3} = 0.66$

$V_A - 6 - \cancel{\left(3\times\frac{2}{3}\right)}$

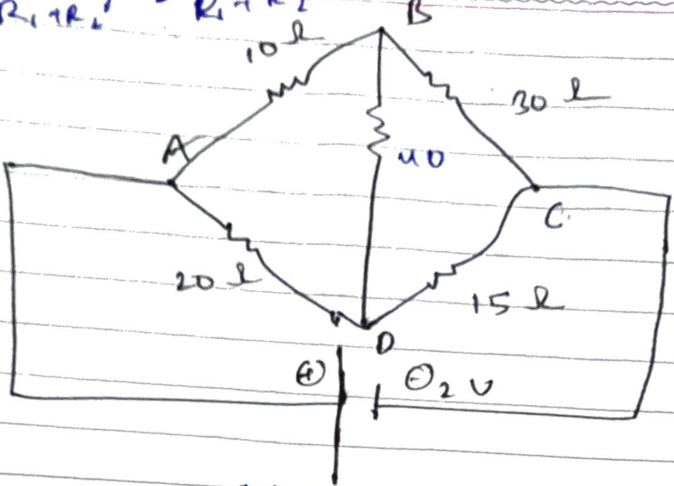
$V_A - 8 = 0$

$V_{th} = \underline{8}$

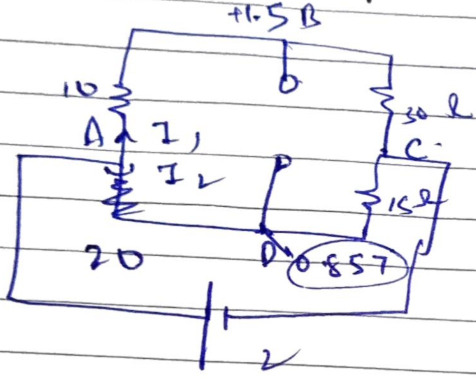


$V_1 = V_x \frac{R}{R_1+R_2}$, $V_2 = \frac{R_2}{R_1+R_2}$

(iii) Q1



Sol^n



~~$R_{net} = \frac{\overset{8}{40} \times \overset{7}{35}}{75}$~~

~~75~~ ~~15~~ 3

$= \frac{56}{3}$

$V_{BC} = 30 I_1$

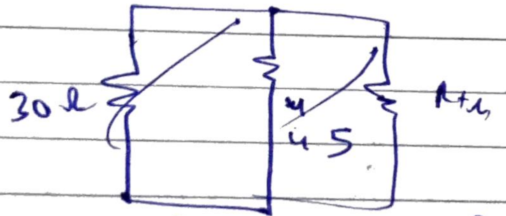
$= 30 \times \frac{V}{R_1+R_2} = \frac{60}{40}$

$= 1.5 V$

$V_{DC} = 15 I_2$

$= 15 \times \frac{V}{20+15} = \frac{30^6}{35_7} = 0.857$

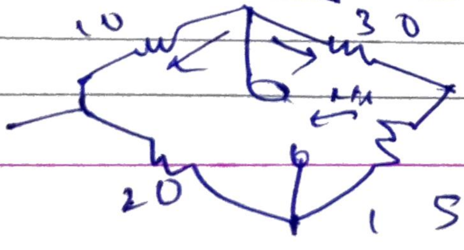
$$V_{BD} = \begin{array}{r} 1.500 \\ -\ 0.857 \\ \hline 0.643 \end{array} V$$



Q1

~~$\frac{30 \times 45}{75}$~~ 10

~~$\frac{30 \times 45}{75}$~~



$R_{th} = (10 \| 30) + (20 \| 15)$

$= \frac{10 \times 30}{40} + \frac{20 \times 15}{35}$

$= 7.5 + 8.57$

$= 16.07\ \Omega$

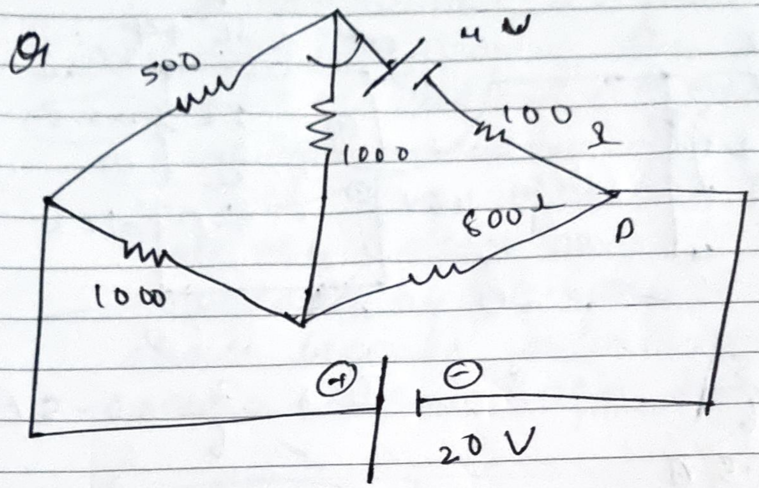
"11.45mA"

$\boxed{I = ?.?}$

$I \Rightarrow \frac{0.642}{16.07}$

$\Rightarrow 0.04$

Q1



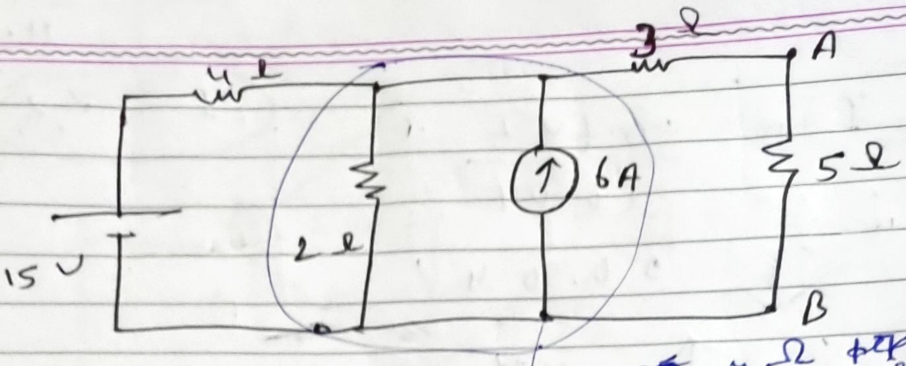
"Current in middle branch."

$V_{th} \Rightarrow 2.22\ V$

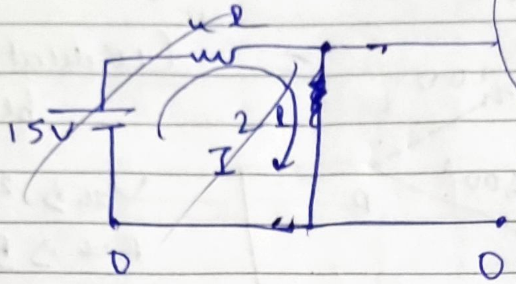
$R_{th} \Rightarrow 527.78\ \Omega$

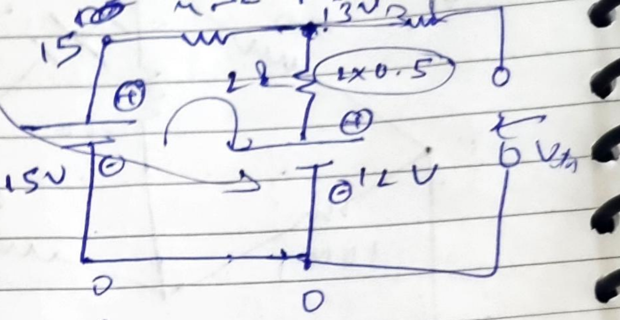
$I_L \Rightarrow 1.5\ mA$

Q1.



Sol →





~~$I = \frac{15}{6} = 2.5A$~~

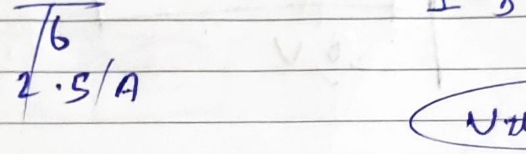
$I = \frac{3}{6} = 0.5A$

$\boxed{V_{th} = 13V}$

$15 - 4I - 2I - 12 = 0$

~~$I = 3$~~

R_{th}

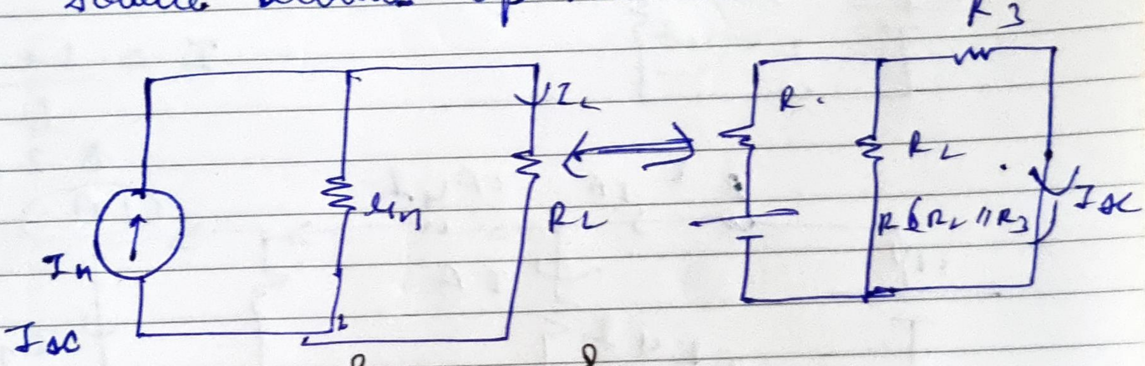


$R_{th} = \frac{4 \times 2}{4+2} + 3 = \frac{8}{6} + 3$

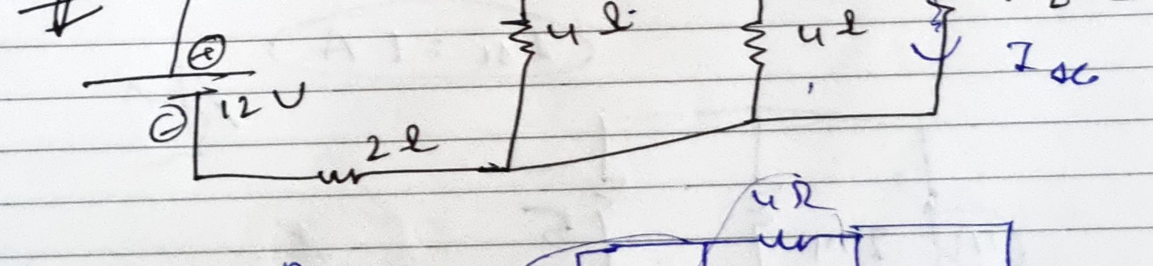
$= 4.33 Ω$

$I = \frac{13}{4.33} = \boxed{3A}$

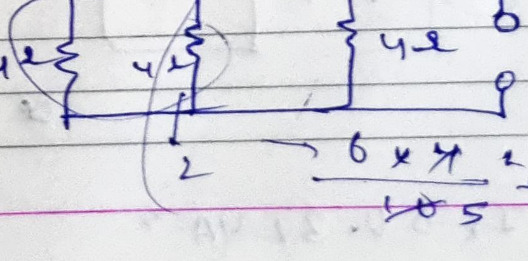
(ii) Norton's theorem: Any two terminal network, consisting of voltage sources and resistances, can be converted into a constant source and a ||el resistance. The magnitude of constant current is equal to the current which will flow if the two terminals are short circuited and ||el resistance is the equivalent resistance of the whole network viewed from open circuited terminals after all the voltage and current sources are replaced by the internal resistance of voltage source becomes short circuited and current source becomes open circuited.



e.g.

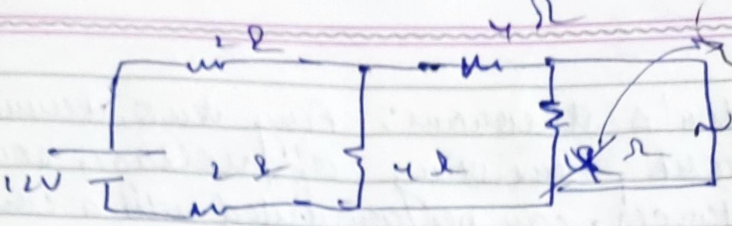


Sol → R →



$\rightarrow \frac{6 \times 4}{\cancel{10}\ 5} = \boxed{2.4\Omega}$

"S.K. Bhhatacharya"
→ Pearson Publication"



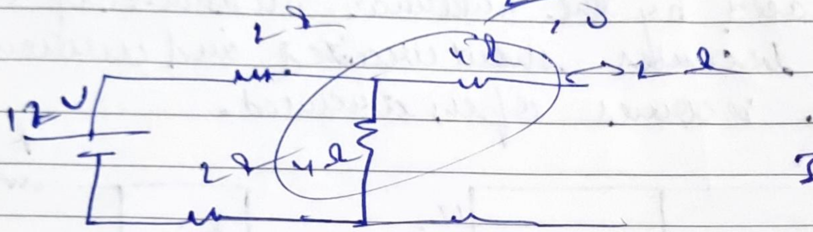
No ristance ↓ "due to short circuit branch"

$\frac{8 \times 4}{12\ 3}$ R net = $\frac{8}{3} + 4$

= $\frac{20}{3}$

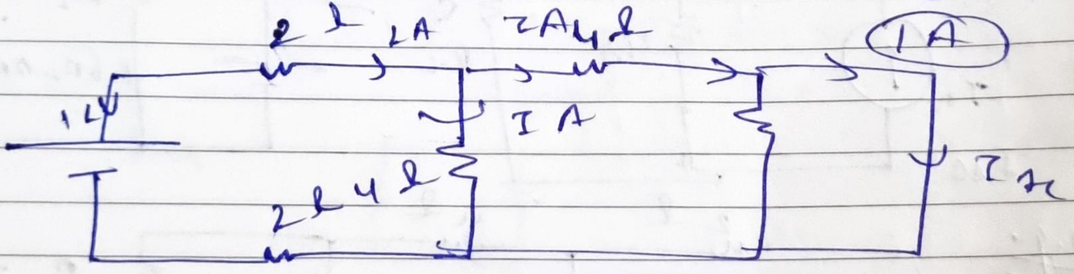
I = $\frac{12 \times 3}{20}$ = 1.8 = 1.8 A

= $\frac{36}{20}$

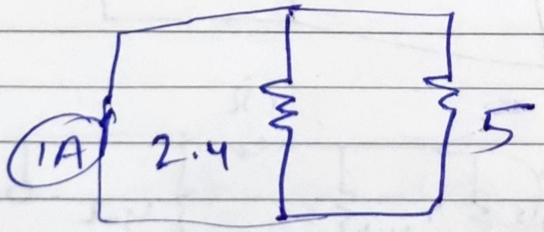


I = $\frac{12}{6}$

= 2A



$\boxed{I_{sc} = 1 A}$



$\frac{1}{6.4}$

I_L = 0.324A"

[redacted]

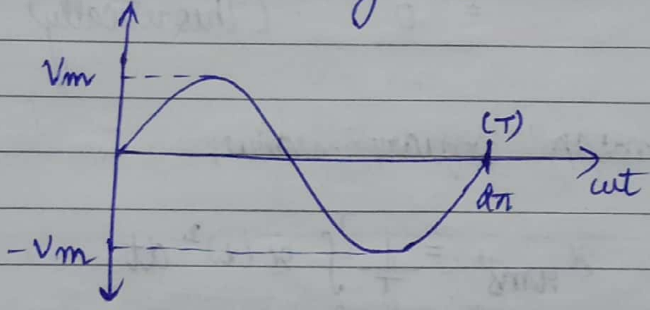
✓

AC signals

So far we have studied opera^{n} of circuit ~~with~~ for DC signal, now we will provide sinusoidal signal as input.

$$V(t) = V_m \underbrace{\sin}_{\text{nature}}(\omega t)$$

V_m = Amplitude
ω = frequency
t = time
ωt = argument



$$\omega T = 2\pi$$

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

$$\omega = 2\pi f$$

$$\underset{\text{(rad)}}{2\pi} = 860^\circ$$

$$1\ \text{rad} = 57{\cdot}3^\circ$$

conversion factor

$$\boxed{\begin{aligned} \text{rad} &= \frac{\pi}{180} \times {}^\circ \\ {}^\circ &= \frac{180}{\pi} \times \text{rad} \end{aligned}}$$

✓ Average value of Alternating signal:

In general, average value of general signal $x(t) = \frac{1}{T}\int_0^T x(t)\,dt$

$$V_{avg} = \frac{1}{\pi}\int_0^{\pi} V_m \sin d(\omega t)$$

$$= 0.63 V_m$$

for $$V_{avg} = \frac{1}{\pi}\int_0^{2\pi} V_m \sin d(\omega t)$$

$$= 0 \quad \text{(Theoretically)}$$

Root mean square value,

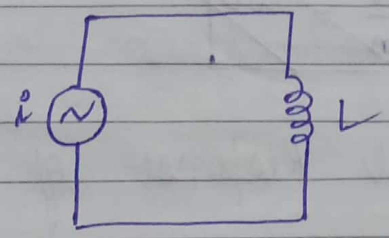
$$x_{rms} = \frac{1}{T}\int_0^T x(t)^2\,dt$$

$$V_{rms} = \frac{1}{2\pi}\int_0^{2\pi} (V_m \sin \omega t)^2\, d(\omega t)$$

$$= 0.707\, V_m$$

✓ Response of AC signal in inductor or capacitor:

i)



(lags by 90°)

$$i = I_m \sin \omega t$$

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

$$V = \underline{\omega L I_m} \cos \omega t$$

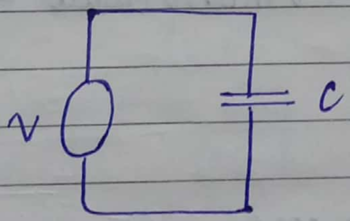
$$= V_m \sin(\omega t + 90)$$

$$V_m = \omega L I_m$$

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

---

ii)



(leads by 90°)

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

$$i = C\frac{dv}{dt}$$

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

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

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

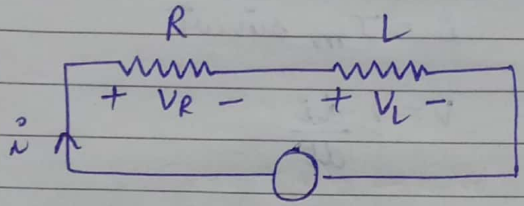
$$I_m = \omega C V_m$$

$$\boxed{\frac{1}{\omega C} = \frac{V_m}{I_m}}$$

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

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

✓ # Sinusoidal Response of series R-L circuit:



$$V_R = iR = R I_m \sin \omega t$$

$$V_L = \omega L I_m \sin(\omega t + 90^\circ)$$

$$V = V_R + V_L$$

$$V_m \sin(\omega t + \underset{\substack{\uparrow \\ \text{phase shift}}}{\theta}) = R I_m \sin(\omega t) + \omega L I_m \sin(\omega t + 90^\circ)$$

$$V_m \sin \omega t \cos \theta + V_m \sin \theta \cos \omega t = R I_m \sin \omega t + \omega L I_m \sin \omega t \cos 90^\circ + \omega L I_m \sin 90^\circ \cos \omega t$$

here,

$$V_m \cos \theta = R I_m$$

$$V_m \sin \theta = \omega L I_m$$

$$V_m^2 = (R I_m)^2 + (\omega L I_m)^2$$

$$V_m = I_m \sqrt{R^2 + (\omega L)^2}$$

$$V_m = I_m \underset{\substack{\downarrow \\ \text{impedence}}}{Z}$$

→ $R + j\omega L$

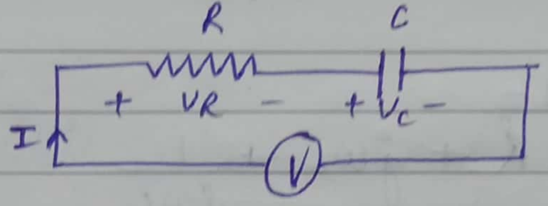
lag by $\frac{\omega L}{R}$

$\sqrt{R^2+(\omega L)^2} \angle \tan^{-1}\left(\frac{\omega L}{R}\right)$

$$z = \sqrt{R^2+(\omega L)^2} \angle \tan^{-1}\left(\frac{\omega L}{R}\right)$$

$$I_m = \frac{V_m}{z} = \frac{V_m}{\sqrt{R^2+(\omega L)^2}} \angle -\tan^{-1}\left(\frac{\omega L}{R}\right)$$

Sinusoidal Response of series R-C circuit:



$V = V_m \sin \omega t$

$V = I\left(R + \frac{1}{j\omega C}\right)$

$V = I\left(R - \frac{j}{\omega C}\right]$

$z = R - \frac{j}{\omega C}$

$z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} \angle -\tan^{-1}\frac{1}{\omega RC}$

current leads by $\frac{1}{\omega RC}$

$I = \frac{V}{z}$

$= \frac{V}{\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2} \angle -\tan^{-1}\frac{1}{\omega RC}}$

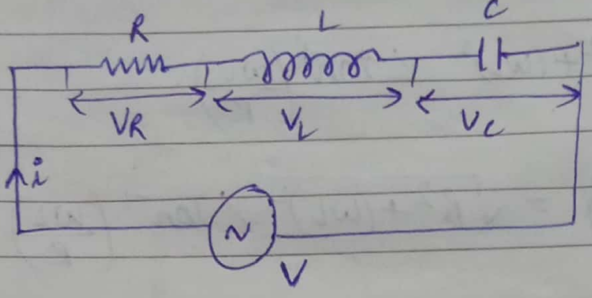
$X_c = \frac{1}{\omega C}$

$= \frac{1}{0}$

$= \infty$

$= \frac{V}{\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}} \angle \tan^{-1}\left(\frac{1}{\omega RC}\right)$

✓ ✦ Series RLC circuit :



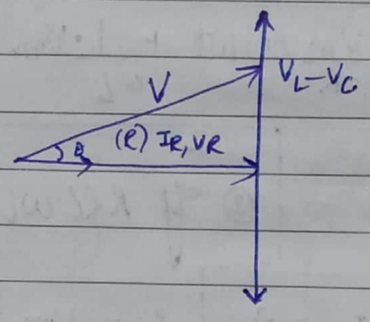
$$V = V_R + V_L + V_c$$
$$= iR + iX_L + iX_c$$
$$= i\left(R + j\omega L + \frac{1}{j\omega c}\right)$$

$$\begin{cases} X_L = j\omega L = jX_L \\ X_c = \frac{1}{j\omega c} \approx \frac{-j}{\omega c} = -jX_c \end{cases}$$

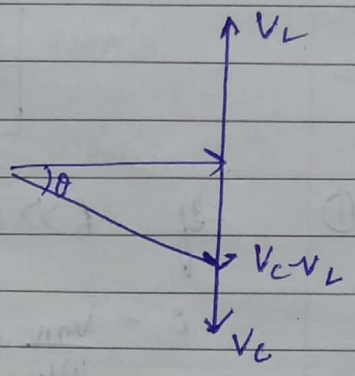
$$V = IZ$$
$$Z = R + j\omega L + \frac{1}{j\omega c}$$
$$Z = R + j\omega L - \frac{j}{\omega c}$$
$$Z = R + j\left(\omega L - \frac{1}{\omega c}\right)$$
$$\text{mag.} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega c}\right)^2}$$
$$\tan^{-1}\left(\frac{\omega L - \frac{1}{\omega c}}{R}\right)$$

① circuit becomes inductive when $\omega L > \frac{1}{\omega C}$

② circuit becomes capacitive $\frac{1}{\omega C} > \omega L$

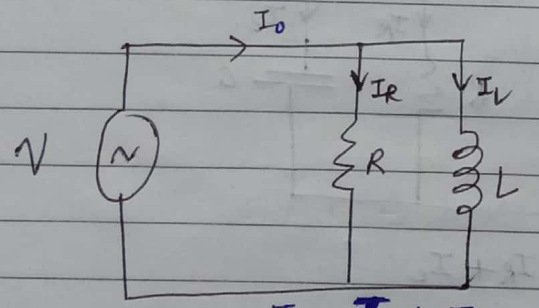


(inductive)



(capacitive)

Sinusoidal response of $||^{l}$ R-L ckt



$V = V_m \sin \omega t$

$$I_0 = I_L + I_R$$

$$I_R = \frac{V_m \sin \omega t}{R} = \frac{V}{R} \quad ; \quad I_L = \frac{V}{X_L}$$

$$I_0 = \frac{v}{R} + \frac{v}{X_L}$$

$$I_0 = v\left(\frac{1}{R} + \frac{1}{j\omega L}\right)$$

opposite of impedence → Y admittance → $\left(I = \frac{1}{Y}\right)$

$$\boxed{Y = \frac{1}{R} + \frac{1}{j\omega L} = \frac{1}{R} - \frac{j}{\omega L}}$$

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Date

Sinusoidal i/p , $v = v_m \cos \omega t$

$$I = I_R + I_L$$

$$I = \frac{v}{R} + \frac{1}{L}\int v\,dt$$

$$\boxed{I = \frac{V_m}{R}\cos\omega t + \frac{1}{\omega L}\cdot V_m \sin\omega t}$$

① if $R >> \omega L$

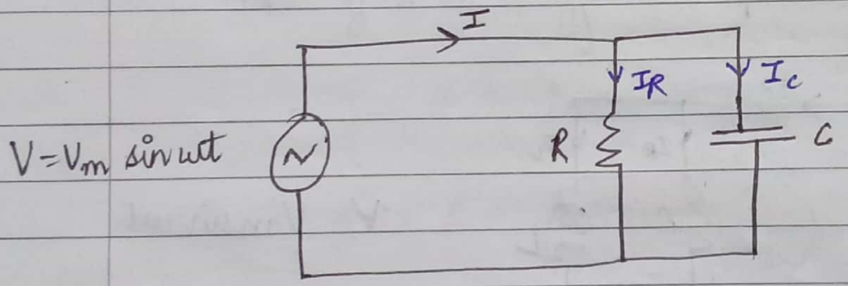
Phasor

$$i = \frac{V_m}{\omega L}\cos(\omega t - 90^\circ)$$

② if $R << \omega L$

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

Sinusoidal series of $||^{l}$ R-L circuit.



$$I = I_R + I_c$$

$$I = \frac{v}{R} + \frac{v}{\cancel{\frac{1}{j\omega C}}\ \frac{1}{j\omega C}}$$

$$I = \frac{v}{R} + jv\omega C$$

$$I = I_R + I_c$$

$$= \frac{V_m \sin\omega t}{R} + C\frac{dv}{dt}$$

$$= \frac{V_m \sin\omega t}{R} + \omega C V_m \cos\omega t$$

Scanned by CamScanner

i) if $R >> X_C$

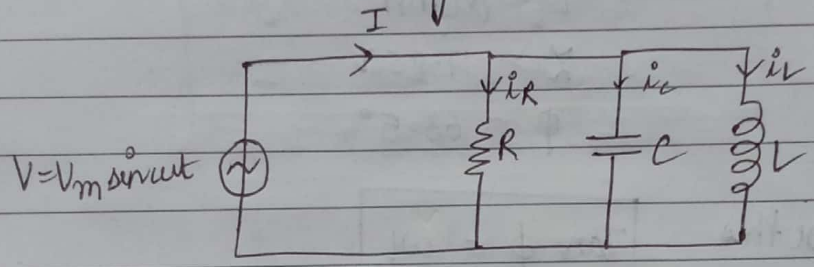
$$i = i_C = \omega C V_m \sin(\omega t + 90^\circ)$$

ii) if $R << X_C$

$$i \approx i_R \approx \frac{V_m}{R} \sin\omega t$$

---

sinusoidal series of $||^l$ R-L-C circuit



$$I = i_R + i_C + i_L$$

$$I = \frac{V}{R} + \frac{V}{X_L} + \frac{V}{X_C}$$

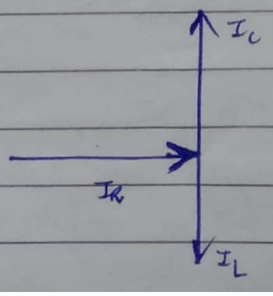
~~$I = \frac{V_m}{R} \sin\omega t$~~

$$I = \frac{V}{R} + \frac{V}{j\omega L} + \frac{V}{\frac{1}{j\omega C}}$$

$$I = \frac{V}{R} + \frac{V}{j\omega L} + V j\omega C$$

$$I = \frac{V}{R} + \frac{1}{L}\int V dt + C\frac{dV}{dt}$$

$$= \frac{V_m}{R}\sin\omega t - \frac{V_m}{L}\frac{\cos\omega t}{\omega} + \cancel{C} V_m \omega C \cos\omega t$$



(all values in rms)

Page No.
Date

Q In a R-L circuit the inductance being 20 milli henry (mH), impedence 17.85Ω ϕ ~~angle of the lag~~ of the input current from the applied voltage. find the value of Ω & R.

$\omega = 796.875$ rad/s
$R = 8\Omega$

$L = 20mH$
$Z = 17.85\Omega$
$\phi = 63.5°$

Use this $\boxed{\tan\phi = \frac{\omega L}{R}}$

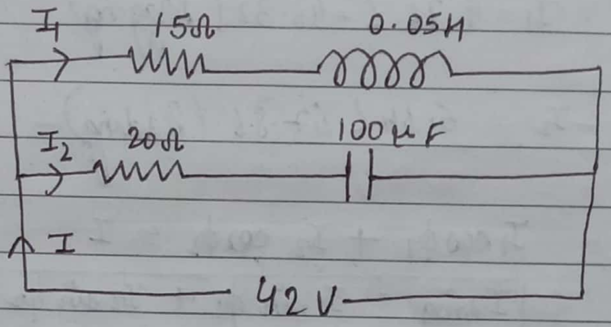
Q Applied voltage is 11ˡ RLC circuit is given by,

$v = 50\sin\left(5000t + \frac{\pi}{4}\right)V$
& $R = 20\,\Omega$
$L = 1.6\times10^{-3}H$
$C = 20\,\mu F$

find total current?

$I = 1.975\angle 18.5A$

Q Determine rms value of current in each branch and total current of the circuit draw its phasor diagram.



$f = 50Hz$

$$Z_1 = R_1 + j\omega L_1$$

$$= 15 + j(2\pi) \times 50 \times 0.05$$

$$= 15 + j(15.71)$$

$$Z_1 = \sqrt{(15)^2 + (15.71)^2}$$

$$= 21.72\,\Omega$$

$$\tan^{-1}\left(\frac{15.71}{15}\right) = \angle 46.32 \text{ (lagging voltage)}$$

$$Z_2 = 20 + (-j) \times \frac{1 \times 10^4}{2\pi \times 50 \times 100 \times 10^{-6}}$$

$$= 20 + (-j) \times \frac{100}{\pi}$$

$$= 20 - 31.81j$$

$$|Z_2| = 37.58 \qquad \angle 57.86^\circ \text{ (leading)}$$

$$I_1 = \frac{V}{Z_1} = \frac{212}{21.72 \angle 46.32} \qquad I_2 = \frac{212}{37.58}$$

$$\angle 57.86$$

$I_1 = 9.76 \angle -46.32$ (lagging)

$I_2 = 5.64 \angle 57.86$ (leading)

$$I_1 \cos\phi_1 + I_2 \cos\phi_2 = I$$

$$\boxed{I_{img} = I_1 \sin\phi_1 + I_2 \sin\phi_2}$$

$$I = I_R + j I_{img}$$

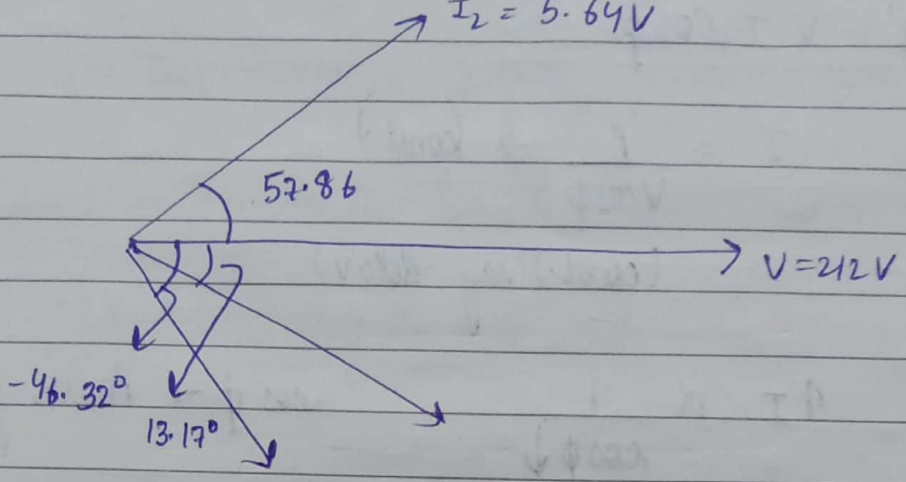
$$\phi = \tan^{-1}\left(\frac{I_1}{I_R}\right)$$

$$I_{real} = 9.76 \cos(46.32) + 5.64 \cos(57.86)$$
$$= 9.74$$

$$I_{img} = -2.28$$

$$\phi = \tan^{-1}\left(\frac{I_{img}}{I_R}\right) = -13.17°$$

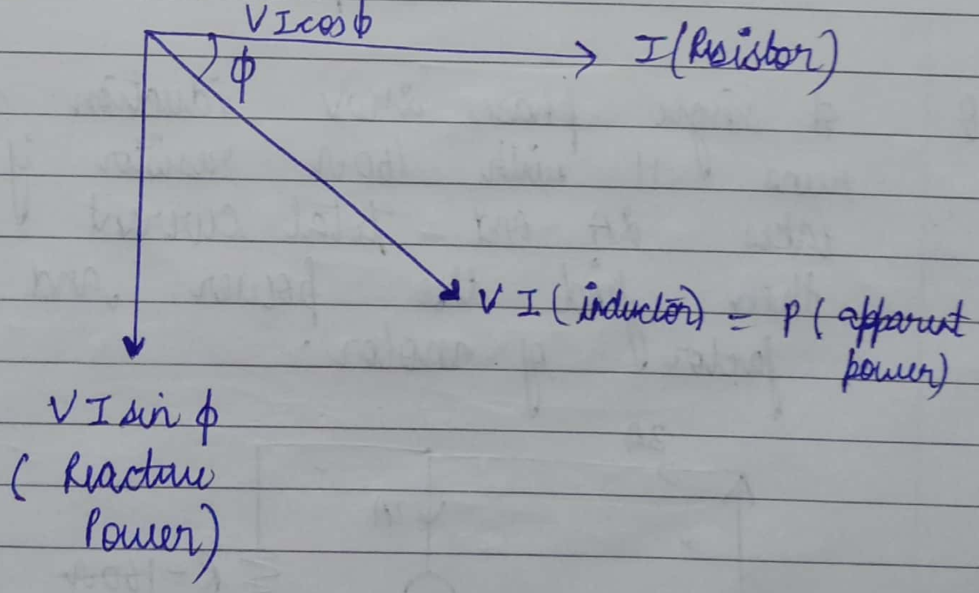
Reference line (which is common) in this case voltage is common.



$\frac{1}{X_L}$ = susceptance

✓ conductance + suspectanse = admittance (Z^{-1})
$(X_C \text{ or } X_L)^{-1}$

Real / actual / active power



Resistor also has P = V I cos φ
But φ is 0

Real power → power consumed by load

Reactive power → not consumed by load.

$P = V I \cos\phi$

$$I = \frac{\overset{\rightarrow \text{(const)}}{P}}{\underset{\text{(const.)(say 220V)}}{V}\cos\phi}$$

$$\uparrow I \propto \frac{1}{\cos\phi \downarrow}$$

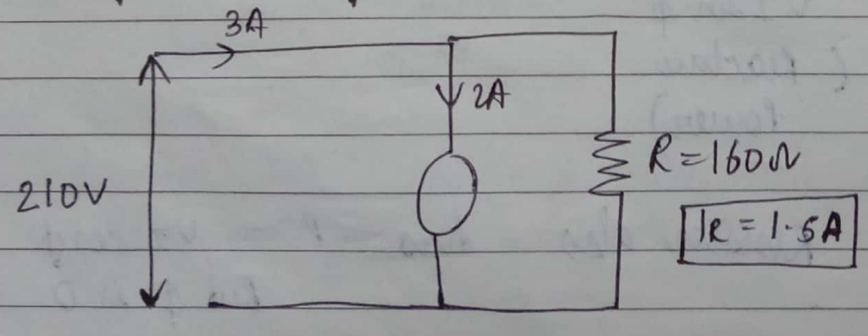
$\cos\phi \rightarrow$ Power factor

if $\cos\phi < 1$, i increases (i.e. equip is drawing more current from source)

Real power consumed by inductor / capacitor = 0

$$V I \underline{\cos\phi}$$
↳ $\pi/2$

Q A single phase 240V induction motor runs || with 160Ω resistor if motor takes 2A and total current is 3A, then find the power and power factor of motor.



there will be lagging power factor in motor since more current is drawn than should be.

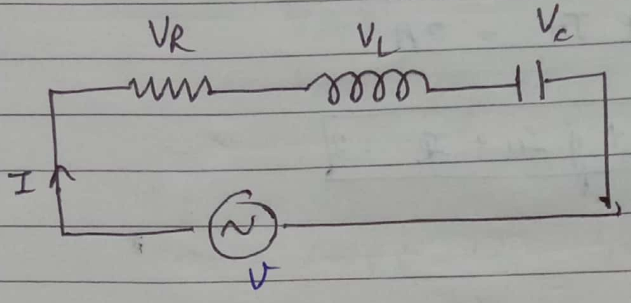
$$I_m = I_{wt} + j I_{\mu}$$

$$I_m + I_r = 3A$$

$$\boxed{I_w + j I_u + I_R = 3}$$

Series Resonance :

①



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

$$Z = R + j\omega L + \frac{1}{j\omega C}$$

$$Z = R + j\left(X_L - X_C\right)$$

$$I = \frac{V}{R + j(X_L - X_L)}$$

at resonance

$$\boxed{X_L = X_C}$$

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

② $\cos\phi = \frac{R}{Z}$

$$X_L = X_L$$

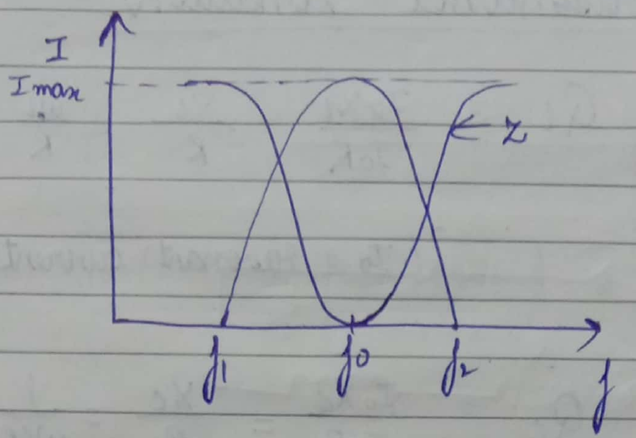
$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

③

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



f_1 & f_2 : half power frequency

↑ lower half power ν

↑ higher half power ν

Q factor at resonance:

$$Q = \frac{V_L}{V} = \frac{V_c}{V}$$

When not in resonance condition

$$Q_L = \cancel{\frac{I_L \times R}{I \times R}} \quad \frac{I_L \times X_L}{I \times R} = \frac{I_L X_L}{IR}$$

$$Q_c = \frac{I_c \times X_c}{I \times R} = \frac{I_c X_c}{IR}$$

$$\boxed{Q = \frac{\omega_0 L}{R} = \frac{1}{C\omega_0 R}}$$

In resonance condition :

$$Q_L = \frac{I_0 X_L}{I_0 R} = \frac{X_L}{R} = \frac{\omega_0 L}{R} = \frac{1}{\sqrt{LC}} \cdot \frac{L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

(I_0 = resonant current)

$$Q_C = \frac{I_0 X_C}{I_0 R} = \frac{X_C}{R} = \frac{1}{\omega_0 C R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

(I_0 = resonant current)

✓ Bandwidth of series resonating ckt →

at resonance : $\boxed{X_L = X_C}$

at half power " :

$$X = \pm(X_L - X_C) = R$$

higher पर X_L exceed करेगा

lower " X_C " करेगा

for f_2, $\left(\omega_2 L - \frac{1}{\omega_2 C}\right) = R$ —①

for f_1, $\left(\omega_1 L - \frac{1}{\omega_1 C}\right) = -R$ —②

(Book में kaafi है पर जितना class mein करवाया है उतना ही करना)

Adding ① & ②,

$$(\omega_2+\omega_1)L - \frac{1}{C}\left(\frac{\omega_1+\omega_2}{\omega_1\omega_2}\right) = 0$$

$$L = \frac{1}{C}\left(\frac{1}{\omega_1\omega_2}\right)$$

$$\boxed{\omega_1\omega_2 = \frac{1}{LC}} \quad — ③$$

Subtracting ① & ② and divide by L:

then we'll get

$$\boxed{(\omega_2-\omega_1) = \frac{R}{L}} \quad — ④$$

$$Q = \frac{\omega_0 L}{R} \quad \star$$

$$\boxed{\frac{R}{L} = \frac{\omega_0}{Q}} \quad — ⑤$$

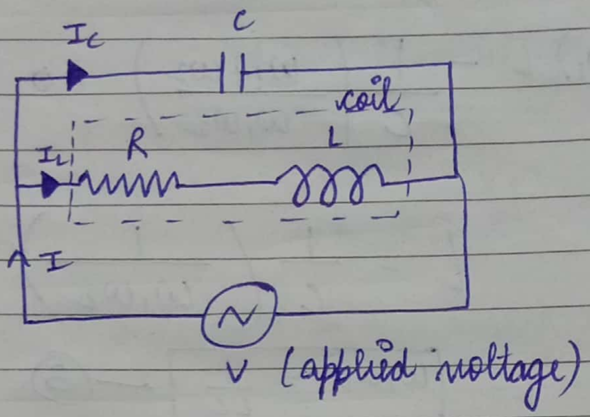
from eq^n — ④

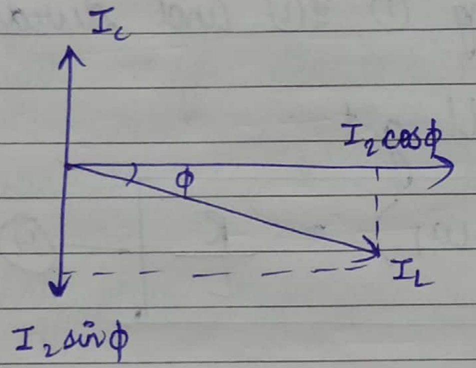
$$\omega_2 - \omega_1 = \frac{\omega_0}{Q}$$

$$\boxed{Q = \frac{\omega_0}{\omega_2-\omega_1}} \boxed{= \frac{f_0}{f_2-f_1}} \boxed{= \frac{\text{resonant } \nu}{\text{Bandwidth}}}$$

Imp. 0 Derivation of calculating Bandwidth

Parallel resonance :





$$\boxed{I = I_L \cos\phi}$$

★ Resonance, तब आएगी जब imaginary part zero होगा

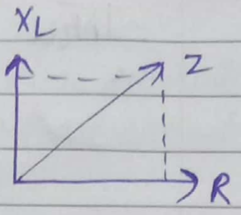
∴ at resonance,

$$I_C = I_L \sin\phi$$

$$\frac{V}{X_C} = \frac{V}{(R+jX_L)} \times \frac{X_L}{Z_L}$$

$$\boxed{R+jX_L = Z_L}$$

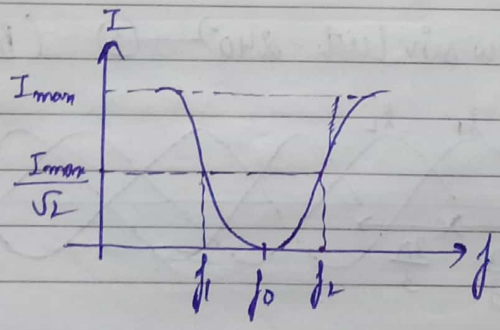
$$\boxed{\frac{V}{X_C} = \frac{V}{Z_L} \times \frac{X_L}{Z_L}}$$



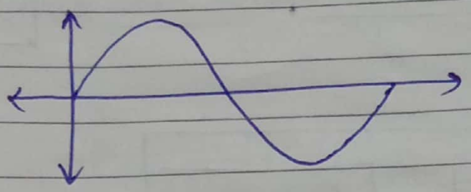
$$\boxed{f_0 = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}}$$

$$\frac{V}{Z_\Omega} = \frac{V}{Z_L} \times \frac{R}{Z_L}$$

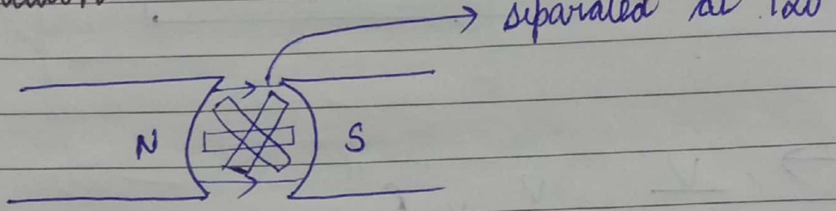
$$\boxed{Z_\Omega = \frac{L}{CR}}$$



Three phase signals (for uninterrupted power supply)



→ Generation :

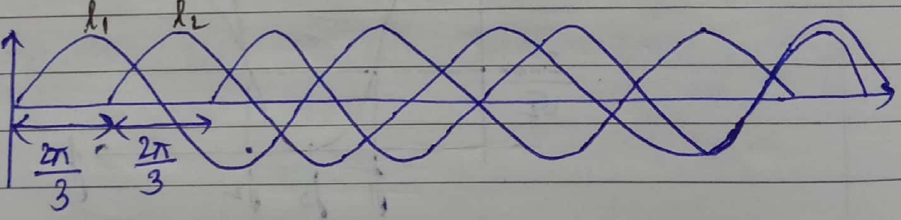


$$e = -\frac{d\phi}{dt}$$

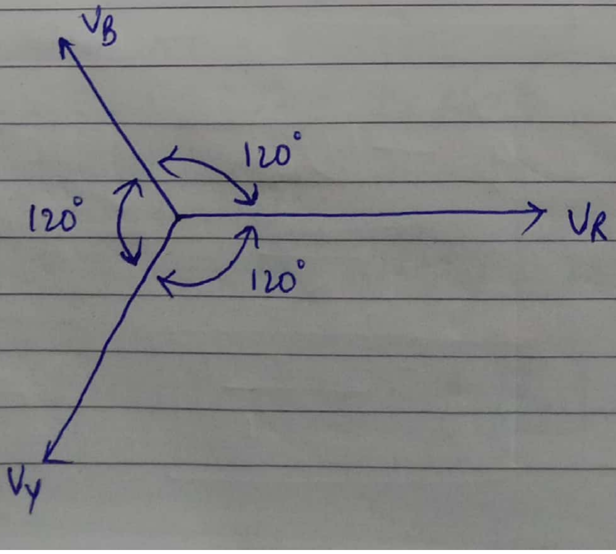
e_1 = Em sin ωt ——— ① (Red colour)

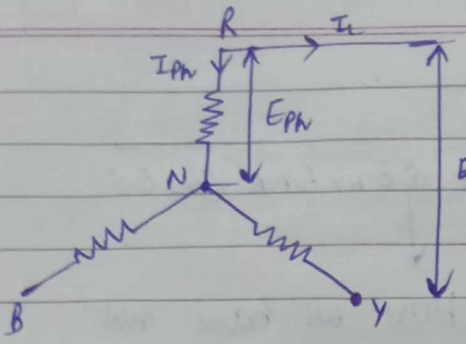
e_2 = Eω sin(ωt − 120°) ——— ② (Yellow colour)

e_3 = Eω sin (ωt − 240°) ——— ③ (Blue colour)

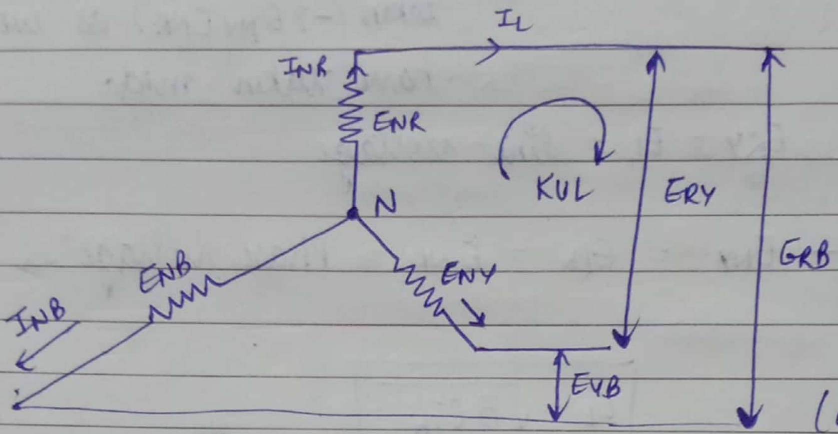


→





I_L = line current = I_{NR}
⇒ Phase current

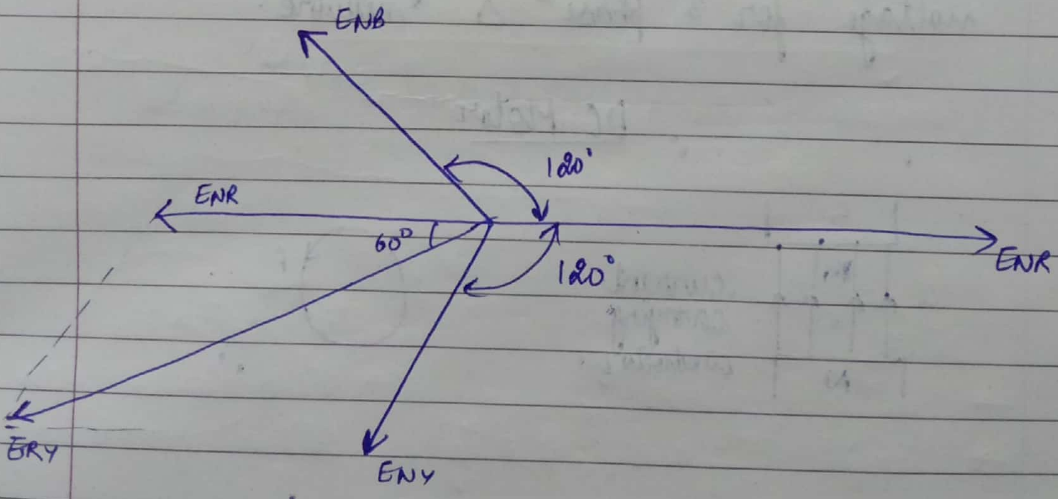


(all parts are identical)

$$\vec{E}_{NR} + \vec{E}_{RY} - \vec{E}_{NY} = 0$$

$$\vec{E}_{NR} + \vec{E}_{RY} = \vec{E}_{NY}$$

$$\vec{E}_{RY} = \vec{E}_{NY} - \vec{E}_{NR}$$



By ||gm law :

$$E_{RY} = \sqrt{E_{NY}^2 + E_{NR}^2 + 2E_{NY}E_{NR}\cos 60^\circ}$$

↓

(Here we have not taken $(-2E_{NY}E_{NR})$ as we have taken mod.

$E_{RY} = E_L$ = line voltage

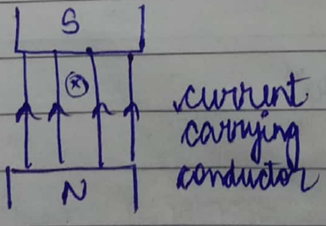
if given points are identical ← $E_{NY} = E_{Ph} = E_{NR}$ = Phase voltage

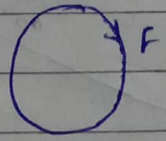
$$\boxed{E_L = \sqrt{3E_{Ph}^2}}$$

$$\boxed{E_L = \sqrt{3}\,E_{Ph}}$$

Q find relationship ① line current and phase current, ② line voltage and phase voltage for 3 phase Δ network.

DC Motor





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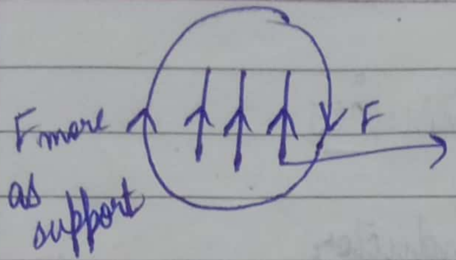


F (higher to lower)

$F = BIL$ (FLHR)

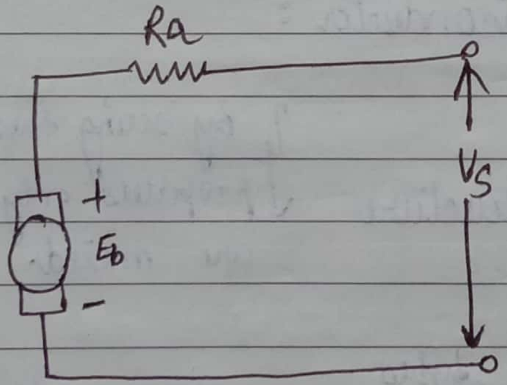
$E_b = \frac{\phi P N Z}{60A}$ ↙ Back emf

ϕ = flux

P = no. of poles

N = speed of rotation of conductor

A = no. of parallel path

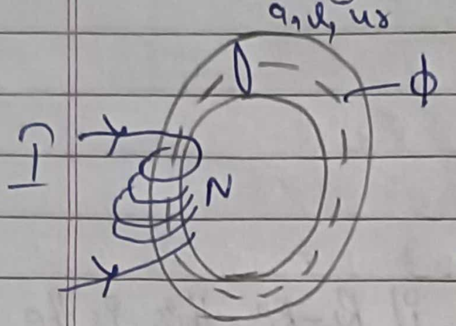


(I_a = armature current)

$V_S = E_b + I_a R_a + V_{brush}$

Unit-3

Magnetic Circuits



Consider a magnetic ring as shown in figure with n numbers of turns in wire. when Current I is passed through Solenoid, flux φ is set up in the Core.

- flux density in the Core (B) = φ/A (web/m² or T)

Mag Force (H) = $\frac{B}{\mu_0 \mu_r} = \frac{\phi}{a\mu_0\mu_r}$

According to work law, the work done in moving a unit pole once around the magnetic circuit is equal to the Amphere turns enclosed by the magnetic circuit.

H = magnetic intensity

$\Rightarrow Hl = NI$ {mmf = magneto motive force} {unit = Amp turns}.

$\Rightarrow \frac{\phi \cdot l}{a\mu_0\mu_r} = NI \Rightarrow \phi = NI \times \frac{a\mu_0\mu_r}{l}$

$$\boxed{\phi = \frac{NI}{l/a\mu_0\mu_r} = \frac{\text{mmf}}{\text{Reluctance}}}$$

Reluctance → The oposition offered to the magnetic flux by the magnetic circuit.

Rem

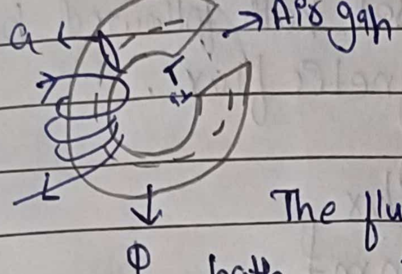
$$\boxed{S = \frac{l}{a\mu_0\mu_r}}$$ AT/web.

Permeance → it is a measure of easness by which flux can be set up in the material.

Permence (P) = $\frac{1}{S}$ unit = Henry or Web/AT.

Reluctivity → it is a specific Reductance of a magnetic material and Analogus to Resistivity.

* Leakage flux & fringing.



Consider a magnetic ring as shown in figure with n numbers of turns.

The flux which does not follow the intended path in a magnetic circuit is called leakage flux. When current I flows through a solenoid as shown in figure, magnetic flux is produced by it. Most of this flux follows the intended path and passes through air gap. This flux is called useful flux ϕ_u.
However some of flux is just set up around the coil and it not utilized for any work. this flux is called Leakage flux ϕ_L.

$$\boxed{\phi_{Total} = \phi_u + \phi_l}$$

fringing → it is clear from the figure that useful flux when setup in the air gap, it tends to bulge outward at b & b'. This increase the effective area in the air gap and decreases flux density this effect is known as fringing. The fringing ∝ length of air gap.

+ Comparision b/w Electric & Magnetic Circuits.

Similarities

Electric Circuit	Magnetic Circuit.
The closed path followed by electric Current is called electric circuit.	Closed path followed by magnetic flux.
Current	flux
Emf	mmf
Resistance	Reluctance.
Conductance	Permeanance.
Resistivity	Reluctivity.
Current density	flux density
Electric intensity	magnetic intensity.

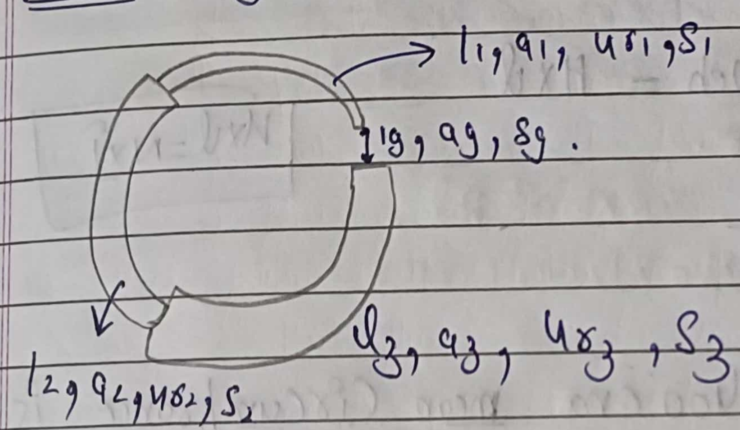
Differences

Electrical	Magnetic.
• Electric Current Actually flows in a circuit	• Magnetic flux does not flow, but it sets up in the magnetic circuit.
• for Electrical Current their are large no of perfect insulator like glass, air etc. which does not allow current to pass through them under normal Conditions	• for magnetic flux their is no perfect insulator, it can even be set up in non magnetic material like air rubber glass etc with reasonable mmf.
• The Resistance of an electric circuit is Almost Conctent, as its value depends on ρ. which is Almost Constant. However the value ρ & R may vary slightly if temp changes.	• The Reluctance of magnetic circuit is not Constant rather it varies with the value of B. it's because the value of uR Changes Continously in the change B.

Energyis Exhanded Continously As long as the Current flows through an electric circuit. The Energy is dissapiated in the form of Heat

Once the magnetic flux is set up in the magnetic circuit, no energy is exhanded. However a small amount of energy is required at the time of set up of flux in the circuit.

Series magnetic circuit.



$$\text{Total mmf} = \phi \times S$$
$$= S_1 + S_2 + S_3 + S_g$$
$$S = \frac{l}{a\mu_0\mu_r}$$

$$S_{net} = \frac{l_1}{a_1\mu_0\mu_{r1}} + \frac{l_2}{a_2\mu_0\mu_{r2}} + \frac{l_3}{a_3\mu_0\mu_{r3}} + \frac{l_g}{a_g\mu_0}$$

$$\text{Total Emf} = \phi \times \left[\frac{l_1}{a_1\mu_0\mu_{r1}} \cdots\cdots \frac{l_g}{a_g\mu_0}\right]$$

$$= \frac{\phi l_1}{a_1\mu_0\mu_r} --- \frac{\phi l_g}{a_g\mu_0}$$

We know that $B = \frac{\phi}{a}$

$$So = \frac{B_1 l_1}{\mu_0\mu_{r1}} + \frac{B_2 l_2}{\mu_0\mu_{r2}} \cdots + \frac{B_g l_g}{\mu_0}.$$

$$= H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g.$$

Also we know that $h = \frac{B}{\mu_0\mu_r}$

formula

- Total mmf $= \phi \times S = \phi \times \frac{l}{\mu_0 \mu_r a}$
- Total mmf $= N \times i$ {N → No of turns}
- So $\boxed{Ni = \phi \times \frac{l}{\mu_0 \mu_r a}}$
- Total Amp turns / web $= N \times I$
- Total Amp turns / web $= H \times l$ $\boxed{H \times l = N \times I}$
- $H = \frac{B}{\mu_0 \mu_r} = \frac{B}{\mu_0}$

Q An iron ring of 400 cm mean circumfrance is made from round iron of crossection 20 cm². its permeability is 500 if it is wound with 400 turns what current would be required to produce a flux of 0.001 web.

⇒ $\mu_r = 500$

$$Ni = \phi \times \frac{l}{\mu_0 \mu_r a}.$$

$$i = \frac{1}{1\cancel{000}} \times \frac{400 \times 10^{-2}}{\mu_0 \times 500 \times 20 \times 1\cancel{0}^{-4}}$$

$$\Rightarrow \frac{4}{\mu_0 \times 500 \times 2} = \frac{\cancel{2}}{\cancel{500}\mu_0} = \cancel{3.183\,Amp}$$

$$\underline{\underline{7.958\,A}}$$

Q A flux density of 1.2 web/m² is required in 2mm air gap. of an Electro magnetic having a iron Path 1m long Calculate its magnetising force and current requ if the electromagnet has 1273 turns Assume $\mu_r = 1500$.

=>

~~$\frac{\Phi}{A} \times \frac{l}{\mu_0 \mu_r} = Ni$~~.

~~$H \times l = N \times I$~~

~~$\frac{B}{\mu_0 \mu_r} \times l = N \times I$~~

~~$\frac{1.2 \times 1}{\mu_0 \times 1500} = 1273 \times i$~~

$l_g = 2\times10^{-3}$

$l = 1m$.

~~$i = \frac{12}{10} \times \frac{1}{1500 \times \mu_0 \times 1273}$~~

~~$N \times I = \Phi\left[\frac{1}{\mu_0 \mu_r a} + \frac{l_g}{\mu_0 a}\right]$~~

~~$N \times I = 102\left[1 + \frac{2}{1000}\right]$~~

~~$I = \frac{12}{12730}\left[\frac{1}{40} + \frac{2}{1000}\right]$~~

$= 9.426\times10^{-4}\left[795777.7\right]$

$H_i = \frac{B}{\mu_0 \mu_r} = 636.6A$

$H_g = \frac{B}{\mu_0} = 954900 A$

$H_i l_i = 636.66 \times 1 = 636.66$. + = Ampturns

$H_g l_g = 954900 \times \frac{2}{1000} \Rightarrow \underline{\underline{1908.8}}$. $= \underline{\underline{2546.4}} = N \times I$

Q Estimate the no of Amp turns nessecary to produce a flux of 100000 lines round an iron ring of 6 cm² crossection and 20 cm mean diammeter, having a air gap of 2mm wide Across it μ_r of iron = 1200.

Relation 1web = 10^8 lines of force

$\Rightarrow$

$Hl =$ ~~B~~

$Hl = \dfrac{\Phi}{A \cdot \mu_0 \mu_r} \cdot l =$

$\cancel{\dfrac{10^{-3}}{6\times10^{-4} \times \mu_0 \times 1200} \times 2\pi 10 \times 10^{-2}}$

$\dfrac{1 web}{10^3} = \dfrac{10^8}{10^3}$

Total length $= \pi d = \underline{\underline{20\pi}}$ $\dfrac{2\pi}{10}$

$l_{iron} = \dfrac{2\pi}{10} - \dfrac{2}{1000} \Rightarrow \dfrac{2}{10}\left(\pi - \dfrac{01}{100}\right)$

$l_g = \dfrac{2}{1000}$

$H_i l_i = \dfrac{10^{-3}}{6\times10^{-4} \times \mu_0 \times 1200}\left[\dfrac{2}{10}\left(\pi - \dfrac{1}{100}\right)\right]$

$= 70.62$

$H_g l_g = \dfrac{10^{-3}}{6\times10^{-4} \times \mu_0} \times \dfrac{2}{1000} = 2652.5$

Amp tur. 2723.12 =

Ans - 3344.79A

Q Calculate the Relative permeability of an Iron ring when the exciting Current taken by 600 turn Coil ~~taken~~ is 1.2 Amp. and total flux = 1 milli web (10^{-3}) Circunfrance of the Ring is 0.5m and Area of Crosssection is 10cm².

→

$$60\times12 = \frac{\Phi}{A\,\mu_0\mu_r}\cdot l$$

$$60\times12 = \frac{10^{-3}\times\frac{1}{2}}{10\times10^{-4}\times\mu_0\times\mu_r}$$

$$\mu_r = \frac{\cancel{10}}{\cancel{10}\times2\times\mu_0\times60\times12}$$

$$\mu_r = \frac{1}{2\times\mu_0\times60\times12} = \underline{\underline{552.6}}\ ✓$$

Q An iron ring of mean length of 1m has an air gap of 1mm and a weiding of 200 turns. if the $\mu_r = 500$. when a Current of 1Amp flows through coil find $\frac{\Phi}{A}$

→

$$200 = \frac{\Phi}{A\,\mu_0}\left[\frac{0.999}{500} + 0.001\right]$$

$$200 = \frac{B}{\mu_0}\left[2.998\times10^{-3}\right].$$

$$\frac{200\,\mu_0\times10^{3}}{2.998} = B \rightarrow \underline{\underline{0.0838}}\ ;\ \underline{\underline{\text{web/m}}}$$

Inductance

Expression for self inductance. ① $e = L \cdot \frac{di}{dt}$

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

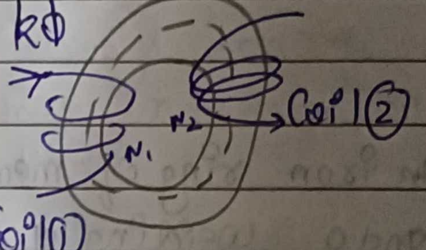
② $L = \frac{N\phi}{I}$ ③ $L = \frac{N^2}{S}$

Expression for mutual inductance.

① $e_m = M \cdot \frac{dI_1}{dt}$ ② $M = \frac{N_2 \phi_{12}}{I_1} = \frac{N_1 \phi_{21}}{I_2}$.

$M = \frac{e_m \cdot dt}{dI_1}$ ③ $M = \frac{N_1 N_2}{S}$

Coefficient of Coupling.



$K = 0$

$K = 1$

when Current flows through one Coil it produces flux ϕ_1. The whole of this flux may not be linking with the other Coil Coupled to it as shown in figure it may be reduced because of leakage flux ϕ_1. by a fraction of K known as Cofficient of Coupling. thus the fraction of magnetic flux produced by Current in one Coil that links with the other is known as Cofficient of Coupling.(K). if the flux produced by one Coil completely links with other then the Value of K is 1 and Coil are said to be magnetically tightly Coupled.

if the flux produced by one Coil does not link at all with other than the value of K is zero and Coil are said to be magnetically isolated.

Consider the Ring as shown in figure when current I_1 flows through coil 1

$$L_1 = \frac{N_1 \phi_1}{I_1} \quad M = \frac{N_2 \phi_{12}}{I_2}. \quad M = \frac{N_2 R \phi_1}{I_1}. \quad \text{—} ①$$

$$L_2 = \frac{N_2 \phi_2}{I_2}, \quad m = \frac{N_1 \phi_{21}}{I_2} \quad m = \frac{N_1 R \phi_2}{I_2}. \quad \text{—} ②.$$

on multiplying LHS & RHS.

$$m \times m = \frac{N_2 R \phi_1 \times N_1 R \phi_2}{I_1 \times I_2}$$

$$m^2 = L_1 L_2 R^2$$

$$m = R\sqrt{L_1 L_2}$$

$$\boxed{R = \frac{m}{\sqrt{L_1 L_2}}.}$$

Q1 An air cort $\{\mu_r = 1\}$ solenoid has 300 turns, its length is 25 cm and its cross section 3cm² Calculate its self inductane in Henry.

$$L = \frac{N^2}{S} \Rightarrow \quad L = \frac{300 \times 3\cancel{0}\cancel{0} \times 3 \times \cancel{10}^{-4} \times 1\ \mu_0}{25 \times \cancel{10}^{-2}}$$

$$\frac{9 \times 3\cancel{00}^{\times 4}}{\cancel{25}} \Rightarrow 1.0357 \times 10^{-4}.$$

$$\boxed{S = \frac{l}{\mu_0 \times \mu_r \times a}}$$

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~~**Q2** A Coil wound on an Iron Core of permeability 500, has 200 turns and a Cross sectional area of 8cm². Calculate the inductance of Coil.~~

$$\cancel{\Rightarrow L = \frac{N^2}{S} \Rightarrow 200\times 2}$$

Q2 Calculate the inductance of toroid, 25cm mean diatmer and 6.25 cm² cross section wound uniformly with thousand turns of wire. Calculate emf induced when Current in it increases at rate of 100 Amp per second. $l = \pi d$

$$e = L \cdot \frac{di}{dt} \qquad e = \frac{N^2}{l} \times 9 \times 40 \times 1 \times 100 = 0.1$$

Q3 Two Coils A and B of 600 & 1000 turns resp. Connected in series on same magnetic circuit of reluctance 2×10^6 Amp/turn. Assuming that their is no flux leakage, Calculate ① self inductance of each Coil
② Mutual " of two Coil.

$$\Rightarrow \cancel{L_1 = \frac{N^2}{l} \times 9 \times 40} \Rightarrow \qquad \cancel{S = N\phi}$$

$$L_1 = \frac{N^2}{S} = \frac{6\cancel{0} \times \overset{3}{\cancel{60}} \times 1\cancel{00}}{\cancel{2} \times 10^{2}} \Rightarrow 18\times10^{-2}$$

$$L_2 = \frac{N^2}{S} = \frac{1\cancel{000} \times 1\cancel{000}}{2\times1\cancel{0^6}} \Rightarrow 0.5 \Rightarrow 50\times10^{-2}.$$

$$\frac{6\cancel{00} \times 1\cancel{000}}{2\times100} \Rightarrow \frac{6}{20} \Rightarrow \frac{3}{10} = 0.3$$

(vi) what would be the mutual inductance if the coff of coupling is 75%.

$RM \Rightarrow 0.3 \times \frac{3}{4} = \underline{\underline{0.225}}$.

Q The Self inductance of a Coil of 500 turn is ·25H if 60% of flux is linked with a second Coil of 10,000 turns, Calculate
(i) mutual inductance of two coil
(ii) Emf induced in 2nd when current changes at rate of 100 Am/Sec.

$\Rightarrow$ $L = 0.25 \quad N_1 = 500, \quad N_2 = 10000$

~~$M = N_2 K \frac{\Phi_1}{I_1} - N_2 K \circ L_1 = M = 10000 \times \frac{60}{100} \times \frac{25}{100}$~~

~~$\underline{\underline{250 \times 6}} = M$.~~

~~$250 \times 6 = \frac{60}{100} \sqrt{\frac{25}{100} \times L_2}$~~

~~$\frac{2500 \times 2500 \times 100}{25} = L_2$.~~

$L_1 = \frac{N \Phi_1}{I_1}$

$\frac{25}{100} = 500 \times \frac{\Phi_1}{I_1}$

$\frac{\overset{5}{\cancel{25}}}{\cancel{5}} \times 10^{-4} \Rightarrow \underline{\underline{5 \times 10^{-4}}} = \underline{\underline{\frac{\Phi_1}{I_1}}}$

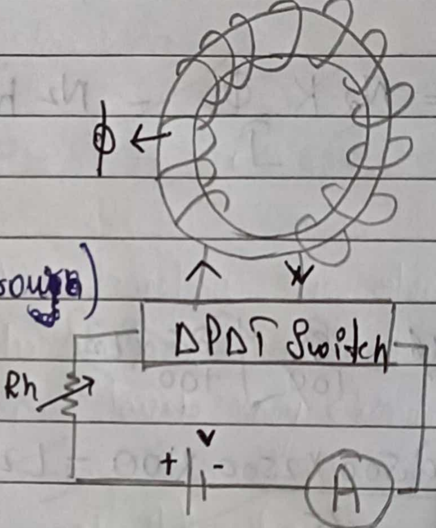
(ii) ~~250×6.~~

$M = 10000 \times \frac{60}{100} \times 5 \times 10^{-4} \Rightarrow \frac{30}{10} \Rightarrow \underline{\underline{3H}}$.

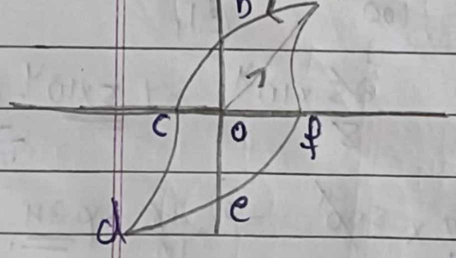
$e = M \times \frac{di}{dt} \Rightarrow 3 \times 100 = \underline{\underline{300}}$.

B-H Curve or Hystensis looh.

When a magnetic matorial is magnetise, first in one direction and then in other, it is found that flux density (B) logs behind applied magnetising force (H). this phenomenea is known as Hystensis. Stensis is a term derived from greek word. "hysterefum" meaning to lag behind. To understand this consider a ring on which a solenoid is bound uniformly.



The solenoid is connected to DC source through a DPDT (Double Pole Double through) switch whichis reverssible.



when the field intensity (H) is increased gradually, by increasing current in the solenoid, the flux density (B) also increases. until saturation point a is reached and curves obtain is oa. if now the magnetising force is gradually reduced to zero by decreasing current in the solenoid, the flux density does not become zero. and curve so obtained is ab. when magnetising force (H) is zero, the flux density still has value ob.

Residual magnetism & Retentivity.

The value of flux density ob retained by magnetic material is known a Residual magnetism & Power

To demagnatise the magnetic ring, the magnetising force (H) is reversed by reversing the direction of flow of current in the solenoid. this Can be Achive by changing the position of DPDT switch. when H is increased in reverse direction, the flux density starts decreassing and becomes zero and curve follows the path. vc. thus resudual magnetism of material is wiped of by applying magnetising force in opposite direction.

Coppersive force

The value of magnetising force oc required to wipe off the residual magnetism is called Coppersive force. To Complete the loop, the magnetising force (H) in increased in revere direction till saturation point reaches and followw th path cd. Again H is ↑ in +ve direction by changing the position of dpdt switch and ↑ing the current in the solenoid. The Curve follows the path efa and the loop is Completed.

Hence of is the total amount of Coppersive force required to wipe of be amount of residual magnetism in one Complete Cycle of magnetization.

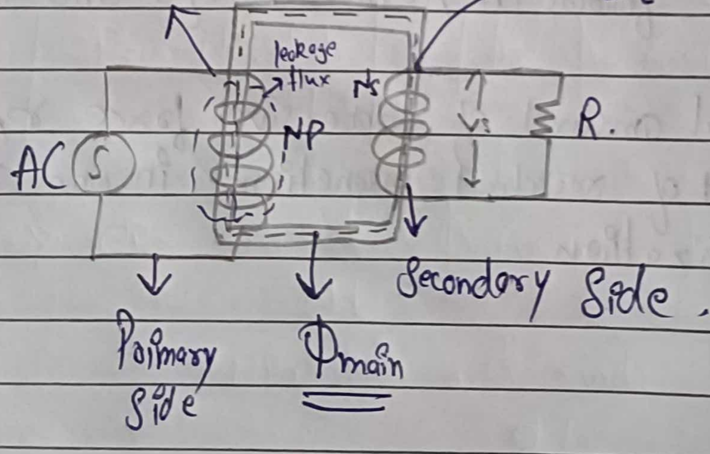
losses in magnetic circuits

- Hysteresis
- Eddy Current

Transformer.

It is a static device which transfers ac electrical power from one circuit to another without change in frequancy but voltage level may change.

$EP = -NP.\frac{d\Phi}{dt}$ $\quad$ $Ns.\frac{d\Phi}{dt} = Es$



$$\boxed{\Phi_T = \text{leakage flux} + \text{main flux.}}$$

Construction of transformer.

(I) Magnetic Circuit (Core) → material with low permeability as well as low reluctivity.

C RGO (Cold Rolled Grain oriented) } } Special type of man-made
HRGO (Hot Rolled " ") material.

(II) Electric Circuit (widing) → We generally use Cu, but due to unavailability of Expensive we use Aluminium nows.

(III) Dielectric Circuit → for insulation purposes

(IV) Tank & Accessories. → (i) As we Add oil in the transfor for high efficiency and observtion of Heat. But due to change in temp the volume of the liquid will change so we always. Create a setup for this kind of problem.

(I) Breather (Silica gel) → Cooling medium ($CaCl_2$)

(II) Bushings → To insulate the direct Connection through transformer.

* Classification.

① On the basis of Service.
(a) distribution → 24 hours. we use them.
(b) Power → we use it at a peak time.

② On the basis of Voltage level
(a) Stepup (b) Stepdown.
$V_s > V_P$ $V_P > V_s$.

③ on the basis of Core

ⓐ Shell → winding is Surrounding the Core.

(b) Core → Core is Surrounding the winding.

✓ Use and throw type. [illegible]

Emf equation of transformer.

when an alternating Voltage is applied across the primary of transformer, it takes magnetising Current and flux (ϕ) is set up in the Core. The flux ϕ is uniformly distributed over the Core and linked with both the windings. The main flux ϕ is of alternating nature and hence emf is induced in the primary winding which is given by faraday's law.

$$\boxed{e_P = -N_P \cdot \frac{d\phi}{dt}} \qquad \boxed{\phi = \phi_m \cos(\omega t).}$$

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

$\phi_m \rightarrow$ Constant

$$= -N_P \cdot \phi_m \cdot \frac{d \cos \omega t}{dt}$$

$$\frac{d \cos\theta}{dt} = \sin\theta$$

$$= +N_P \cdot \omega \cdot \phi_m \sin \omega t$$

for Max Emf $\sin \omega t = 1$, $\omega t = 90°$

0. 8611

$E_{P\max} = N_P \phi_m \omega$, $E_{P(rms)} = \frac{N_P \phi \omega}{\sqrt{2}}$ $\therefore \omega = 2\pi f$

$E_{P\,rms} = \sqrt{2}\cdot\pi \cdot N_P \phi f = \boxed{4.44\ N_P \phi f}$

Also $\boxed{E_{P\,rms} = 4.44\ N_P\ B_m \cdot A_i \times f}$

$E_{Secondary\,(Rms)} = 4.44\ N_s\ \phi_m f$
$= 4.44\ N_s\ B_m\ A_i \cdot f$

* transformation ratio $\rightarrow \boxed{\frac{N_P}{N_s} = \frac{V_P}{V_s} = \frac{E_P}{E_s} = \frac{I_s}{I_P} = a}$

Q A Single phase transformer have 350 primary & 1050 secondary turns. The net Cross sectional area of the core is 55 cm². if the primary winding is connected to 400V 50 Hz single face supply. Calculate (i) Max value of ϕ density in core (ii) voltage induced in Secondary coil.

$\rightarrow$

$400 = 4.44 \cdot 350 \cdot B_m \cdot 55 \times 10^{-4} \times 50$

$B_m = 0.93\,T$

(ii) $\frac{E_P}{E_s} = \frac{N_P}{N_s}$ $\rightarrow$ 1200V why KVA is used → As Seen Cu loss of a transformer depends on Current and iron losses on voltage. Hence loss depends on VA ie voltage Ampere and not on phase angle b/w voltage and Current. And it is independent of load power factor.

Q A 25 KVA transformer has 500 turns on primary and 40 turns of secondary. The primary is connected to 3000 V 50 Hz. Calculate (i) Primary and Secondary Current at full load. (ii) Secondary Emf (iii) Max ϕ is the Core.

⇒ Primary Current at full load.

$$I_P = \frac{25 KVA}{E_P} = \frac{\cancel{25}\times 1000\ VA}{\cancel{3000}\ V}$$

8.33A

$$\frac{8.33}{x} = \frac{4\cancel{0}}{50\cancel{0}} \quad \frac{2}{25} \Rightarrow 104.125 A$$

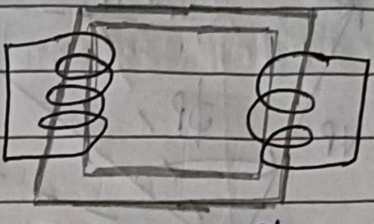
(ii) Secondary Emf

$$\frac{25\cancel{500}}{2\cancel{40}} = \frac{3000}{x} \qquad x = 240V$$

(iii) $E_P = 4.4\ N_P\ \phi f$

$$\phi = \frac{E_P}{4.4\times N_P\times f} = \frac{3000}{4.4\times 500\times 50} = 0.0272\ wb$$

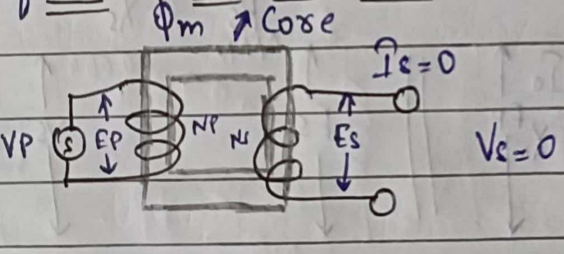
Transformer on DC

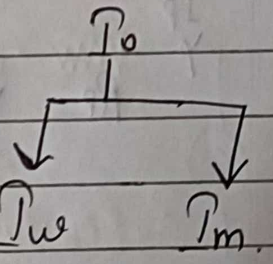


A transformer Can not work on dc supply. if a Rated DC Voltage is applied across the primary, a flux of Constant magnitude will be set up in the Core. Hence their will not be any self induced emf in the primary winding to oppose the applied voltage. The resistance of the primary winding is very low and the primary Current will be quiet high, this Current is much more than the rated full load Current. Thus it will produce lot of heat (i^2R loss) and burns the insulation of primary Coil and the transformer will be damaged that is why DC Can not be applied on a transformer.

* Transformer on different types of load.

① transformer on no-load.

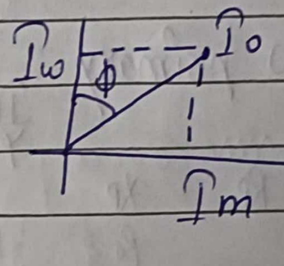




$I_w = I_o \cos\phi_o$.

$I_m = I_o \sin\phi_o$.

$I_o = \sqrt{I_w^2 + I_m^2}$.

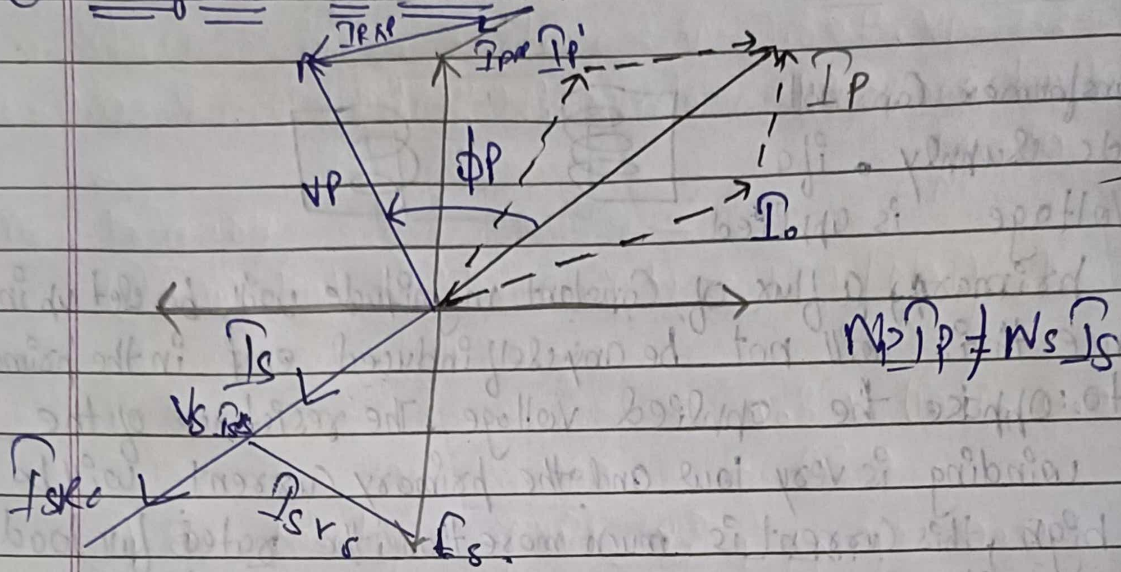


At Secondary side no Current is drawn.
So

$I^2R = 0$, $I_p = I_o$

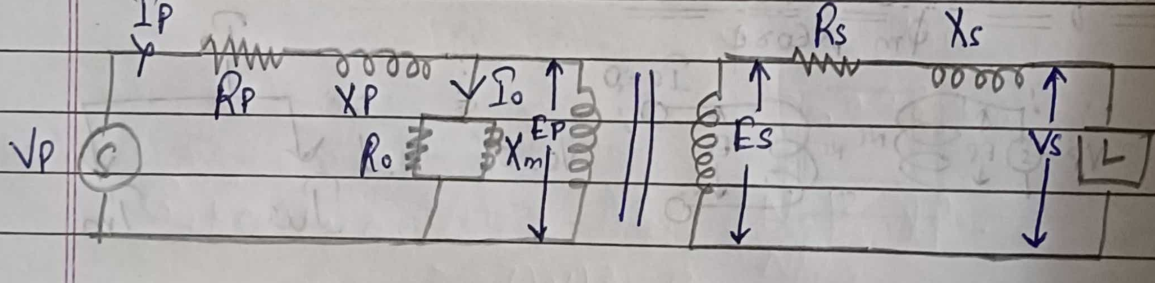
But flux is set up so Emf will be their.

② transformer on R-load.

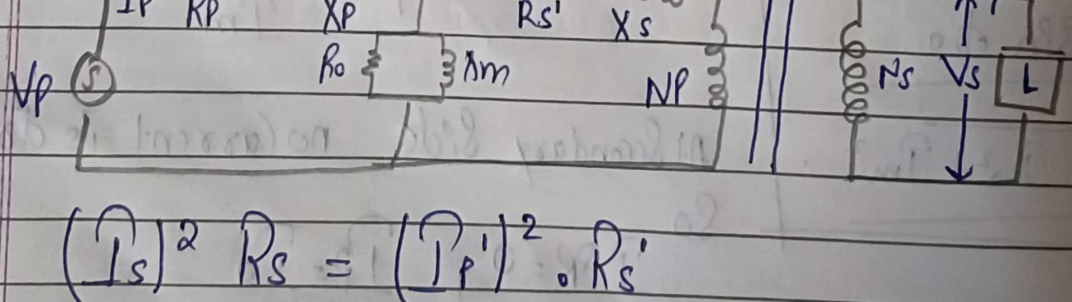


Equivalent Circuits of a transformer

The Equivalent Circuit of a transformer is quite helpful in pre determin the behaviour of the transformer under various Conditions of operations. from the Equivalent Circuit parameters.



* Refer to primary. we have.

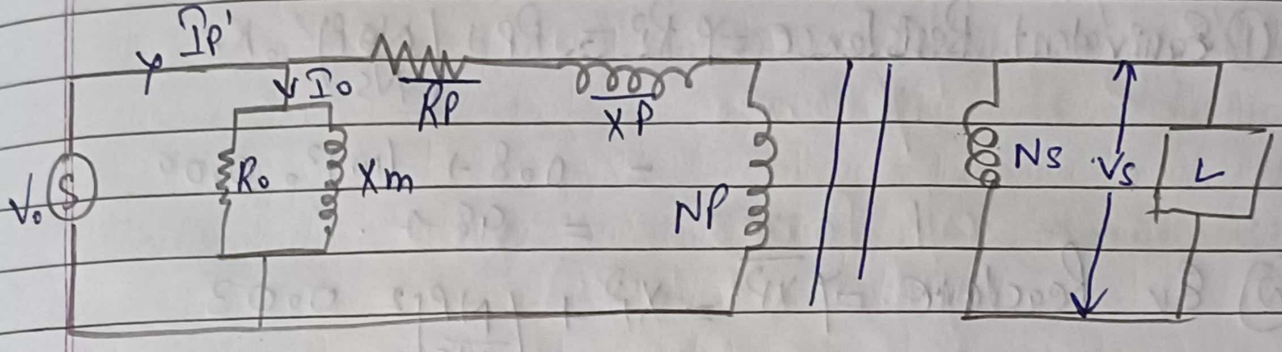


$$(I_s)^2 R_s = (I_p')^2 \cdot R_s'$$

$$\left(\frac{I_s}{I_p'}\right)^2 \cdot R_s = R_s'$$

$$\boxed{R_s' = R_s \left(\frac{N_P}{N_S}\right)^2 = a^2 R_s}$$

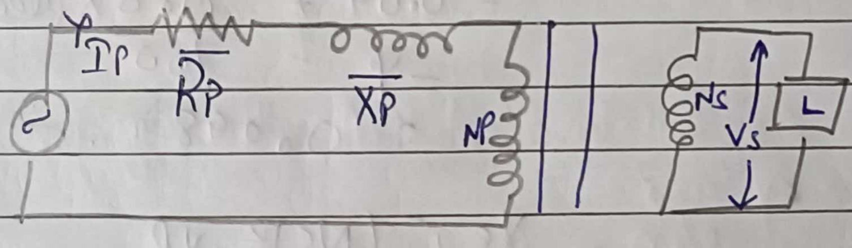
ie $$\boxed{X_s' = X_s \cdot \left(\frac{N_P}{N_S}\right)^2 = a^2 X_s}$$



$$\overline{R_P} = R_P + R_s' = R_P + a^2 R_s$$

$$\overline{X_P} = X_P + X_s' = X_P + a^2 X_s$$

final simplified Equation Circuit refer to primary.



① Equivalent Resistance ⇒ $\overline{R_P} = R_P + a^2 R_s = R_P + \left(\frac{N_P}{N_S}\right)^2 R_s$.

② Equivalent Reactance ⇒ $\overline{X_P} = X_P + a^2 X_s = X_P + \left(\frac{N_P}{N_S}\right)^2 X_s$.

③ Equivalent Impedence ⇒ $\overline{Z_P} = \sqrt{\overline{R_P}^2 + \overline{X_P}^2}$

Eqn Circuit refer to Secondary.

① Eq Resistance ⇒ $\overline{R_s} = R_s + a^2 R_P = R_s + \left(\frac{N_s}{N_P}\right)^2 \cdot R_P$.

② Eq Reactance ⇒ $\overline{X_s} = X_s + a^2 X_P = X_s + \left(\frac{N_s}{N_P}\right)^2 \cdot X_P$.

③ Eq Impedence ⇒ $\overline{Z_s} = \sqrt{\overline{R_s}^2 + \overline{X_s}^2}$

Q A 25KVA 2200/220 V 50Hz single phase transformer has following resistance & leakage Reactance : $R_P = 0.8\,\Omega$, $X_P = 3.2\,\Omega$, $R_S = 0.09\,\Omega$ $X_S = 0.03\,\Omega$ Calculate (i) Eq resistance (ii) Eq reactance for Primary & Se

$$\frac{N_P}{N_S} = 10$$

Ans Primary

① Equivalent Resistance $\Rightarrow \overline{R_P} = R_P + \left(\frac{N_P}{N_S}\right)^2 \cdot R_S$

$$= 0.8 + (10)^2 \cdot 0.09$$
$$= 98\,\Omega.$$

② Eq Reactance $\Rightarrow \overline{X_P} = X_P + \left(\frac{N_P}{N_S}\right)^2 0.003$

$$= 12.2\,\Omega.$$

Secondary.

① Eqn Resistance $\Rightarrow \overline{R_S} = R_S + \left(\frac{1}{10}\right)^2 R_P.$

$$= 0.09 + \frac{0.8 \times ([illegible])}{100}$$
$$\Rightarrow 0.098\,\Omega.$$

Eq Reactance $X_S + \left(\frac{N_S}{N_P}\right)^2 X_P.$

$$= 0.03\,\Omega.$$

Voltage Regulation ⇒ The Voltage regulation of a transformer is defined as the net change in secondary terminal Voltage from no load to full load expressed as % of its rated voltage for the same primary voltage.

$$\% VR = \frac{V_{snl} - V_{sfl}}{V_{sfl}} \times 100$$

nl → no load
fl → full load.

$$\% VR = \frac{I_s [R_s \cos\phi \pm X_s \sin\phi]}{V_s} \times 100 \quad \{\text{for Secondary}\}$$

$$\% V_R = \frac{I_P [R_P \cos\phi \pm X_P \sin\phi]}{V_P} \times 100 \quad \{\text{for Primary}\}$$

- + sign is used for lagging loads / inductive load / lagging power factor.
- − Sign is used for leading loads / Capacitive load / leading power factor.

Losses in Transformer

↓ Core (const losses) {P_i}
↓ Iron losses
↓ Hysteresis
↓ Eddy Current.

{P_c} ↓ Copper (variable)
↓ winding (I^2R).
$= k^2 P_c$
↳ fraction of load
if loss = 50%
$k = 1/2$.

Efficiency of a transformer.

Efficiency of a transformer is defined as the ratio of o/p power to i/p power

$$\% \eta = \frac{\text{O/P Power}}{\text{I/P Power}} \times 100$$

$$= \frac{\text{O/P Power}}{(\text{O/P Power} + \text{losses})} \times 100$$

$$= \frac{\text{O/P Power}}{(\text{O/P power} + \text{iron loss} + \text{Copper loss})} \times 100$$

$$\boxed{\% \eta = \frac{V_s I_s \cos\phi}{V_s I_s \cos\phi + P_i + P_c}}$$

⇒ if n is the fraction of full load at KVA then Efficiency at this fraction is given by

$$\% \eta = \frac{n V_s I_s \cos\phi}{n V_s I_s \cos\phi + P_i + n^2 P_c} \times 100.$$

$$\boxed{\% \eta = \frac{n \, KVA \times 1000 \times \cos\phi}{n KVA \times 1000 \times \cos\phi + P_i + n^2 P_c} \times 100}$$

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Conditione.

for max Efficiency → The Efficiency of a transformer at a given load & power factor is given by

$$\eta = \frac{V_s I_s \cos\phi}{V_s I_s \cos\phi + P_i + (I_s)^2 R_{es}}$$

The terminal voltage Vs is approx Constant. Thus for a given power factor, ~~is given by~~ η depends upon load Current Is.

on Dividing Numr & Denr by Is.

$$\eta = \frac{V_s \cos\phi}{V_s \cos\phi + \frac{P_i}{I_s} + I_s R_{es}} \quad \text{—} ①$$

from Eq ① the numr is Const & eff will be max if denominator will be min.

ie

$$\frac{d}{dI_s}\left[V_s \cos\phi + \frac{P_i}{I_s} + I_s R_{es}\right] = 0$$

$$0 - \frac{P_i}{I_s^2} + R_{es} = 0.$$

$$I_s^2 R_{es} = \boxed{P_i = P_c} \quad - ②.$$

$$\%\eta = \frac{V_s I_s \cos\phi}{V_s I_s \cos\phi + 2P_i} \times 100$$

Current at Max Condition.

$$I_s = \sqrt{\frac{P_i}{R_{es}}}$$

Load at Max Condition.

$$P_i = P_c$$

$$P_i = n^2 P_c$$

$$n = \sqrt{\frac{P_i}{P_c}}.$$

Ⓠ A 2 KVA 400/200 Volts 50 Hz Single phase transformer has the following perimeter. as refer to primary side

$\overline{rP} = 3\Omega$, $\overline{XP} = 4\Omega$

determine the regulation of transformer wha

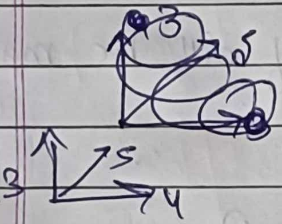
(i) Full load with point at power factor lagging. 6·1.

(ii) " " " " " " " " leading. 0

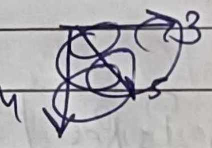
(iii) Half load " " " " " lagging. 3

Sol

$$\% VR = \frac{IP\left[\overline{RP}\cos\phi \pm \overline{XP}\sin\phi\right]}{VP} \times 100.$$



$\cos\phi = \frac{4}{5}$, $\sin\phi = \frac{3}{5}$



$$= \frac{\overset{5}{\cancel{2}} \times \overset{100}{\cancel{1000}} \times VA}{\cancel{400}}\left(3(0.8) + (0.6)4\right).$$

$$\Rightarrow 5(2.4 + 2.4).$$

Q in a 25 KVA 2000 by 200 Volt transformer have iron and Copper losses of 350 watt and 400 watt respectivly, Calculate its Efficiency at unity P.f at (1) full load
(II) Half load.

$$\eta\% = \frac{\cancel{V_s I_s \cos\phi}}{} = \frac{n\,KVA \times 1000 \times \cos\phi}{n\,KVA \times 1000 \times \cos\phi + P_i + n^2 P_c}$$

unity Pf means $\boxed{\cos\phi = 1}$

full load $\underline{\underline{n = 1}}$.

$P_i = 350$, $P_c = 400$.

$$\Rightarrow \frac{25 \times 1000}{25000 + 350 + 400} \times 100 = \underline{\underline{97.087\%}}.$$

$\boxed{96.50}$ $\underline{\text{Ans}}$

(II) At half load $\underline{\underline{n = \frac{1}{2}}}$

$$\eta\% = \frac{n\,KVA \times 1000 \times \cos\phi}{n\,KVA \times 1000 \times \cos\phi + P_i + n^2 P_c}.$$

$$= \frac{\frac{1}{2} 25 \times 1000 \times 1}{\frac{25 \times 1000}{2} + 350 + 100} \Rightarrow \underline{\underline{96.52\%}}.$$

Q A 220 by 400 volt 10KVA 50Hz single phase transformer has a full load of Copper loss 120 watt. if its has a efficiency of 98% at full load and unity PF, determine the iron loss. (i) -

(ii) what would be η if at half load at Power factor lagging $\cos\phi = 0.8$ Ans 97.237.

(i) $$98 = \frac{10\times1000}{10\times1000 + P_i + 120}\times100.$$

$$10000 + P_i + 120 = \frac{10^6}{98}.$$

$$P_i = 84.08 \text{ watt}.$$

(ii) $$\eta = \frac{\overset{5}{\cancel{10}}\times1000\times0.8}{0.8\,(5000) + 84.08\cdot\frac{120}{4}} = 97.22\%$$

$$98.77 = \frac{400\times1000\times0.8}{400\times1000\times0.8 + P_i + P_c}$$

$$P_i + P_c = -316760.14$$

$$99.13 = \frac{\frac{1}{2}\,400\times1000}{200\times1000 + P_i + \frac{P_c}{4}}.$$

$$4P_i + P_c = -791929.78.$$

$$3P_i =$$

$$P_i = 131984$$

131kw.

Ⓠ The Efficieny of 400 KVA single phase transformes is 98.77%. when delivering full load at ~~pointed~~ $\overset{0.8}{}$ power factor and 99.13% at half load. and unit powerfactor Calculate P_i & P_c.

$\Rightarrow$ Pointed pf

$\cos\phi = 0.8$

$$98.77 = \frac{200 \times 1000 \times}{200 \times 1000 + x + y}$$

$$99.13 = \frac{200 \times 1000}{200 \times 1000 + x + \frac{y}{4}}$$

$$2 \times 10^5 + x + y = \frac{2 \times 10^5}{98.77}$$ $\Rightarrow$ $x + y = -197,975.0$

$$2 \times 10^5 + x + \frac{y}{4} = \frac{2 \times 10^5}{99.13}$$ $4x + y = -791929.7$

$3x = 593954.7$

$x = 197984.9$

$y =$

$P_i = 1.012$ Kw.

$P_c = 2.973$ Kw.

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Q in a 50 KvA the iron and Copper loss are 350 & 425 watt resp. Calculate efficiency at
(I) full load with unity PF
(II) Half — " —
(III) full load with 0.8 PF. Also determine max Efficiency
(IV) and load at which Max Efficency occurs.

$$K = \sqrt{\frac{P_i}{P_C}} = \sqrt{\frac{350}{425}} = 0.907$$

load at which max Efficiency occur = K × full load in KvA
0.907 × 50 KVA
= 45.35 KvA

= 98.31 %

imp

(I) $\frac{50 \times 1000 \times 1}{50 \times 1000 + 350 + 425}$ = 499.84 %.

Ans = 98.48

(II) $\frac{25 \times 1000}{25 \times 1000 + 350 + \frac{425}{4}}$ = 98.556 %.

(III) $\frac{50 \times 1000 \times 0.8}{50 \times 1000 \times 0.8 + 350 + 425}$ = 499.80 %.

All day Efficiency

$$\% \eta_{Allday} = \frac{O/P \text{ in Kwh for 24 hours}}{I/P \text{ in Kwh for 24 hours}} \times 100.$$

$$\boxed{= \frac{O/P}{O/P + \text{losses}} \quad (\text{in Kwh for 24h})}.$$

Q A 20 KVA transformer on domestic load, which can be taken as day has a full day efficiency of 95.3%, the copper loss them being twice of iron loss. Calculate its allday efficiency on following daily cycle (1) No-load for 10hr
(II) Half load for 8hr.
(III) full load for 6hr.

(1) full load at O/P = 20×1 = 20Kwh

$$\text{full load I/P} = \frac{O/P}{\eta} = \frac{20}{95.3} \times 100. = 20.986 \text{ Kw}.$$

Total losses = $P_i + P_c$ = IP − OP

$P_i + P_c = 0.986$ Kw — ①

given that $P_c = 2P_i$ — ②.

losses at full load. $P_i = 0.3287$ Kw $P_c = 0.6574$ Kw.

Now total = 0 + (20×8) + (1×20×6)

= 200 Kwh.

iron Ko load se Koi faraq nahi padte

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Ironloss in 24hrs $\Rightarrow 0.3287 \times 24$
$= 7.89$ Kwh.

Culoss in 24hr in Kwh.

$\Rightarrow 0 + \left(\frac{1}{2}\right)^2 \times 0.6574 \times 8 + (1)^2 \times 0.6574 \times 6.$

$\Rightarrow$ 5.259 Kwh.

$\% \eta_{allday} = \frac{O/P}{O/P + losses}$ [for 24hr in Kwh] $\times 100.$

$= \frac{200}{200 + 7.89 + 5.259} \times 100 = 93.83\%$

Q A transformer has max η of 98%. at 15 KVA at unity PF, it is loaded as follows (i) 12hr → 2Kw, 0.5Pf
(ii) 6hr → 12Kw, 0.8Pf
(iii) 6hr → 18Kw, 0.9Pf

Sol

Ans P_i = .153Kw
P_c = 1053Kw

Hr	load Kw	Pf	load (KVA) = Kw/PF.	fraction of load $x = \frac{\text{given load in KVA}}{\text{full load in KVA}}$
12	2Kw	0.5	2/0.5 = 4KVA	$x = \frac{4}{15} = 0.267$
6	12Kw	0.8	15KVA	= 1
6	18Kw	0.9	20KVA	= 1.33 {here transfo can get damage}

- Open circuit → Iron loss.
- closed circuit → Culoss

Formula's

- No load Power factor $(\cos\phi) = \frac{W_0}{V_0 I_0}$.
- Working Component ⇒ $I_w = \frac{W_0}{V_0}$
- Magnetising Component ⇒ $I_m = \sqrt{I_0^2 - I_w^2}$
- $R_0 = \frac{V_0}{I_w}$, $X_0 = \frac{V_0}{I_m}$

$W_c = I^2_{sc} \cdot R_{es}$. I_{sc} = ammeter reading.

$V_{sc} = I_{sc} Z_{es}$.

$X_{es} = \sqrt{(Z_{es})^2 - (R_{es})^2}$

Q The following test data is obtained on a 5KVA 220 by 440 Vall single phase
OC test. → iron loss
220V, 2A, 100 watt. on lone voltage side.

Sc test → Culoss
40V, 11.04, 200 watt on high voltage side.
determine %η at full load at 0.9 PF and regulation.

⇒ $\% \eta = \frac{\text{n KVA} \cos\phi}{\text{n KVA} + \text{iron loss} + \text{Cu loss}}$.

$$\Rightarrow \left(\frac{(5 \times 1000 \times 0.9)}{\left(\frac{5 \times 1000}{0.9}\right) + 100 + 200} \right) = 93.75 \%$$

Q A 5KVA 400 by 200 volt 50Hz single phase transformer give following result. during no load and short circuit

No lod => 400V, 1A, 60 wat (ise

SC => 15V, 12.5A, 150 watt. (Primary side]

Calculate (i) No load parameters R_0 & X_m
(ii) Equivalent Resistance and reactance refer to primar
(iii) Regulation at full load
(iv) Iron and Cu loss at full lood
(v) Efficiency at full load and 0.8 PF.

Q A 200 KVA 1000 by 250 Volt 50Hz single phase transformer give following test result

SC Test 250V, 18 A, 1300 watt.

Calculate All day efficiency if the transformer is loaded

→ 8 hours full load at 0.8 PF

→ 10 h half load at 1 PF

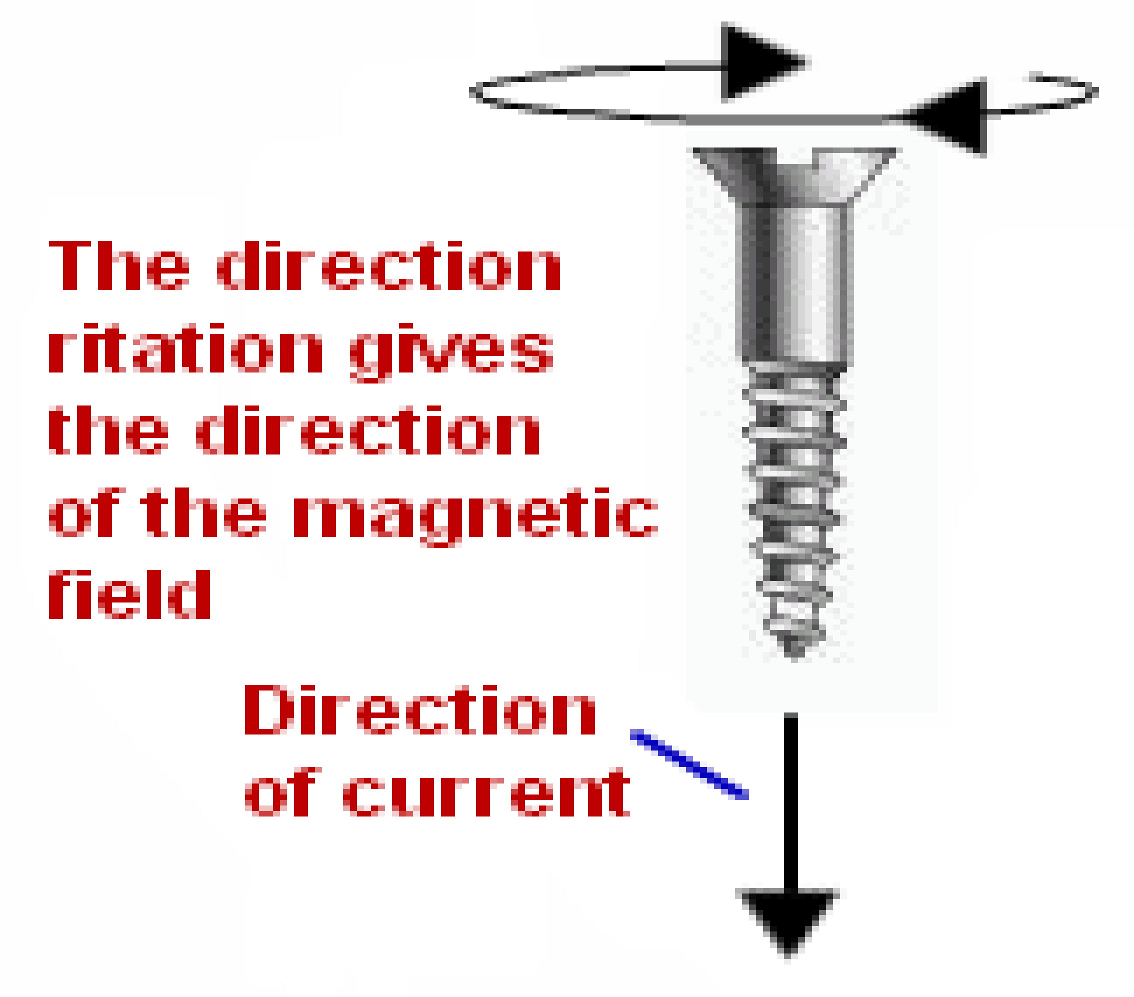
→ 6 h no load.

⇒

Unit 4

D C Machines

Maxwell’s Cork screw Rule :

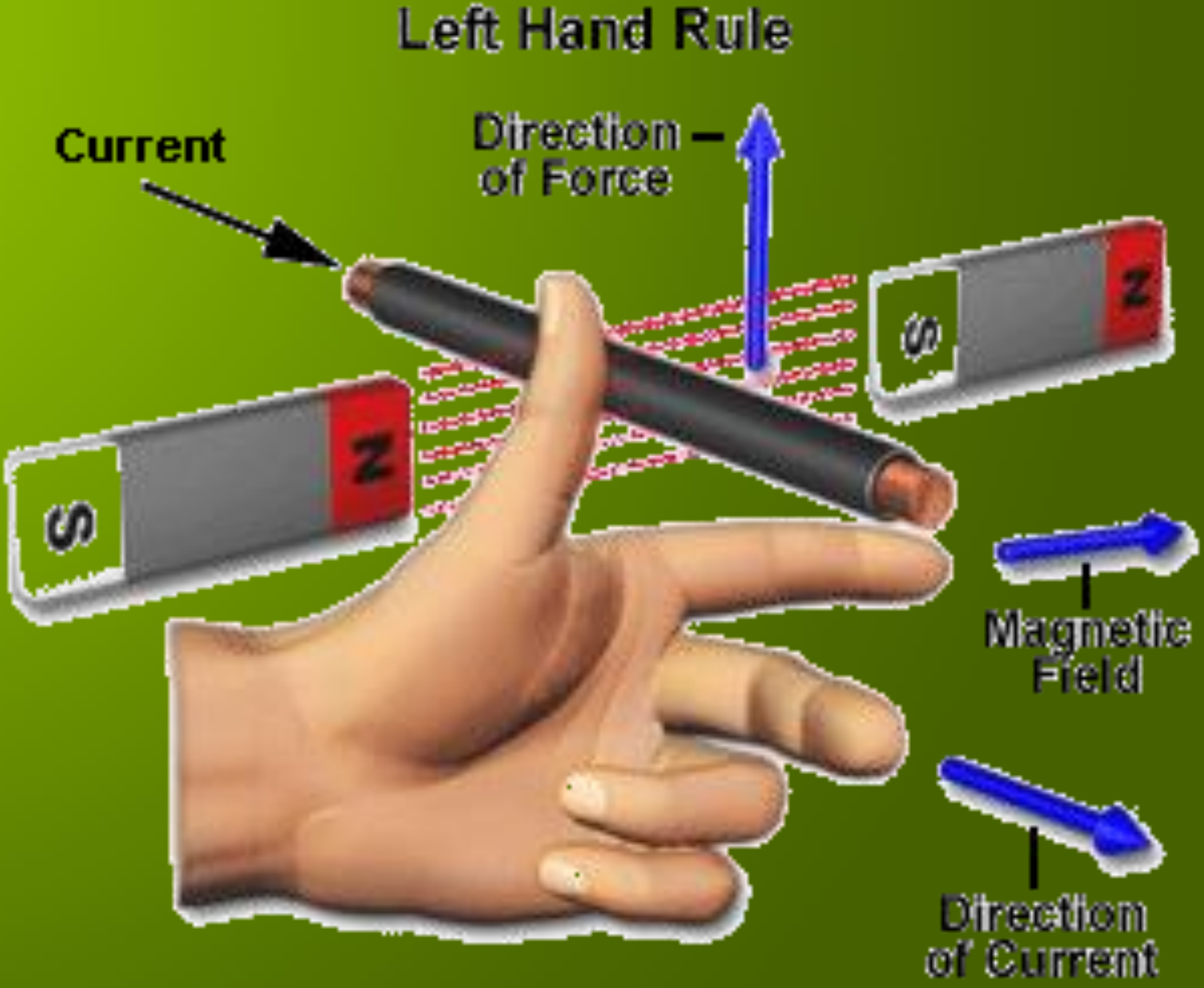


The direction ritation gives the direction of the magnetic field

Maxwell’s Cork screw Rule :

Hold the cork screw in yr right hand and rotate it in clockwise in such a way that it advances in the direction of current. Then the direction in which the hand rotates will be the direction of magnetic lines of force .

Fleming’s left hand rule

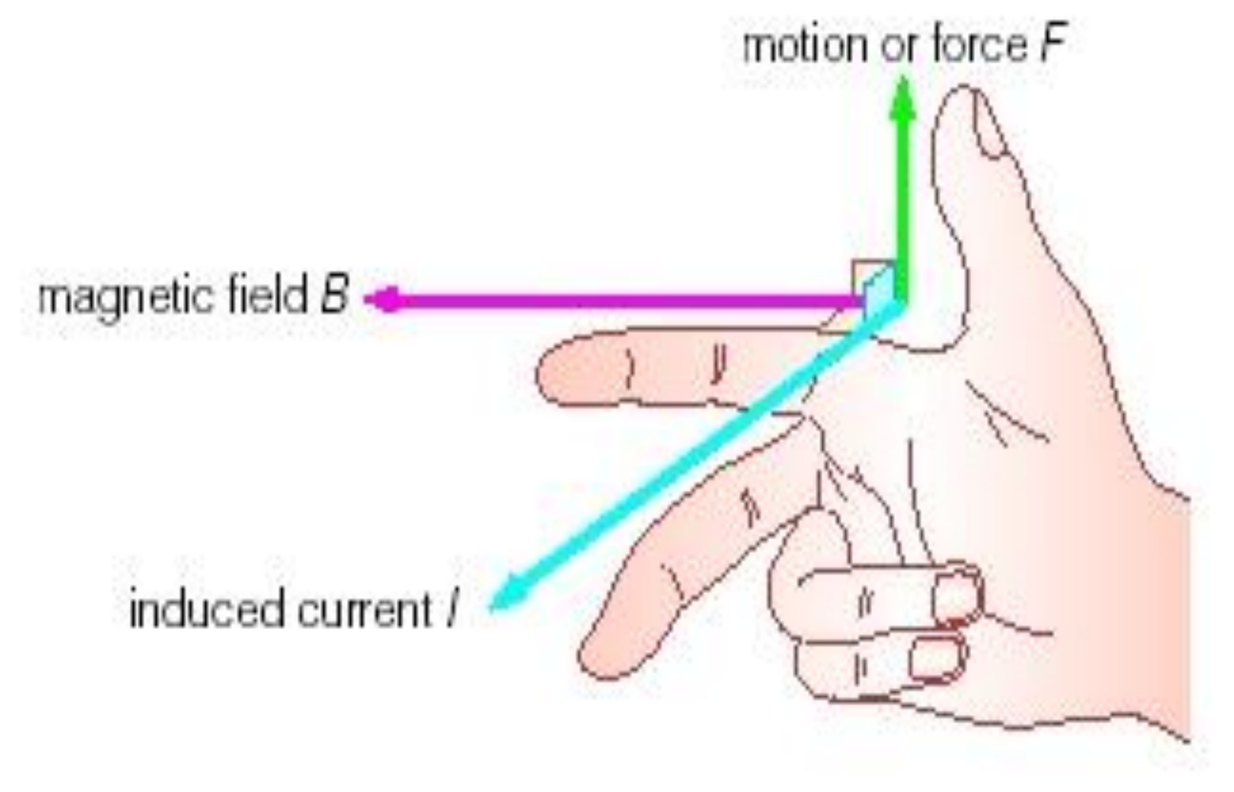


Fleming’s left hand rule

- Used to determine the direction of force acting on a current carrying conductor placed in a magnetic field .
- The middle finger , the fore finger and thumb of the left hand are kept at right angles to one another .
  - The middle finger represent the direction of current
  - The fore finger represent the direction of magnetic field
  - The thumb will indicate the direction of force acting on the conductor .

This rule is used in motors.

Fleming's Right hand rule



Fleming’s Right hand rule

- Used to determine the direction of emf induced in a conductor
- The middle finger , the fore finger and thumb of the left hand are kept at right angles to one another.
  - The fore finger represent the direction of magnetic field
  - The thumb represent the direction of motion of the conductor
  - The middle finger will indicate the direction of the inducted emf .

This rule is used in DC Generators

Len’s Law

The direction of induced emf is given by Lenz’s law .

According to this law, the induced emf will be acting in such a way so as to oppose the very cause of production of it .

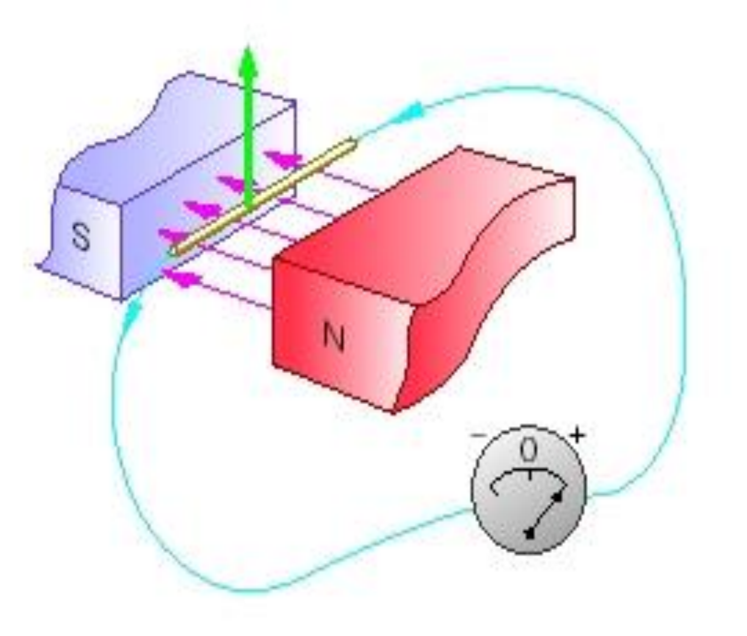
- $e = -N \, (d\O/dt)$ volts

DC Generator

Mechanical energy is converted to electric energy

Three requirements are essential

1. Conductors
2. Magnetic field
3. Mechanical energy



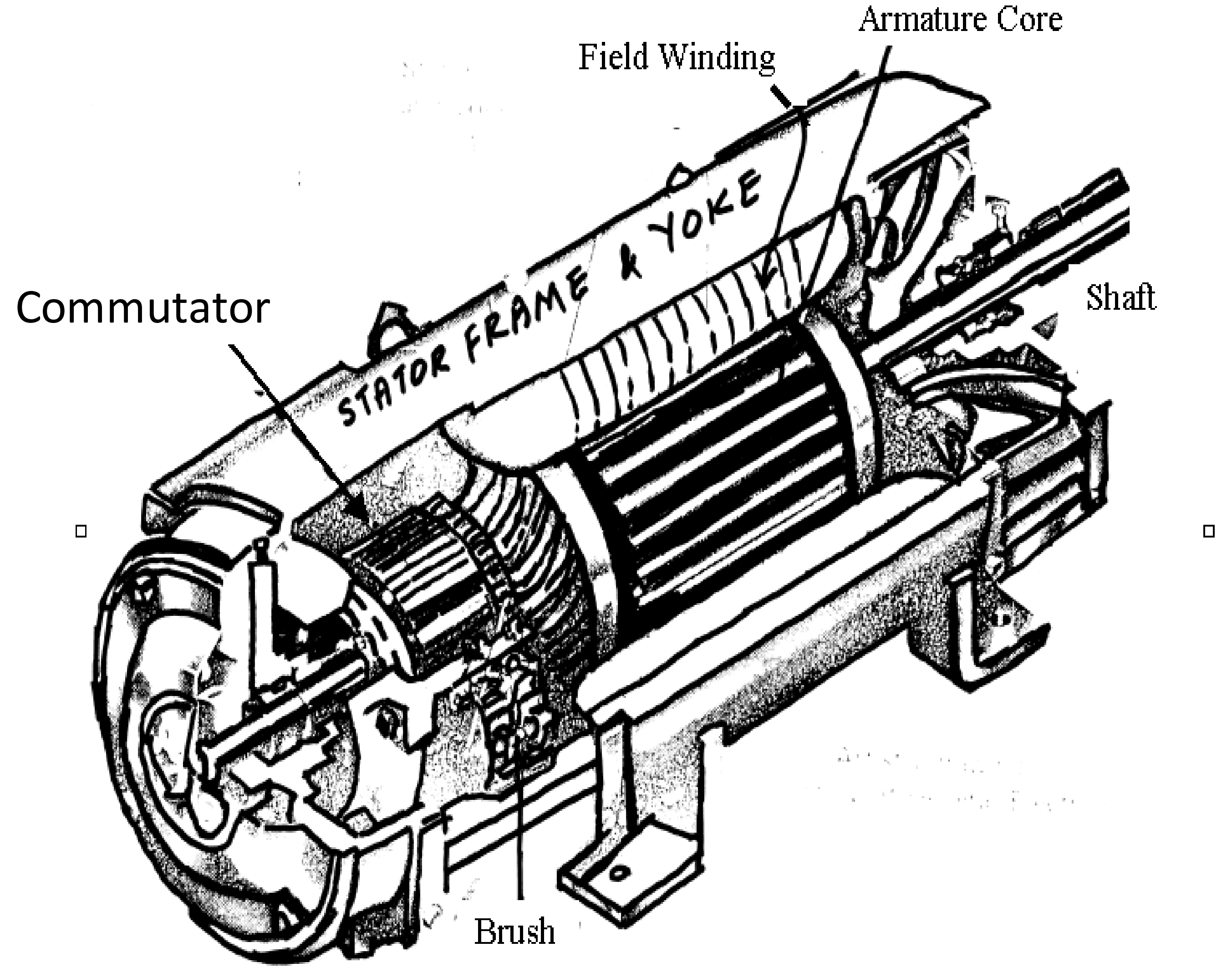
Working principle

- A generator works on the principles of Faraday’s law of electromagnetic induction

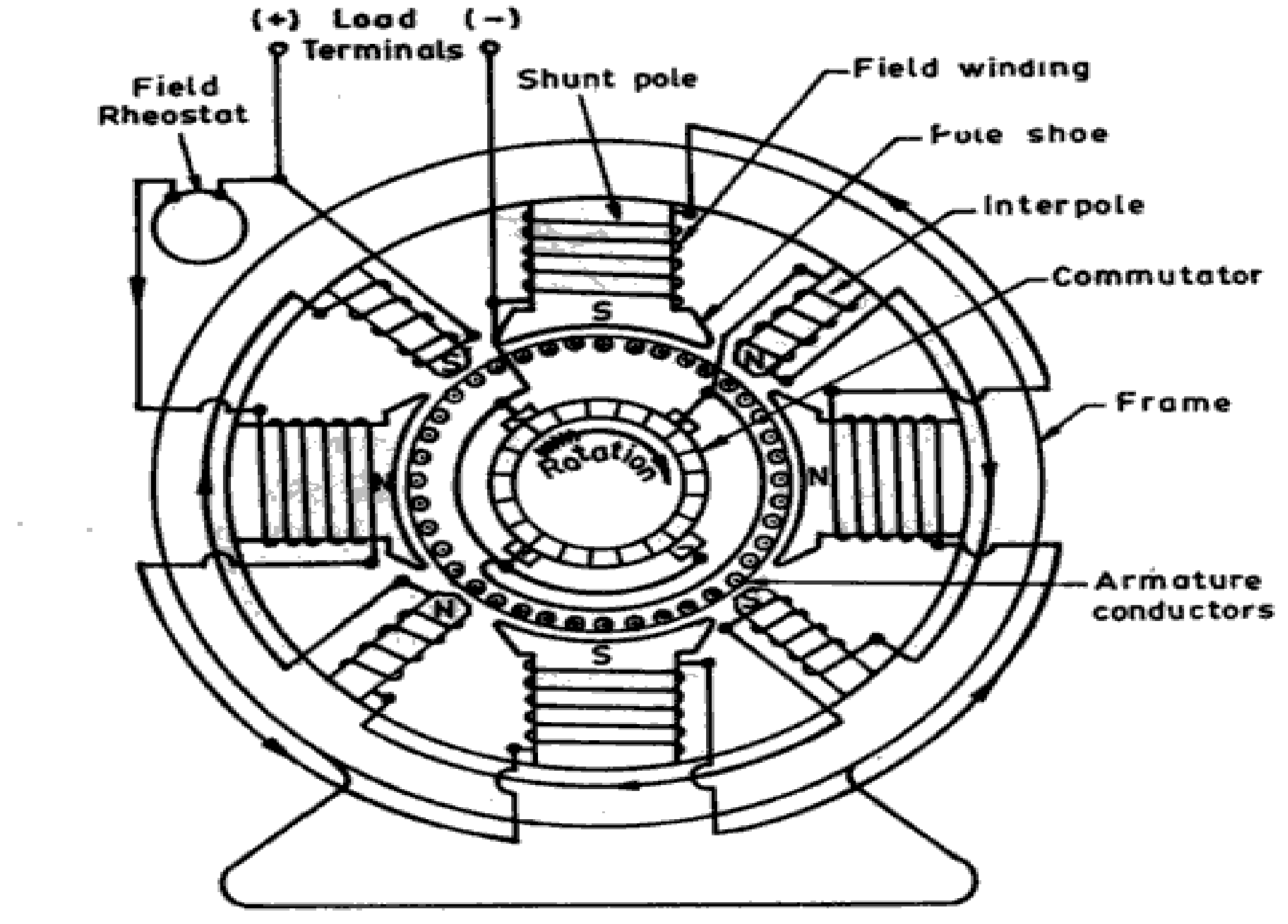
- Whenever a conductor is moved in the magnetic field , an emf is induced and the magnitude of the induced emf is directly proportional to the rate of change of flux linkage.

- This emf causes a current flow if the conductor circuit is closed .

DC Machine

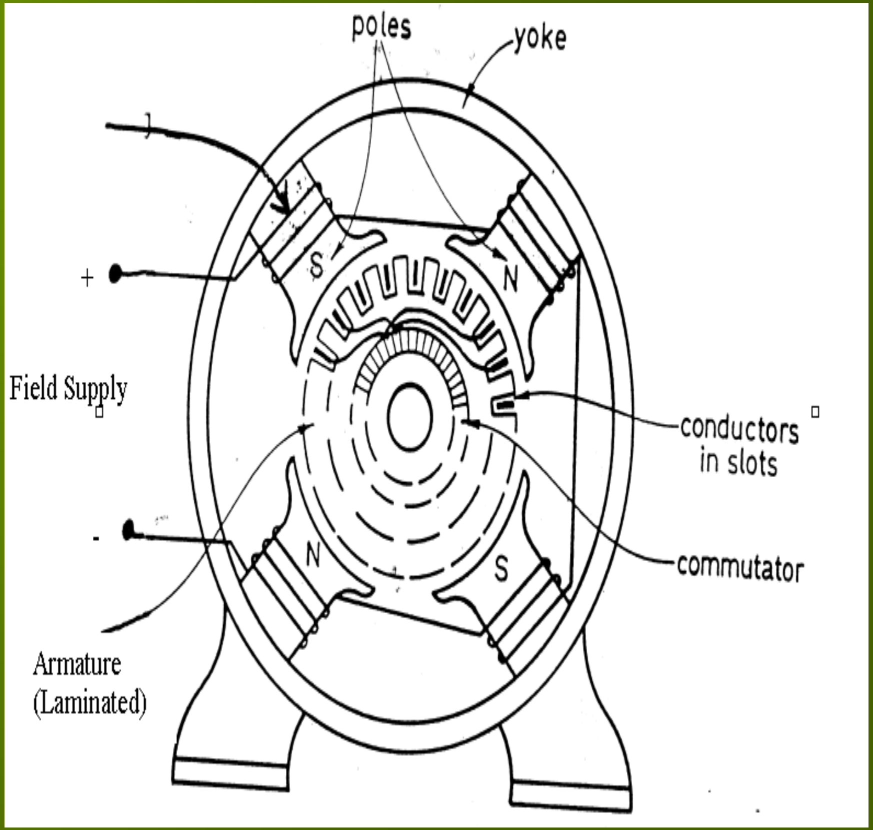

Armature Core
Field Winding
STATOR FRAME & YOKE
Commutator
Shaft
Brush

Sectional view of a DC machine

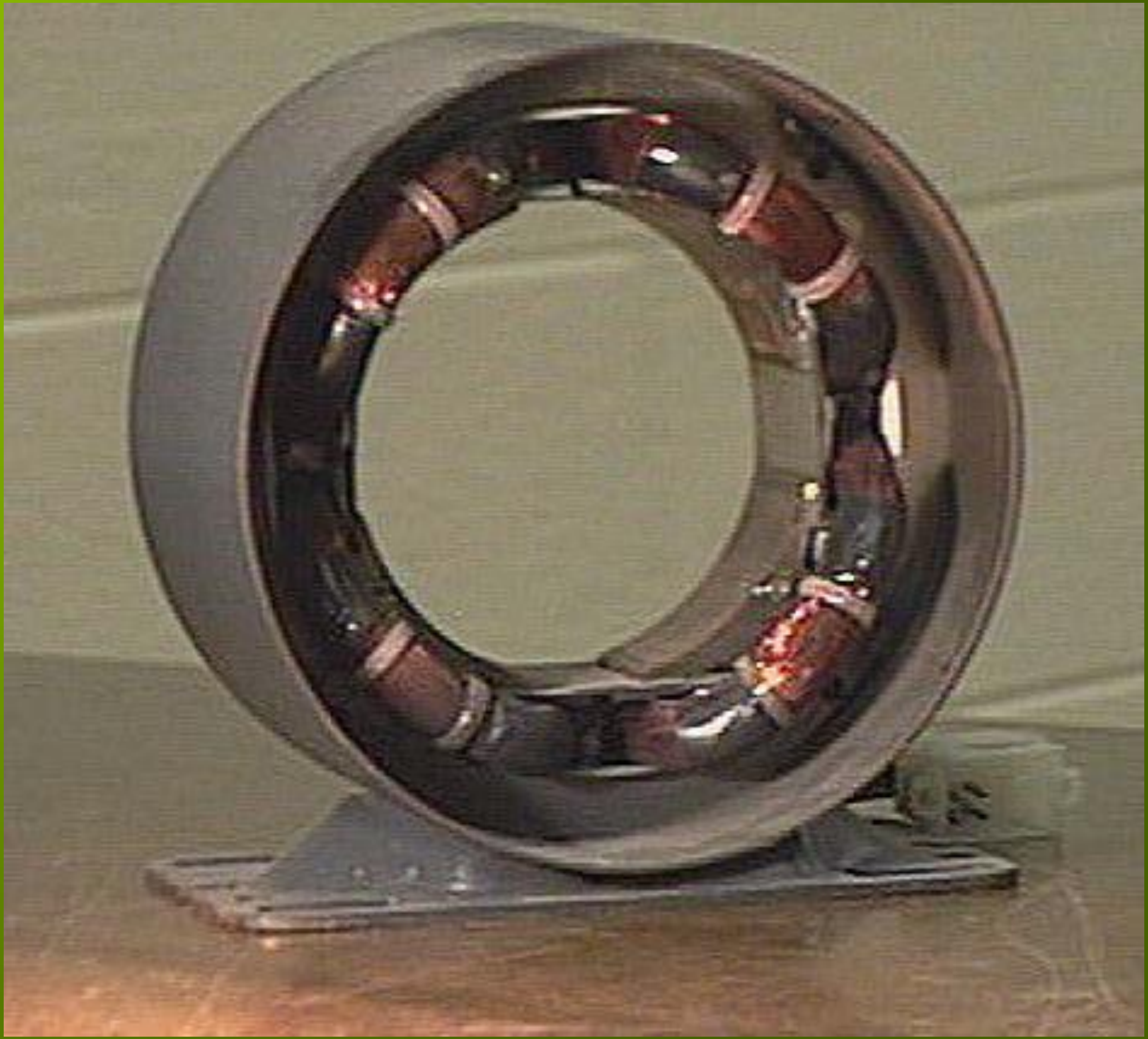


Construction of DC Generator

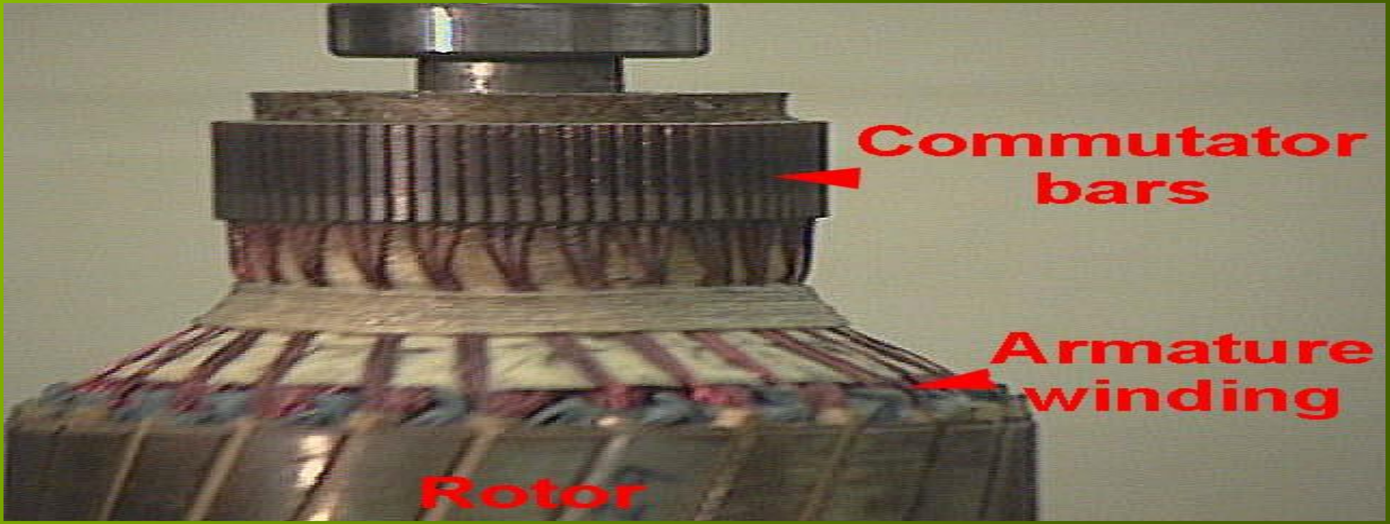
- Field system
- Armature core
- Armature winding
- Commutator
- Brushes



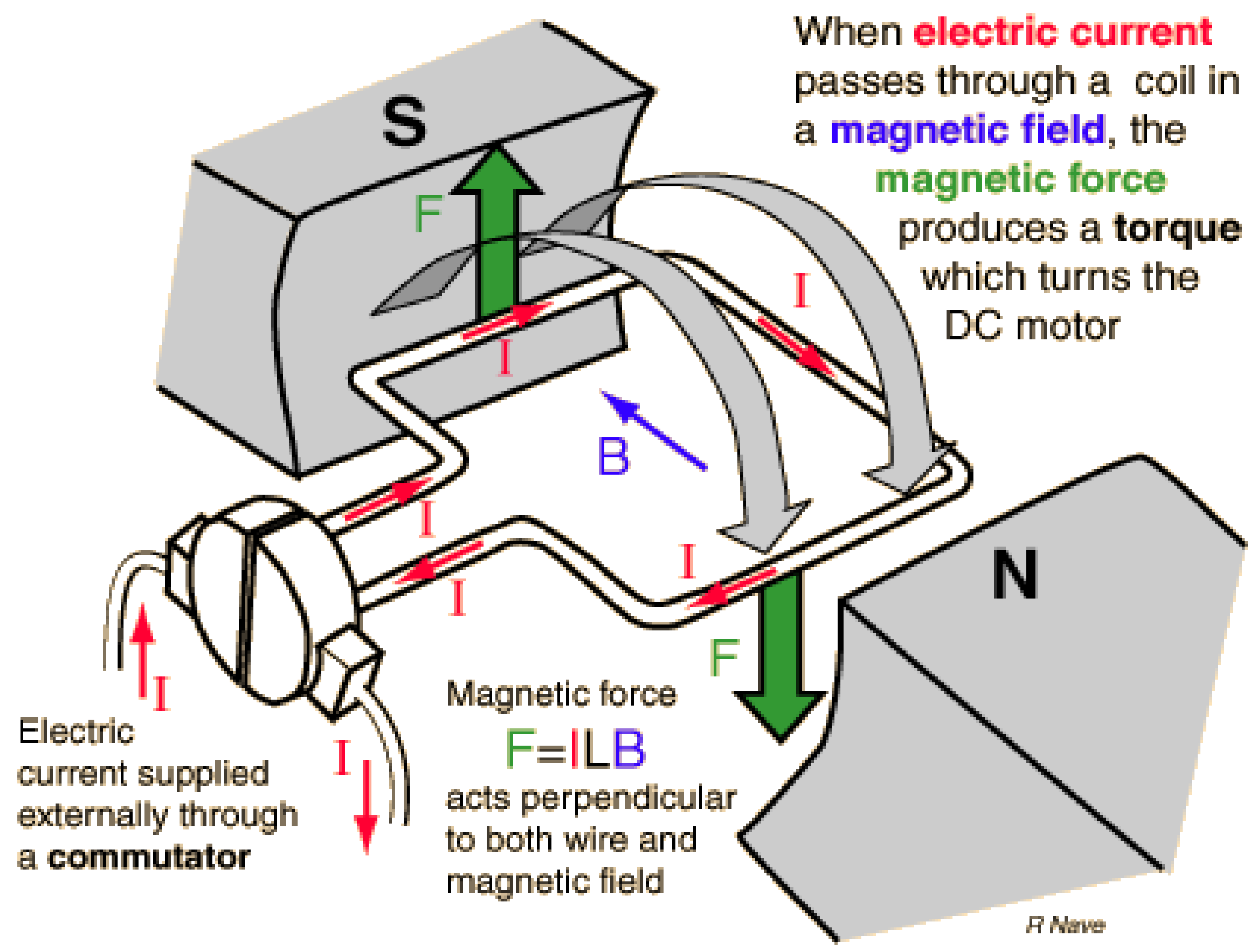
Field winding



Rotor and rotor winding



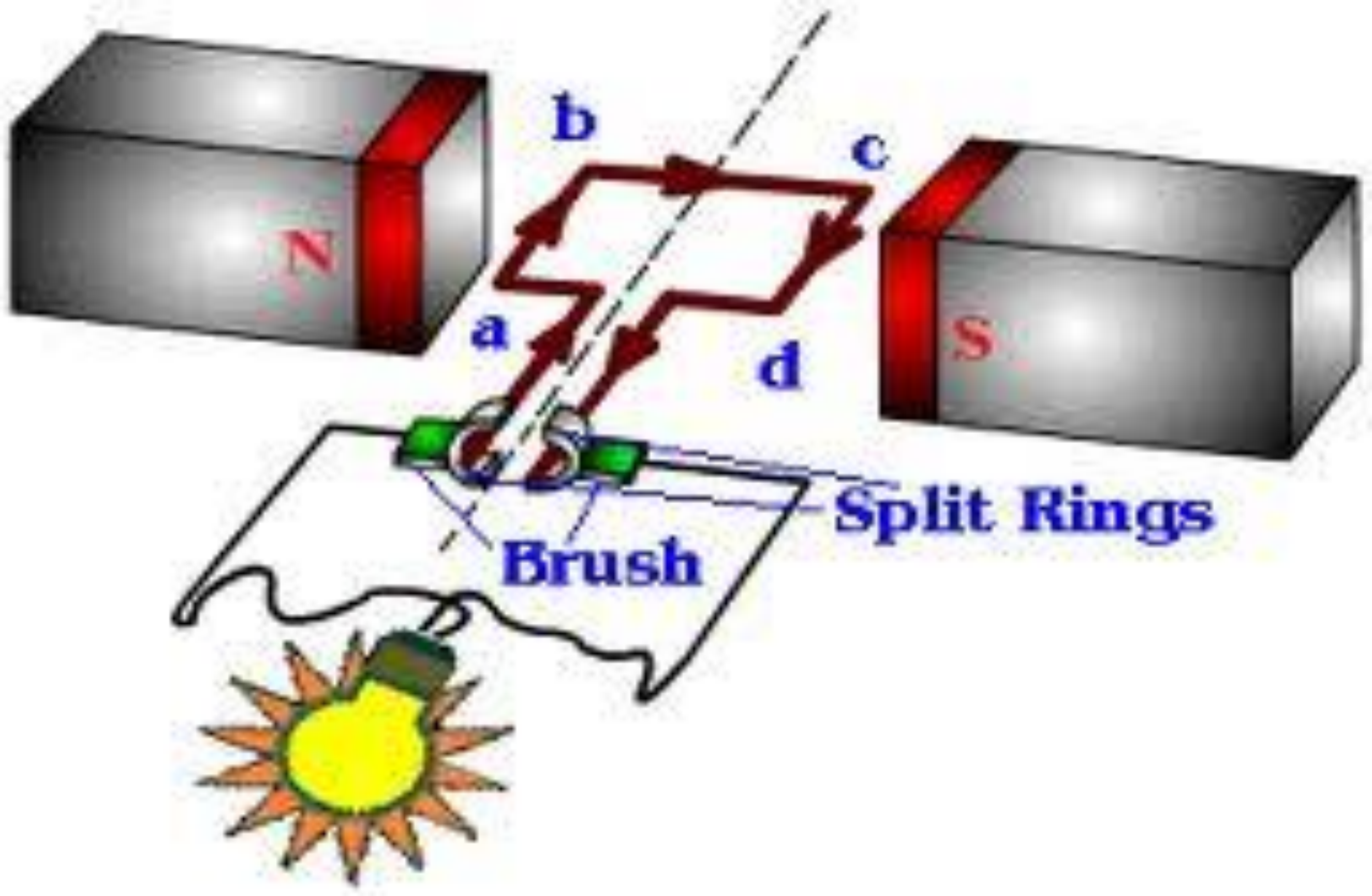
Working principle of DC motor


When **electric current** passes through a coil in a **magnetic field**, the **magnetic force** produces a **torque** which turns the DC motor

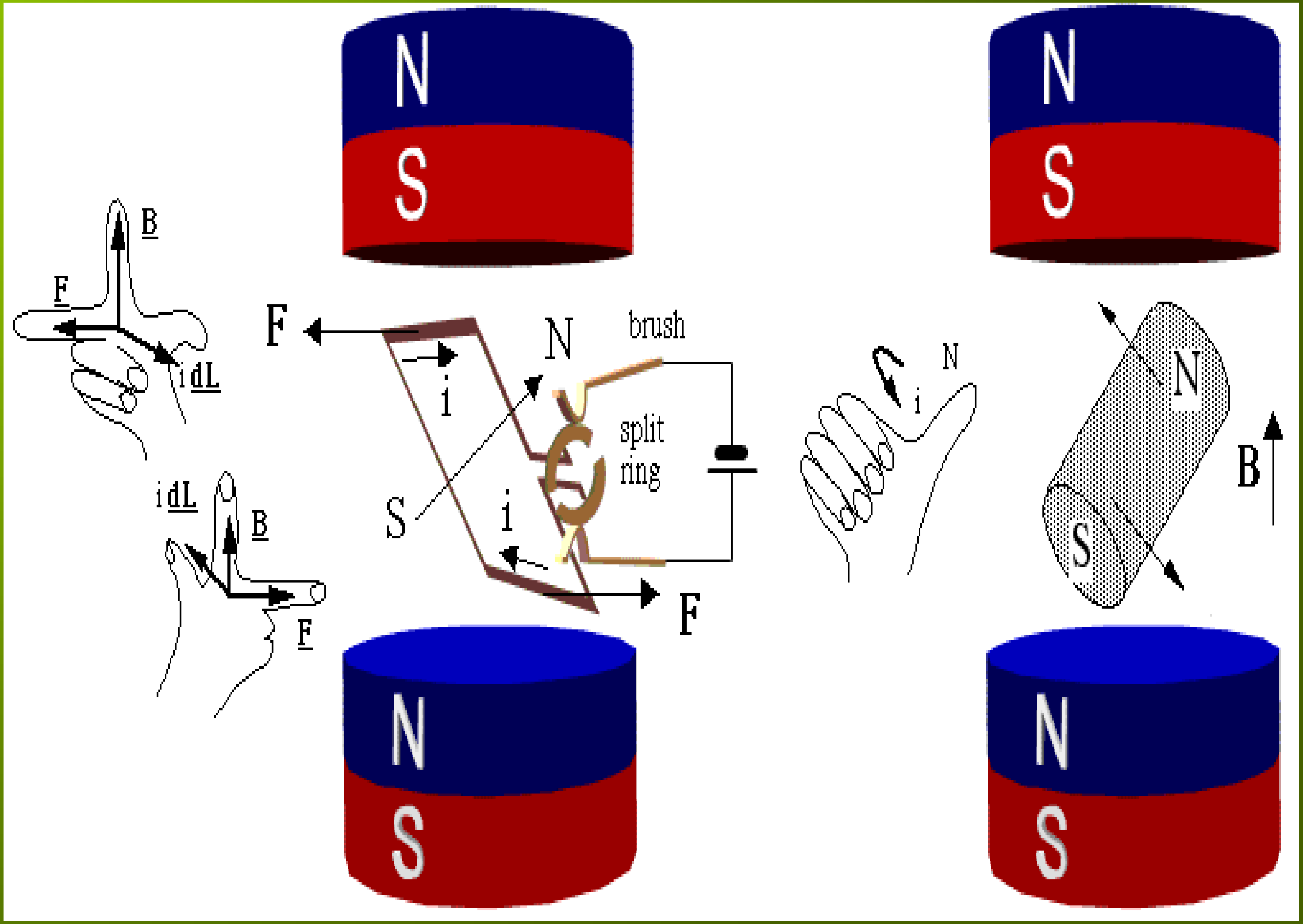
Electric current supplied externally through a **commutator**

Magnetic force $F=ILB$ acts perpendicular to both wire and magnetic field

Working principle of DC motor



Force in DC motor



Armature winding

There are 2 types of winding

Lap and Wave winding

Lap winding

- **A = P**

- The armature windings are divided into no. of sections equal to the no of poles

Wave winding

- **A = 2**

- It is used in low current output and high voltage.

- 2 brushes

Field system

- It is for uniform magnetic field within which the armature rotates.
- Electromagnets are preferred in comparison with permanent magnets
- They are cheap , smaller in size , produce greater magnetic effect and
- Field strength can be varied

Field system consists of the following parts

- Yoke
- Pole cores
- Pole shoes
- Field coils

Armature core

- The armature core is cylindrical
- High permeability silicon steel stampings
- Impregnated
- Lamination is to reduce the eddy current loss

Commutator

- Connect with external circuit
- Converts ac into unidirectional current
- Cylindrical in shape
- Made of wedge shaped copper segments
- Segments are insulated from each other
- Each commutator segment is connected to armature conductors by means of a cu strip called riser.
- No of segments equal to no of coils

Carbon brush

- Carbon brushes are used in DC machines because they are soft materials
- It does not generate spikes when they contact commutator
- To deliver the current thro armature
- Carbon is used for brushes because it has negative temperature coefficient of resistance
- Self lubricating , takes its shape , improving area of contact

Brush rock and holder

Carbon brush

- Brush leads (pig tails)
- Brush rocker (brush gear)
- Front end cover
- Rear end cover
- Cooling fan
- Bearing
- Terminal box

EMF equation

Flux cut by 1 conductor in 1 revolution = $P * \phi$

Flux cut by 1 conductor in 60 sec = $P \phi N / 60$

Avg emf generated in 1 conductor = $P\phi N/60$

Number of conductors in each parallel path = Z / A

$E_g = P\phi NZ/60A$

Types of DC Generator

DC generators are generally classified according to their method of excitation .

- Separately excited DC generator
- Self excited D C generator

Further classification of DC Generator

- Series wound generator
- Shunt wound generator
- Compound wound generator
  - Short shunt & Long shunt
  - Cumulatively compound

    &

    Differentially compound

Losses in DC Generators

1. Copper losses or variable losses
2. Stray losses or constant losses

<u>Stray losses</u> : consist of (a) iron losses or core losses and (b) windage and friction losses .

<u>Iron losses</u> : occurs in the core of the machine due to change of magnetic flux in the core . Consist of hysteresis loss and eddy current loss.

<u>Hysteresis loss</u> depends upon the frequency , Flux density , volume and type of the core .

Losses

Hysteresis loss depends upon the frequency , Flux density , volume and type of the core .

Eddy current losses : directly proportional to the flux density , frequency , thickness of the lamination .

Windage and friction losses are constant due to the opposition of wind and friction .

Applications

Shunt Generators:

a. in electro plating

b. for battery recharging

c. as exciters for AC generators.

Series Generators :

A. As boosters

B. As lighting arc lamps

DC Motors

Converts Electrical energy into Mechanical energy

Construction : Same for Generator and motor

Working principle : Whenever a current carrying conductor is placed in the magnetic field , a force is set up on the conductor.

Back emf

The induced emf in the rotating armature conductors always acts in the opposite direction of the supply voltage .

According to the Lenz's law, the direction of the induced emf is always so as to oppose the cause producing it .

In a DC motor , the supply voltage is the cause and hence this induced emf opposes the supply voltage.

Classification of DC motors

DC motors are mainly classified into three types as listed below:

- Shunt motor
- Series motor
- Compound motor
    - Differential compound
    - Cumulative compound

Speed control of DC motors

According to the speed equation of a dc motor

N ∞ Eb/ϕ

∞ V- Ia Ra/ ϕ

Thus speed can be controlled by-

Flux control method: By Changing the flux by controlling the current through the field winding.

Armature control method: By Changing the armature resistance which in turn changes the voltage applied across the armature

Flux control

Advantages of flux control:

- It provides relatively smooth and easy control
- Speed control above rated speed is possible
- As the field winding resistance is high the field current is small. Power loss in the external resistance is small . Hence this method is economical

Disadvantages:

- Flux can be increased only upto its rated value
- High speed affects the commutation, motor operation becomes unstable

Armature voltage control method

- The speed is directly proportional to the voltage applied across the armature .
- Voltage across armature can be controlled by adding a variable resistance in series with the armature

Potential divider control :

If the speed control from zero to the rated speed is required , by rheostatic method then the voltage across the armature can be varied by connecting rheostat in a potential divider arrangement .

Starters for DC motors

Needed to limit the starting current .

1. Two point starter
2. Three point starter
3. Four point starter

Applications:

Shunt Motor:

- Blowers and fans
- Centrifugal and reciprocating pumps
- Lathe machines
- Machine tools
- Milling machines
- Drilling machines

Applications:

Series Motor:

- Cranes
- Hoists , Elevators
- Trolleys
- Conveyors
- Electric locomotives

Applications:

Cumulative compound Motor:

- Rolling mills
- Punches
- Shears
- Heavy planers
- Elevators

SUBJECT : ELECTRICAL ENGINEERING (EIR2C4)

UNIT V

ROTATING ELECTRICAL MACHINES

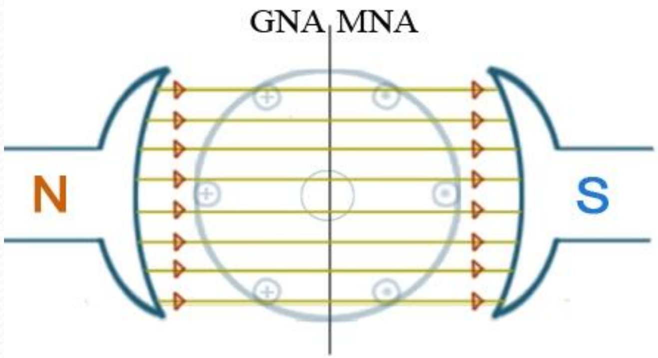
TOPICS COVERED:

ARMATURE REACTION, COMMUTATION AND LOSSES IN DC MACHINES

Armature reaction in DC machine

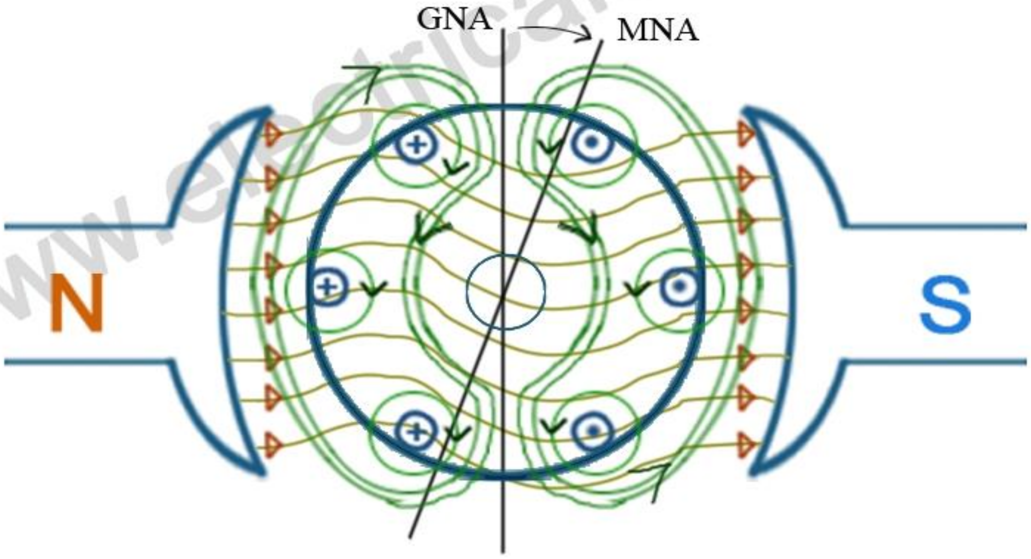
In a DC machine, two kinds of magnetic fluxes are present;
'armature flux' and 'main field flux'.
The effect of armature flux on the main field flux is called as armature reaction

The effect of armature reaction is well illustrated in the figure below.



Main field flux

Armature Flux



Distortion of main field flux due to armature flux - Armature reaction

Commutation

- Commutation in DC machines is the process by which the reversal of current takes place.
- In DC generator this process is used to convert the induced AC in the conductors to a DC output.
- In DC motors commutation is used to reverse the directions of *DC current* before being applied to the coils of the motor.

Consider, no current is flowing in the armature conductors and only the field winding is energized (as shown in the first figure of the above image).

The second figure in the above image shows armature flux lines due to the armature current. Field poles are de-energised.

Now, when a DC machine is on load, both the fluxes will be active.

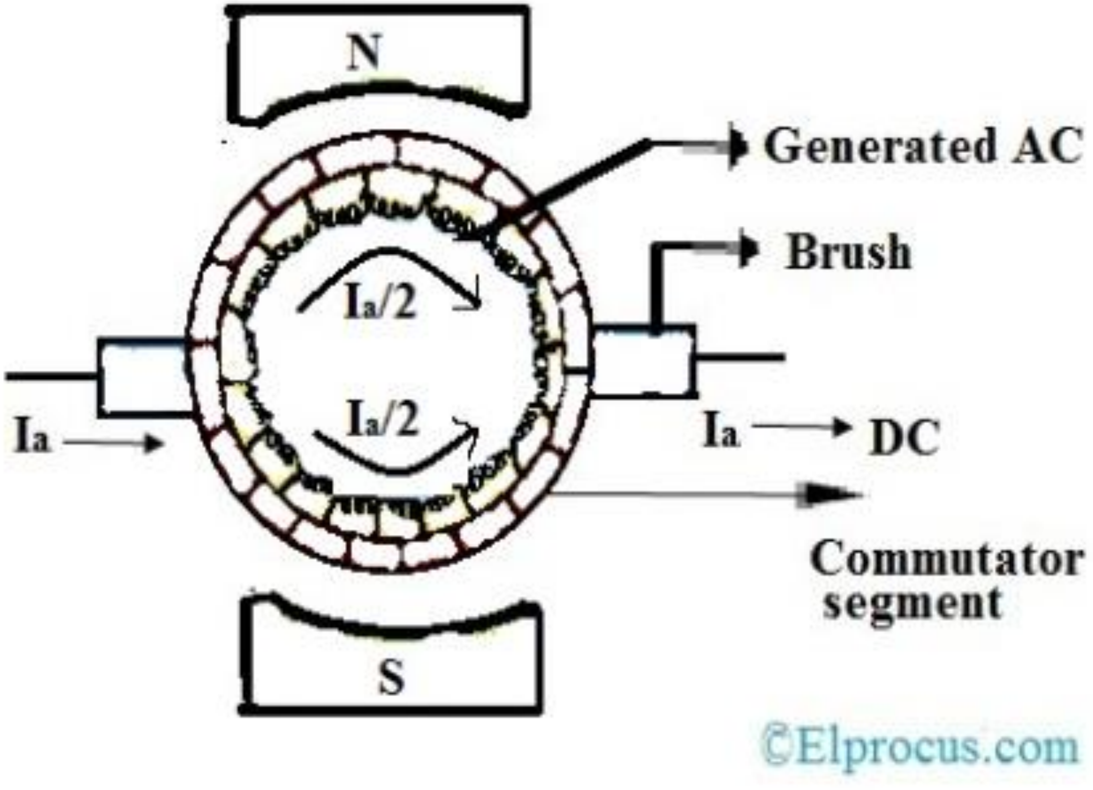
The armature flux cross magnetises the main field flux and, hence, disturbs the main field flux (as shown in third figure the of above image).

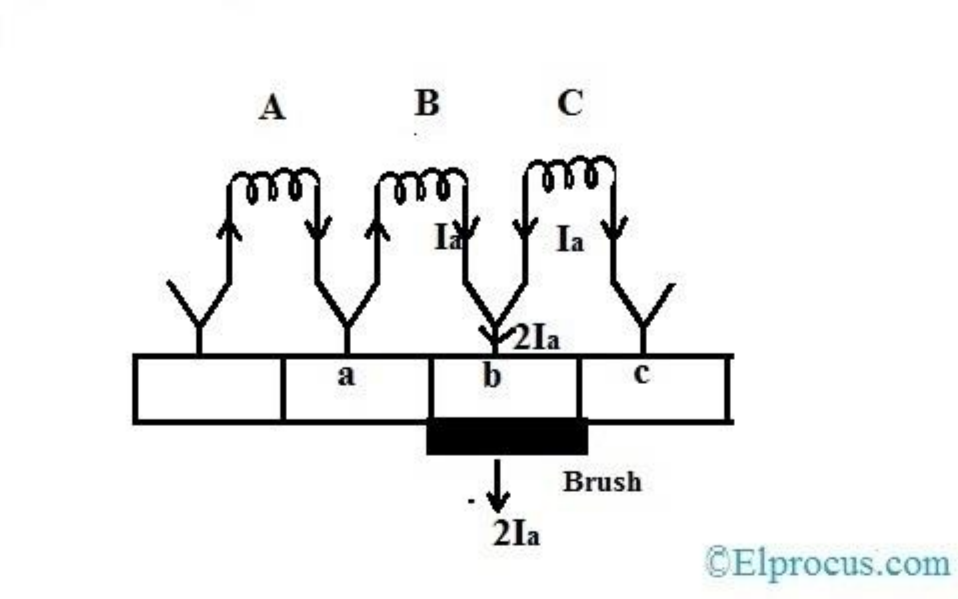
This effect is called as armature reaction in DC machines.

Commutation in DC Machine

- For the transformation of current, the Commutator segments and brushes should maintain a moving contact all time.

The time for which the coil is short-circuited for a very short period with the help of brushes, is known as commutation period.





Let the current flowing through the conductor be Ia. Let a, b, c be the Commutator segments of the motor. Now, the current reversal in the coil can be understood by the below steps.

Position-1

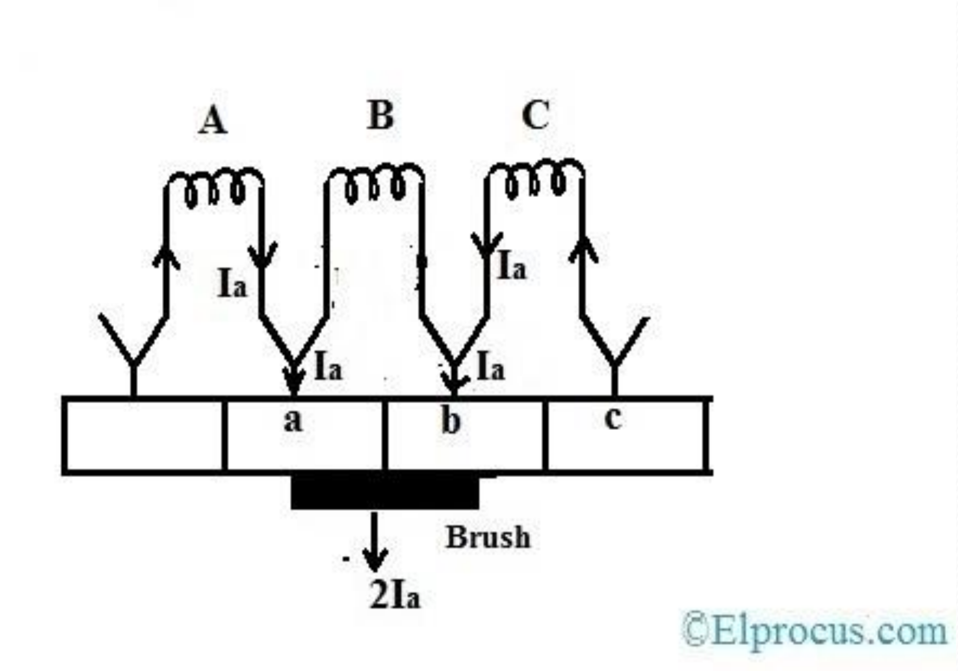
- Let the Armature starts rotating, then the brush moves over the commutator segments.
- Let the first position of the brush commutator contact be at segment b as shown above. As the width of the commutator is equal to the width of the brush, in the above position the total areas of commutator and brush are in contact with each other.
- The total current conducted by the commutator segment into the brush at this position will be 2Ia.

Position-2

- Now the armature rotates towards the right and the brush comes in contact with the bar a.
- At this position, the total conducted current will be 2Ia, but the current in the coil changes. Here the current flows through two paths A and B. 3/4th of the 2Ia comes from the coil B and remaining 1/4th comes from coil A.
- When KCL is applied at the segment a and b, the current through the coil B is reduced to Ia/2 and the current drawn through segment a is Ia/2.

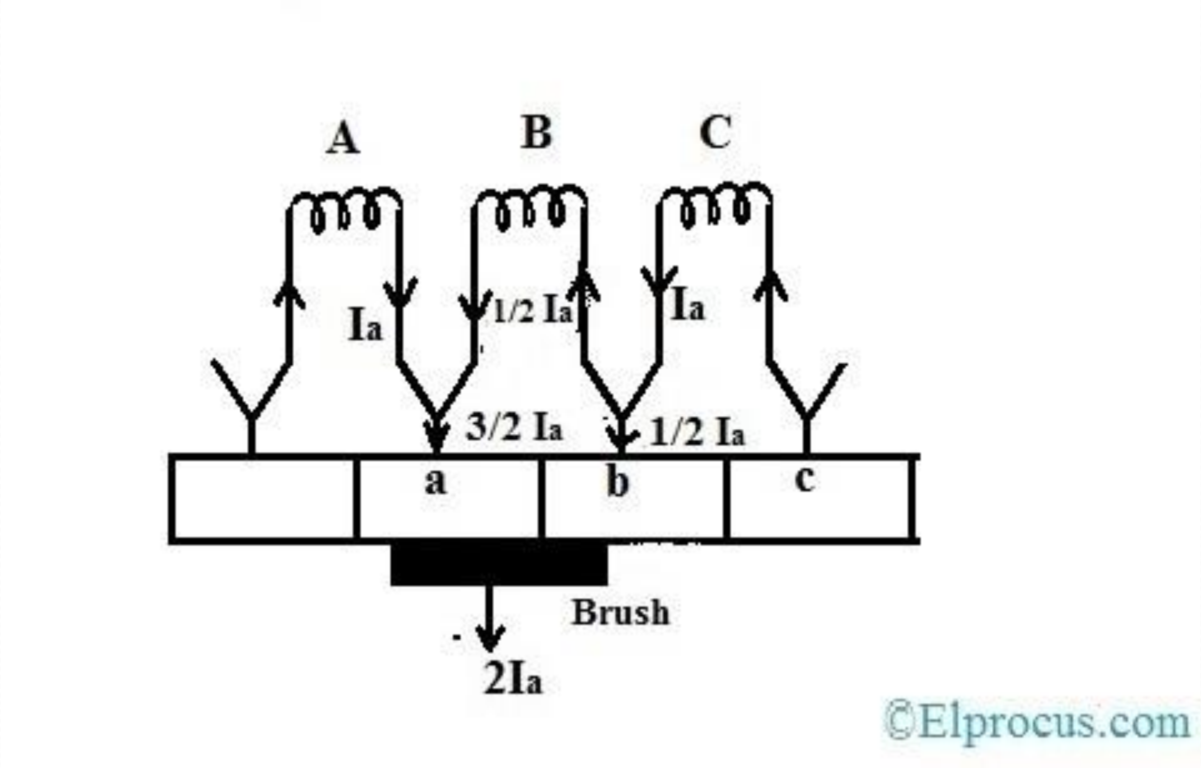
Position-3

- At this position half of the brush, a surface is in contact with segment a and the other half is with segment b. As the total current drawn trough brush is 2Ia, current Ia is drawn through coil A and Ia is drawn through coil B. Using KCL we can observe that the current in coil B will be zero.



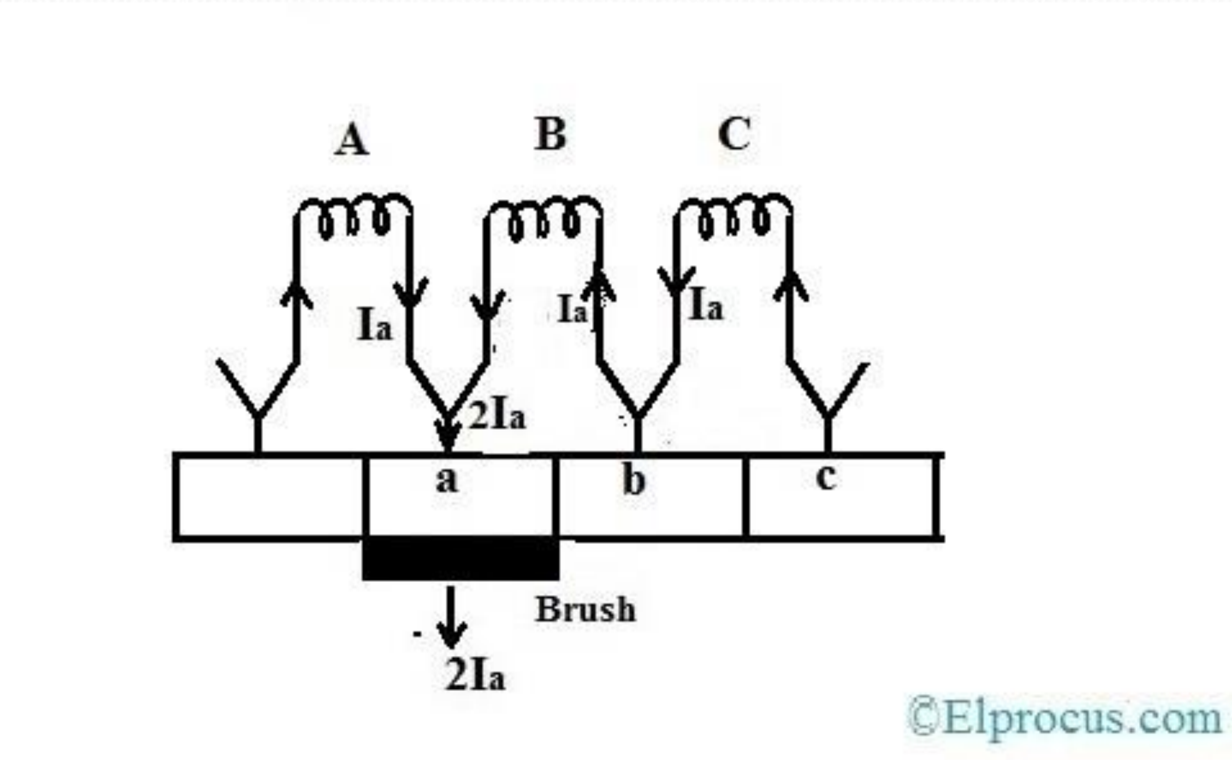
Position-4

- In this position, one-fourth of the brush surface will be in contact with segment b and three fourth with segment a. Here the current drawn through coil B is – Ia/2. Here we can observe that the current in coil B is reversed.



Position-5

- At this position, the brush is in full contact with segment a and the current from coil B is Ia but is reverse direction to the current direction of position 1.Thus commutation process is completed for segment b.



Losses in DC machine

- Copper losses
  - Armature Cu loss
  - Field Cu loss
  - Loss due to brush contact resistance
- Iron Losses
  - Hysteresis loss
  - Eddy current loss
- Mechanical losses
  - Friction loss
  - Windage loss

Copper losses

- These losses occur in armature and field copper windings. Copper losses consist of Armature copper loss, Field copper loss and loss due to brush contact resistance.
  - I2R losses (where, Ia = Armature current and
    Ra= Armature resistance)
  - This loss contributes about 30 to 40% to full load losses.
- The armature copper loss is variable and depends upon the amount of loading of the machine.
-

In the case of a shunt wounded field, field copper loss is practically constant. It contributes about 20 to 30% to full load losses.

- Brush contact resistance also contributes to the copper losses. Generally, this loss is included into armature copper loss.

Iron losses (Core losses)

- As the armature core is made of iron and it rotates in a magnetic field, a small current gets induced in the core itself too.
- Two losses occurs
    - Eddy Current
    - Hysteresis

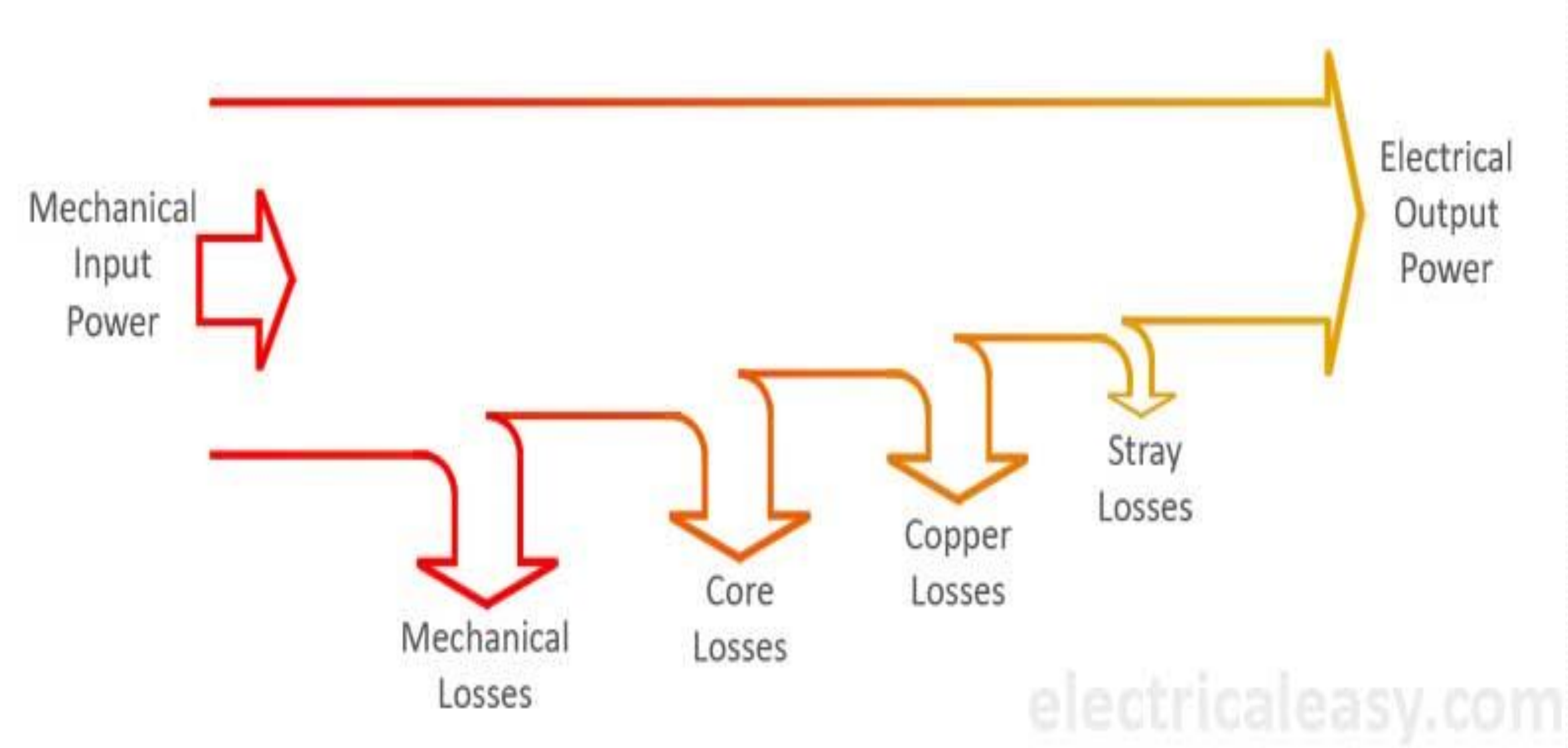
Mechanical Losses

- Mechanical losses consist of the losses due to friction in bearings and commutator segment.
  These losses contributes 10 to 20% of full load losses.

Stray Losses

- Apart from losses stated above, there may be small losses present which are called as stray losses or miscellaneous losses.
- These losses are difficult to calculate .
- This losses arises due to inaccuracies in the designing and modelling of the machine.
- stray losses are assumed to be 1% of the full load.

Power Flow diagram



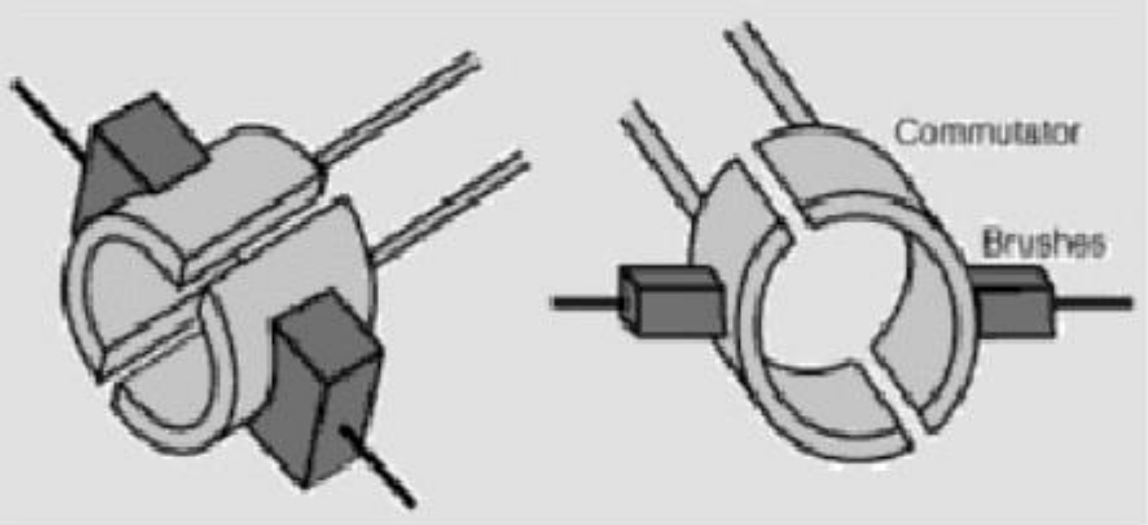
Power flow diagram of a DC generator

Thank You

COMMUTATION

COMMUTATION???

- The process by which the current in the short circuited coil is reversed while it crosses the MNA is called ‘*Commutation*’
- The brief period during which the coil remains short-circuited is known as ‘*Commutation Period*’



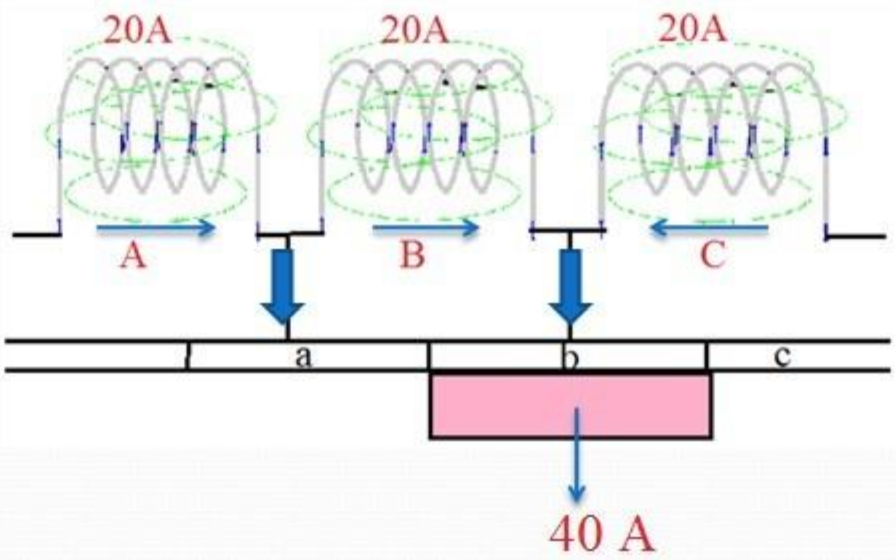
- If the current reversal ie. The change from ‘+I’ to zero and then to ‘-I’ is completed by the end of short circuit or commutation period, then the commutation is ‘*ideal commutation*’.

- If current reversal is not complete by that time, then it will result in sparking in the brushes resulting in a ‘*non-ideal commutation.*’

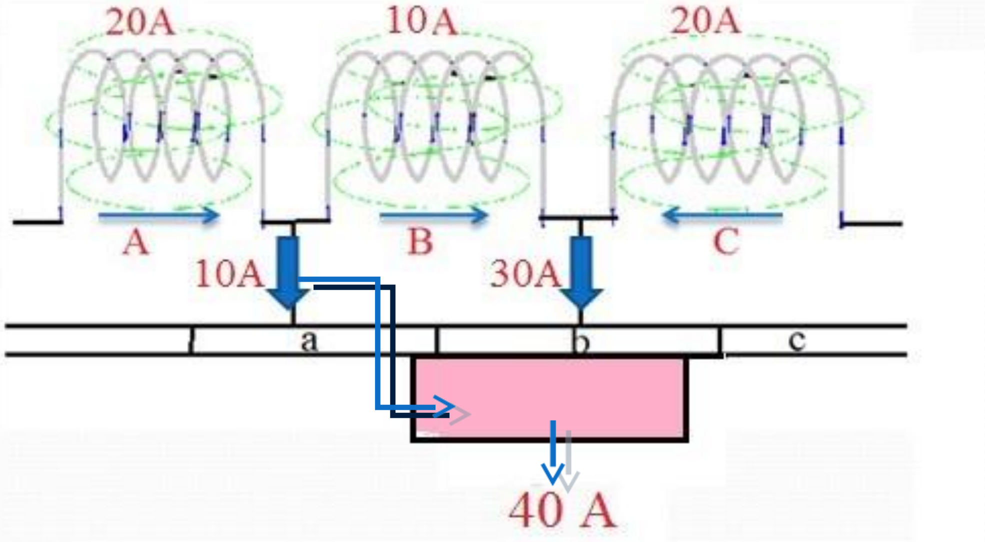
- Let us discuss the process of commutation or current reversal in more detail with the help of the figures.

- Consider the fig shown below-
- Coil B is about to be short circuited because brush is about to come in contact with commutator segment ‘a’.
- It is assumed that each coil carries 20A,so that brush current is 40A.
- Prior to the beginning of short-circuit, coil B belongs to the group of coils lying to

the left of brush & carries 20A

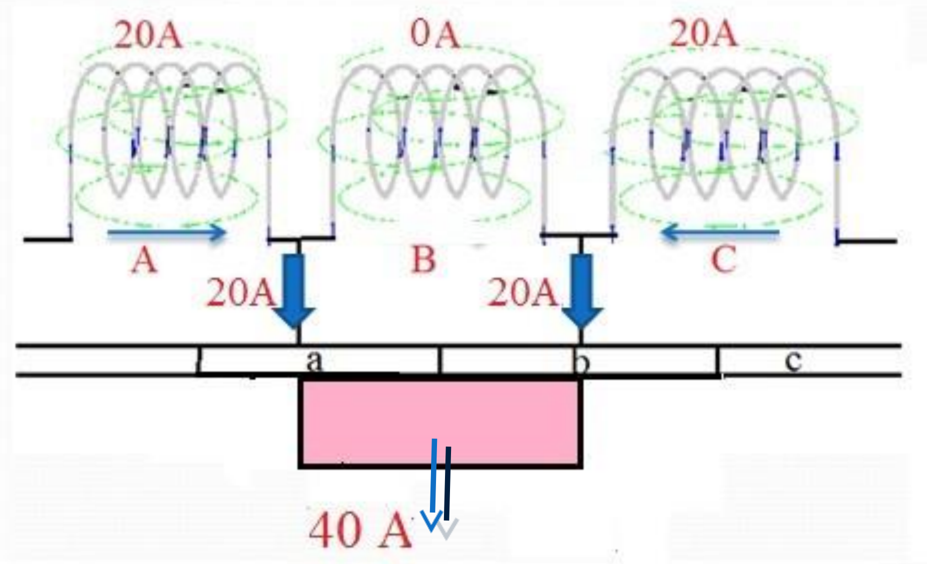


- In the fig shown here coil B has entered its period of short circuit and approximately at one-third of this period.
- The through coil B has reduced down from 20A to 10A because the other 10A flows via segment ‘a’.



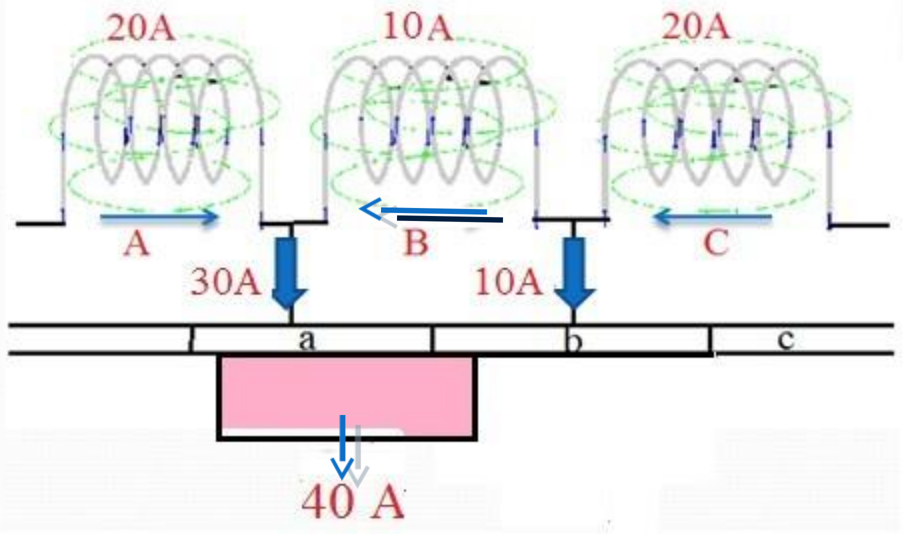
- As the area of contact of brush is more with segment ‘b’ than with segment ‘a’, it receives 30A from the former, the total again being 40A.

- Again consider the fig shown-
- Now the coil B is in the middle of the short-circuite period.
- The current through it has decreased to zero.



- The two currents of 20A each, pass to the brush directly from coil A & coil C as shown. The brush contact areas with the two segment ‘b’ & ‘a’ are equal.

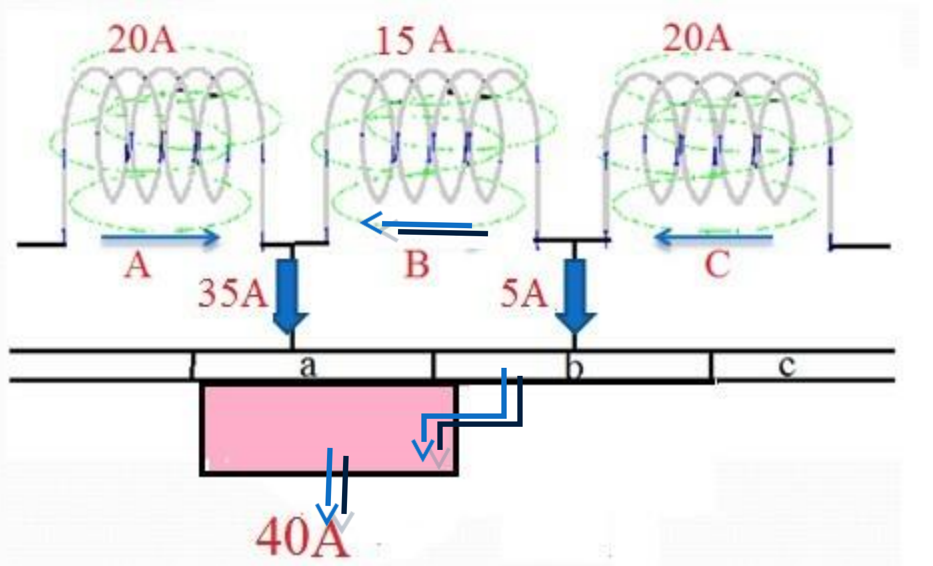
- Consider the shown below:-In this fig coil B has became the part of the group of coils lying to the right of the brush.
- It is seen that brush contact area with segment ‘b’ is decreasing rapidly whereas that with segment ‘a’ is increasing.



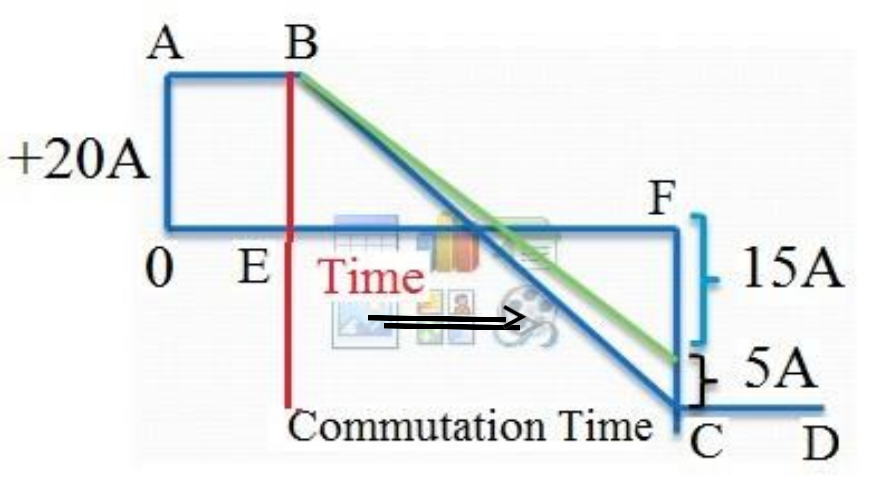
- Coil B now carries 10A in the reverse direction which combine with 20A supplied by coil A to make up 30A that passes from segment ‘a’ to the brush, the other 10A is supplied by coil C to the brush.

- From the fig show now depicts the moment when coil B is almost at the end of commutation period. For ideal commutation, current through it should have reversed by now but, as shown it is carrying 15A only (instead of 20 A).
- The difference of current between coils C & B

ie. 20-15=5A, jumps directly from segment ‘b’ to the brush through air producing spark.



- If the change of current through coil B are plotted on a time base it will be represented by a horizontal line AB upto the beginning of commutation period.
- From the finish of commutation the current will be represented by another horizontal line CD.
- The way in which current changes from its positive value to zero and then to negative value depends on how coil B undergoes commutation.



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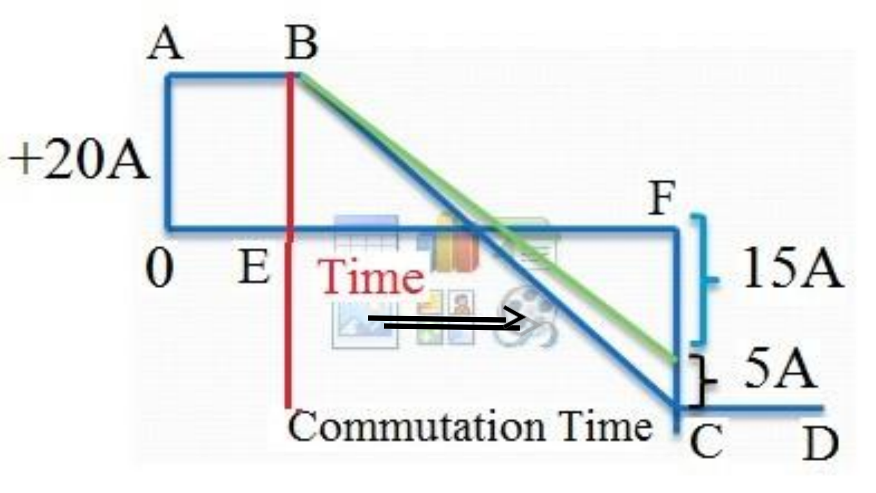
- From the finish of commutation the current will be represented by another horizontal line CD.
- The way in which current changes from its positive value to zero and then to negative value depends on how coil B undergoes commutation.



SUBJECT : ELECTRICAL ENGINEERING (EIR2C4)

UNIT V

ROTATING ELECTRICAL MACHINES

Topics

- EMF equation of DC generator
- Examples on EMF equation
- Torque equation of DC motor
- Examples on Torque equation
- Types of DC motor and generator

EMF equation of DC generator

Derivation

- Let,
- ϕ = Flux per pole in Weber.
- Z = Total number of armature conductors.
- N = Armature rotation in revolution per minute (r.p.m).
- P = Number of poles.
- A = Number of parallel paths in armature.
- E = e.m.f induced in any parallel path or generated e.m.f

- According to Faraday's law's of Electromagnetic induction.

$$= \frac{d\phi}{dt} = \frac{\text{flux cut}}{\text{time taken}} \text{ volt}$$

- Average e.m.f generated / conductors –

Flux cut / Conductors in one revolution, $d\phi = \phi P$ wb.

Number of revolutions / minute = N / 60

Time taken for one revolution, – $dt = \frac{60}{N}$ second.

e.m.f generated / conductor $= \frac{d\phi}{dt} = \frac{\phi P}{60/N} = \frac{\phi PN}{60}$ volt

Total e.m.f generated between the terminals

E = average e.m.f generated per conductor * number of conductor in each parallel path

$$= \frac{\phi PN}{60}\frac{Z}{A}\text{ volt}$$

$$\boxed{E = \frac{\phi PN}{60}\frac{Z}{A}\text{ volt}}$$

Where A = P for lap winding
A = 2 for wave
winding.

Example 2 : A 4 pole generator with wave wound armature has 50 slots each having 20 conductors. The flux per pole is 10 mWb. At what speed must the armature rotate to give an induced emf of 0.24 kV. What will be the voltage developed, if the winding is lap connected and the armature rotates at the same speed?

Total no. of conductors, Z = 50 x 20 = 1224

Wave winding, A=2
From EMF equation,

N= Eg60A / ΦZP = (240x60x2)/(10/1000x1224x4) = 612.75 rpm

Lap winding, A=P=4

Eg = PΦZN/60A = (4x10/1000x1224x612.75)/(60x4) = 0.125 kV

Torque equation of DC motor

$$T = \frac{\varphi ZP}{2\pi A} \, . I_a$$

For a particular DC Motor, the number of poles (P) and the number of conductors per parallel path (Z/A) are constant.

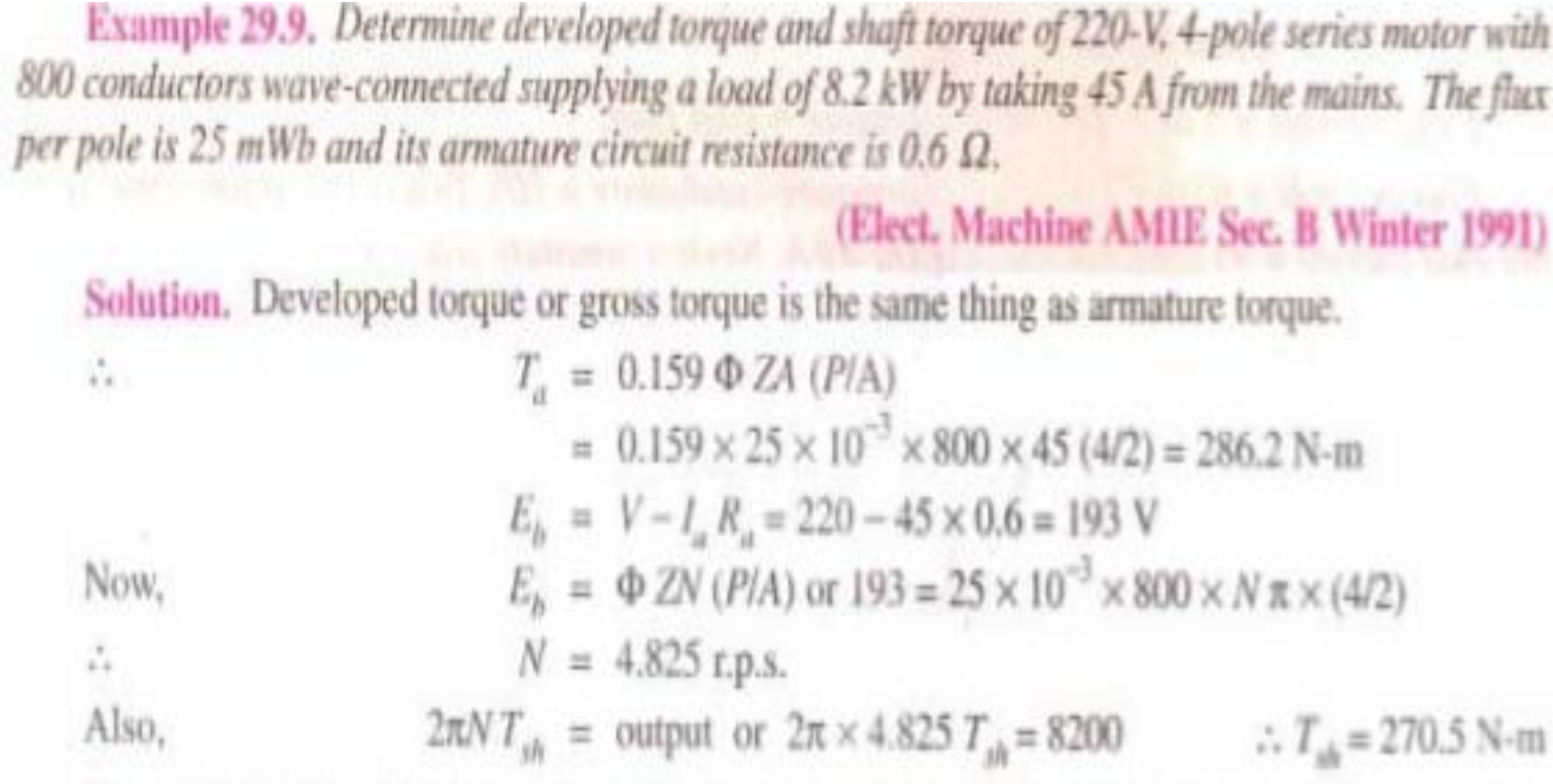
$$T = K\varphi I_a$$

Where,

$$K = \frac{ZP}{2\pi A} \quad \text{or}$$

$$T \propto \varphi I_a \ldots \ldots . (5)$$

A Numerical Question from B.L.Thareja



Example 29.9. *Determine developed torque and shaft torque of 220-V, 4-pole series motor with 800 conductors wave-connected supplying a load of 8.2 kW by taking 45 A from the mains. The flux per pole is 25 mWb and its armature circuit resistance is 0.6 Ω.*

(Elect. Machine AMIE Sec. B Winter 1991)

Solution. Developed torque or gross torque is the same thing as armature torque.

∴ $$T_a = 0.159\,\Phi ZA\,(P/A)$$

$$= 0.159 \times 25 \times 10^{-3} \times 800 \times 45\,(4/2) = 286.2 \text{ N-m}$$

$$E_b = V - I_a R_a = 220 - 45 \times 0.6 = 193 \text{ V}$$

Now, $$E_b = \Phi ZN\,(P/A) \text{ or } 193 = 25 \times 10^{-3} \times 800 \times N\pi \times (4/2)$$

∴ $$N = 4.825 \text{ r.p.s.}$$

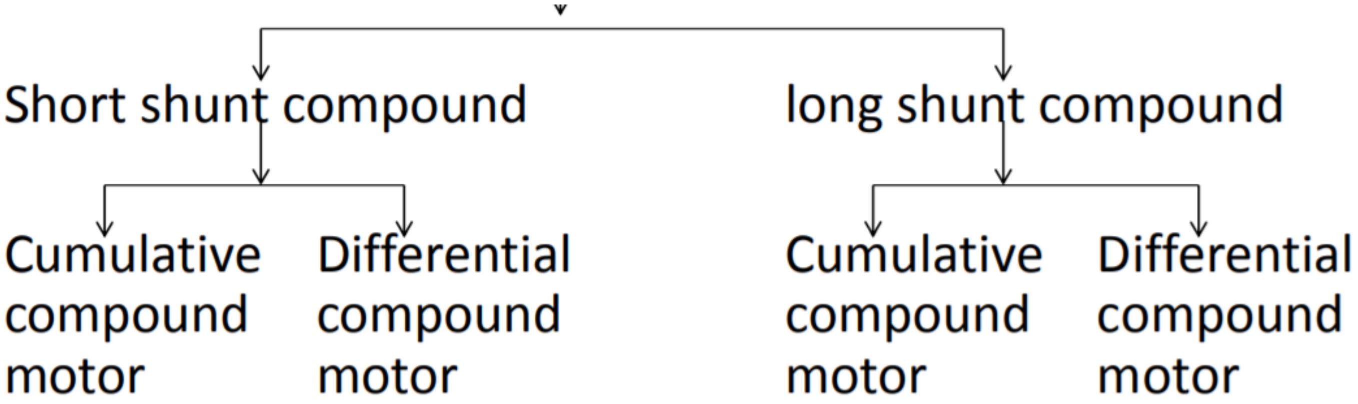
Also, $$2\pi N T_{sh} = \text{output or } 2\pi \times 4.825\, T_{sh} = 8200 \qquad \therefore T_{sh} = 270.5 \text{ N-m}$$

Types of Motor

Types of DC Motor:

Classification of the d.c. motor depends on the way of connecting the armature and field winding of a d.c. motor:

1. DC Shunt Motor
2. DC Series Motor
3. DC Compound Motor



Short shunt compound

long shunt compound

Cumulative compound motor

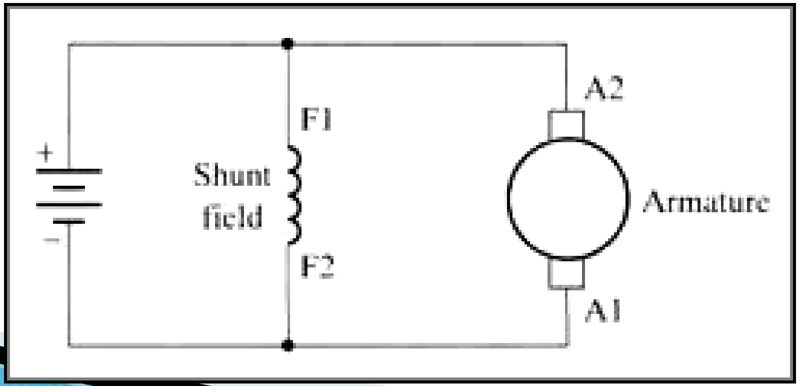
Differential compound motor

Cumulative compound motor

Differential compound motor

DC Shunt Motor:

- In dc shunt motor the armature and field winding are connected in parallel across the supply voltage
- The resistance of the shunt winding Rs is always higher than the armature winding resistance Ra
- as field current is responsible for generation of flux.
- So $\varnothing \propto Ish$
- So shunt motor is also called as constant flux motor



- $E_{b=} V_L - I_a R_a$
- $I_a = I_L + I_{sh}$
- $V_L = E_b + I_a R_a$

$$I_{sh} = V_L / R_{sh}$$

DC SERIES MOTOR

- □In series wound motor the field winding is connected in series with the armature. Therefore, series field winding carries the armature current.

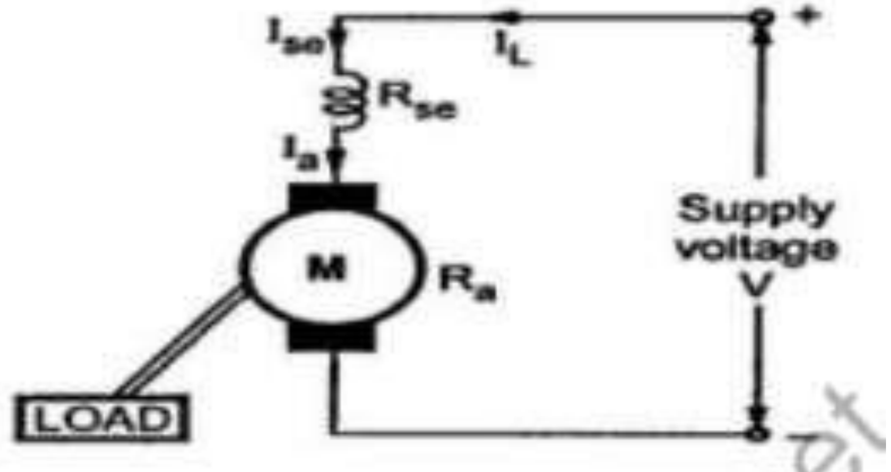


Fig. 1.31 DC Series Motor

- $E_b = V_L - I_a R_a - I_{se} R_{se}$

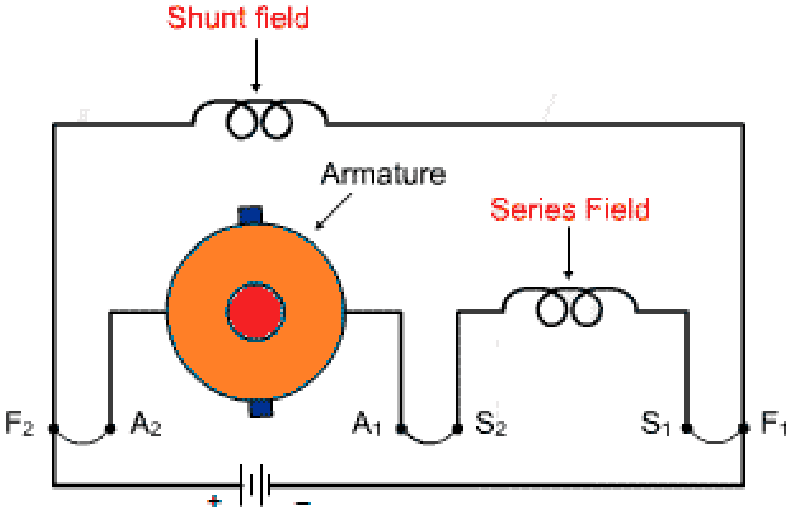
- $I_a = I_L = I_{se}$

- $V_L = E_b + I_a R_a + I_{se} R_{se}$

DC COMPOUND MOTOR

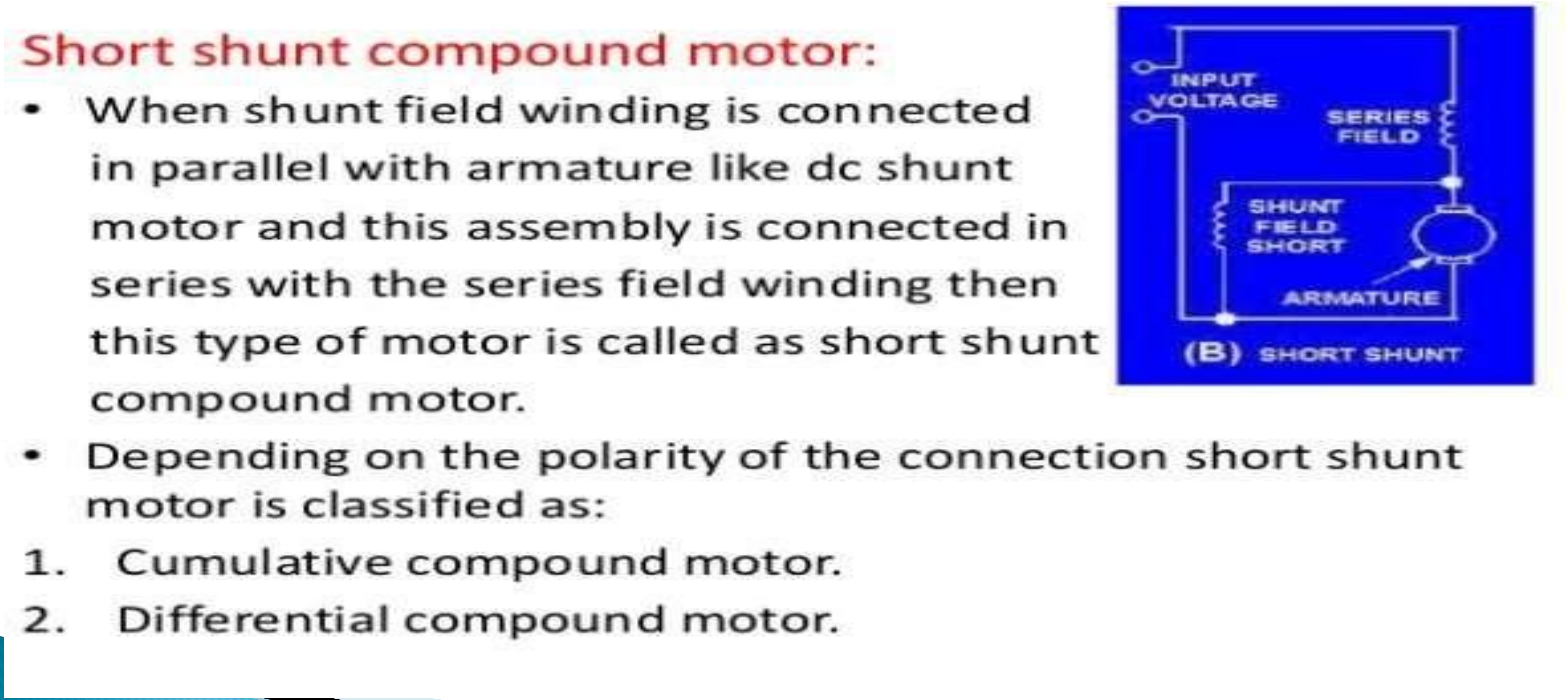
- Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections

1. Short-shunt connection
2. Long shunt connection



Schematic diagram of dc compound motor

SHORT SHUNT CONNECTION



Short shunt compound motor:

- When shunt field winding is connected in parallel with armature like dc shunt motor and this assembly is connected in series with the series field winding then this type of motor is called as short shunt compound motor.
- Depending on the polarity of the connection short shunt motor is classified as:

1. Cumulative compound motor.
2. Differential compound motor.

- $E_b = V_L - I_a R_a - I_{SE} R_{SE}$

- $I_a = I_L - I_{sh}$

- $I_L = I_{SE}$

- $V_L = E_b + I_a R_a + I_{SE} R_{SE}$

- $I_{sh} = V_L \ \underline{R_{sh}}$

- $E_b = V_L - I_a R_a - I_{SE} R_{SE}$

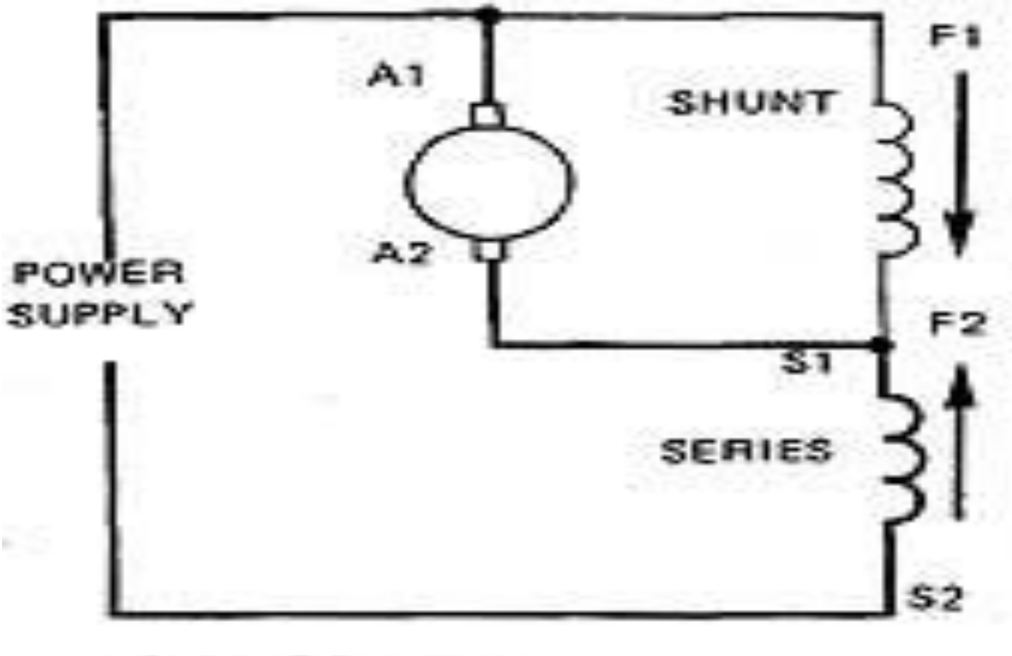
- $I_L = I_{SE} = I_L - I_{sh}$

- $V_L = E_b + I_a R_a + I_{SE} R_{SE}$

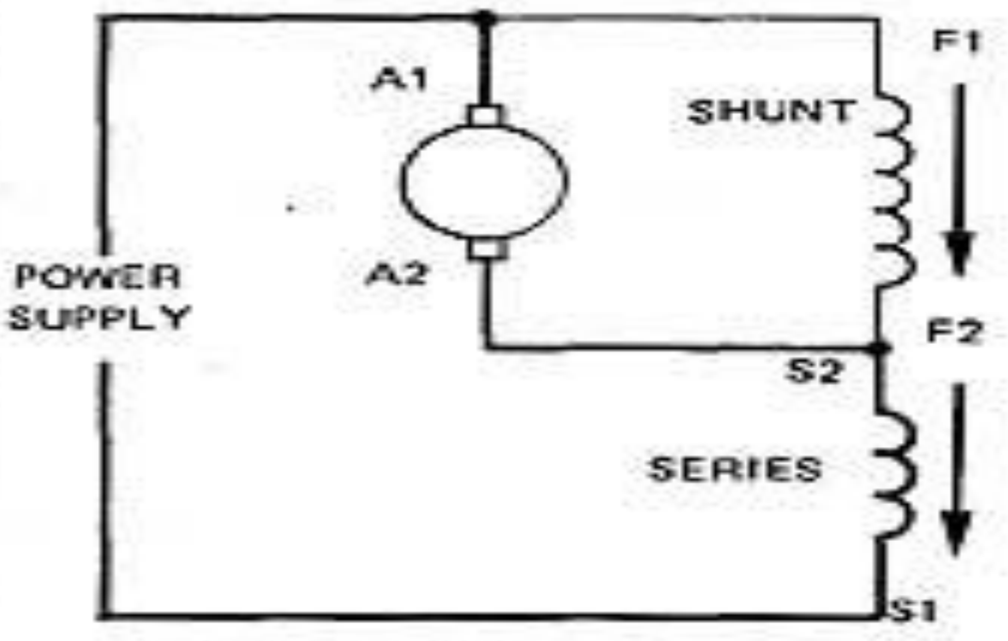
LONG SHUNT CONECTION

When shunt field is connected in parallel with both series field winding and armature winding.

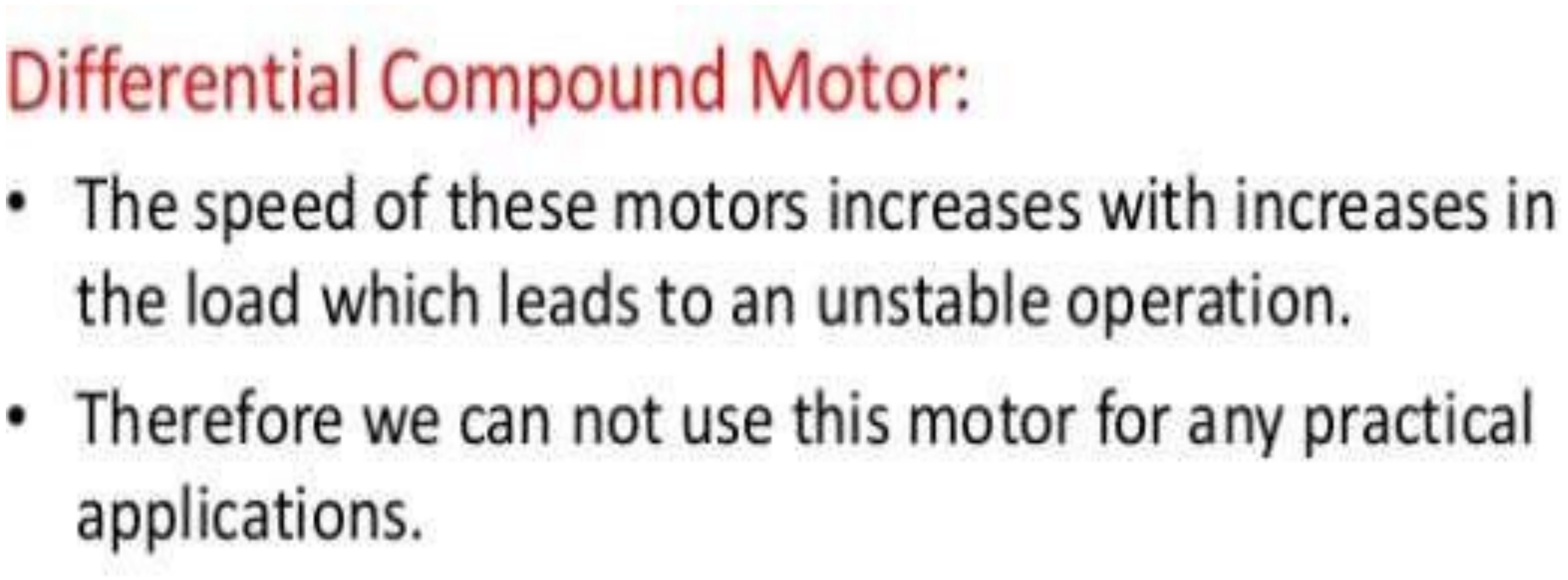
Two Types:-
Cumulative compound motor
Differentially compound motor



DIFFERENTIAL
- CONSTANT SPEED
- LOW STARTING TORQUE



CUMULATIVE
- SERIES CHARACTERISTICS
- HIGH STARTING TORQUE

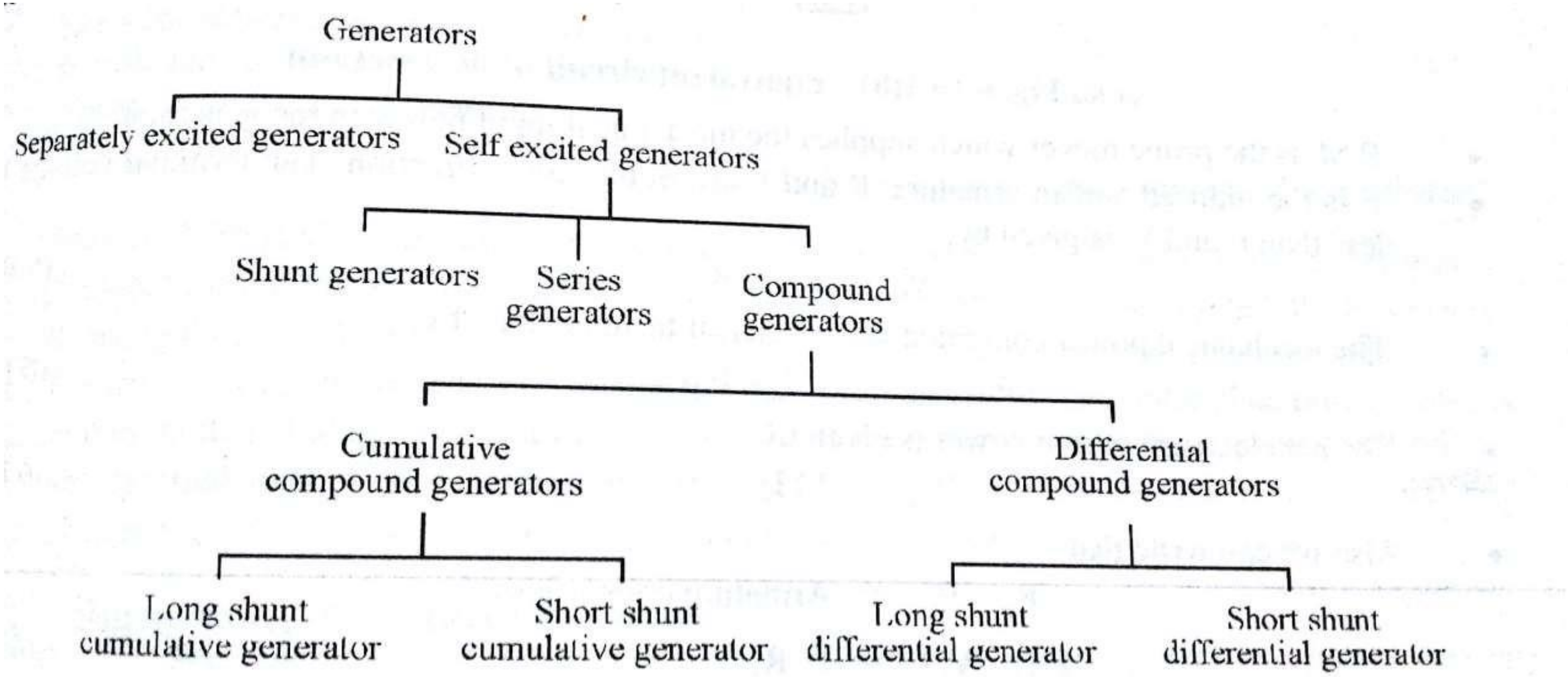


Differential Compound Motor:

- The speed of these motors increases with increases in the load which leads to an unstable operation.
- Therefore we can not use this motor for any practical applications.

Types of DC generator

CLASSIFICATION



APPLICATIONS

- Shunt generator:

Lighting loads Battery charging

- Series generator:

For the arc lamps

As constant current generator As

boosters on D.C. generator

- Separately Exicted generator:

The application of these generator have limitations , because they need a separate excitation for the field winding. Some of the application are electro-refining of materials or electro-plating

- Cumulative compound generator:
- Used for domestic lighting
- For energy transmission over a long distance.
- Differential compound generator:

Its important application is electric arc welding