Faradays First Law :

Whenever the magnetic flux linking in a Coil or a circuit changes, an Emf is Induced in it.

Faradays Second Law :

It states that the magnitude of Induced emf in a Coil is equal to the rate of change of Magnetic flux linkages. i.e.,

$$e = -N\frac{d\phi}{dt} \quad \text{Volt}$$

According to Lenz law, voltage is Induced in the direction to oppose the change in flux that produced it. Therefore a minus sign is usually given to the right hand side Expressi

DC Machines

DC Machine :

→ A Common name given to two types of Machines generator and motor.

→ Because ~~their~~ ~~is~~ the same generator can be operated as a motor vice versa.

DC Generator :-

→ It Converts the given Mechanical Energy into Electrical Energy

Faraday's Laws of Electromagnetic Induction :-

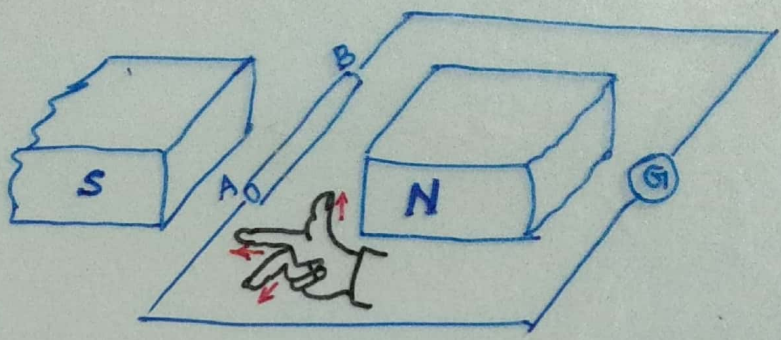
Faraday's 1st law :- Whenever a conductor cuts the magnetic flux a dynamically Induced emf is produced in that Conductor

Second Law :- The magnitude of Induced emf in a Coil is equal to the rate of change of flux linkages.

Direction of Induced Emf and Current :-

The Direction of Induced Emf and hence current in a Conductor or Coil can be determined by Fleming's Right hand Rule.

Fleming's Right-hand Rule :- Stretch out the fore finger, middle finger and thumb of your right hand so that they are at right angles to one another. if the fore finger points in the direction of magnetic field, thumb in the direction of motion of Conductor, then the middle finger will point in the direction of Induced Current.



Thumb : Direction of motion of Conductor

Fore Finger : Direction of magnetic field.

Middle Finger : Direction of Induced Current.

Modes of flux linkage :-

→ When the flux linking a Conductor (or Coil) changes, an Em.f is Induced in it. This change in flux linkages Can be brought about in the following ways :

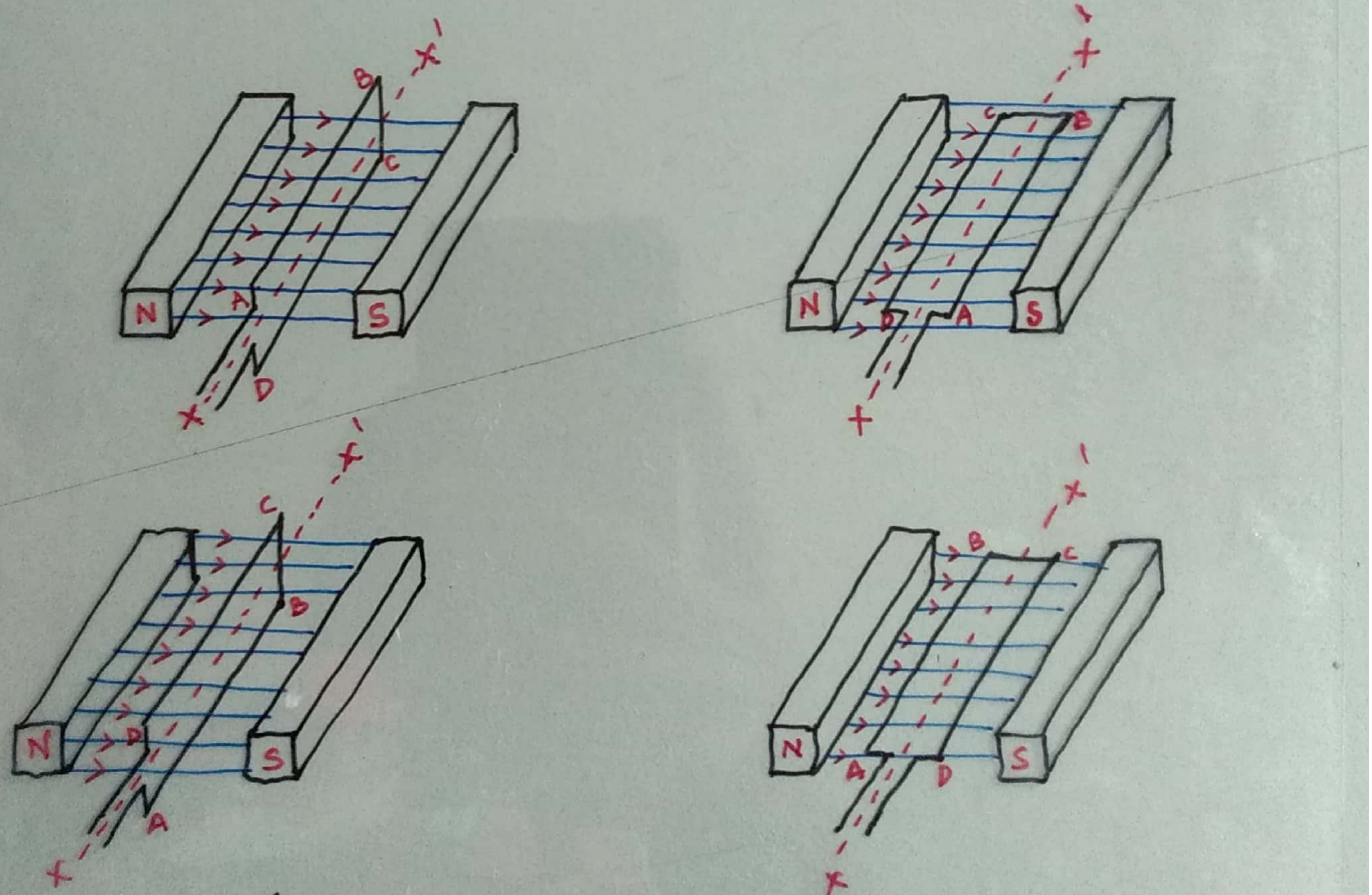
(i) The Conductor is moved in a stationary magnetic field in such a way that the flux linking it changes in magnitude. The Emf Induced in this way is called Dynamically Induced e.m.f. (as in an a.c. or d.c. generator).

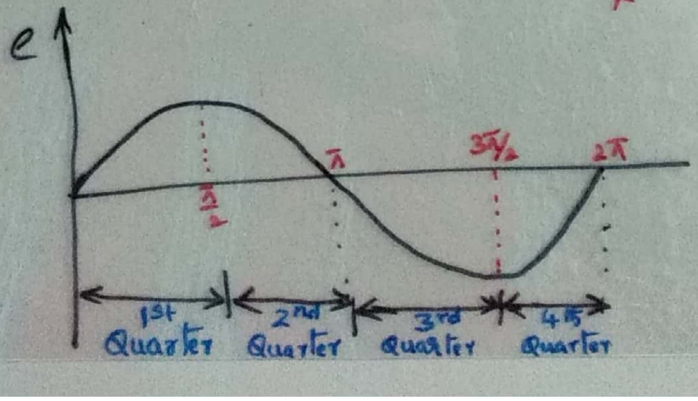
(ii) The Conductor is stationary and the magnetic field is moving or changing. The Emf Induced in this way is called Statically Induced Emf. (as in a transformer)

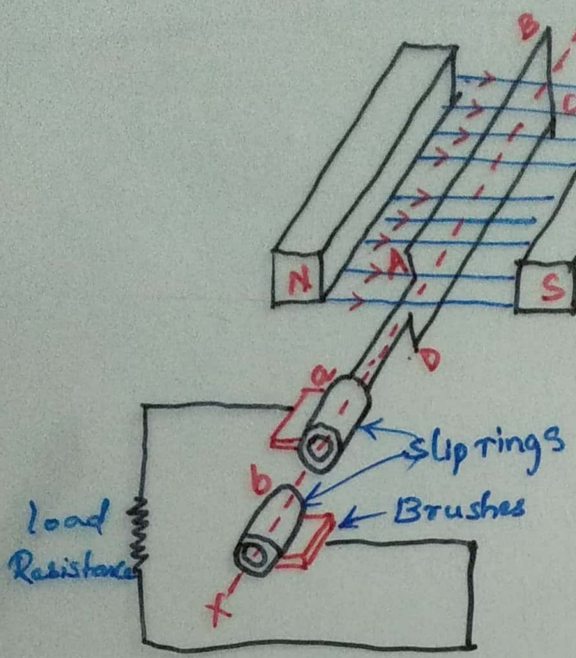
Generator Principle :-

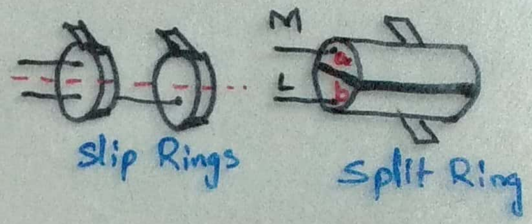
→ An Electric generator is based on the principle that whenever flux is cut by a conductor, an emf is induced which will cause a current to flow if the conductor circuit is closed. The direction of induced e.m.f (and hence current) is given by Fleming's Right hand Rule. Therefore, the essential components of a generator are.

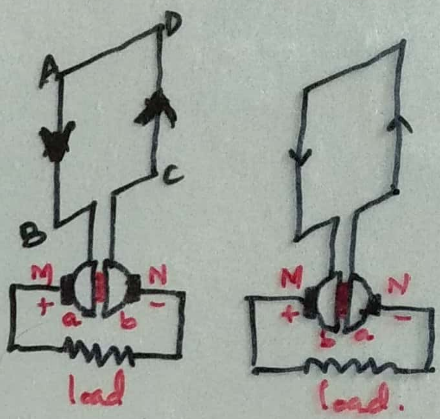
(i) a magnetic field.
(ii) Conductor or a group of Conductors.
(iii) Motion of Conductor w.r.t. magnetic field.

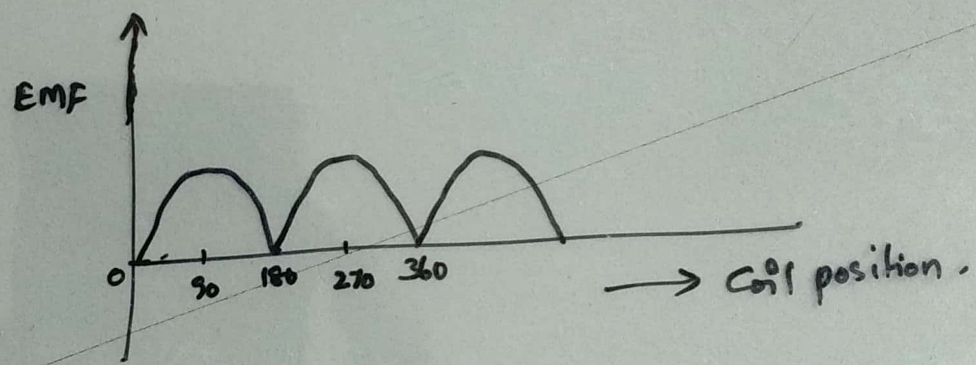





B
X'
C
N
A
S
D
a
slip rings
b
Brushes
load Resistance
X


M
a
L
b
Slip Rings
Split Ring

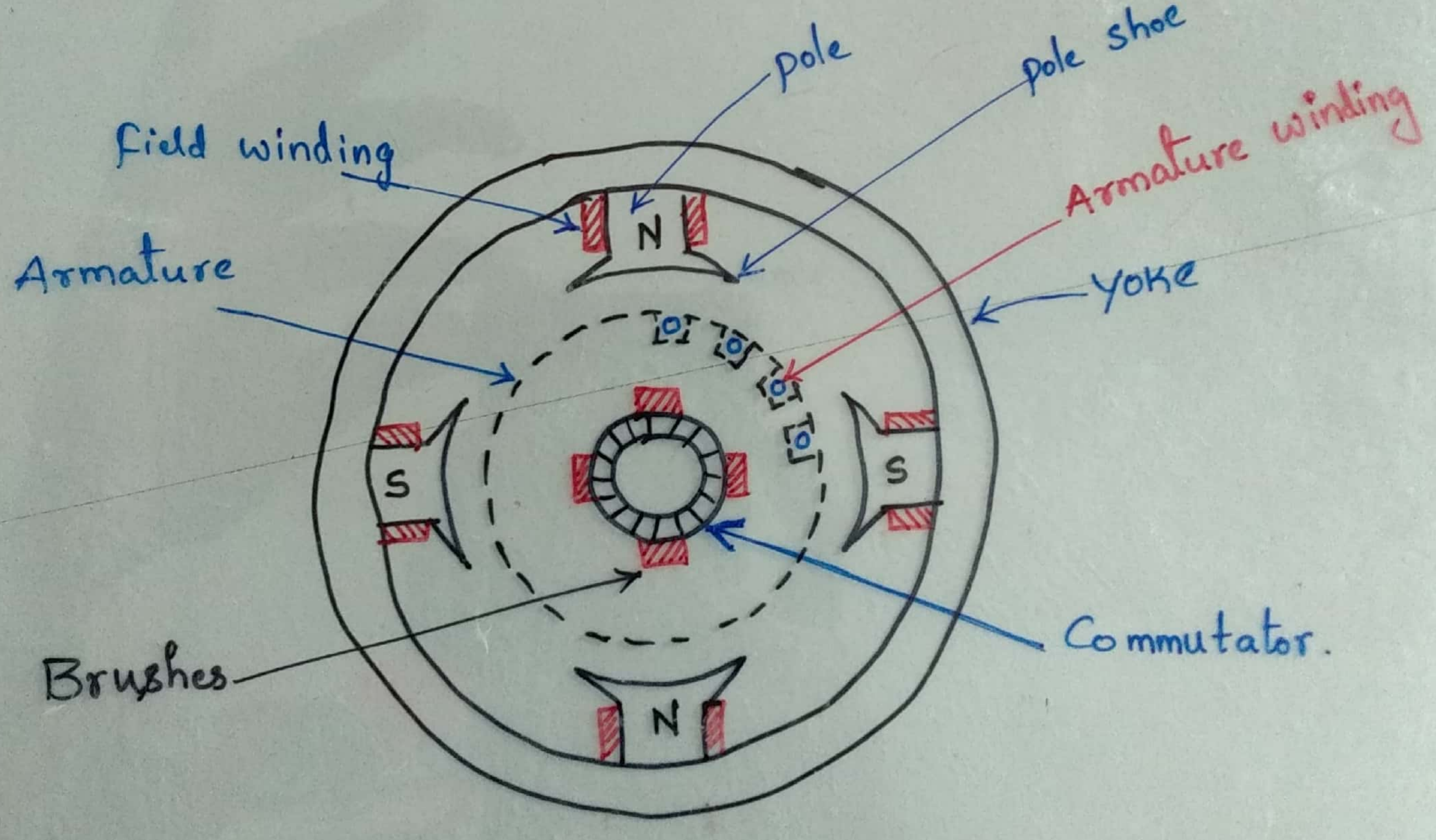

A
D
C
B
M
N
+
-
a
b
load
M
N
+
-
b
a
load.


EMF
0
90
180
270
360
Coil position.

Construction of D.C. Generator :-

The DC generators and D.C motors have the same general Construction. In fact, when the machine is being assembled, the workmen usually donot know whether it is a dc generator or motor. Any d.c. generator can be run as a d.c. motor and vice versa

→ All D.C machines have five ~~princip~~ parts mainly
(i) field System (ii) Armature Core (iii) Armature winding
(iv) Commutator (v) Brushes.



yoke : It acts as protecting Cover to the entire machine yoke provides mechanical strength and Support to the poles (which are bolted to the yoke).

→ It also provides a return path to the flux.

→ It must possess low reluctance (Ex: Cast iron, Cast steel)

Field System :

pole core : It Carries the field winding, ~~pole~~

→ The purpose of a pole is to produce working flux in a machine.

→ The basic source of flux is a permanent magnet (which is uncontrollable in nature). generally Small machines use permanent magnet. but electromagnets are preferred in medium and large rating machines because they are easily available and also Controllable.

→ pole Core gives the accomodation for the field winding when Excited with DC Supply, it acts as pole and produces flux.

pole shoe :- It gives the mechanical support for the field system or field winding. It reduces the Reluctance of the magnetic field, it distributes the main field flux, uniformly in the air gap.

Brushes :-

→ Collects the Current in generator or gives the current to the Conductor through the Commutator segments.

→ Brushes are made with Carbon or Copper material

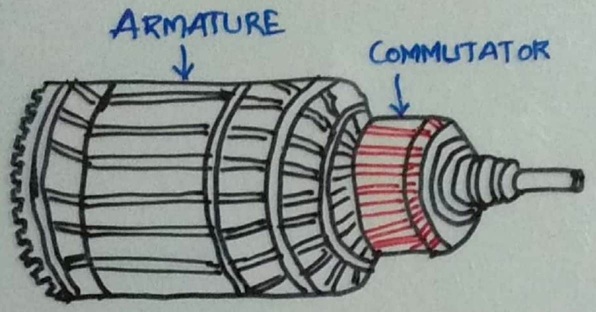
→ ~~Multiple~~ Multipole Machines have as many brushes as they have poles.

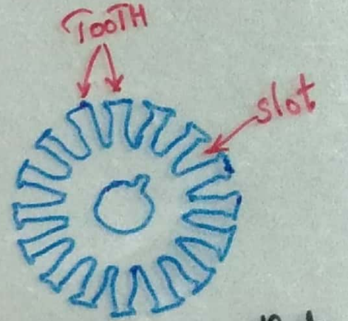
Armature Core :-

→ Armature Core is keyed to the machine shaft and rotates between the field poles. it consists of slotted soft-iron laminations (about 0.4 to 0.6mm thick) that at stacked to form a cylindrical core.

→ The purpose of laminating the Core is to reduce eddy current loss.

→ Armature core provides accomodation for the armature winding.





Armature winding :-

→ The slots of a armature core hold Insulated conductors that are connected in a suitable manner. This is known as armature winding. This is the winding in which "working" Emf is Induced.

→ The armature conductors are connected in series-parallel the

→ The conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current.

Commutator :-

→ A Commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.

→ Commutator is made of copper segments.

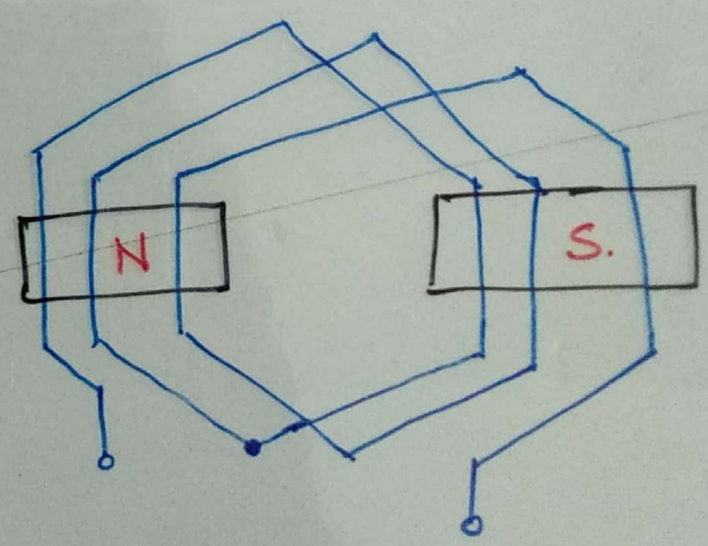
Armature winding :- Armature windings of d.c machines are always of drum type. In this arrangement, the armature conductors, usually in the form of coils, are placed in slots around the complete surface of drum-shaped or cylindrical armature core.

→ The coils are connected in series through commutator segments in such a way that their ~~armature~~ coils e.m.f add to each other.

There are two types of Armature winding.

① Lap winding ② wave winding

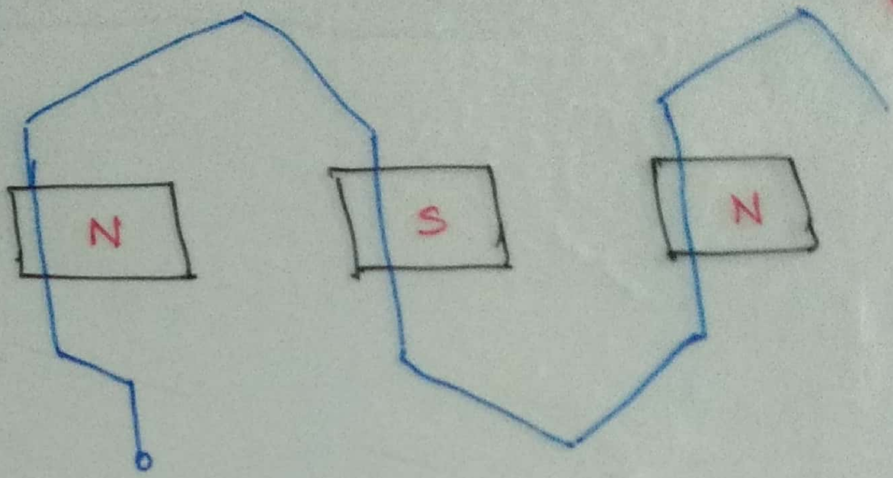
Lap winding :-



→ Finishing end of one coil is connected to beginning end of other coil under same pole

→ Number of parallel paths (A) = P.

Wave winding :-



→ Finishing end of one coil is connected to the beginning end of other coil under adjacent pole.

→ No. of parallel paths (A) = 2

Emf equation of a D.C. Generator :-

Let ϕ = flux/pole in Wb.

Z = Total Number of armature Conductors.

P = Number of poles

A = No. of parallel paths (= P for lap winding, = 2 for Wave winding).

N = Speed of armature in rpm.

E_g = e.m.f of the generator = emf/parallel path.

During one revolution of armature in a P-pole generator each armature Conductor cuts the magnetic flux P-times.

~~So flux cut~~

flux cut by one Conductor in one revolution of the armature,

$$d\phi = P.\phi \text{ webers.}$$

No. of revolutions made by the armature per minute is N.

~~then No. of revolutions made per second is $\frac{N}{60}$.~~

time taken to complete one revolution $dt = \frac{60}{N}$ second.

$$\text{Emf generated/Conductor} = \frac{d\phi}{dt} = \frac{P.\phi}{60/N} = \frac{P\phi N}{60} \text{ Volts.}$$

E_g = e.m.f per parallel path

= (e.m.f/conductor) × no. of Conductors in series per parallel path

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

$$\boxed{E_g = \frac{P\phi NZ}{60 \cdot A}}$$

where $A = 2$ for wave winding

$A = P$ " Lap winding.

Types of DC Generators :- The magnetic field in a d.c. generator is normally produced by electromagnets rather than permanent magnets.

→ Generally, generators are classified according to their methods of field Excitation. on this basis, D.C generators are divided into the following two classes.

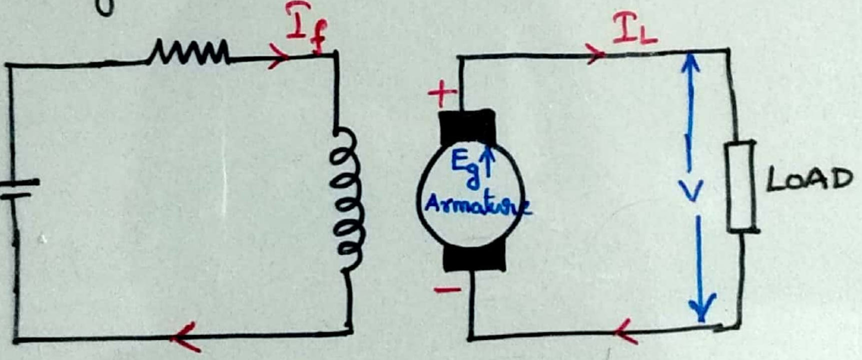
(i) Separately Excited D.C. generators

(ii) Self-Excited D.C generators

Separately Excited D.C. generator :-

→ A D.C generator whose field winding is excited from an Independent external D.C Source, such as a battery, the generator is called a Separately Excited generator.

→ Separately Excited d.c generators are rarely used in practice. The D.C generators are normally of self-Excited type.



Armature current, $I_a = I_L$

terminal voltage $V = E_g - I_a R_a$.

Electrical power developed $= E_g . I_a$

power delivered to load $= E_g . I_a - I_a^2 R_a$

$= I_a (E_g - I_a R_a)$

$= V . I_a$.

Self - Excited D.C. generators :-

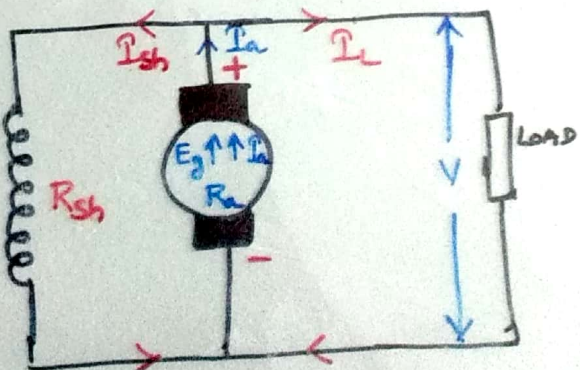
→ A DC generator whose field winding is Excited by the Current supplied by the generator itself, is called a Self - Excited generator.

→ Self Excited generators are classified as
(i) Shunt wound generators
(ii) Series wound generators
(iii) Compound wound generators.

Due to residual magnetism, Some flux is always present in the poles of such machines. when the armature is rotated, a Small Voltage is Induced in the armature winding Owing to residual flux. This Induced Voltage Causes a Small Current to flow in the field coils and thus Increase in flux per pole. The Increase in flux Causes Increase in Induced Voltage which further Increases the field Current and so flux per pole. These events take place rapidly and the generator builds up to the rated Voltage.

Shunt wound generator :-

In a shunt generator, the field winding is Connected in parallel with the armature winding So that terminal Voltage of the generator is applied across it. The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of armature current flows through shunt field winding and rest flows through the load.



Shunt field current, $I_{sh} = V/R_{sh}$

Armature current, $I_a = I_L + I_{sh}$

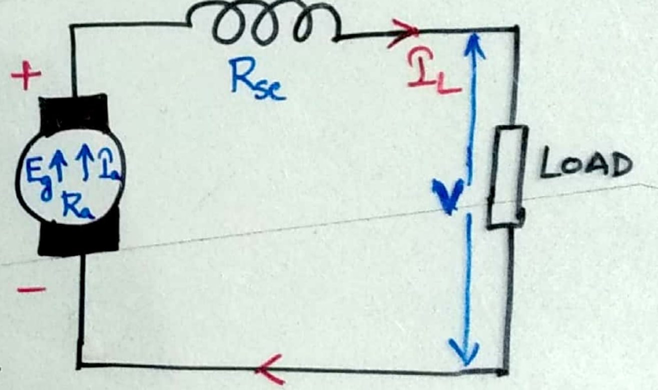
terminal Voltage, $V = E_g - I_a R_a$.

Power developed in armature $= E_g \cdot I_a$.

Power delivered to load $= V \cdot I_L$

Series wound generator :-

→ In a series-wound generator, the field winding is Connected in series with armature winding so that whole armature current flows through the field winding as well as the load. Since the field winding Carries the whole of load current, it has a few turns of thick wire having low resistance.



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

terminal Voltage $V = E_g - I(R_a + R_{se})$

Power developed in Armature $= E_g \cdot I_a$

Power developed to load $= E_g \cdot I_a - I_a^2 (R_a + R_{se})$

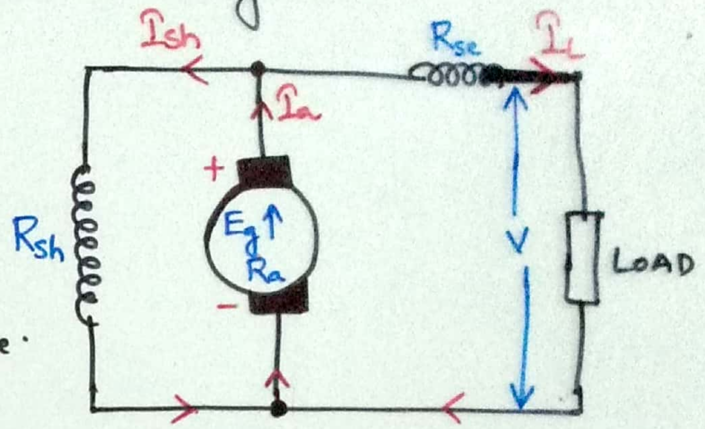
$= I_a [E_g - I_a (R_a + R_{se})]$

$= V \cdot I_a . = V \cdot I_L$

Compound wound generators :-

In a Compound wound generators, there are two sets of field windings on each pole — one is in series and the other in parallel with the armature. A Compound wound generator may be : (a) Short shunt (b) Long shunt.

Short shunt generator :- in which only shunt field winding is in parallel with the armature winding.



Series field current, $I_{se} = I_L$

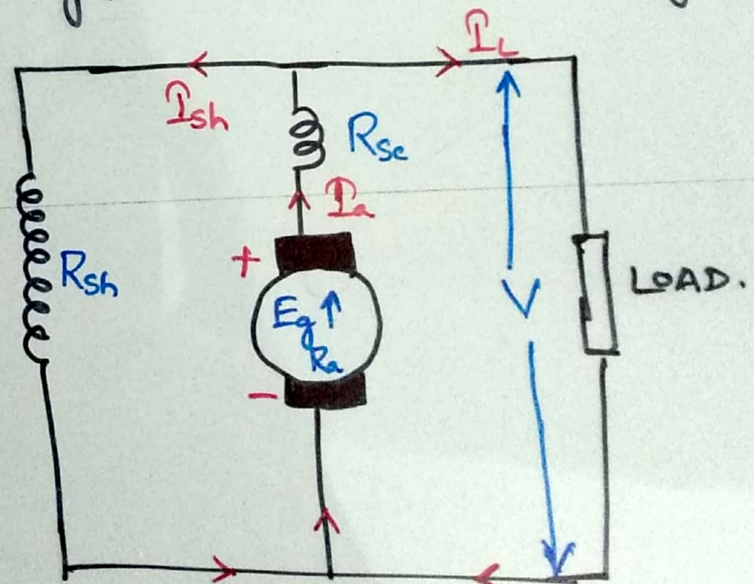
Shunt field current $I_{sh} = \dfrac{V + I_{se} R_{se}}{R_{sh}}$

terminal Voltage $V = E_g - I_a R_a - I_{se} R_{se}$.

Power developed in Armature $= E_g \cdot I_a$.

power delivered to load $= V \cdot I_L$.

Long shunt generator :- in which field winding is in parallel with both series winding (field) and armature winding.



Shunt field current $I_{sh} = \dfrac{V}{R_{sh}}$

Series field Current $I_{se} = I_a = I_L + I_{sh}$

terminal voltage, $V = E_g - I_a (R_a + R_{se})$

Power developed in Armature $= E_g \cdot I_a$

Power delivered to load $= V \cdot I_L$.

DC Generator characteristics :-

1. open circuit characteristics (O.C.C).

→ This curve shows the relation between the generated emf at no-load (E_0) and the field current (I_f) at constant speed.

→ It is also known as magnetic characteristic or no-load ~~sta~~ saturation curve.

2. Internal or Total ~~Internal~~ ~~External~~ characteristic :-

→ This curve shows the relation between the generated emf on load (E) and the armature current (I_a).

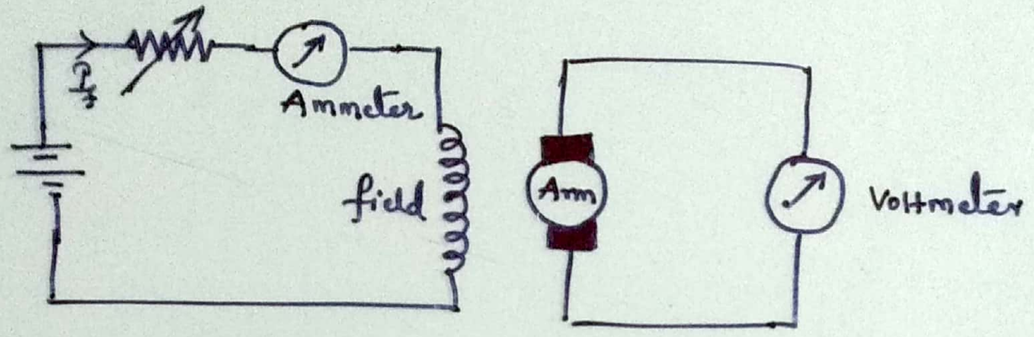
→ The emf E will be less than E_0 due to the effects of armature reaction. Therefore, this curve will lie below the open circuit characteristic.

3. External characteristic

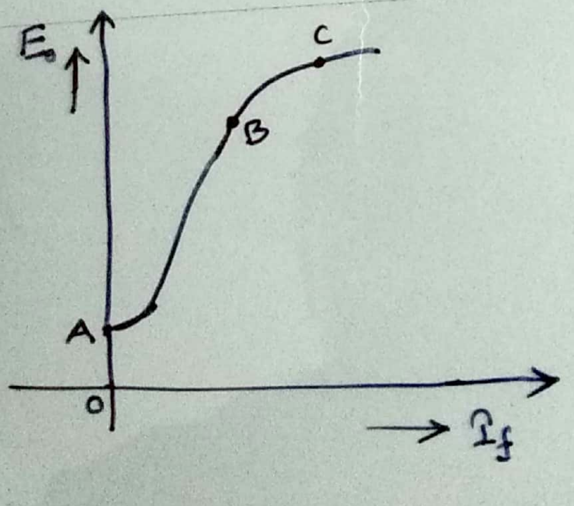
→ This curve shows the relation between the terminal voltage (V) and load current (I_L). The terminal voltage V will be less than E due to voltage drop in the armature circuit. Therefore this curve will lie below the Internal characteristic.

Open circuit characteristic :-

The arrangement for obtaining necessary data to plot this curve is shown below.



The field winding of the d.c. generator (series or shunt) is separately Excited from an External DC source.
The field current (I_f) is varied from zero in steps and the Corresponding Values of generated Emf (E_0) read off on a Voltmeter ~~from~~ across the armature terminals.
on plotting the Relation between E_0 and I_f, we get open Circuit characteristic.



The following points may be noted from O.C.C

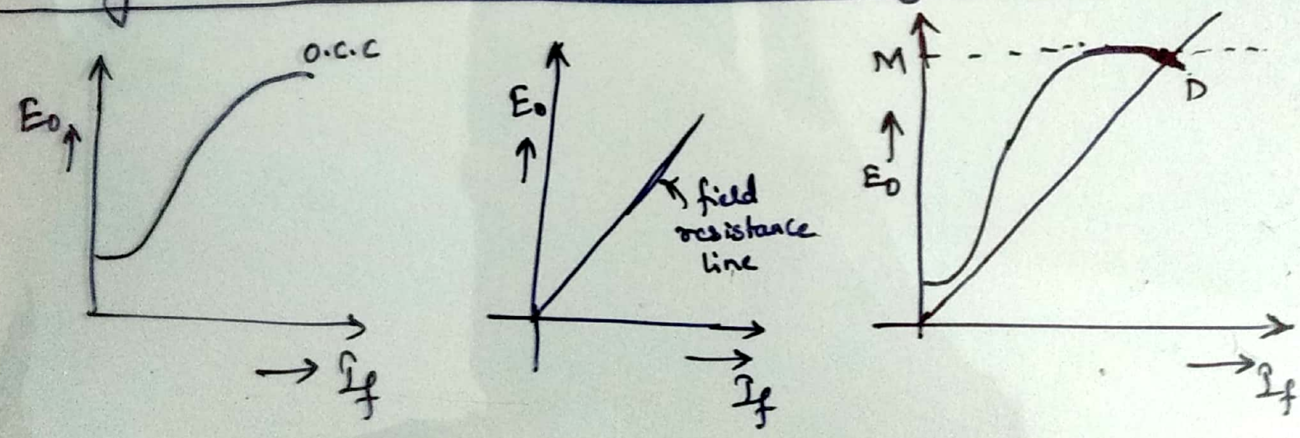
i) when $I_f = 0$, there is some generated emf OA. This is due to residual magnetism in the field poles

(ii) Over a fairly wide range of field current (upto point B in the curve), The current is linear. It is because in this range, reluctance of iron is negligible as compared with that of air gap. The air gap reluctance is constant and hence linear relationship. ③

(iii) After point B on the curve, the reluctance of iron also comes into picture. It is because at higher flux density, μ_r for iron decreases and reluctance of iron is no longer negligible. Consequently, the curve deviates from linear relationship.

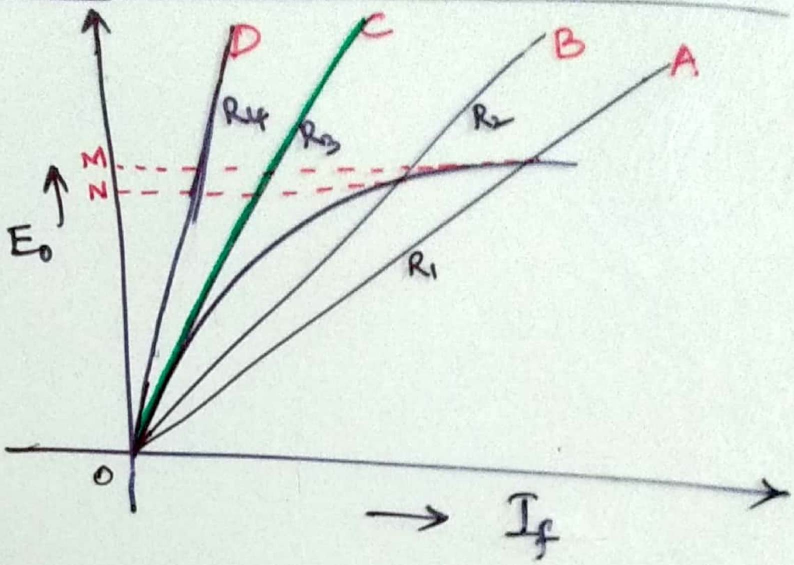
(iv) After point C on the curve, the magnetic saturation of poles begins and E_0 tends to level off.

Voltage Build-up of a Shunt generator :-



Conclusion : The voltage build up of the generator is given by the point of intersection of O.C.C and field resistance line. Thus in above figure D is the point of intersection of O.C.C and field resistance line. Hence generator will build up a voltage OM.

Critical field Resistance for a Shunt generator



- When the field resistance is Increased, the slop of resistance line also ↑.
- When field resistance line becomes tangent (line OC) to o.c.c the generator would just excite.
- If the field circuit resistance is Increased beyond this point (say line OD), The generator will fail to Excite.

Critical field Resistance: The maximum field circuit resistance (for a given speed) with which the shunt generator would just excite is known as Critical field resistance