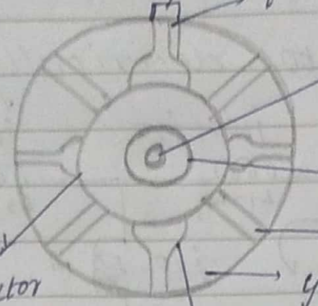
# DC Motor

conversion: direct current electrical energy → mechanical en.

→ Any motor operated under direct current is called DC motor.



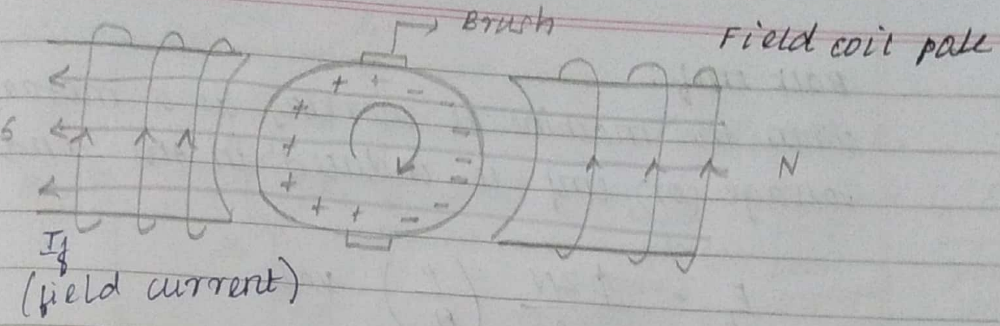

Armature conductor: cylinder of electrical laminations that are insulated from one another

commutator: commutator of DC motor is a cylindrical structure made of copper segment staked together but insulated from each other by Mica.
→ primary function is to supply current to armature pointing.

Brushes: → Made with graphite (or) carbon structure
→ conduct electric current from electric circuit to rotating commutator.

commutator + brush: both together transmitts the power from static electrical circuit to mechanically rotating motor region.

Scanned with CamScanner




→ Magnetic field is induced in the air gap when the field coil is energised.

→ Magnetic field enter from North pole of field coil and leave the DC motor at south pole of field coil.

→ conductors at interpole are subjected to force of same intensity but in opposite direction. These two opposing forces create a torque that causes motor armature to rotate.

Principle: → When a current carrying conductor kept in magnetic field it experienses a force which produces a torque.

(or)

→ When $\bar{E}$ and $\bar{M}$ fields interact, the mechanical force arises.

→ Magnitude of force experience by conductor is given by, $F = BlI$ (N)

B → magnetic field density
l → length of conductor
I → current

→ Direction of motion is given by Flemings left hand rule.

Fore finger - Direction of field
Middle - Direction of current
Thumb - Direction of motion.

Back emf:

When the machine is working as a motor, the voltage (or) emf is induced in the conductor.

$$E_b = \frac{\phi Z N}{60}\left(\frac{P}{A}\right) \text{ volts}$$

$\phi$ - flux per pole

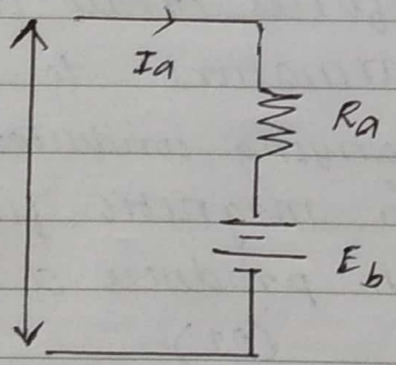
Z - total no. of conductors

N - speed of rotation (rpm)

P - no. of poles

A - no. of parallel paths.

Windings:
- $A = P \rightarrow$ Lap winding
- $A = 2 \rightarrow$ Wave winding




$$V = E_b + I_a R_a \Rightarrow I_a = \frac{V - E_b}{R_a}$$

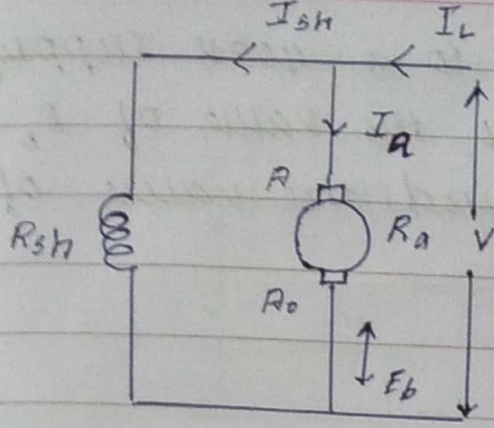
$I_a$ - armature current

$R_a$ - armature resistance

$V$ - applied voltage

$E_b$ - back emf

net voltage $= V - E_b$




$$V = E_b + I_a R_a$$

$$\underbrace{V I_a}_{\text{electric power supply to armature}} = \underbrace{E_b I_a}_{\text{power developed in motor}} + \underbrace{I_a^2 R_a}_{\text{power lost in armature}}$$

$$P_m = E_b I_a$$

power developed in motor depends only on armature current as V and $R_a$ are constant ← $P_m = V I_a - I_a^2 R_a$

$$\frac{dP_m}{dI_a} = V - 2 I_a R_a$$

For max mechanical power $\frac{dP_m}{dI_A} = 0$

(ie) $V - 2 I_a R_a = 0$

$$I_a R_a = \frac{V}{2}$$

W.K.T $V = E_b + I_a R_a$

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

$$E_b = V/2$$

(ie) power developed in armature is max when $E_b = V/2$

1. A DC motor connected to a 460V supply has $R_a = 0.15\,\Omega$ a) calculate the value of $E_b$ when $I_a = 120$ A b) Find the value of $I_a$ when $E_b = 447$V.

a) $V = E_b + I_a R_a$

$460 = E_b + 120\,(0.15)$

$E_b = 442$ V

b) $V = E_b + I_a R_a$

$460 = 447 + I_a\,(0.15)$

$\frac{13}{0.15} = I_a$

$I_a = 86$ amp.

2. A DC motor takes $I_a = 150$A at 440V. If its armature circuit has $R_a = 0.15\,\Omega$, Find $E_b$.

$V = I_a R_a + E_b$

$E_b = V - I_a R_a$

$= 400 - (150)(0.15)$

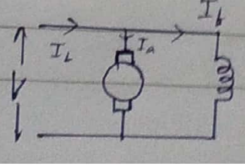
$E_b = 417.5$

Types of DC Motor

1) Self excited motor
2) Separately excited motor
    a) DC shunt motor
    b) DC series motor
    c) DC compound motor

3 types of self excited

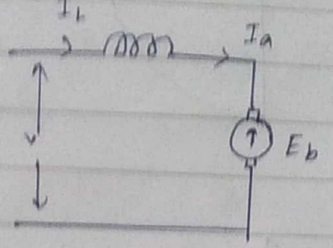
DC shunt: Field winding connected in parallel to armature.




$I_a = I_L - I_f$

$V = E_b + I_A R_A$

DC series: Field winding connected in series to armature

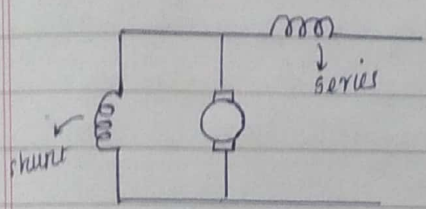
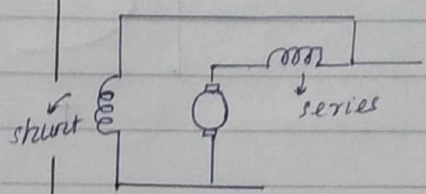



$$I_a = I_L = I_f$$

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

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

DC compound: (shunt + series) → Long shunt / short shunt depending on connections.

| Short shunt | Long shunt |
|---|---|
|   |   |
| Series field winding is connected in series with the parallel combination of armature and shunt field. | Series field winding is connected in series with the armature. |

Characteristics of DC motor: (based on speed and torque)

$T_a \propto I_a$ (torque) (current) $\qquad N \propto E_b/\phi$ (speed)

→ Torque armature current characteristics
→ speed armature current characteristics
→ speed Torque armature current characteristics

Now draw all the above three characteristics graph for separately excited motor.

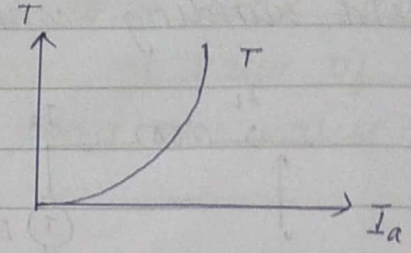
variable speed motor

Series motor charac.:

1. $T \propto \phi I_a$

$\phi \propto I_a$

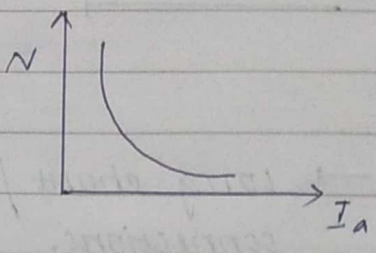
$\therefore T \propto I_a^2$



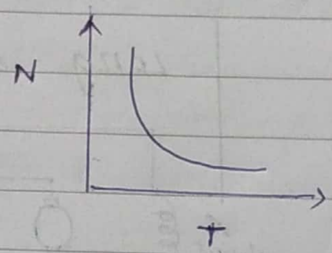

2. $N \propto E_b / \phi$

$\phi \propto I_a$

$\therefore N \propto \frac{1}{I_a}$

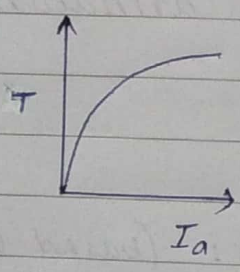


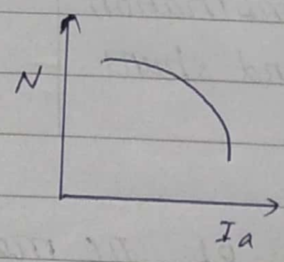

3.

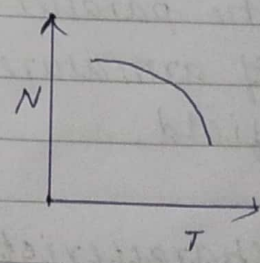



Shunt motor characteristics:

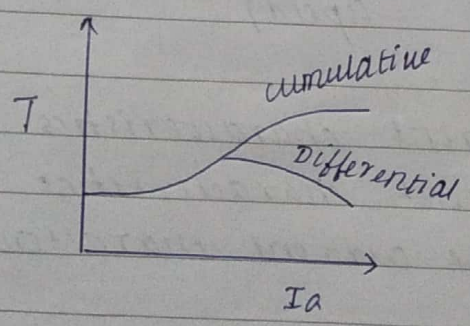
$T \propto I_a$ [$\phi$ - constant]

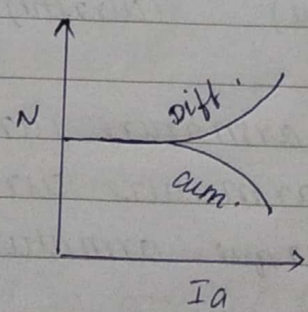


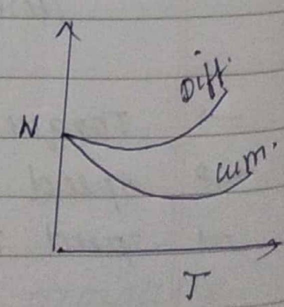




Compound motor characteristics:

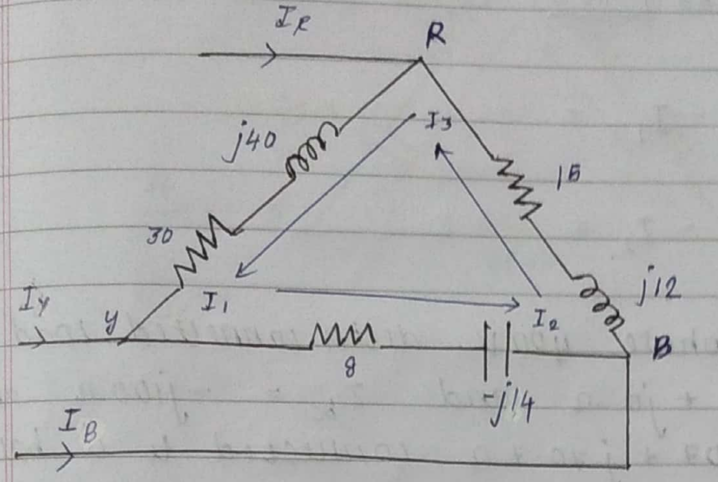


# Unbalanced Delta

1. The unbalanced delta load of Fig is supplied by balanced voltages of 200V in the positive sequence. Find line currents. Take $V_{ab}$ as referrence.




$I_1, I_2, I_3$ - phase current

$I_R, I_Y, I_B$ - line current

Given line voltage $E_L = 200V$

$E_{RY} = 200\angle 0^\circ$ $\quad$ $E_{BR} = 200\angle -240^\circ$ (or) $200\angle 120^\circ$

$E_{YB} = 200\angle -120^\circ$

First we find phase currents,

$$I_1 = \underbrace{\frac{E_{RY}}{30+j40}}_{\text{value b/w branch R and Y}} = \frac{200\angle 0^\circ}{30+j40} = 4\angle -53.13 = (2.4 - j3.2)\,A$$

$$I_2 = \frac{E_{YB}}{8-j14} = \frac{200\angle -120^\circ}{8-j14} = (6.2 - j10.74)\,A$$

$$I_3 = \frac{E_{BR}}{15+j12} = \frac{200\angle -240^\circ}{15+j12} = (1.6 + j10.3)\,A$$

Now we find line current

$I_R = I_1 - I_3$ ( $I_3$ is entering and $I_1$ is leaving the point R)

$= 13.53 \angle -86.5^\circ$

$I_Y = I_2 - I_1 =$

$I_B = I_3 - I_2 =$