✡ DC machines ✡

Lecture: 1

✡ ~~Faraday's law of etc~~

✡ principle of operation of DC generator:

Faraday's law of electromagnetic induction states that 'whenever the flux linking with a conductor changes, an electromotive force (emf) is set up in that conductor.

Dynamically induced emf, $e = \frac{d\phi}{dt}$

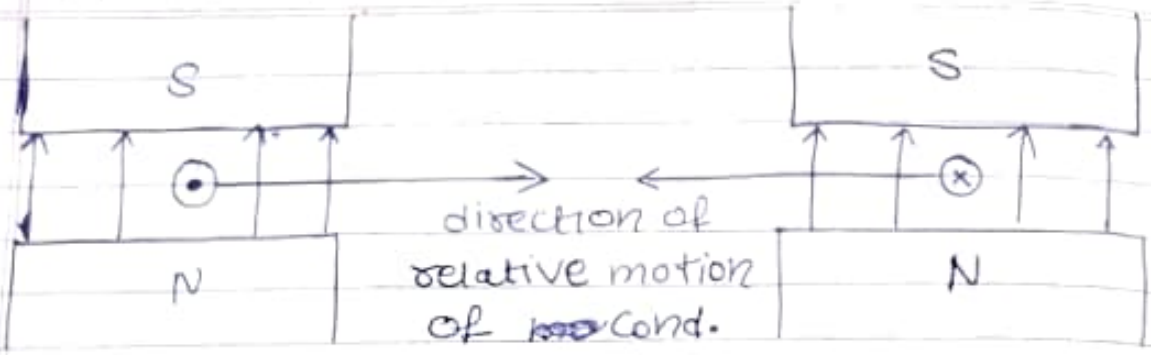
→ Relative motion b/w conductor and flux can be obtained by:
(i) flux is stationary & conductor is moving.
(ii) conductor is stationary & flux is moving.

→ Conductor can be rotated with the help of prime mover.

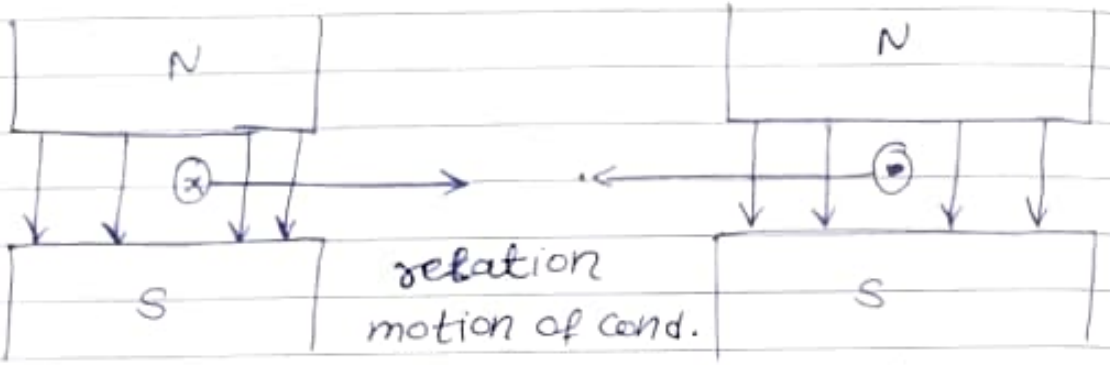
Examples of prime mover: Diesel engine, steam turbine, Diesel turbine etc.

Fleming's Right hand Rule: It three fingers of a right hand namely thumb, index finger and middle fingee are out streched so that everyone of them is at right angles with the remaining two, and if in this position index finger is made to point in the direction of flux, thumb in the direction of relative motion of the conductor w.r.t flux then out stretched middle finger gives the direction of emf induced in the conductor.

★ Direction of emf induced



a) current coming out b) current going in



c) current going in d) current coming out.

★ magnitude of induced emf:

$$e = BlV\sin\theta = E_m \sin\theta \quad \text{(volts)}$$

where,

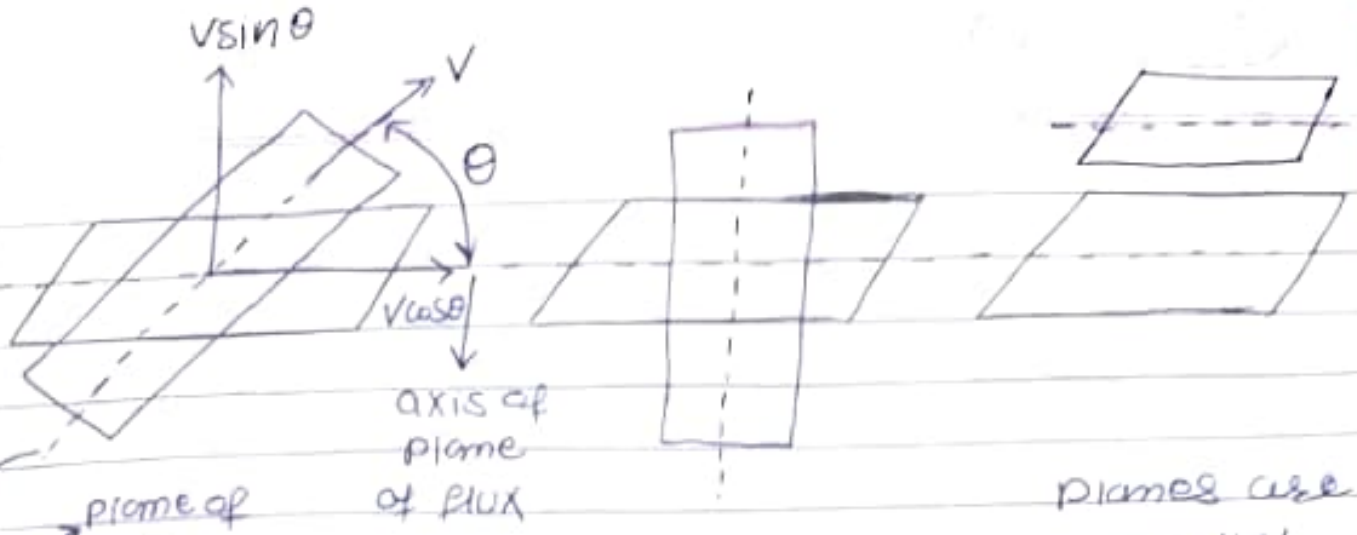
B = flux density (wb/m²)

l = active length of conductor (m)

V = relative velocity of conductor with respect to magnetic flux (m/s)

θ = angle b/w plane of rotation & plane of magnetic flux measured from axis of plane of flux.

* magnitude of emf depends on perpendicular component of relative velocity of conductor.



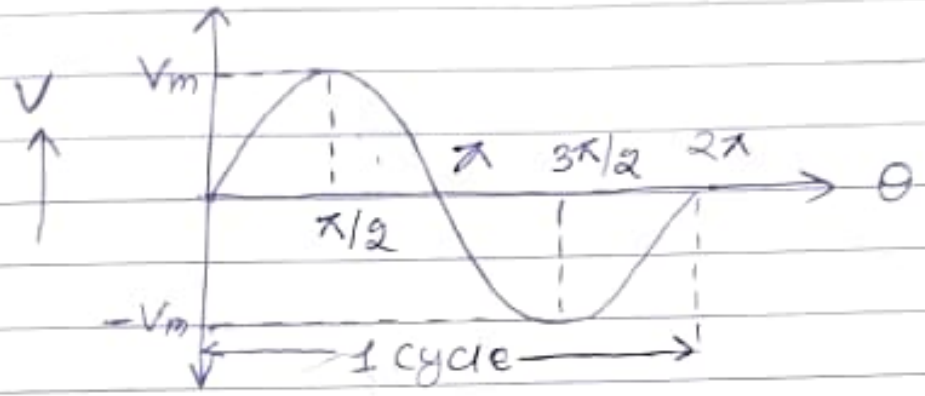
planes are perpendicular
$\theta = 90°$
E is maximum

planes are parallel
$\theta = 0°$
E is zero.

$E \propto V\sin\theta$

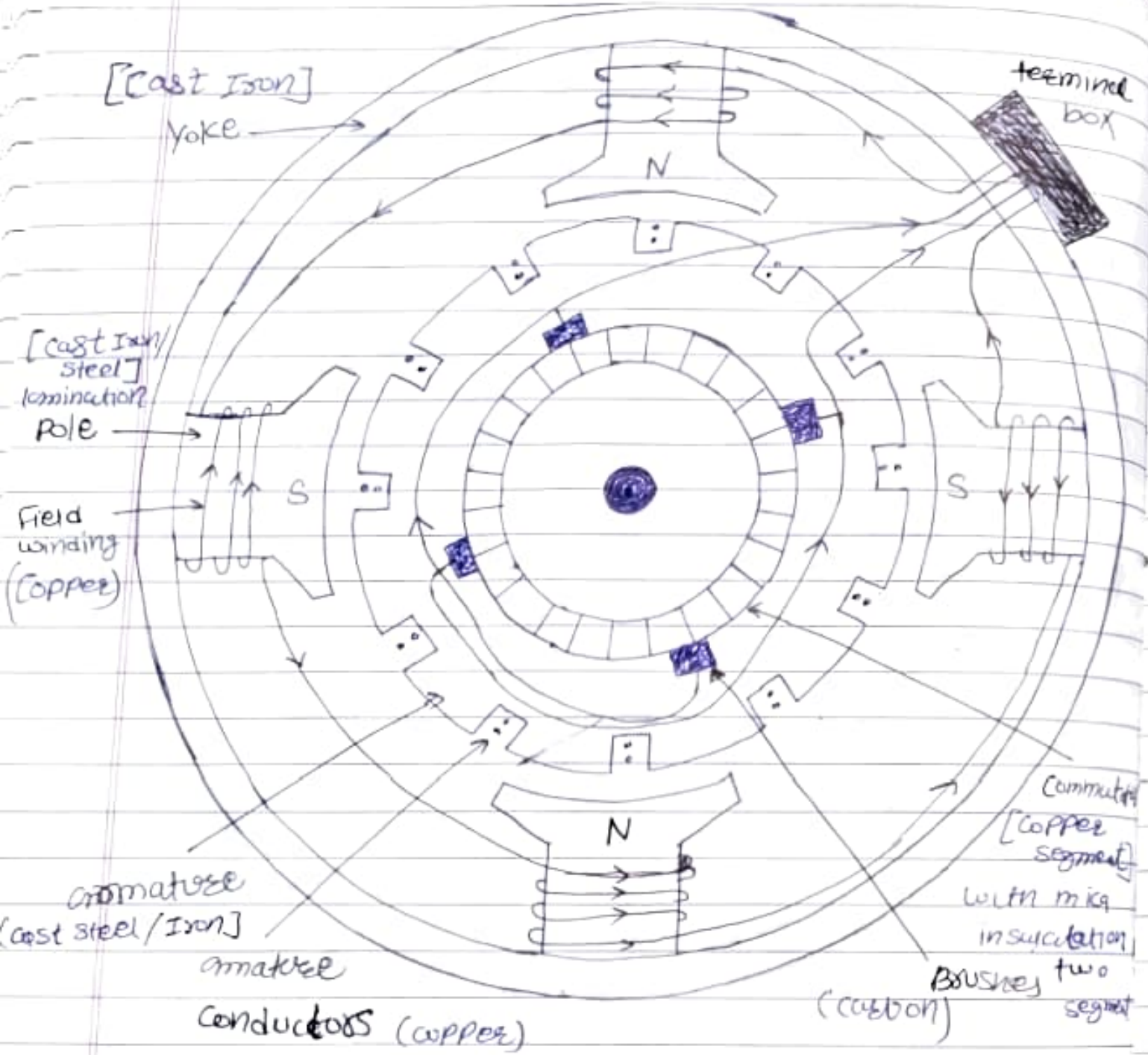
↑

perpendicular comp. of V



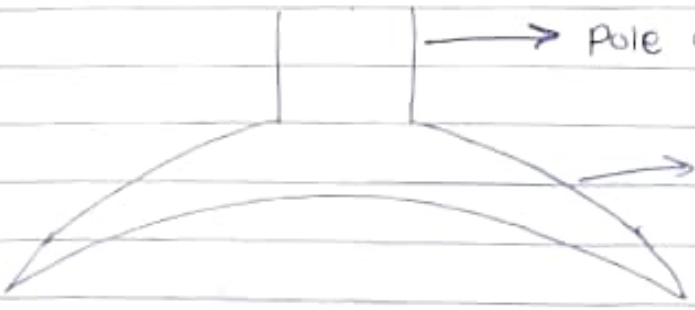
Commutator: A device is used in dc generator to convert alternating induced emf to unidirection d.c emf. It is also called as mechanical rectifier.

★ Construction of DC machines:



1. Yoke ⇒ It protect all component of DC machines from dust, moisture, gases & any other particles.
   ② It provides mechanical support to poles
   ③ provide path for passing of flux.
   ④ made of cast iron or cast steel.

2. Pole



Pole Core: (i) carry field winding

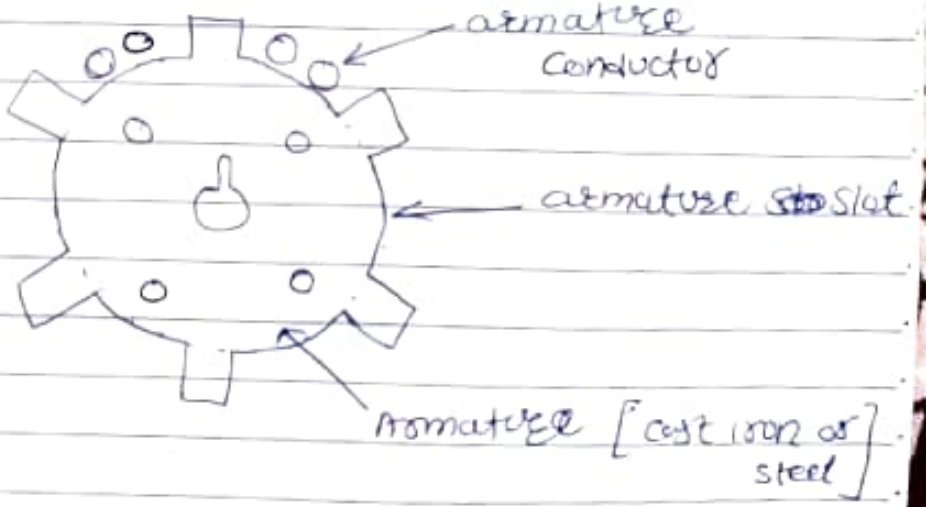
winding responsible for production of flux.

(ii) direct the flux to air gap, armature and to the next pole.

Pole Shoe: to cover maximum armature conductors to cut a flux

Field winding: wire or coil which will carry a current and that current is responsible for production of magnetic flux

Armature:



Emf is induced in armature winding

★ EMF equation of DC generator:

Let,

P = no. of poles of the generator
ϕ = flux produced by each pole (wb)
N = Speed of armature (rpm)
Z = Total no. of conductors in armature.
A = No. of parallel paths in which conductors are distributed.

e = Rate of cutting the flux

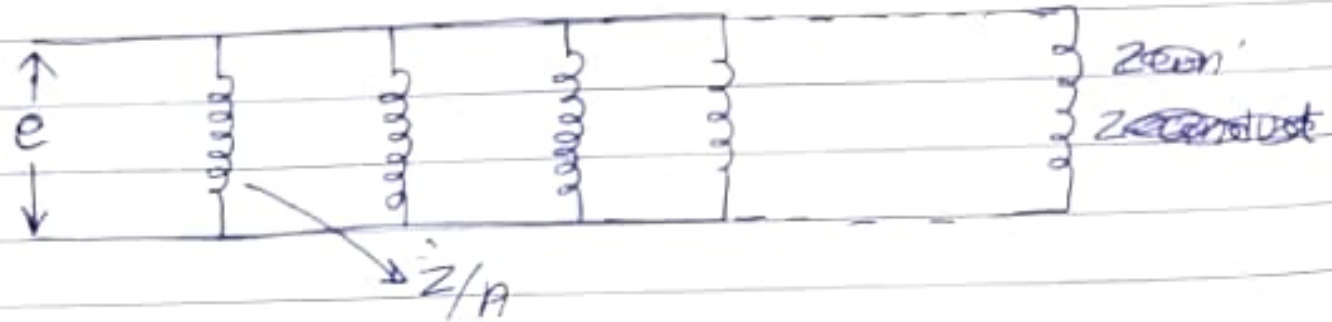
$e = \frac{d\phi}{dt}$ [as per faraday's law of electro-magnetic induction]

Total flux = Flux Produced by each pole × No. of poles.

Total (ϕ) = $\phi \times P$

Time required for a conductor to complete one revolution $= \frac{60}{N}$

$e = \frac{\phi P}{\left(\frac{60}{N}\right)} = \frac{\phi PN}{60}$ [only for one conductor]



Z conductors are distributed in A parallel paths.

① DC generator ② DC motor ③ emf Equation ④ Construction ⑤ type of dc ⑥ types of machine

Effectively Z/A conductors need to be multiplied with emf induced in conductor.

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

emf equation for DC generation.

Lecture: 4

★ Introduction to machine :

Electromechanical conversion

① mechanical Energy $\xrightarrow{\text{generator}}$ electrical energy

② electrical energy $\xrightarrow{\text{motor}}$ mechanical energy

→ as per the supply given, electrical machines are two type:

1. ① AC machine : which work on alternating supply

② DC machine : which works on Direct type supply.

Lecture:5

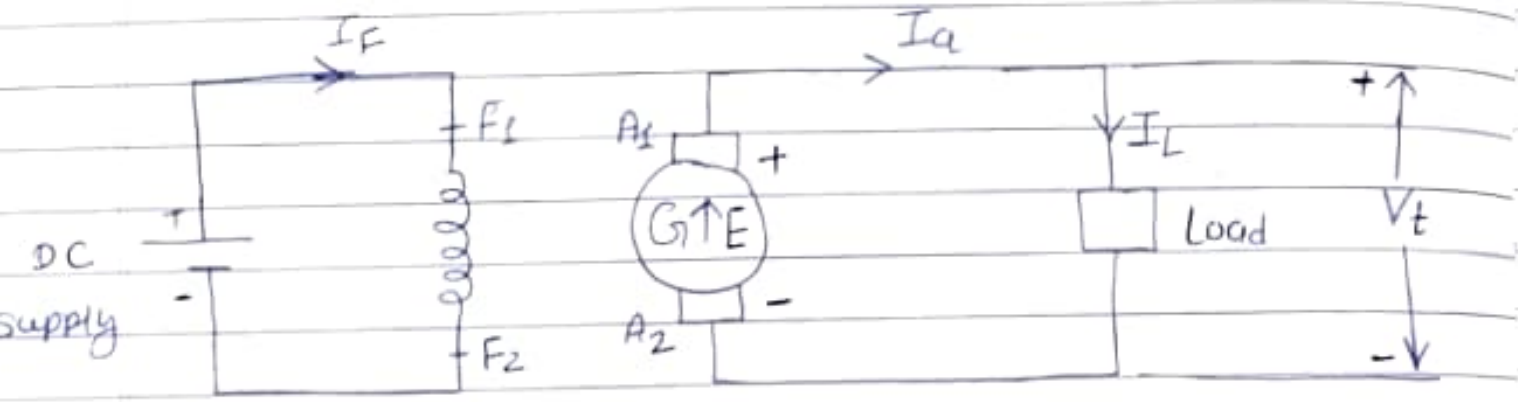
★

★ Types of DC generator

Excitation to field winding

- separately excited generator
- self excited gen.
  - Shunt
  - series

→ Separately excited generator

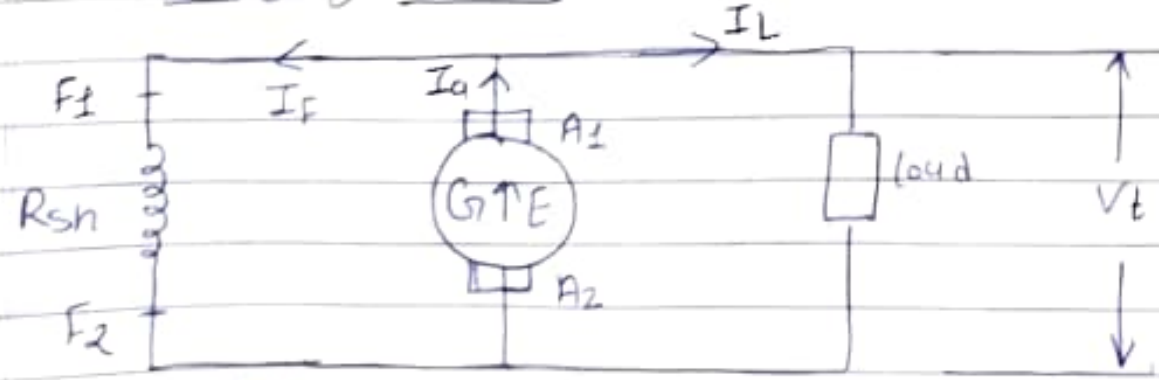


Voltage & current Relations:

$$I_a = I_L$$

$$E = V_t + I_a R_a + V_{Brush}$$

→ Shunt generator:



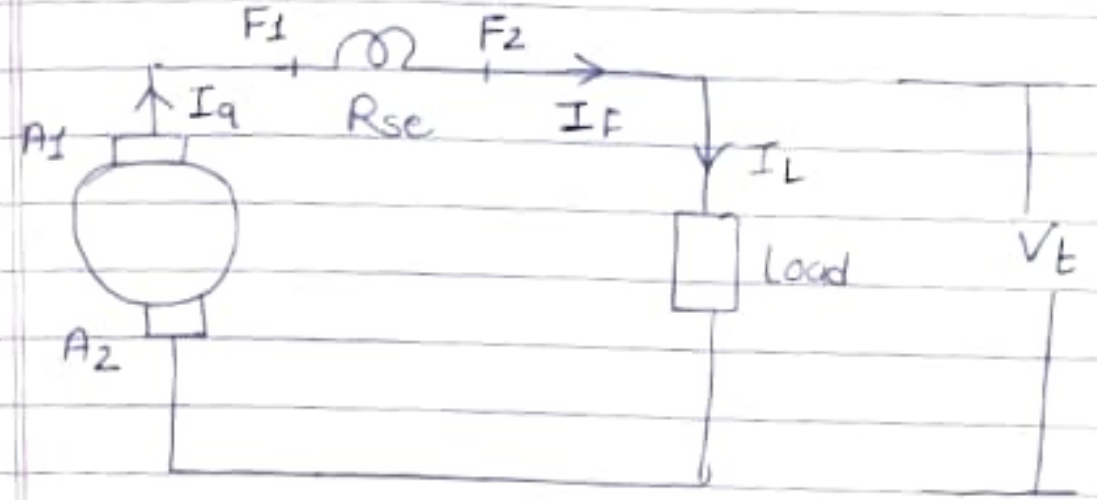
Current and voltage Related Relations

$$I_a = I_L + I_F$$

$$I_F = \frac{V_t}{R_{sh}}$$

$$E = V_t + I_a R_a + V_{brush}$$

→ Series generator:



voltage & current relation:

$$I_a = I_F = I_L$$

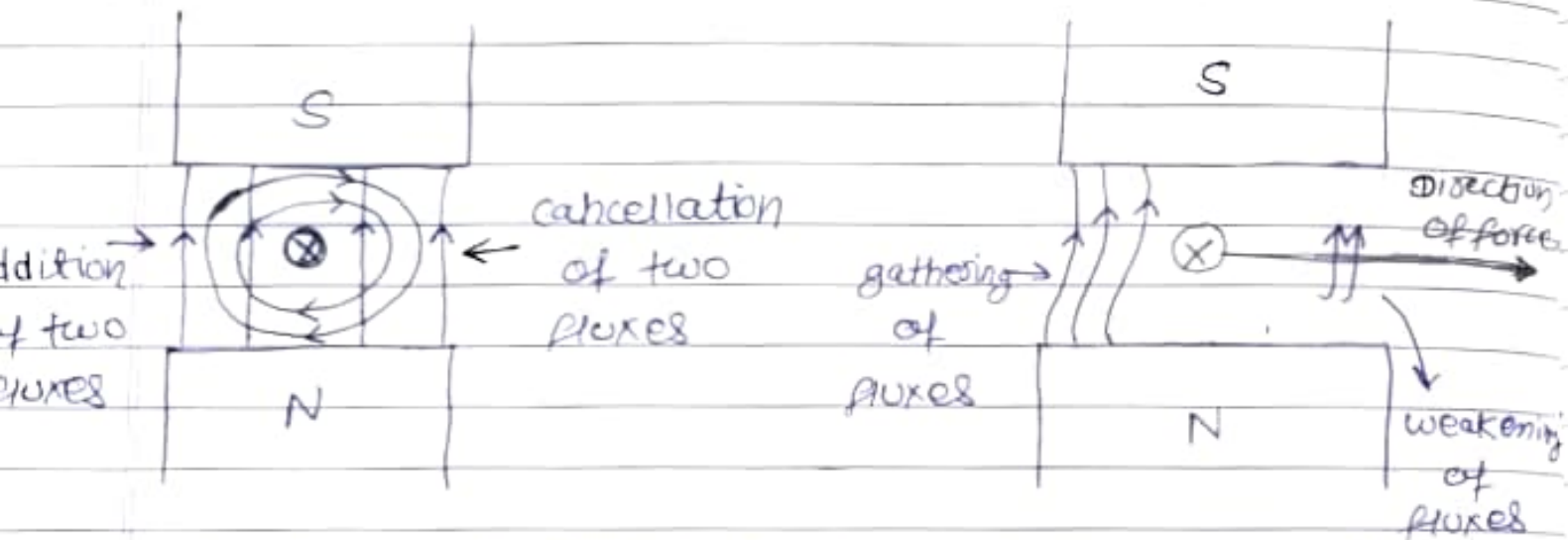
$$E = V_t + I_a R_a + I_a R_{se} + V_{brush}$$

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

★ Working principle of a DC motor:

When a current carrying conductor is placed in a magnetic field: it experiances a machanical force

- flux is created by a field winding
- Armature winding plays a role of current carrying conductor.



- Force is experienced from flux density to low to flux density.

Direction of rotation of motor

Magnitude of the force experienced by armature conductor is, $F = BlI$ (N)

where,

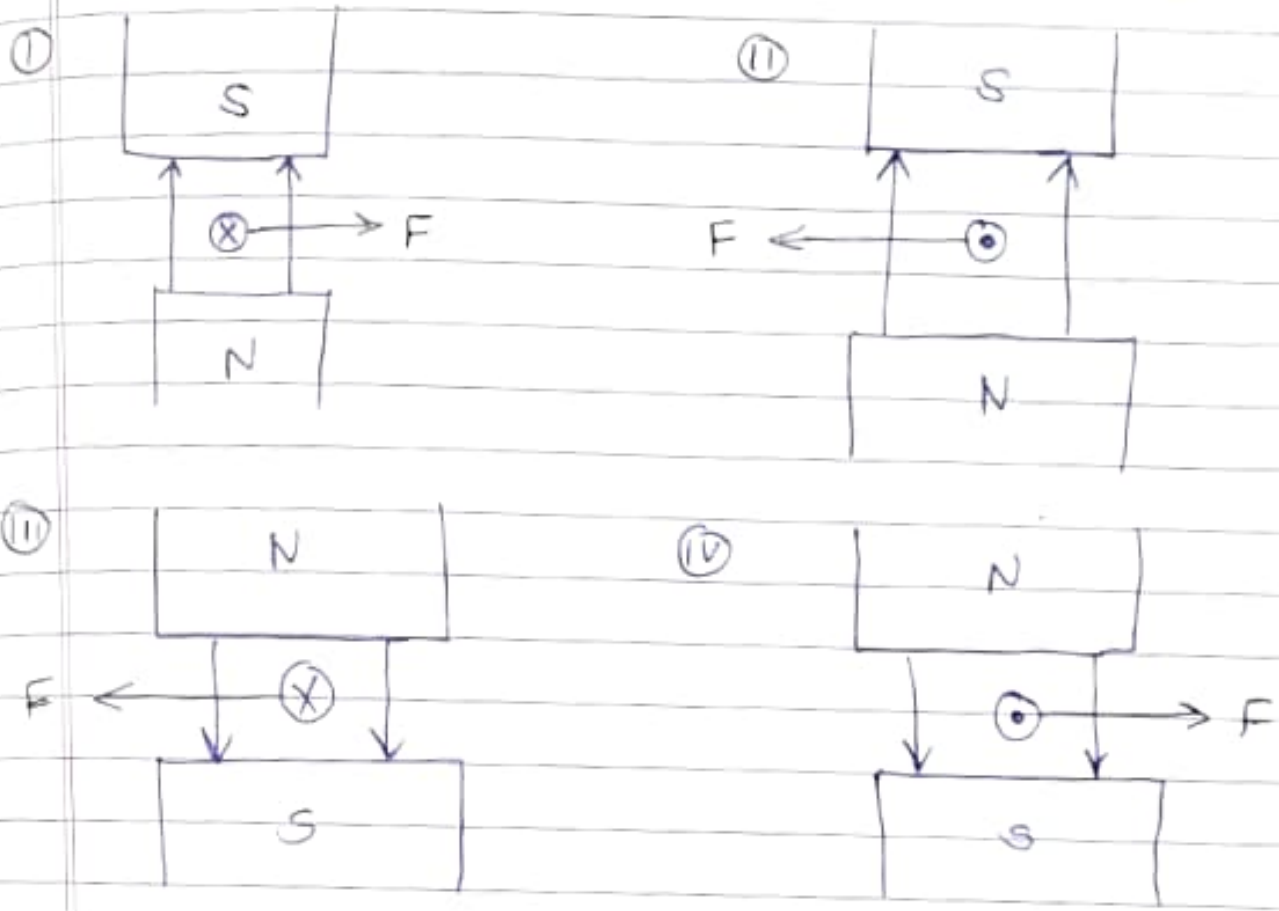
B = magnetic flux density produced by field winding.

l = active length of conductor

I = magnitude of current carrying by the conductor

→ direction of rotation is detetmined by Fleming's left Hand rule.

→ Fleming's left Hand rule: The rules states that, 'out stretch the three fingers of left Hand namely first finger, middle finger and thumb such that they are mutually perpendicular to each other. Now point the first finger in the direction of magnetic field and middle finger in the direction of current then the thumb gives the direction of the force experienced by the conductor.

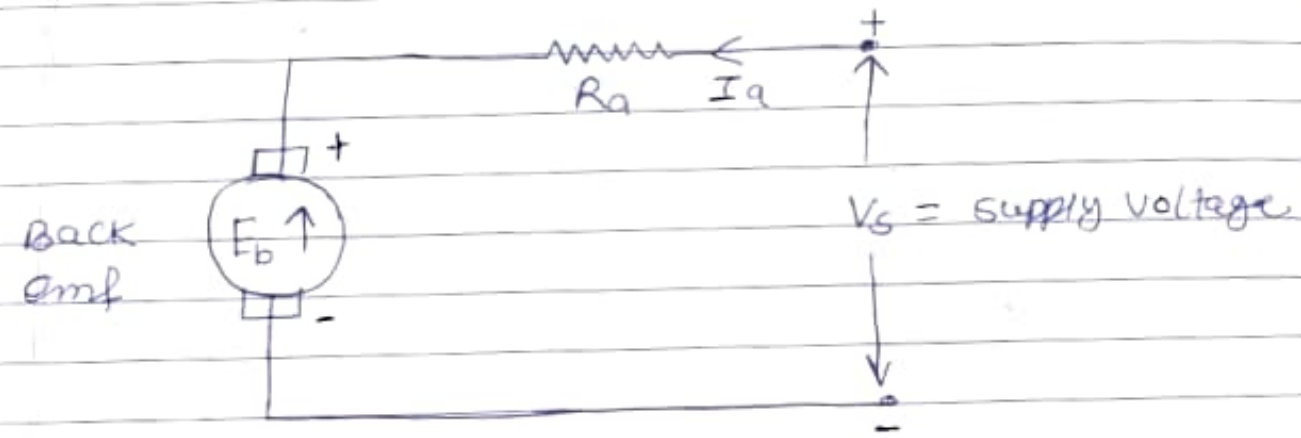


- To reverse the direction of rotation, either direction of main field produced by the field winding is reverse (case 1, 3) or direction of the current passing through armature is reversed (case 1, 2)

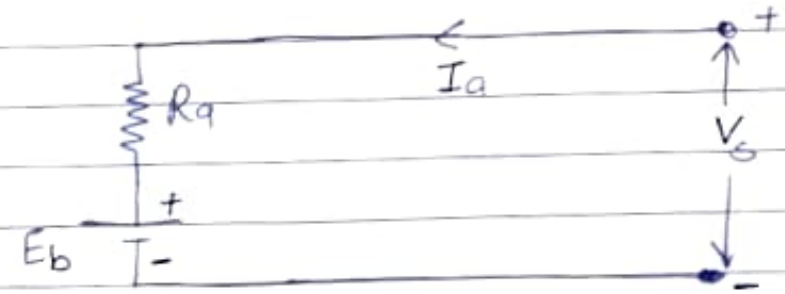
Back emf (E_b): Back emf is generated by generating action (moving conductor cutting the magnetic flux)

$$E_b = \frac{\phi PNZ}{60A}$$ — Emf equation of motor

- Emf is produced because of Faraday's law of electromagnetic induction.
  Direction will be opposite to the supply voltage as per lenz law.



Equivalent circuit diagram



Voltage equation,

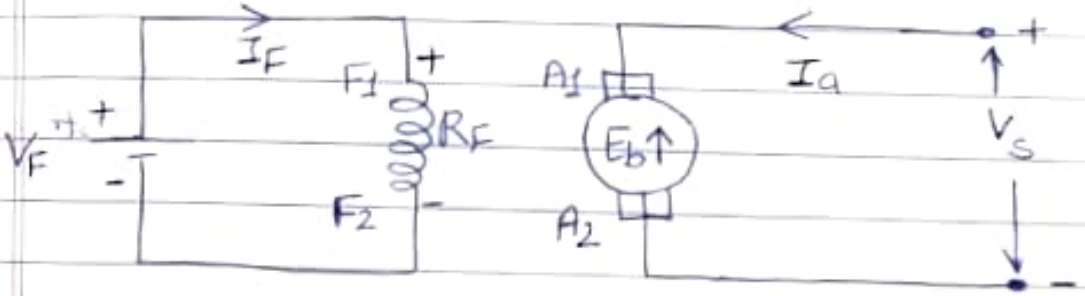
$$V_s = I_a R_a + E_b + V_{brush}$$

- $I_a R_a$: armature resistance drop
- E_b: Back emf
- V_{brush}: Brush resistance drop

Types of DC motor

- Seperately excited [seperate supply to field winding]
- Self Excited [supply to field winding is obtained from armature voltage]
  - Series motor [Field winding is in series with armature winding]
  - Shunt motor [Field winding is in parallel with armature winding]

→ seperately excited motor :



Voltage & current relationship.

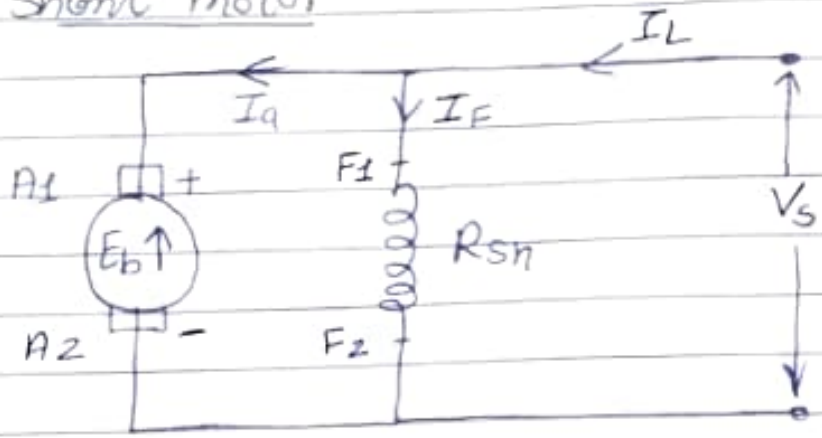
Constant ϕ motor, ϕ only depends on V_F

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

neglecting V_{brush},

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

② Shunt motor



Voltage & current Relationship

$$I_F = \frac{V_s}{R_{sh}}$$

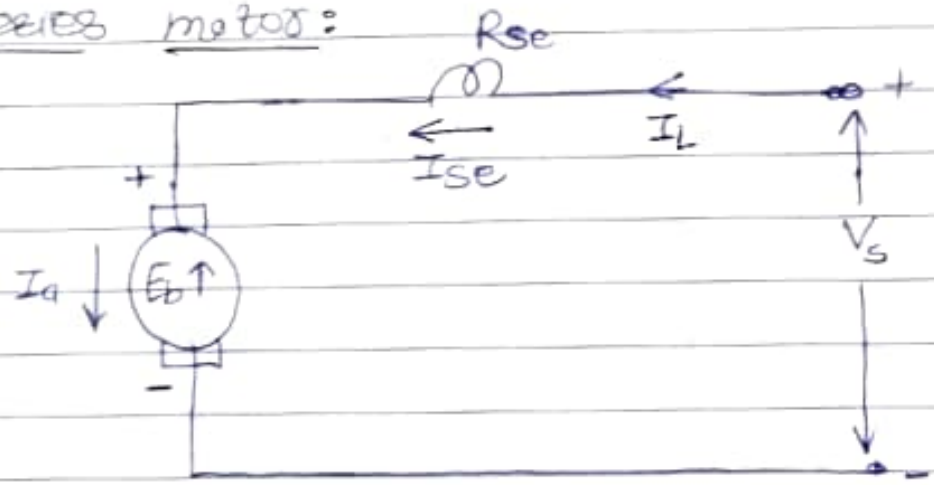
$$V_s = E_b + I_a R_a + V_{brush}$$

$$I_L = I_a + I_F$$

$$\phi \propto I_F$$

I_F is constant because V_s is kept constant.
This motor is also known as constant flux motor.

③ Series motor:



Voltage & current Relationship:

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

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

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

~~$\phi \propto R_{se}$~~ $\phi \propto I_{se} \propto I_a$