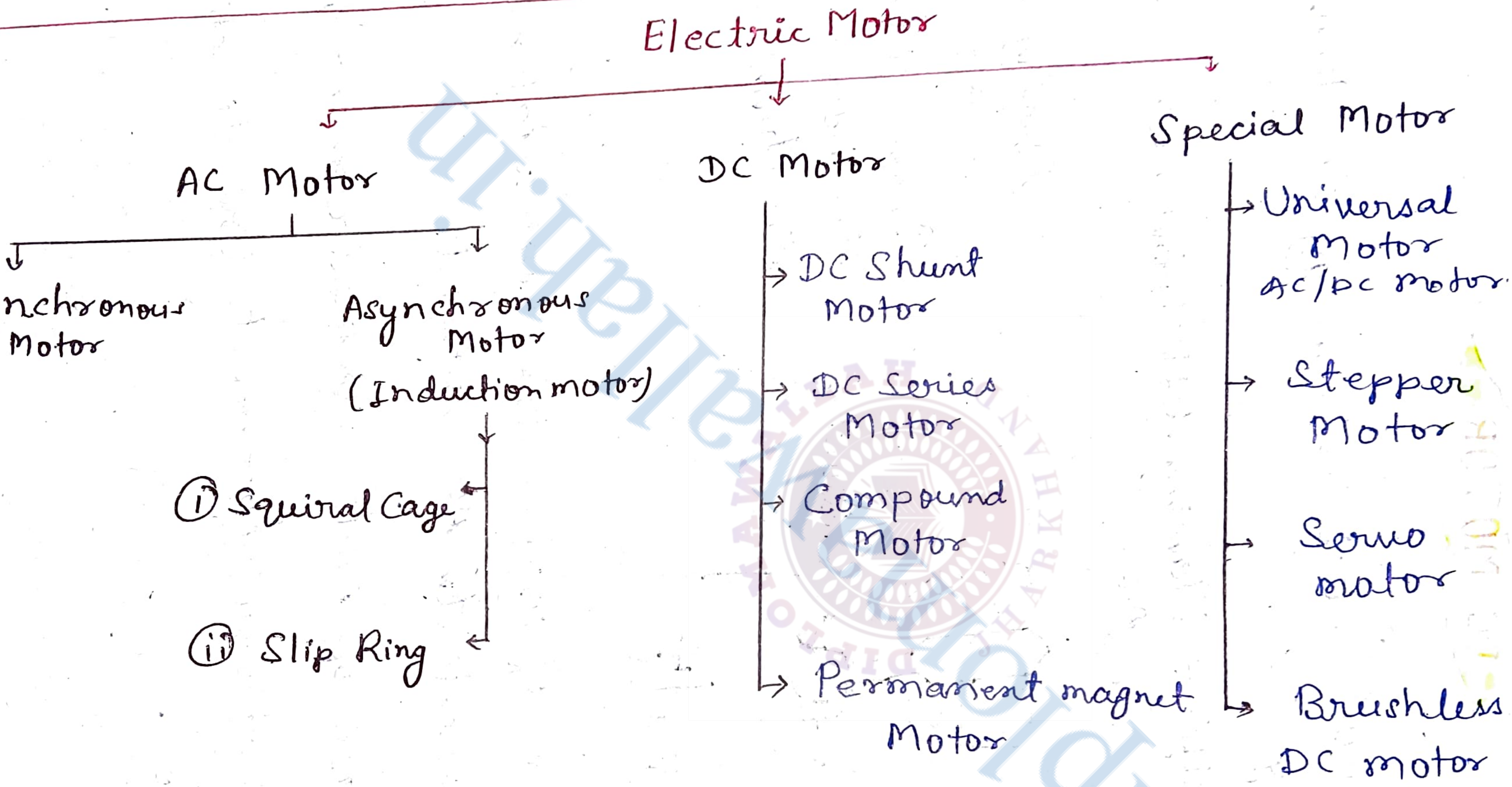
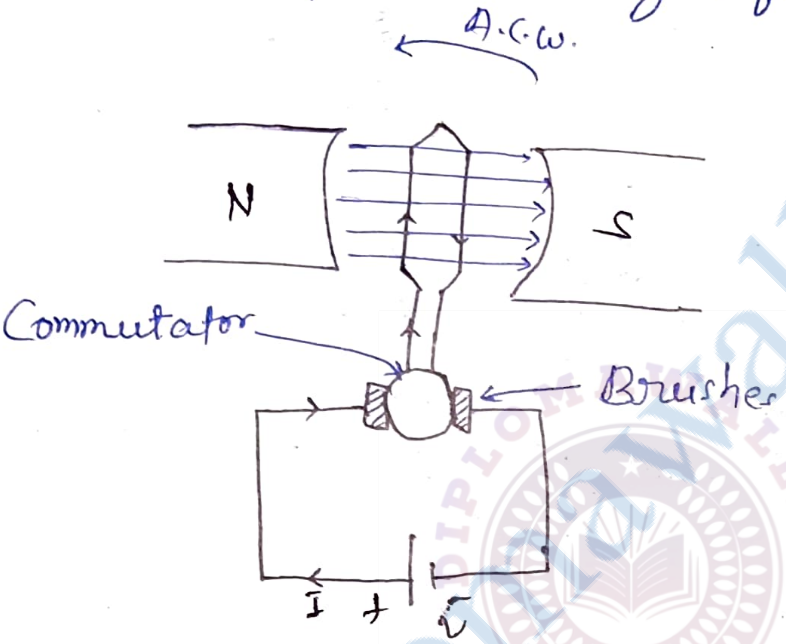

Electric Motor
AC Motor
Synchronous Motor
Asynchronous Motor (Induction motor)
(i) Squiral Cage
(ii) Slip Ring
DC Motor
DC Shunt Motor
DC Series Motor
Compound Motor
Permanent magnet Motor
Special Motor
Universal Motor AC/DC motor.
Stepper Motor
Servo motor
Brushless DC motor

DC MOTOR

→ It convert electrical energy to Mechanical energy.

→ Principle → Flaming left hand rule.



Fleming left hand rule -

① Fore - Flux

(ii) Middle → Current

(iii) Thumb → rotation

(i) In case of motor the commutator convert DC current to AC current.

(ii) In case of motor commutator convert Bi-directional torque to Uni-directional torque.

Principle :-

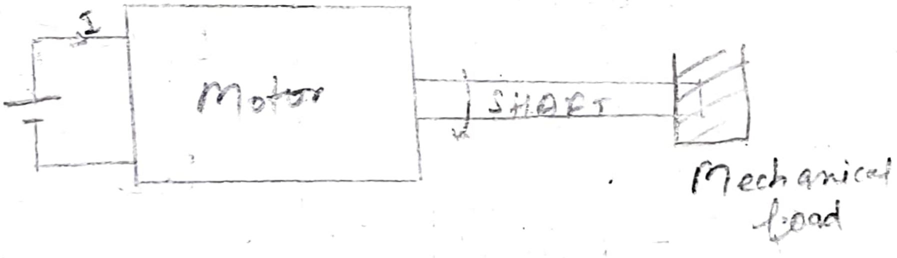
Whenever a current carrying conductor placed in a magnetic field. due to this the torque will produced & this produced torque will rotate the rotor.

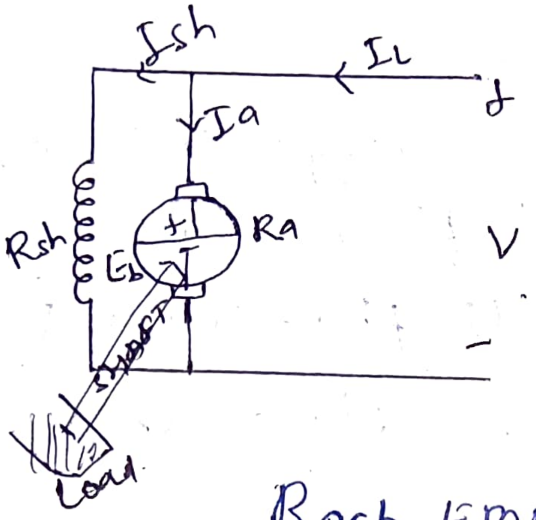
Back Emf :-

An emf induced in armature winding due to opposition of mechanical load, is called Back emf.

$$\boxed{E_b = \frac{NP\phi Z}{60A}}$$

N = Speed.
P = Pole
ϕ = flux per pole
Z = Conductor
A = Parallel path





$$-V + I_aR_a + E_b = 0$$

$$\boxed{V = E_b + I_aR_a}$$

Back EMF: $\boxed{E_b = \frac{NP\phi Z}{60A}}$

$$E_b = \underbrace{\frac{PZ}{60A}}_{\text{constant}} N.\phi$$

$$\boxed{E_b = KN\phi} \quad \boxed{E_b \propto N\phi}$$

$$\boxed{N \propto \frac{E_b}{\phi}} \quad \boxed{\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}} \cdot \frac{\phi_1}{\phi_2}}$$

$$E_b = \frac{NP\phi Z}{60A}$$

$$E_b = \frac{PZ}{60A} \cdot N.\phi$$

$$\because \omega = \frac{2\pi N}{60}$$

$$N = \frac{\omega.60}{2\pi}$$

$$E_b = \frac{PZ}{\cancel{60}A} \cdot \frac{\omega \cancel{60}}{2\pi} \phi$$

$$E_b = \underbrace{\frac{PZ}{2\pi A}}_{\text{motor constant}} \cdot \omega . \phi$$

$$\boxed{E_b = K.\omega.\phi}$$

↑

Motor constant $\left(\frac{PZ}{2\pi A}\right)$

$$\text{volt} = K \frac{\text{rad}}{\text{sec}} . \text{Wb}$$

$$\boxed{K = \frac{Volt \times Sec}{rad \times Wb}}$$

Torque:- Torque is the rotational force produced by the motor shaft to do work.
Unit: Newton-metre (Nm).

$$\boxed{Power\,(P_m) = T.\omega = E_b \cdot I_a}$$

Mechanical power developed.

$$T.\frac{2\pi \cancel{N}}{\cancel{60}} = \frac{\cancel{N} P\phi Z}{\cancel{60} A}.I_a$$

$$T = \underbrace{\left(\frac{PZ}{2\pi A}\right)}_{\text{constant}}\phi \cdot I_a$$

$$T = \underset{\text{motor constant}}{K}\phi . I_a$$

$$\underbrace{\boxed{K = \frac{N.m}{Wb \times amp}}}_{\text{Unit}}$$

$$\boxed{T \propto \phi I_a}$$

or

$$\boxed{\frac{T_2}{T_1} = \frac{I_{a_2}}{I_{a_1}} . \frac{\phi_2}{\phi_1}}$$

Imp point

(i) $N \propto \frac{E_b}{\phi}$.

(ii) $T \propto \phi . I_a$

(iii) $P = T.\omega = E_b \cdot I_a$

Q. In a DC Motor the speed is 1000 rpm & torque is 10 N.m. If the speed becomes 500 rpm. so to maintain same power the torque is = ?

$N_1 = 1000$, $T_1 = 10$ Nm. $N_2 = 500$, $T_2 = ?$

$P = \text{const.}$

$T \cdot \omega = \text{const.}$

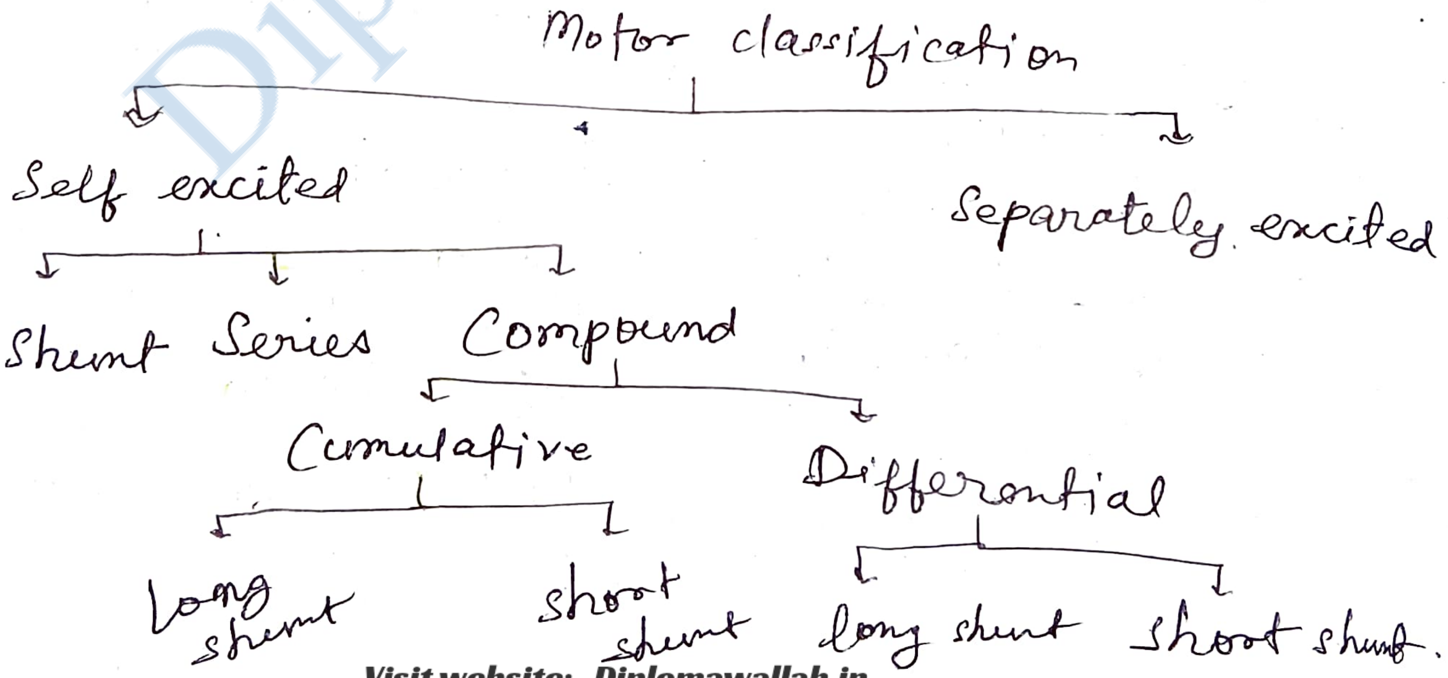
$T_1 \omega_1 = T_2 \cdot \omega_2$

$$T_1 \cdot \frac{2\pi N_1}{\cancel{60}} = T_2 \cdot \frac{2\pi N_2}{\cancel{60}}$$

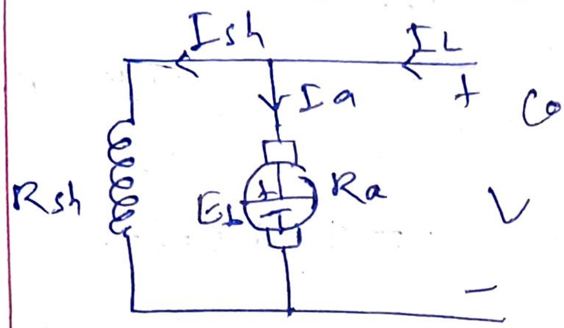
$T_1 N_1 = T_2 N_2$

$10 \times 1000 = T_2 \times 500 \Rightarrow T_2 = \dfrac{10 \times \overset{2}{\cancel{1000}}}{\cancel{500}}$

$\boxed{T_2 = 20 \text{ Nm}}$



① **Shunt** :- Field winding is in parallel with armature.



Constant → $\boxed{I_{sh} = \frac{V}{R_{sh}}}$ V → Constant, Rsh → Constant

$\boxed{V = E_b + I_a R_a}$

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

$\boxed{\phi = \text{Const}}$

$\overset{\text{Constant}}{\phi} \propto \overset{\text{Const}}{I_{sh}}$

→ In a shunt motor flux is remain constant.

$N \propto \frac{E_b}{\phi}$ φ → Const

$\boxed{N \propto E_b}$

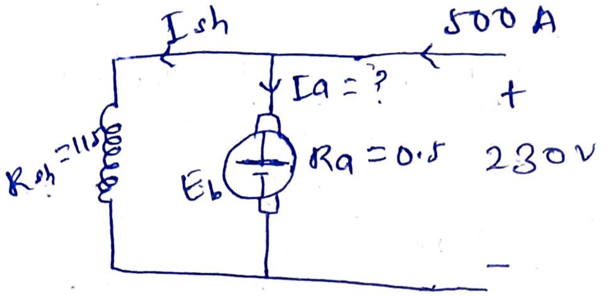
$\boxed{\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}}}$

$T \propto \phi \cdot I_a$ φ ↑ Const

$\boxed{T \propto I_a}$

$\boxed{\frac{T_2}{T_1} = \frac{I_{a_2}}{I_{a_1}}}$

Q. A 230 V DC Shunt draws at current of 50A from supply. The armature resistance & shunt field winding resistance are 0.5 Ω & 115 Ω. Then find (i) Ia (ii) Eb



$$I_{sh} = \frac{V}{R_{sh}} = \frac{230}{115} = 2A$$

$I_L = I_a + I_{sh}$

$I_a = 50 - 2$

$$\boxed{I_a = 48A}$$

$V = E_b + I_a R_a$

$E_b = V - I_a R_a$

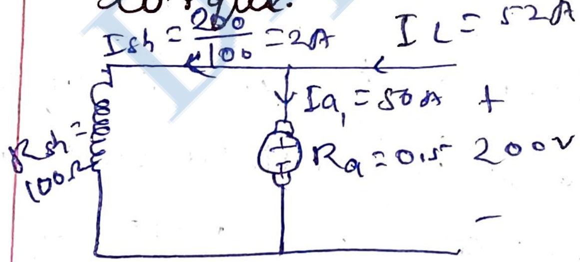
$= 230 - 48 \times 0.5$

$= 230 - 24$

$= 206$ volt

Q. A 200V DC shunt motor runs at 1200 rpm. The armature resistance $R_a = 0.5$ & $R_{sh} = 100\Omega$, the line current drawn by motor is 52A. If an external resistance of 2.5Ω is connect in series with armature than find the speed at which motor will draw same torque.

=)



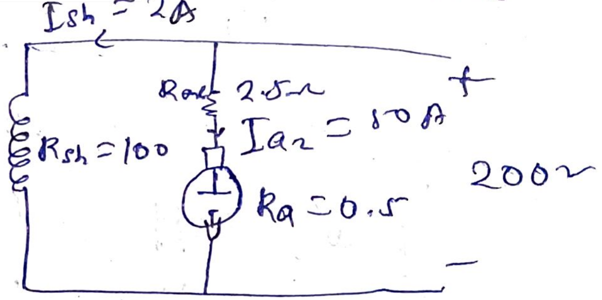
$N_1 = 1200$

$V = E_{b_1} + I_a R_a$

$E_{b_1} = V - I_{a_1} R_a$

$= 200 - 50 \times 0.5$

$$\boxed{E_{b_1} = 175 \text{ volt}}$$



$N_2 = ?$

$T \rightarrow$ Same

$$\boxed{T \propto I_a}$$

$$\boxed{\frac{T_2}{T_1} = \frac{I_{a_2}}{I_{a_1}}}$$

$E_{b_2} = 200 - 50(0.5 + 2.5)$

$E_{b_2} = 200 - 50 \times 3$

$= 200 - 150$

$$\boxed{E_{b_2} = 50}$$

$N \propto E_b$

$$\boxed{\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}}}$$

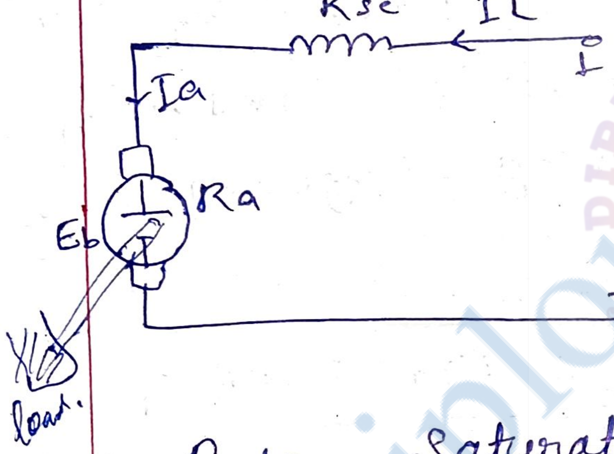
$$\frac{N_2}{1200} = \frac{\cancel{50}\ 2}{\cancel{175}\ 7}$$

$$N_2 = \frac{2}{7} \times 1200$$

$$N_2 = \frac{2400}{7}$$

$$\boxed{N_2 = 342}$$

② **Series Motor :-** In this motor the field winding is remain connected in series with armature.



$\boxed{\phi \propto I_a}$

$\phi \neq$ Constant (Before saturation)

$\phi =$ Constant (After saturation)

Before Saturation

$\phi \neq$ Constant

$$\boxed{N \propto \frac{E_b}{\phi} \propto \frac{E_b}{I_a}}$$

$$\boxed{\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}} \times \frac{\phi_1}{\phi_2}}$$

$T \propto \phi \cdot I_a$

$\{\because \phi \propto I_a\}$

$T \propto I_a \cdot I_a$

$$\boxed{T \propto I_a^2}$$

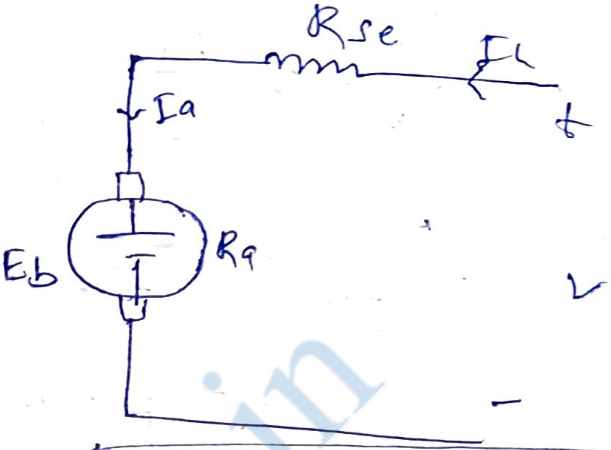
$$\left\{\frac{T_2}{T_1} = \left(\frac{I_{a_2}}{I_{a_1}}\right)^2\right\}$$

After saturation

ϕ = Const.

$\boxed{N \propto E_b}$, $\boxed{T \propto I_a}$

$\boxed{\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}}$, $\boxed{\frac{T_2}{T_1} = \frac{I_{a2}}{I_{a1}}}$



$\boxed{V = E_b + I_a(R_a + R_{se})}$

$\{I_L = I_a = I_{se}\}$

Q. A DC series motor draws a current of 10 amp from supply. If the current is increased by 20%, than find the percentage change in torque.

$\boxed{T \propto I_a^2}$ $\boxed{I_{a1} = 10A}$

$\frac{T_2}{T_1} = \left(\frac{I_{a2}}{I_{a1}}\right)^2 = \left(\frac{12}{10}\right)^2$ $\boxed{I_{a2} = 10 + 2 = 12 A}$

$\frac{T_2}{T_1} = \frac{144}{100} \Rightarrow \frac{T_2}{T_1} = 1.44$

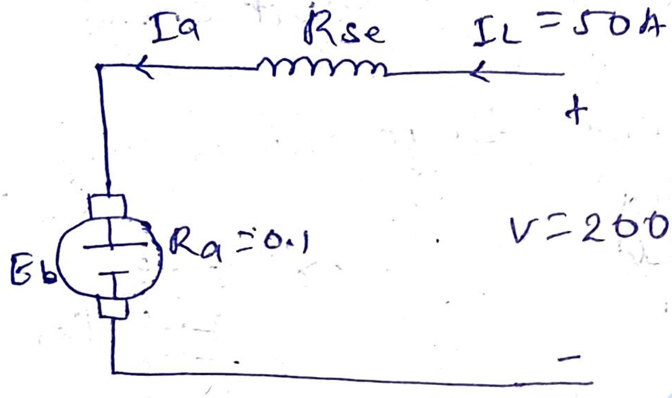
$\left(\frac{T_2}{T_1} - 1\right) \times 100 = (1.44 - 1) \times 100$

$= 44\%$

In A 200 V DC Series Motor the line current drawn by motor is 50 amp & $R_a = 0.1\,\Omega$ & $R_{se} = 0.15\,\Omega$ find the value of

① Back emf.

(ii) Mechanical power developed.



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

$$E_b = V - I_a(R_a + R_{se})$$

$$E_b = 200 - 50\,(0.1 + 0.15)$$

$$= 200 - 50 \times 0.25$$

$$= 200 - 12.5$$

$$= \underline{187.5 \text{ volt}}$$

Mechanical power developed

$$P_m = E_b \cdot I_a$$

$$= 187.5 \times 50$$

$$= 9375$$

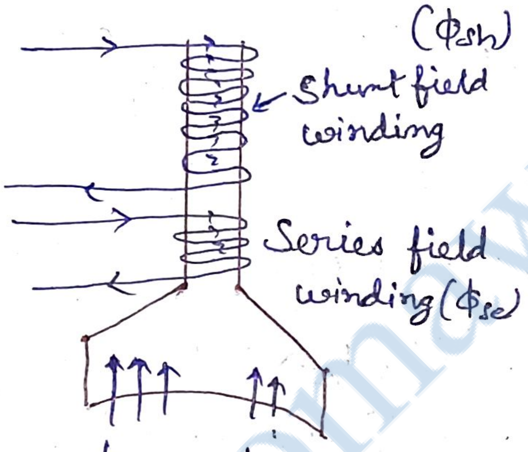
$$= 9.375 \text{ KW}.$$

③ Compound Motor

Combination of Series and shunt windings.

- Cumulative Compound → Long shunt / short shunt
- Differential compound → Long shunt / short shunt

Cumulative Compound



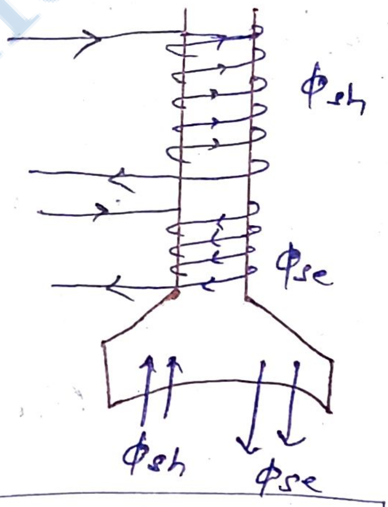
$$\boxed{\phi_{net} = \phi_{sh} + \phi_{se}}$$

- The magnetic field of the shunt and series windings aid each other.
- higher starting torque

- Uses :- Elevators, rolling mills

- $V = E_b + I_a(R_a + R_{se})$

Differential compound

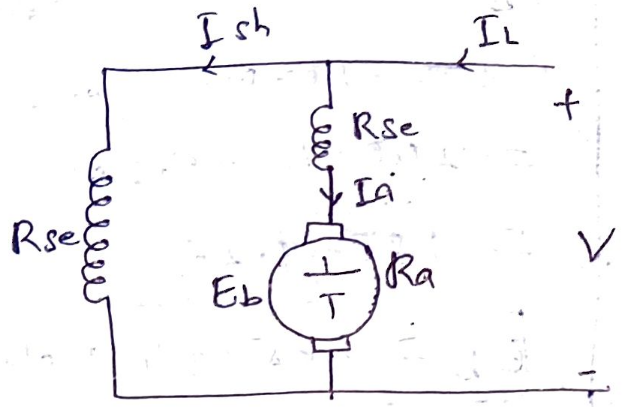


$$\boxed{\phi_{net} = \phi_{sh} - \phi_{se}}$$

- The magnetic field of the shunt and series windings oppose each other.
- poor torque.

- $V = E_b + I_a(R_a \pm R_{se})$

① Long Shunt :-

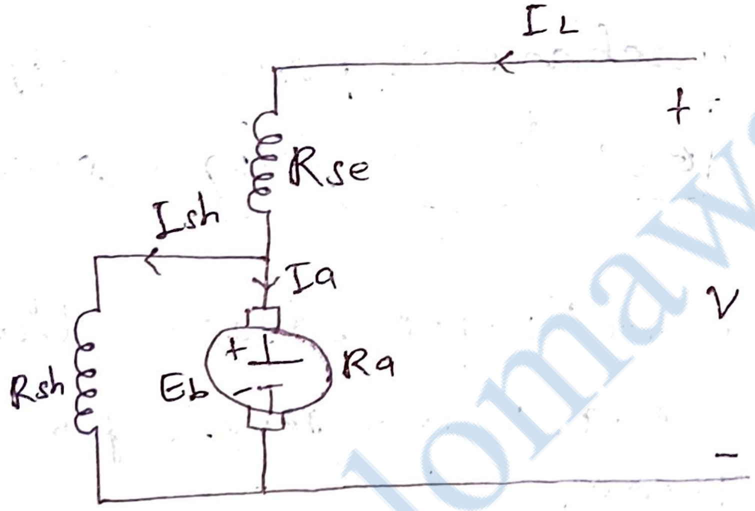


$$\boxed{I_{sh} = \frac{V}{R_{sh}}}$$

$$\boxed{V = E_b + I_a(R_a + R_{se})}$$

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

(ii) Short shunt :-



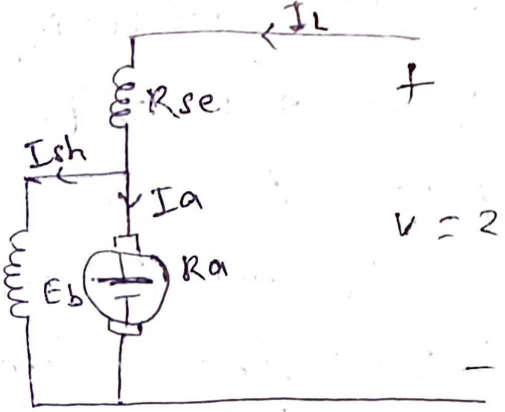
$$V = E_b + I_aR_a + I_LR_{se}$$

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

$$\boxed{I_{sh} = \frac{V - I_LR_{se}}{R_{sh}}}$$

Q. For a 200 V DC. Short shunt motor given below $R_a = 0.2\ \Omega$, $R_{se} = 0.3$, $R_{sh} = 50\ \Omega$, $I_L = 50A$. find armature current & Back emf.

⇒



$$I_{sh} = \frac{V - I_L R_{se}}{R_{sh}}$$

$$= \frac{200 - 50 \times 0.3}{50}$$

$$= \frac{200 - 50 \times 0.3}{50}$$

$$= \frac{200 - 15}{50}$$

$$I_{sh} = \frac{185}{50}$$

$$\boxed{I_{sh} = 3.7 A}$$

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

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

$$= 50 - 3.7$$

$$\boxed{I_a = 46.3 A}$$

$$V = E_b + I_L R_{se} + I_a R_a$$

$$E_b = V - I_L R_{se} - I_a R_a$$

$$= 200 - 50 \times 0.3 - 46.3 \times 0.2$$

$$= 200 - 15 - 9.26$$

$$= 185 - 9.26$$

$$\boxed{E_b = 175.74 \text{ volt}}$$

Imp. point

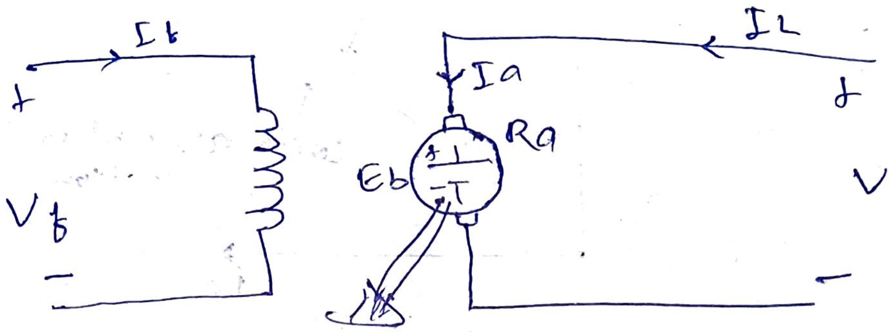
- At maximum mechanical power output

$\boxed{I_a R_a = \frac{V}{2}}$; $\boxed{E_b = \frac{V}{2}}$, $\boxed{\eta = 50\%}$

- Therefore we will not design the DC motor for maximum mech power output condition.

* Separately Excited :-

A separately excited motor is a type of DC motor in which the field winding is energized by an independent external DC source, separate from the armature supply. This allows independent control of the magnetic field and the armature current, enabling precise control of the motor speed and torque.



$$\boxed{V = E_b + I_a R_a}$$

$$\boxed{I_L = I_a}$$

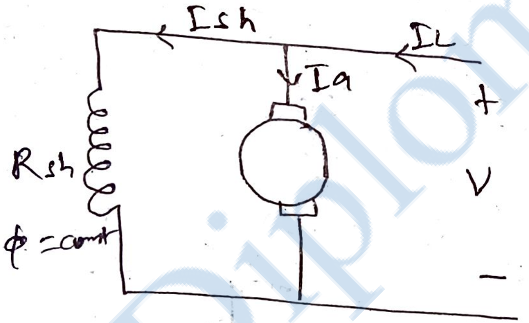
★ Characteristics and applications

① Speed vs Armature current

② Torque vs Armature current

③ Torque vs speed.

Shunt motor



① Torque vs I_a.

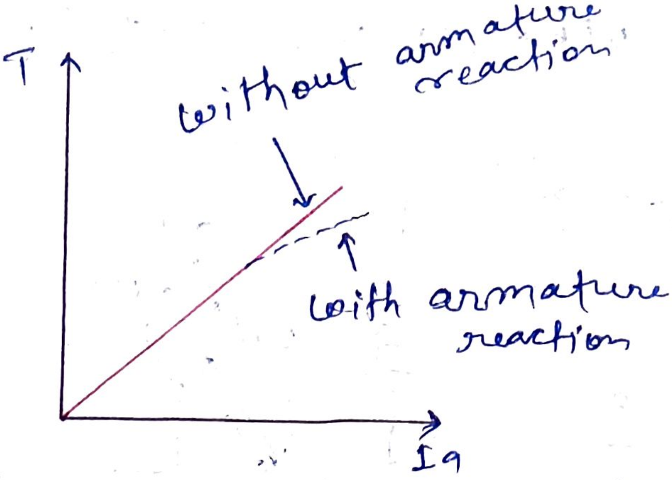
→ We know that

$T \propto \underset{\uparrow \text{const}}{\phi} . I_a$

$$\boxed{T \propto I_a}$$

NOTE: If we consider the armature reaction effect, because of de-magnetizing flux will reduce ($\phi\downarrow$).

$\downarrow T \propto \phi\downarrow I_a$



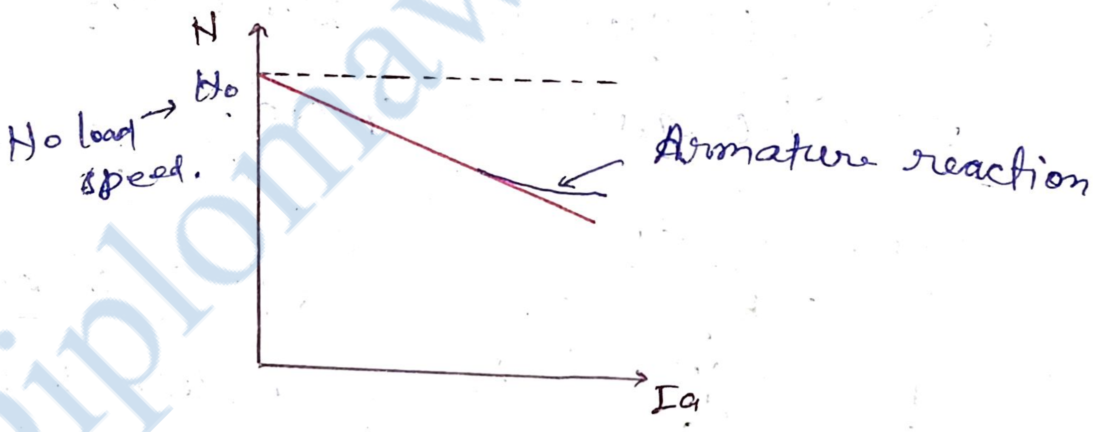
② Speed vs Armature current

In case of shunt motor ϕ = const

$N \propto E_b$

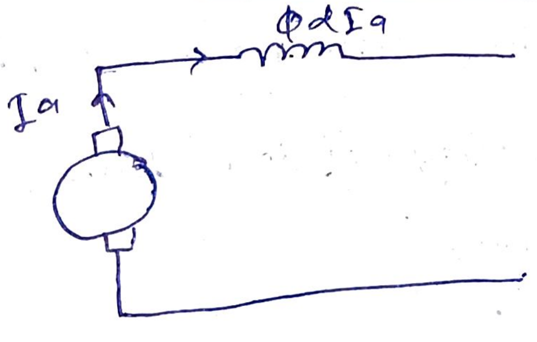
$$\boxed{N \propto (V - I_aR_a)}$$

$y = c + mx$



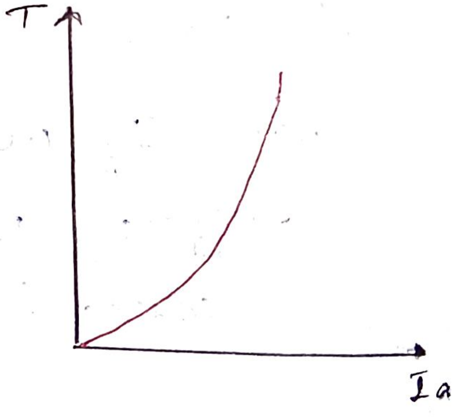
For Series motor

① Torque Vs Ia



$T \propto \phi . I_a$

$$\boxed{T \propto I_a^2}$$

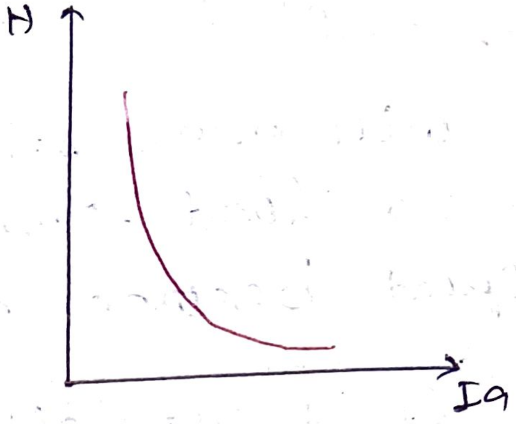


② Speed Vs Ia

$N \propto \frac{E_b}{\phi}$

$\because \phi \propto I_a$

$N \propto \frac{E_b}{I_a}$



→ We will never start series motor on no load condition because the speed becomes dangerously high.

Compound motor

Cumulative compound

$$\boxed{\uparrow \phi_{net} = \phi_{sh} + \phi_{se}\uparrow}$$

→ If $I_a \uparrow$, $\phi_{se} \uparrow$

$\phi_{net} \uparrow$

$\downarrow N \propto \frac{E_b}{\phi \uparrow}$

Differential compound

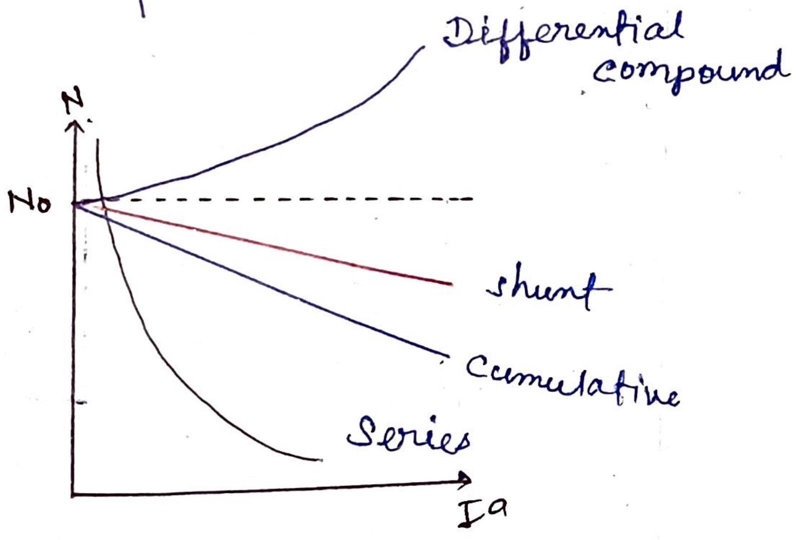
$$\downarrow \boxed{\phi_{net} = \phi_{sh} - \phi_{se}\uparrow}$$

$\phi_{se} \propto I_a$

$\uparrow N \propto \frac{E_b}{\phi \downarrow}$

If $I_a \uparrow$, $\phi_{se} \uparrow$

① Speed vs Ia



Imp. point

→ We will never start dc. series motor on no load condition, because the speed becomes dangerously high.

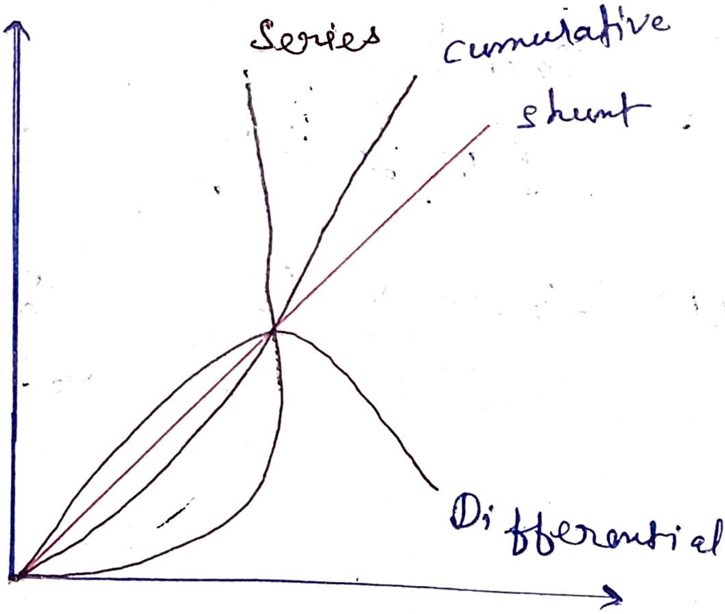
→ $$\boxed{\text{Speed regulation} = \frac{N_{N.L} - N_{F.L}}{N_{F.L}} \times 100}$$

→ Speed regulation of differential compound dc. motor is -ve.

→ Speed regulation of DC. shunt motor is Best.

→ Series motor has worst speed regulations.

② Torque vs Ia

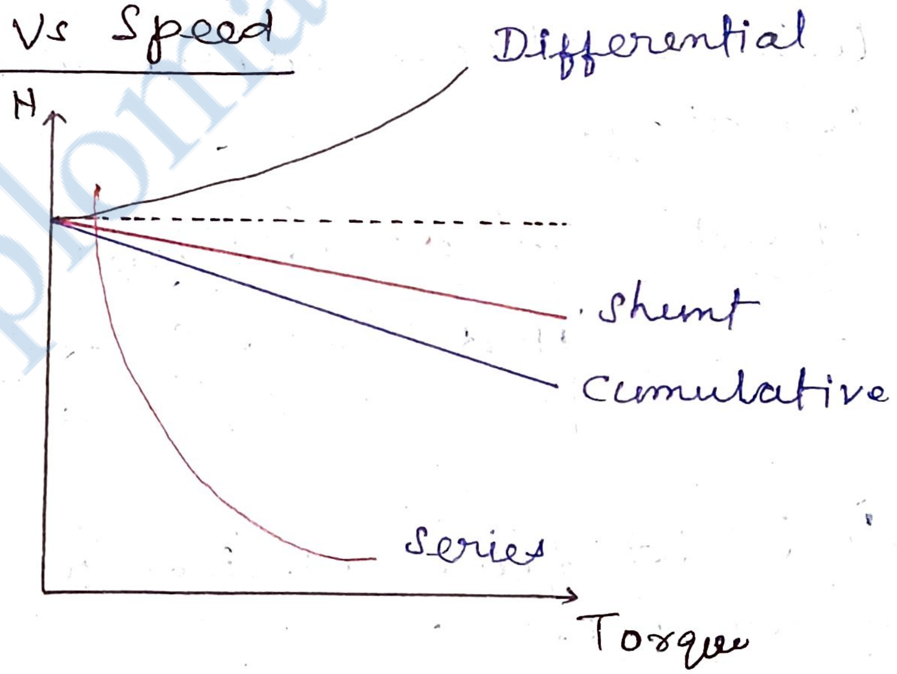


- In a differential compound motor the torque is first increase & than Decrease.

* Applications :-

Shunt	Series	Cumulative	Differential
• Machine tools • Lathe machine • Milling m/c • Drilling m/c • Centrifugal pump	• Lift • Crane • Hoist • DC Traction • For high starting torque	• Steel rolling • Elevator • Sheer • Punches	No practical application.

◆ Torque Vs Speed



→ During starting speed $\boxed{N=0}$, $\boxed{E_b=0}$

for motor $V = E_b + I_a R_a$

$$I_a = \frac{V - E_b}{R_a}.$$

Q. Why we need starter to start d.c. series motor.

Ans:- During start the speed of motor is zero, Back emf is also zero. Therefore large amount of armature current will flow through the armature, due to this large amount of heat will produced which can damage winding.

Speed Control Method of Shunt motor

$$\boxed{N \propto \frac{E_b}{\phi} \propto \frac{V - I_a R_a}{\phi}}$$

① Field flux control or field weakening control.

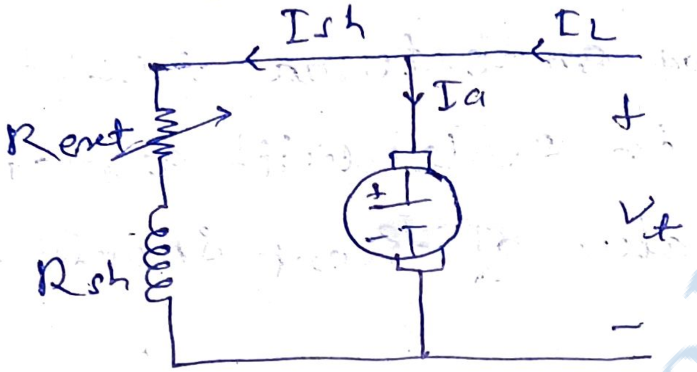
② Armature resistance control

③ Supply voltage control

① Field flux Control

→ In this method an external resistance is connected in series with field winding.

→ Initially the value of Rext should be low.



$$\boxed{I_{sh} = \frac{V}{R_{sh} + R_{ext}}}$$

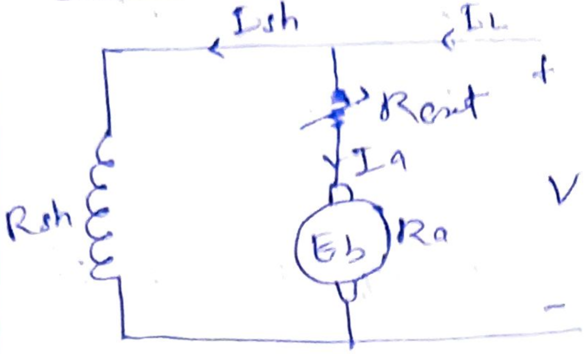
→ When the value of Rext increases the field winding current will decreases.

→ This method is used to control the speed above the rated speed.

→ $\underset{\substack{\uparrow \\ \text{variable}}}{T} \propto \underset{\substack{\uparrow \\ \text{variable}}}{\phi} \cdot \underset{\substack{\uparrow \\ \text{const}}}{I_a}$, $\underset{\substack{\uparrow \\ \text{const}}}{P} = \underset{\substack{\uparrow \\ \text{const}}}{E_b} \cdot \underset{\substack{\uparrow \\ \text{const}}}{I_a}$

⇒ Therefore this method is also called constant power variable torque method.

② Armature resistance control method.



$\phi =$ const.

$N \propto [V - I_a(R_a + R_{ext})]$

- → In this method an external resistance is connected in series with armature.
- → Initially the value of R_{ext} should be low.
- → When we will increase the value of R_{ext}, $E_b = V - I_a(R_a + R_{ext})$ will decrease. Therefore the speed will also decrease.
- → Therefore this method is used to control the speed below the rated speed.
- → $E_b = V - I_a(R_a + R_{ext})$

  when, $R_{ext} \uparrow$, If $I_a(R_a + R_{ext}) = V$

  then $E_b = 0$, $N = 0$

  This condition is known as stalling condition.
- → At stalling condition armature current

  $I_a(R_a + R_{ext}) = V$

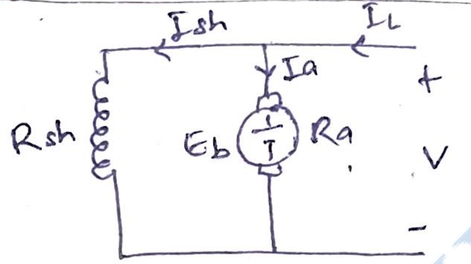
$$\boxed{\underset{\uparrow}{I_a} = \frac{V}{R_a + R_{ext}}}$$

Stalling current.

→ $\underset{\text{const.}}{\underset{\uparrow}{T}} \propto \underset{\text{const}}{\underset{\uparrow}{\phi}} \cdot \underset{\text{const}}{\underset{\uparrow}{I_a}}$ $\qquad$ $\underset{\text{variable}}{\underset{\uparrow}{P}} = \underset{\text{Variable}}{\underset{\uparrow}{E_b}} \cdot I_a \leftarrow \text{Const}$

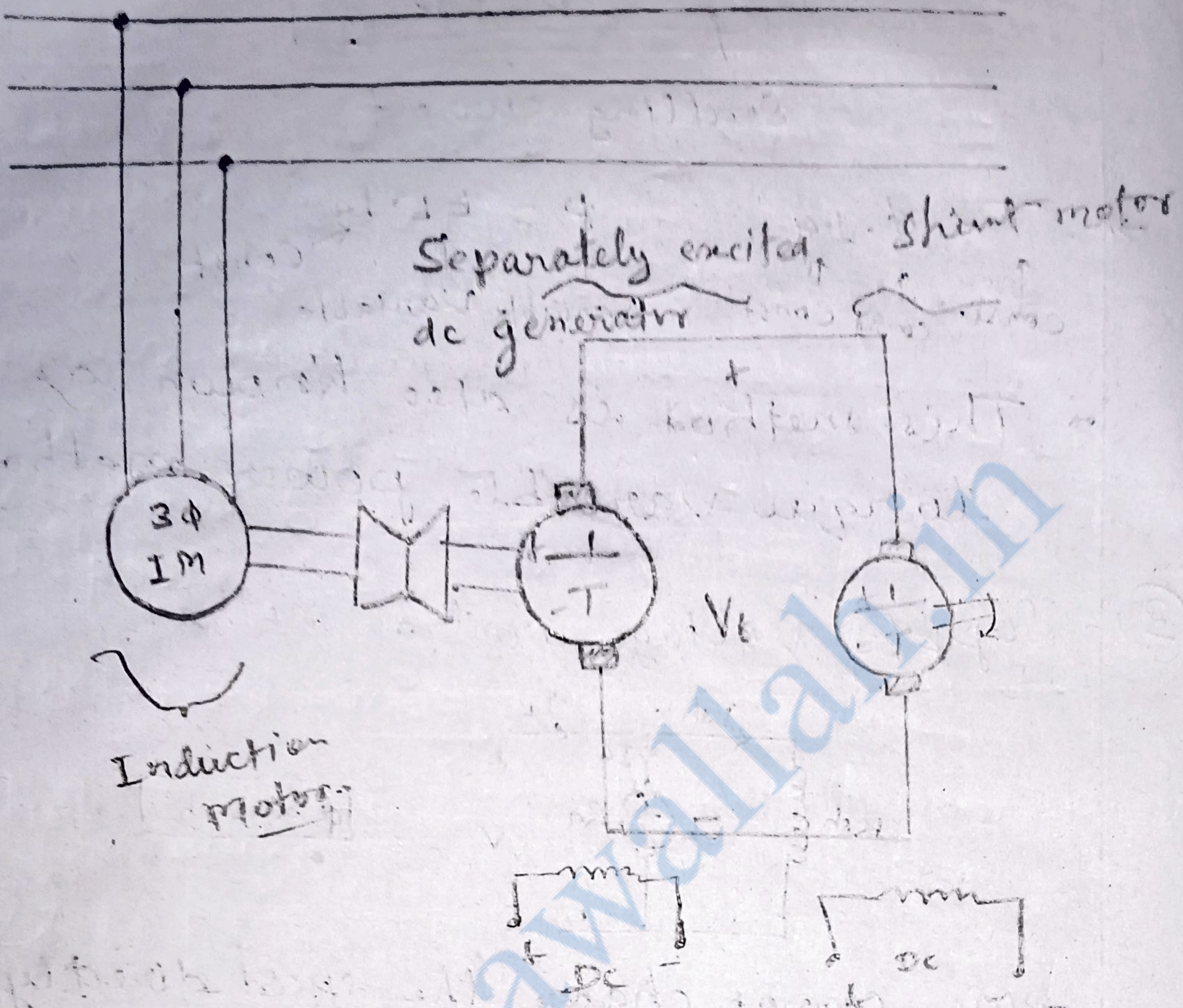
→ This method is also known as const. torque variable power method.

③ Supply voltage control method



$$\boxed{\phi \propto I_{sh}}$$

- We cannot change the speed directly using this method.
- In this method we will use special arrangement that is called Ward leonard Eligner system.
- We can control the speed above & below the rated by using this method (wide rang of speed control is possible).



→ In this method a motor generator set is used.

Motor → Induction Motor

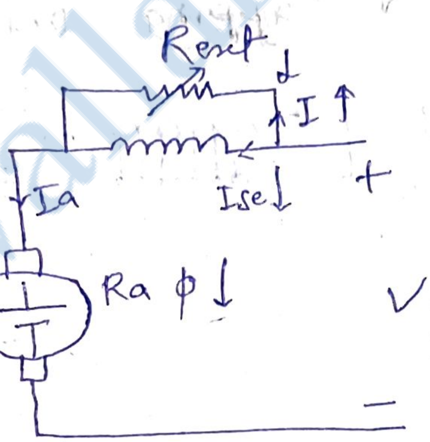
Generator → Separately excited

→ We can control speed in both direction by using this method.

Speed Control method for series motor :-

i) Field diverter Control
ii) Armature diverter control
iii) Armature resistance control
iv) Field tapping control
v) Supply voltage control
vi) Series & Parallel operation.

(i) Field diverter control

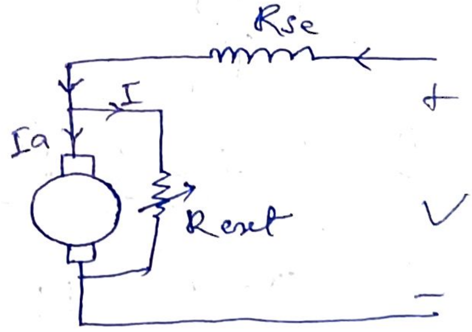


→ In this method an external resistance is connected across series field winding.

→ Initially value of Rext is high.

→ This method is used to control the speed above the rated speed.

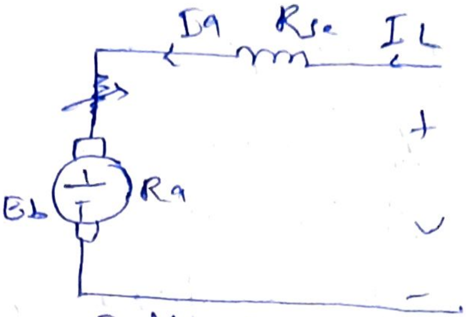
(ii) Armature diverter control



In this method a diverter resistance is connected across armature due to this the current armature current is reduced, to maintain same torque the flux will increase & speed will decrease.

(iii) Armature resistance control

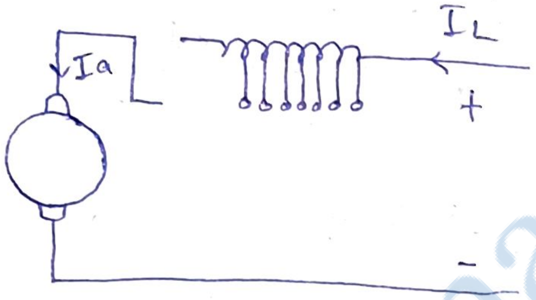
- → If the value of R_{ext} is increases than E_b will decreases & speed will also decreases.
- → We will not prefer this method because of high power loss.



Initially R_{ext} → law

$$\boxed{E_b = V - I_a(R_a + R_{se} + R_{ext})}$$

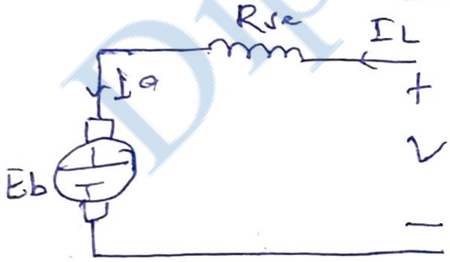
(iv) Field tapping control



→ In this method ~~we~~ we will provide the tapping on series field winding.

→ and by changing series field ampere turn we can change the speed both direction.

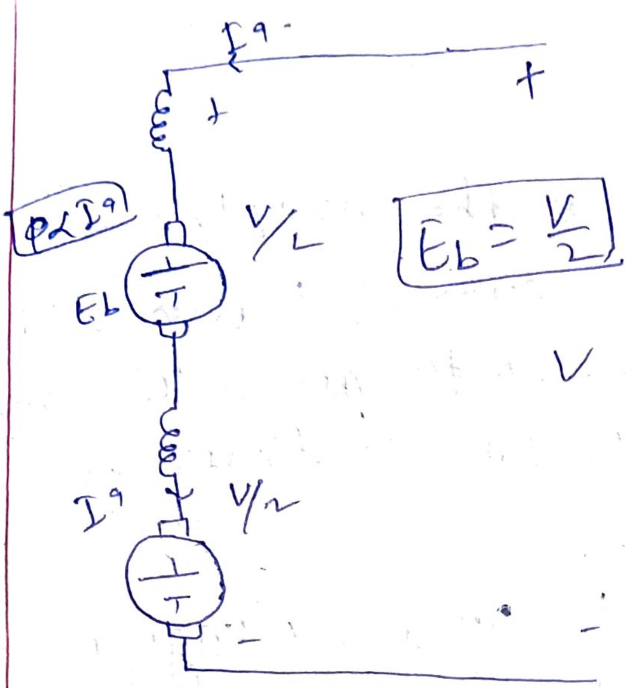
(v) Supply voltage control



$$\boxed{E_b = V - I_a(R_a + R_{se})}$$

(vi) Series & Parallel operation

Case-1 If we ~~cannot~~ connect two identical motor in series.



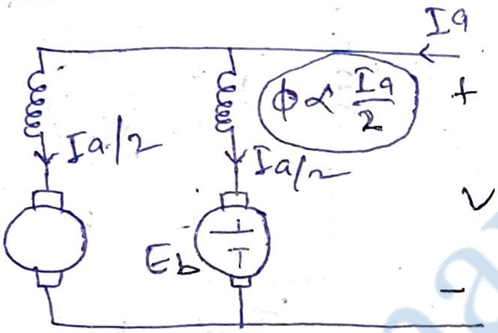
$$\boxed{E_b = \frac{V}{2}}$$

Speed of each motor

$$N_s \propto \frac{E_b}{\phi} \propto \frac{V/2}{I_a}$$

$$\boxed{N_s \propto \frac{V}{2I_a}}$$

Parallel



Speed of each motor

$$N_p \propto \frac{E_b}{\phi} \propto \frac{V}{I_a/2}$$

$$\boxed{N_p \propto \frac{2V}{I_a}}$$

Braking of DC Motor :-

There are two types of Breaking is used.

① Mechanical Braking → We will not prefer

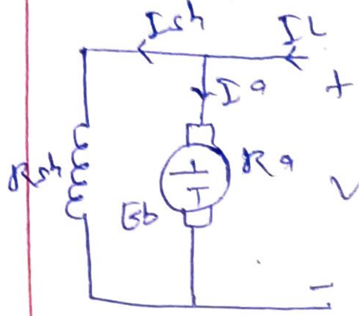
② Electrical Braking → Most widely used.

Electrical Braking

- Plugging Braking
- Rheostat Braking
- Regenerative Braking

① Plugging :-

~~If~~ NOTE: If we reverse the supply terminal than both armature current & flux will ~~remain~~ becomes -ve. so torque will remain +ve. so motor will run continuously is same direction.

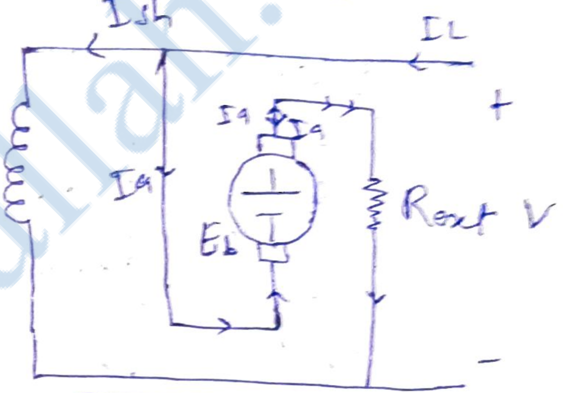


Before plugging

$V = E_b + I_a R_a$

$$\boxed{I_a = \frac{V - E_b}{R_a}}$$

During plugging



$$\boxed{T \propto \phi I_a}$$

$$\boxed{I_a = \frac{V + E_b}{R_a + R_{ext}}}$$

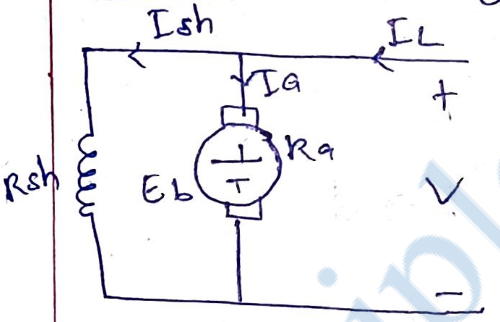
→ In this method we will disconnect the armature terminal from supply and we will again connect in opposite polarity, due to this the armature current will get reverse & torque becomes -ve which produce Braking.

→ When the motor reaches near to zero condition we will provide the sufficient amount of mechanical braking & supply terminal will disconnect otherwise there will be a problem of speed reversal.

NOTE:- • This is quick Braking method.
• To limit the excessive armature current an external resistence is connected in series with armature.

② Rheostat Braking OR Dynamic Braking

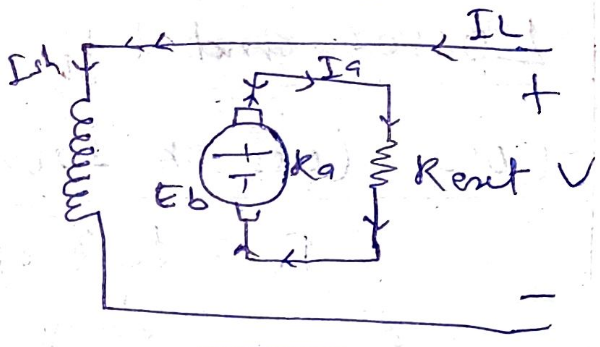
Before Braking



$$V = E_b + I_a R_a$$

$$\boxed{I_a = \frac{V - E_b}{R_a}}$$

During Braking



$$\boxed{I_a = \frac{E_b}{R_a + R_{ext}}}$$

→ In this method the armature is disconnected from the supply in running condition and How it is short circuited with the help of an external resistence But field winding is remain connected to supply.

→ Due to this the direction of armature current will get reversed & torque becomes −ve, then the motor will stopped.

→ There is no speed reversal problem.

③ Regenerative Braking

→ By using this method we cannot stop motor instantly.

→ This method is natural Braking method.

→ It is used in mountain railways.

NOTE :- We cannot apply this method directly to DC series motor because both I_a & ϕ becomes −ve & torque remain +ve.

Losses and Efficiency :-

① Core loss or Iron loss → Fixed

$$P_c = \underset{\substack{\uparrow \\ \text{Eddy current loss}}}{P_e} + P_h \rightarrow \text{Hysteresis loss}$$

→ Minimize the eddy current loss lamination are used & silicon is added to minimize Hysteresis loss.

② Copper loss (I^2R loss or Ohmic loss)

Variable → ⓐ $I_a^2 R_a$ → Armature copper loss (All machine)

Variable → ⓑ $I_a^2 R_{se}$ → Series motor and long shunt motor

Variable → ⓒ $I_L^2 R_{se}$ → Short shunt

② $I_{sh}^2 R_{sh}$ → Shunt & Compound Motor
↳ Fixed.

③ **Mechanical loss**
↑
(Fixed) ↳ Friction & windage loss.

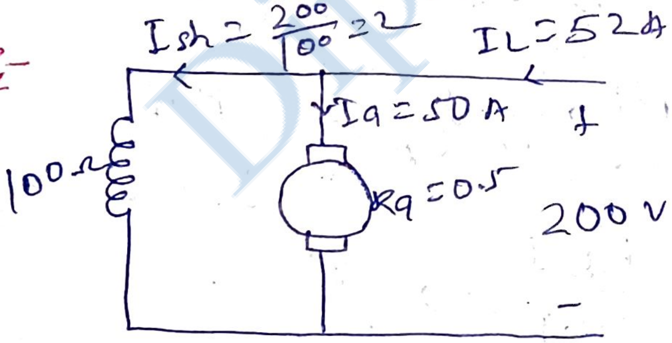
④ **Stray loss** :- Iron loss + Mechanical loss

⑤ **Constant loss**: Iron loss + Mechanical loss + $I_{sh}^2 R_{sh}$

Q. A 200V DC shunt motor draw 52 A from supply. The armature resistance & shunt field winding resistance 0.5 Ω & 100 Ω. Iron loss are 1000W & mechanical loss are 500W than find -

(i) Constant loss
(ii) Variable loss
(iii) Total copper loss

Solve:-



$$\rightarrow I_a^2 R_a = (50)^2 \times 0.5$$
$$= 2500 \times 0.5$$
$$= 1250W$$

$$\rightarrow I_{sh}^2 R_{sh} = (2)^2 \times 100 = 400 \text{watt}$$

Given, Iron loss = 1000

Mech loss = 500

$V \cdot I_L = 200 \times 52$
$= 10400$

$10400 - 1250 - 400 - 1000 - 500 = 7250$

$E_b = V - I_a R_a$

$= 200 - 50 \times 0.5$

$\boxed{E_b = 175}$

~~$E_b \times$~~ $E_b I_a = 175 \times 50 = \underline{8750}$

① Constant loss = Iron loss + Mech loss + $I_{sh}^2 R_{sh}$

$= 1000 + 500 + 400$

$= 1900$ watt

② Variable loss = $I_a^2 R_a = 1250$ watt

③ Total copper loss = $I_a^2 R_a + I_{sh}^2 R_{sh}$

$= 1250 + 400$

$= 1650$ watt

Efficiency :-

Motor

Electrical efficiency $\eta_E = \frac{E_b \cdot I_a}{V \cdot I_L}$

Mechanical efficiency $\eta_m = \frac{P_{sh}}{E_b \cdot I_a}$

$$\eta_E \times \eta_m = \frac{E_b I_a}{V \cdot I_L} \times \frac{P_{sh}}{E_b I_a}$$

$$\boxed{\text{overall efficiency } \eta = \eta_E \times \eta_m = \frac{P_{sh}}{V \cdot I_L}}$$

Generator

$$\eta_g = \frac{V\cdot I_L}{V\cdot I_L + W_c + W_{cu}}$$

↑ Constant loss

Variable loss ($I_a^2 R_a$)

Condition for maximum efficiency

$$I_a^2 R_a = W_c$$

Variable loss = Constant loss

Armature current at maximum efficiency

$$\boxed{I_a = \sqrt{\frac{W_c}{R_a}}}$$

Types of starter :-

① 3- Point starter } For shunt & Compound
② 4- Point starter }
③ 2- Point starter → Only used for series motor

Field flux control method में 4 point starter का use किया जाता है।

Armature reaction :- in DC motor

Imp :-

Ⓑ There are two types of armature reaction in dc motor.

i) De- magnetizing

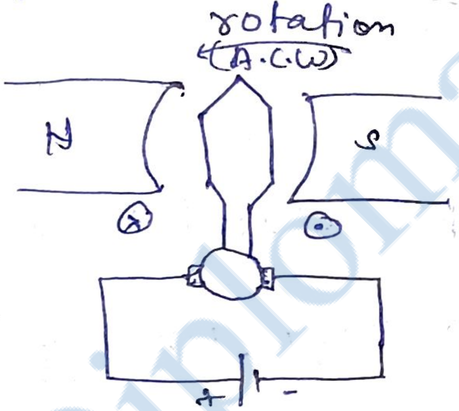
ii) Cross - magnetizing

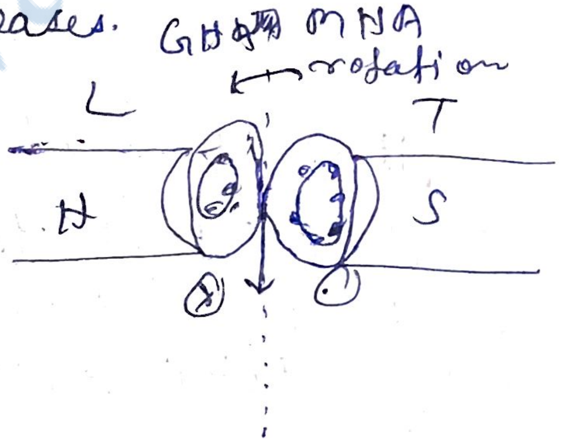
② In case of Motor the MNA is shifted behind the direction of rotation.

③ To improve commutation the Brushes is also shifted behind the direction of rotation.

④ In case of motor the interpole polarity is same as that of Main pole behind.

⑤ Because of armature reaction on the trailing pole tip the concentration of flux decreases & on the leading pole tip it is increases.





Q. A shunt generator is supplying power to DC Bus-bar. If the prime-mover will get damage that it start works as a -

⇒ It works as a shunt motor.

Q. Series Gen → Series motor

Cumulative Compound Gen → Diff. Compound Motor

Testing of DC Machine :-

→ Testing is done to predict the performance any device.

→ There are two types of testing

① Direct test

② Indirect test

① Direct test :- (~~OB~~ or Brake test)

→ This method is applieable only for small rating machine.

② Indirect test :-

→ Swinburn's test

→ Hapkinson's test → Back to Back test

→ Retardation test

→ Field test → only for series machine

Swinburn's test :-

→ This method is applicable of shunt & compound machine.

→ During testing the machine is runs as a motor.

→ During this test there is no load is connected to shaft.

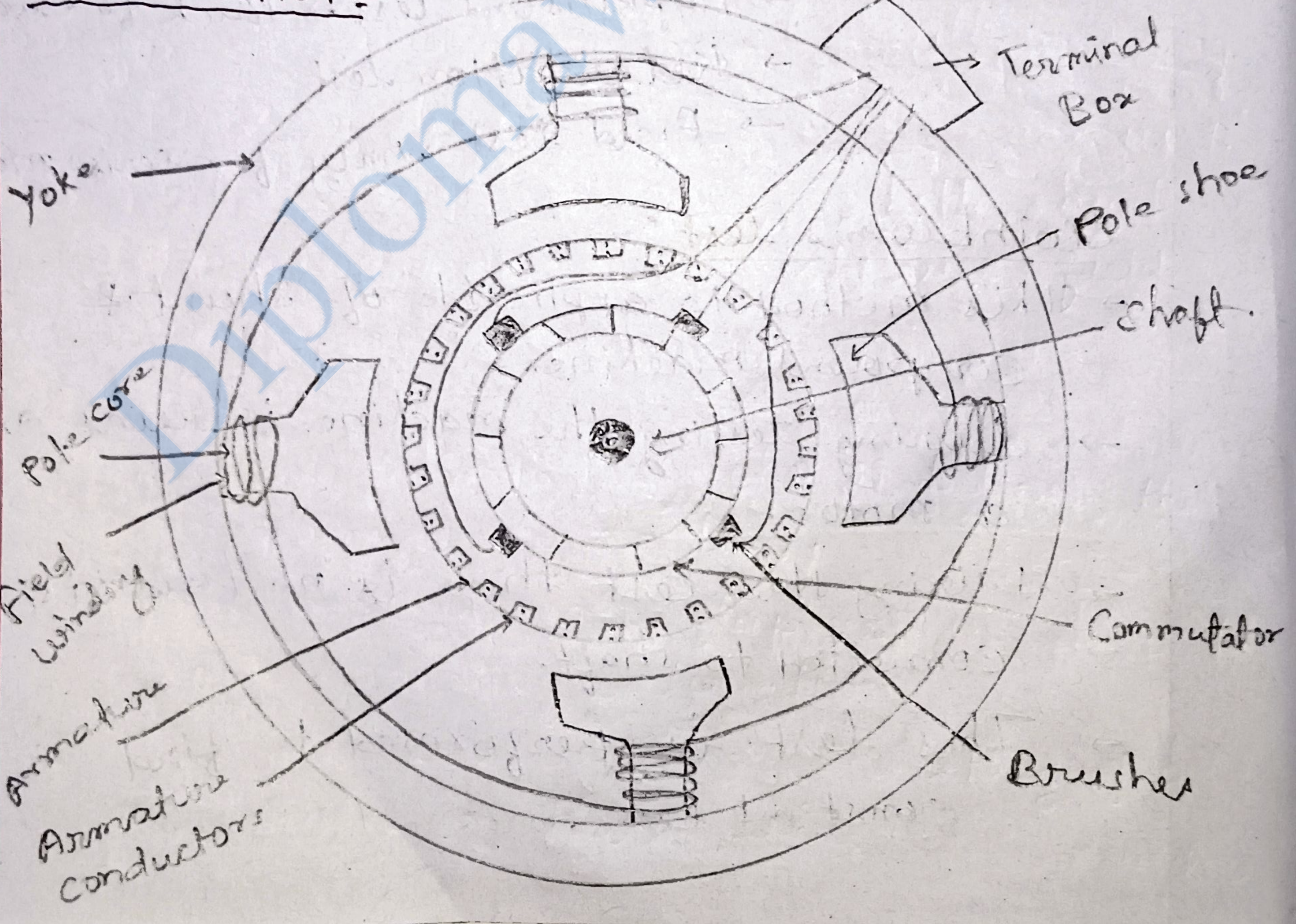
→ This test is performed to find constant loss.

Hopkinson test :-

- → In this test two identical machine is used.
- → Out of these two machine one is works as a generator & another is works as a motor.
- → The shaft of these two machine are mechanically coupled.
- → From this test efficiency will obtained.

DC MACHINE

✲ Construction :-



1. **Stator :-** Stator of a dc machine consists of yoke (for frame), field windings, interpoles, compensating winding, brushes and end covers.

2. **Rotor :-**

Rotor consist of armature core, armature winding, commutator and shaft.

* **Yoke :-** It has two functions:

- It provides path for the pole flux and caries half of it, i.e., $\phi/2$.
- It provides mechanical support to the whole machine. Since the flux carried by yoke is stationary (i.e. constant), it is not laminated.
- Cast iron is used for small dc machines
- fabricated steel for large dc machines.

NOTE :- In case of a dc motor is to be operated through a power electronics converter, the yoke is laminated to reduce the eddy-current losses.

* **Field Pole :-** • Field pole consist of pole core and pole shoes.

- The pole core is made from cast steel but the pole shoe is laminated and fixed to the pole core appropriately.

- The laminated pole is bolted to the yoke.

☆ Field Winding :-

- The pole is excited by a winding wound around the pole core. This winding is called field or exciting winding, is prepared from copper.
- The number of turns and cross-section of field winding depend upon the type of dc machine as under:

(i) For dc shunt machine, large no. of turns of small cross section are used.

(ii) for dc series machine, small number of turns of large cross section are used.

(iii) For dc compound machine, both shunt (thin wire) and series (thick wire) field windings are used.

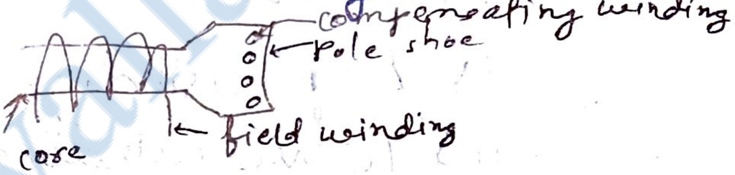
☆ Interpole :-

- These are fixed to the yoke in between the main poles of dc machine.
- These are usually tapered in shape to avoid magnetic saturation.
- The interpole winding consisting of a few turns of thick wire, is connected

in series with the armature so that its magnetomotive force is proportional to armature current.

Compensating Winding

- These windings are placed in pole shoe of a dc machine.
- Compensating winding is also connected in series with the armature circuit.
- This winding is used in large dc machines only.



Brushes :-

- Brushes are attached to commutator segment and they collect current from commutator segment and supplied to load.
- Brushes are made up of carbon for small dc machines, electrographite for all dc machines and copper-graphite for low-voltage high-current dc machines.

Armature core :

- It serves the twin purpose of

ⓘ housing the armature coils in the slots and

ⓘⓘ Providing the low-reluctance path to the magnetic flux $\phi/2$.

- It is made from 0.35 to 0.50 mm thick laminations of silicon steel to keep down the iron losses.

☆ Armature winding

→ The armature winding is made up of copper.

→ It consist of large number of insulated coils, each coil having one or more turns.

There are basically two winding types:

i) Lap winding
ii) Wave winding

Two coils ends of each coil are then connected to the segments of a commutator.

☆ Commutator :-

- It is of cylindrical structure.
- It is built up of wedge-shaped segments of high conductivity hard-drawn copper to reduce its wear and tear.
- Segments are insulated from each other by 0.8mm thick mica sheets.
- It is also known as image of armature winding.

Armature Winding

- The winding used in rotating electrical machines can be classified as
  a) Concentrated winding and
  b) Distributed windings.

Conductor

A length of wire which takes active part in the energy- conversion process is ~~a~~ called a conductor.

Coil side: One coil with any number of turns has two coil-sides.

Pole pitch :-

- A pole pitch is defined as the peripheral distance between identical points on two adjacent poles.
- Pole - pitch is always equal to 180° electrical.

Coil span or coil pitch :-

The distance between the two coil - sides of a coil ~~-span~~ is called coil - span or coil pitch. It is usually measured in terms of teeth, slots or electrical degrees.