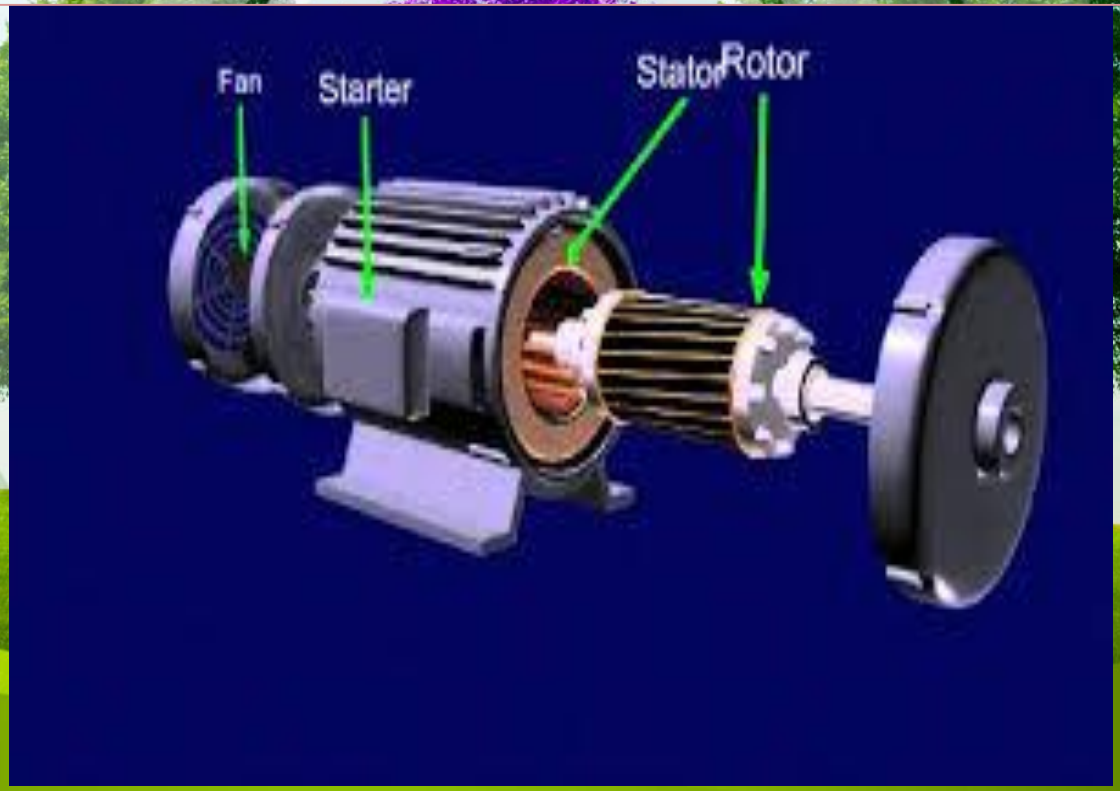
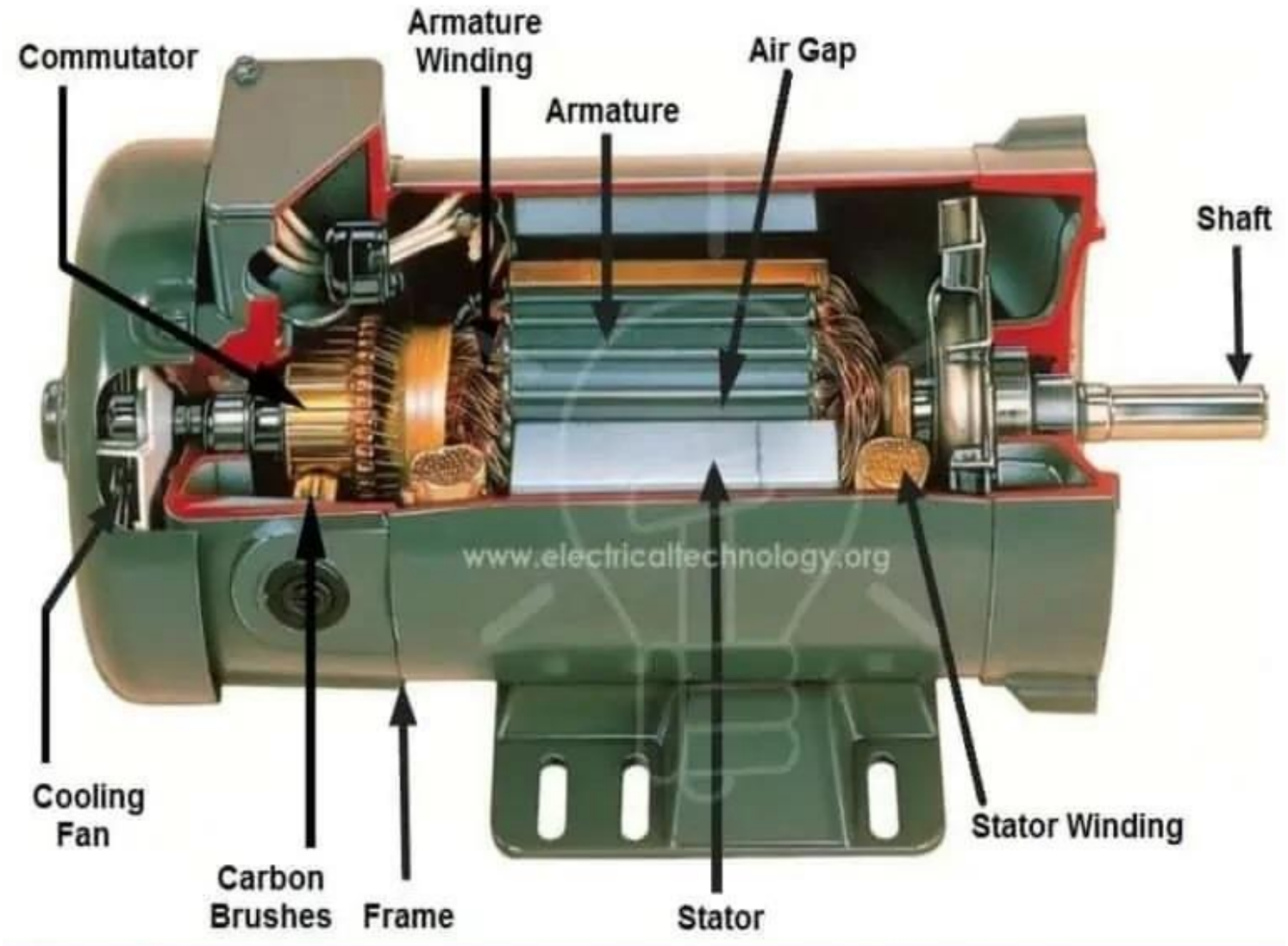
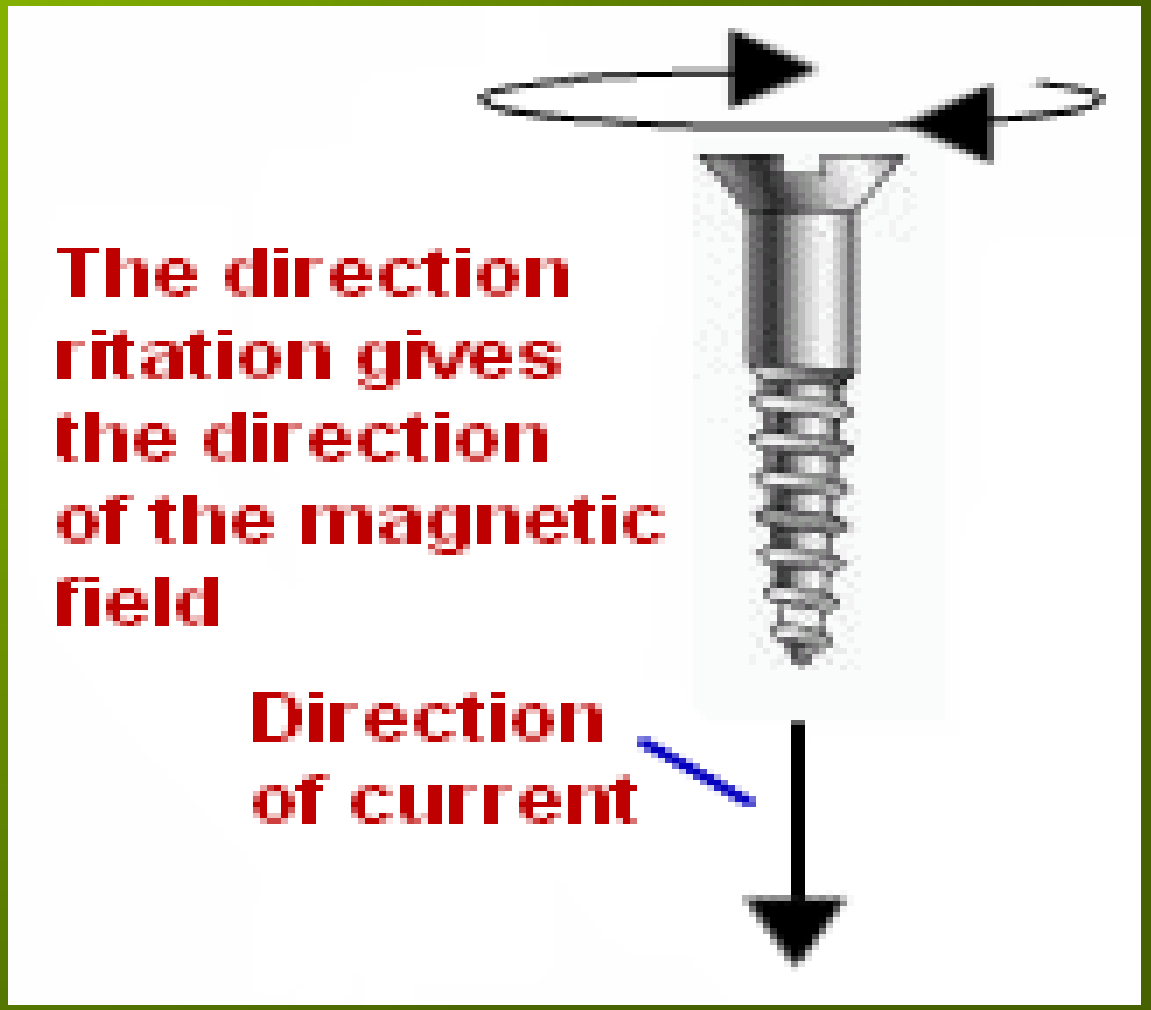
DC MACHINES





Construction of DC Machine

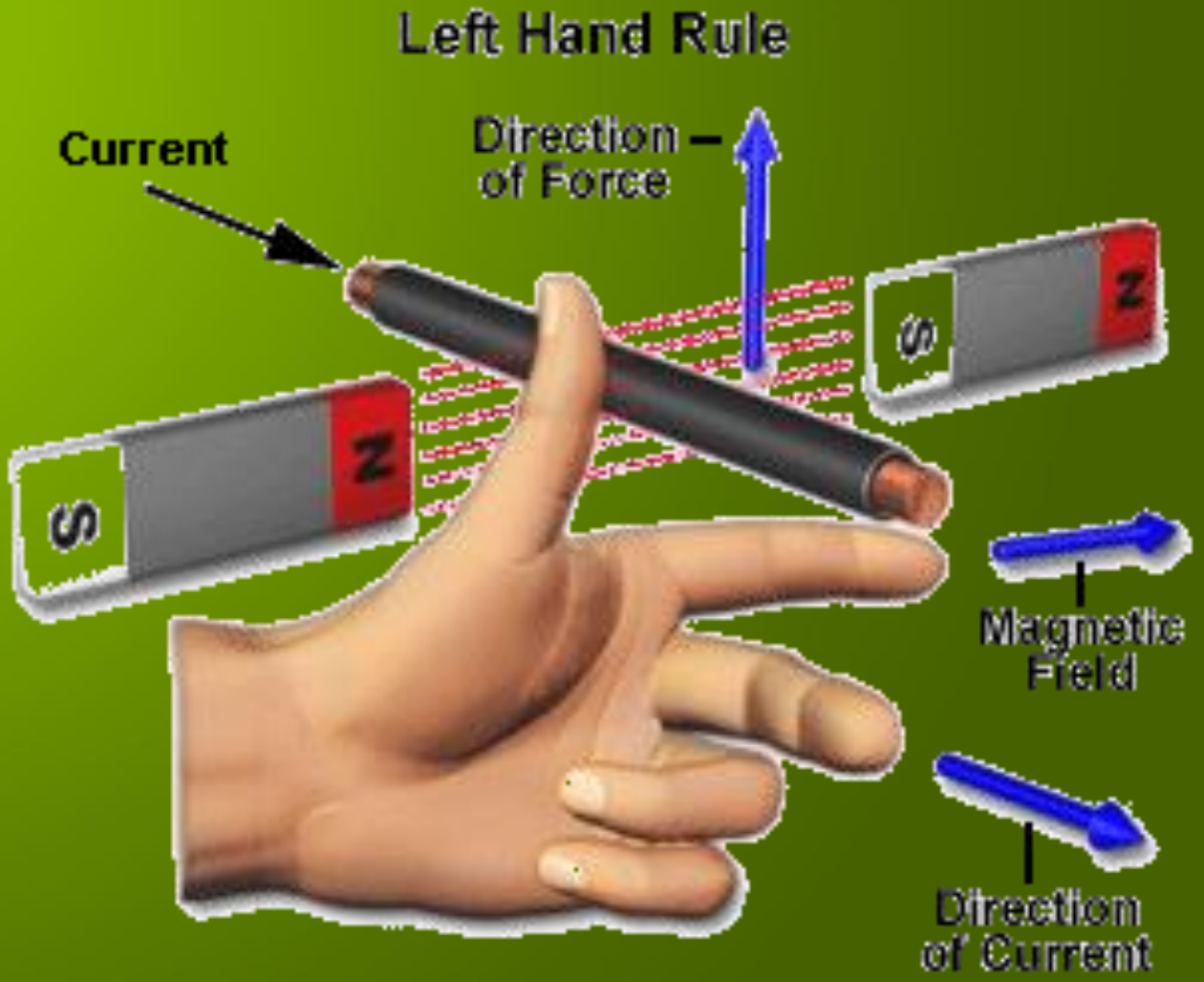
Maxwell's Cork screw Rule :



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

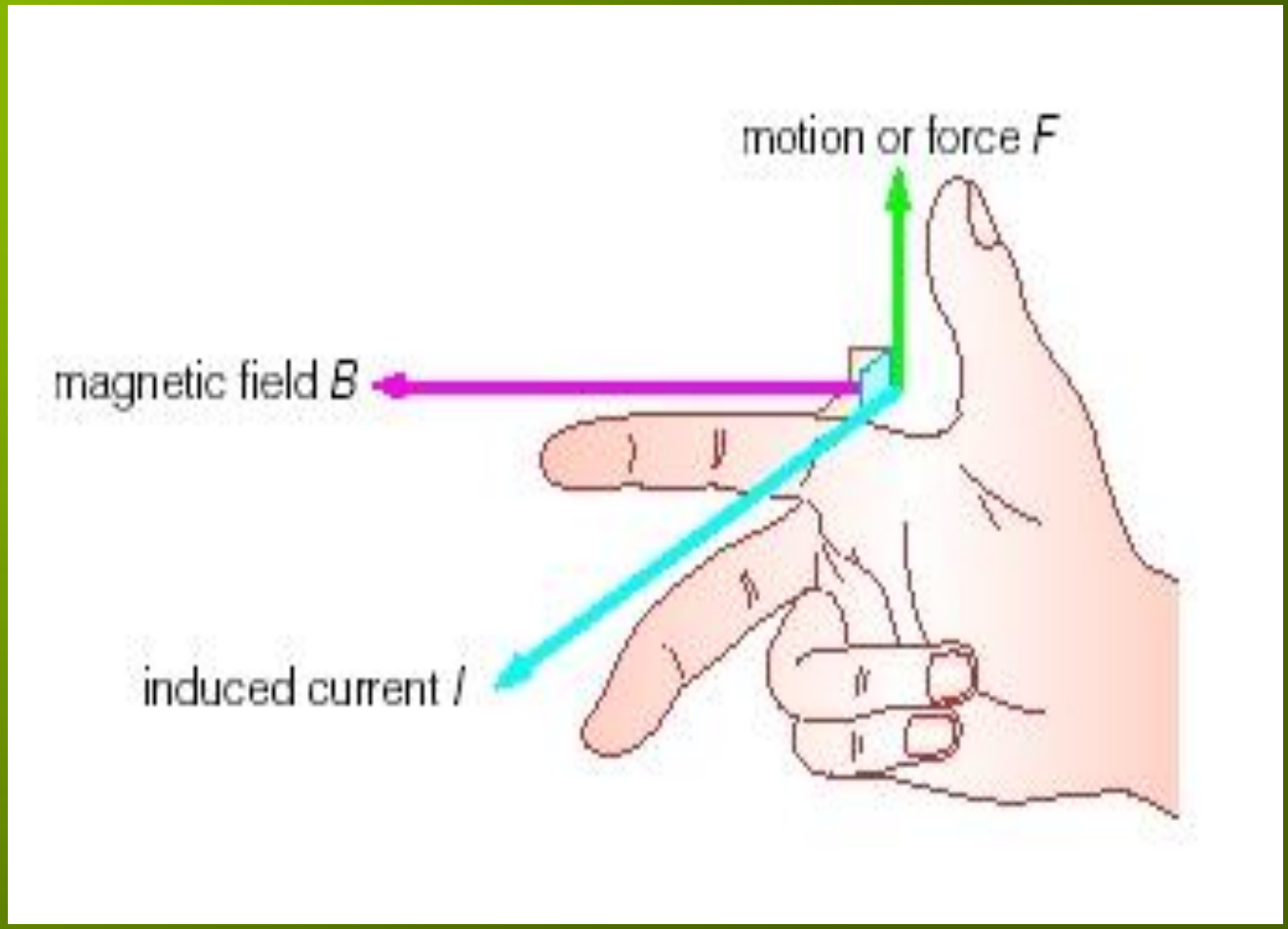


Fleming's left hand rule

- 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

Lenz'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 .

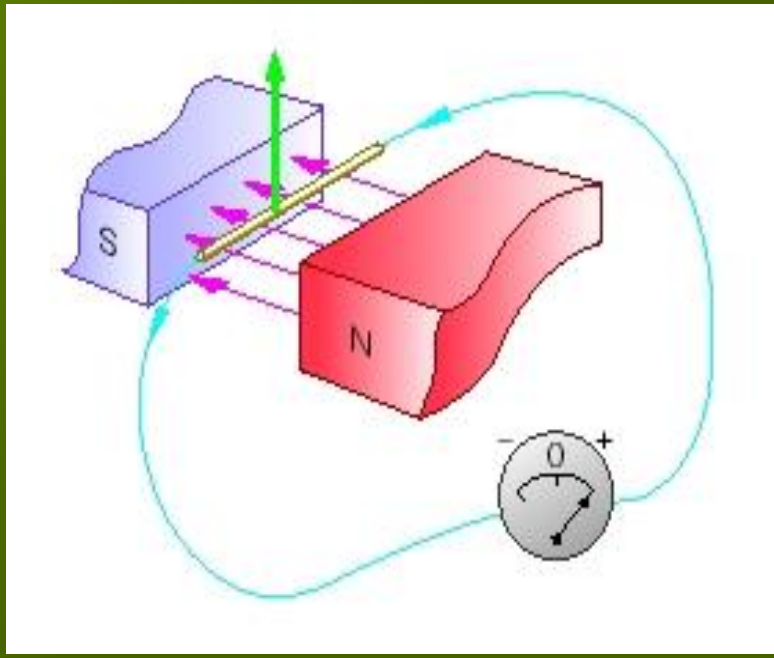
- $e = -N\ (d\Phi/dt)$ volts

DC Generator

Mechanical energy is converted to electric energy

Three requirements are essential

1. Conductors
2. Magnetic field
3. Mechanical energy

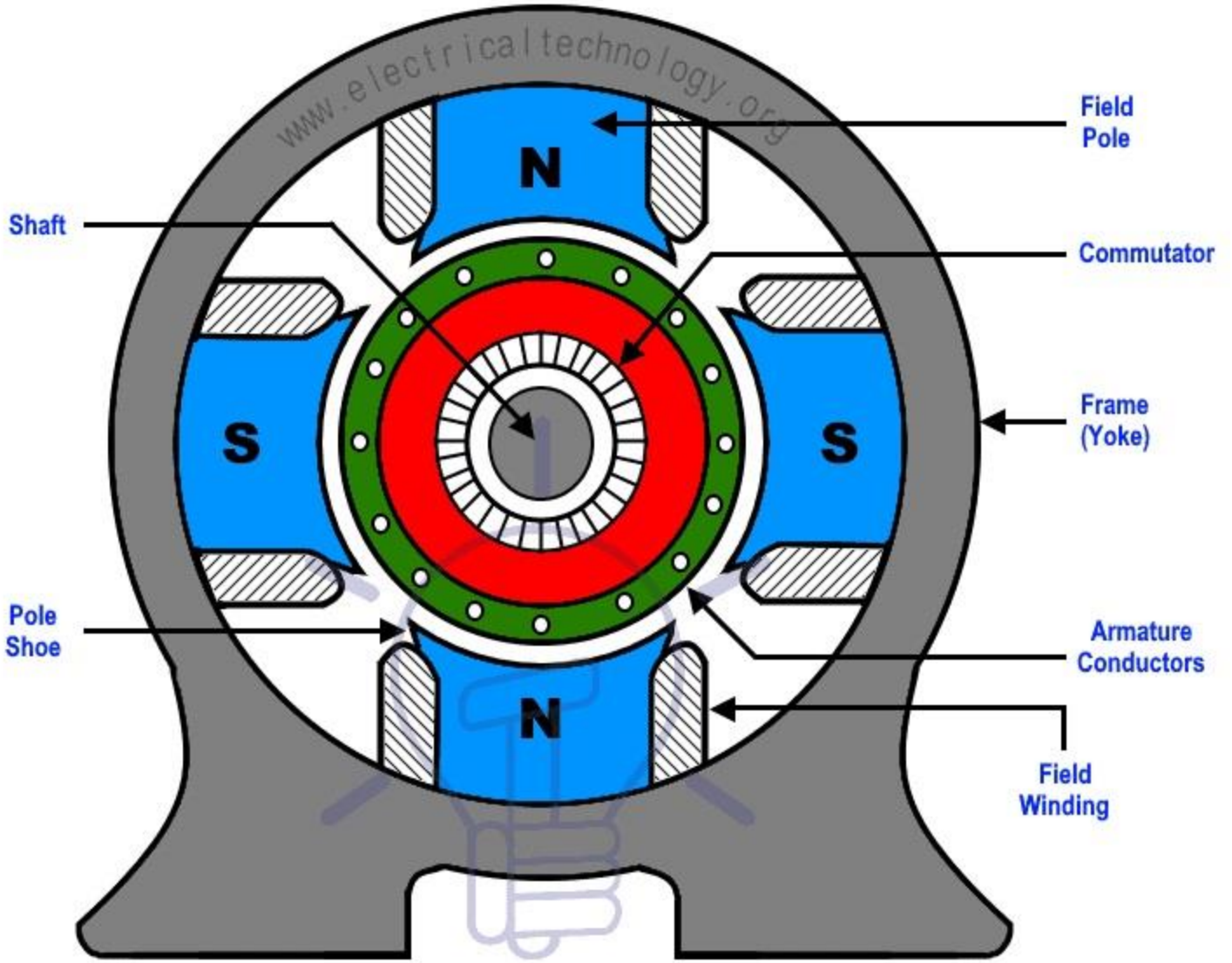


Working principle

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

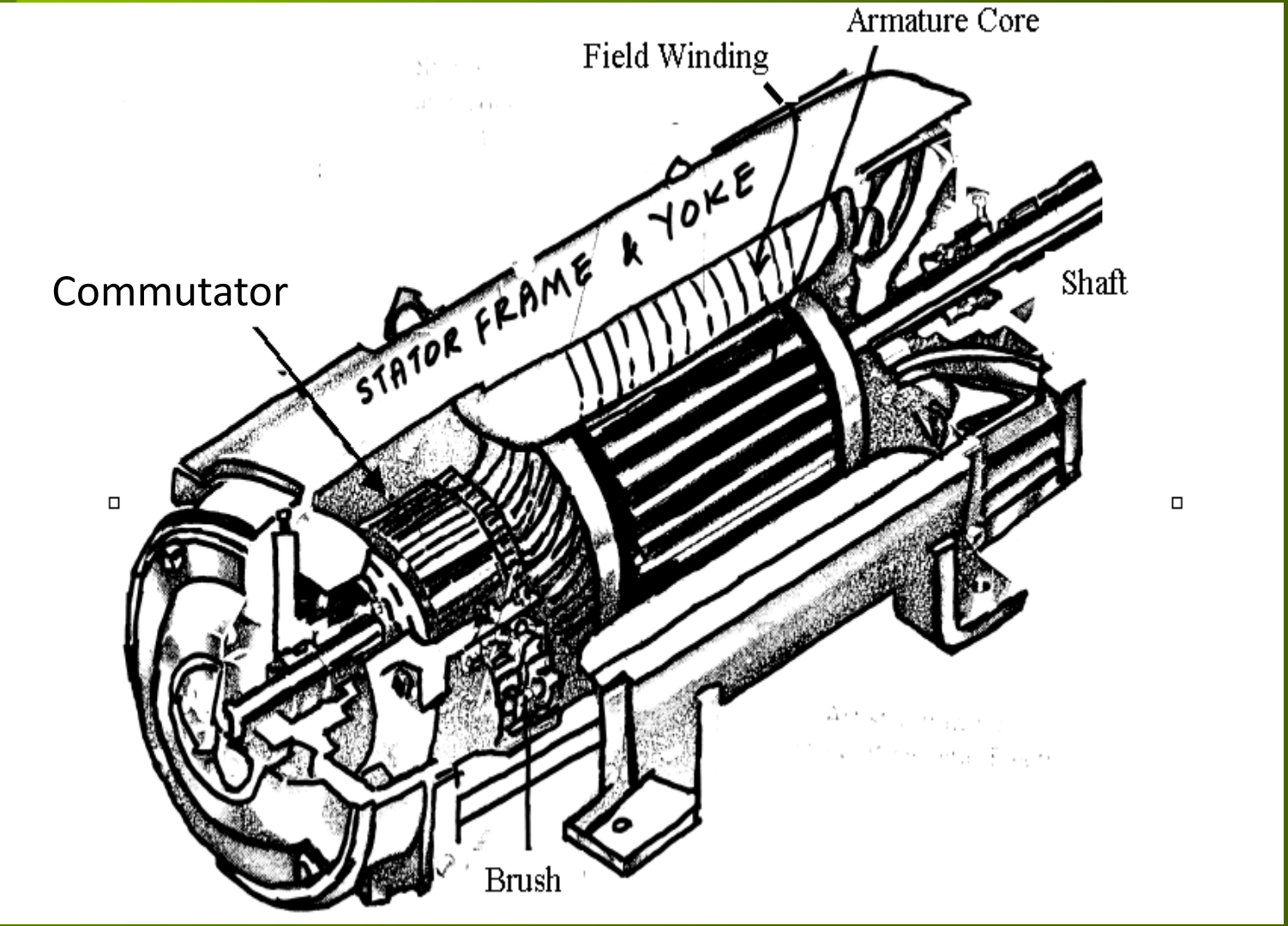
- Whenever a conductor is moved in the magnetic field , an emf is induced and the magnitude of the induced emf is directly proportional to the rate of change of flux linkage.

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

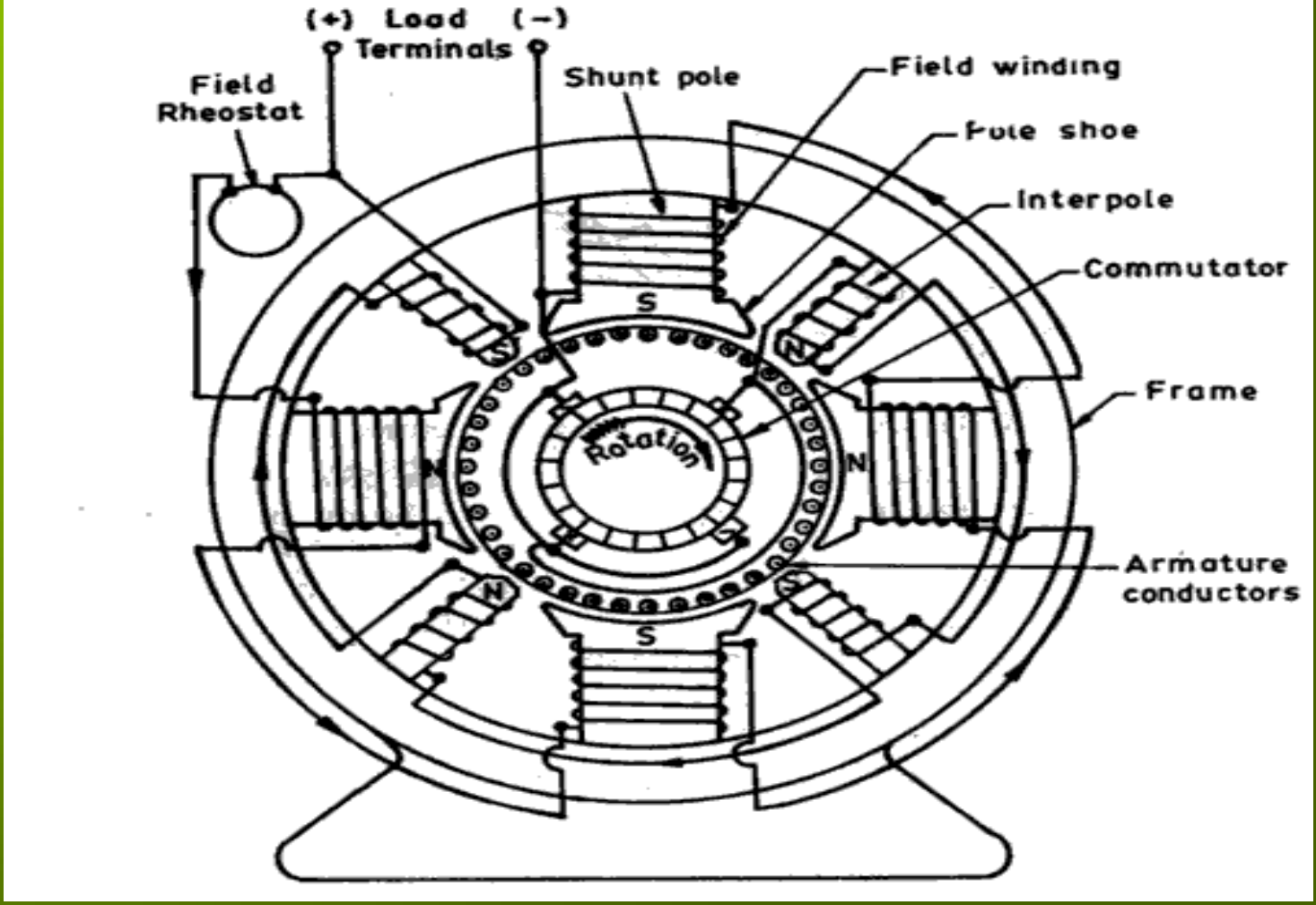


Parts of DC Machine

DC Machine

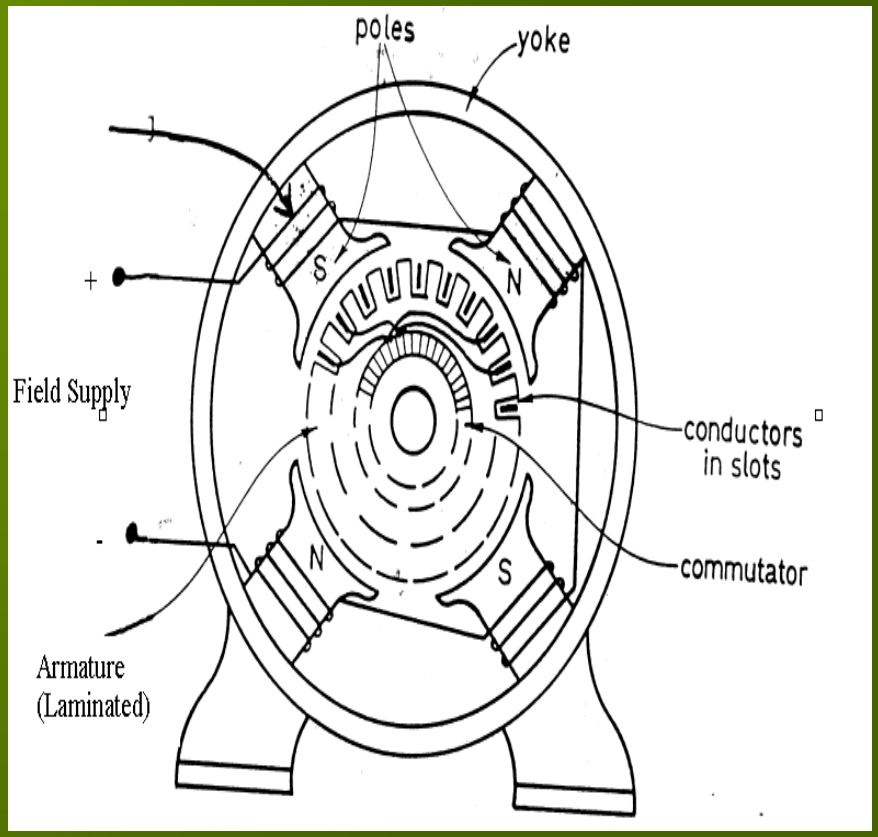


Sectional view of a DC machine

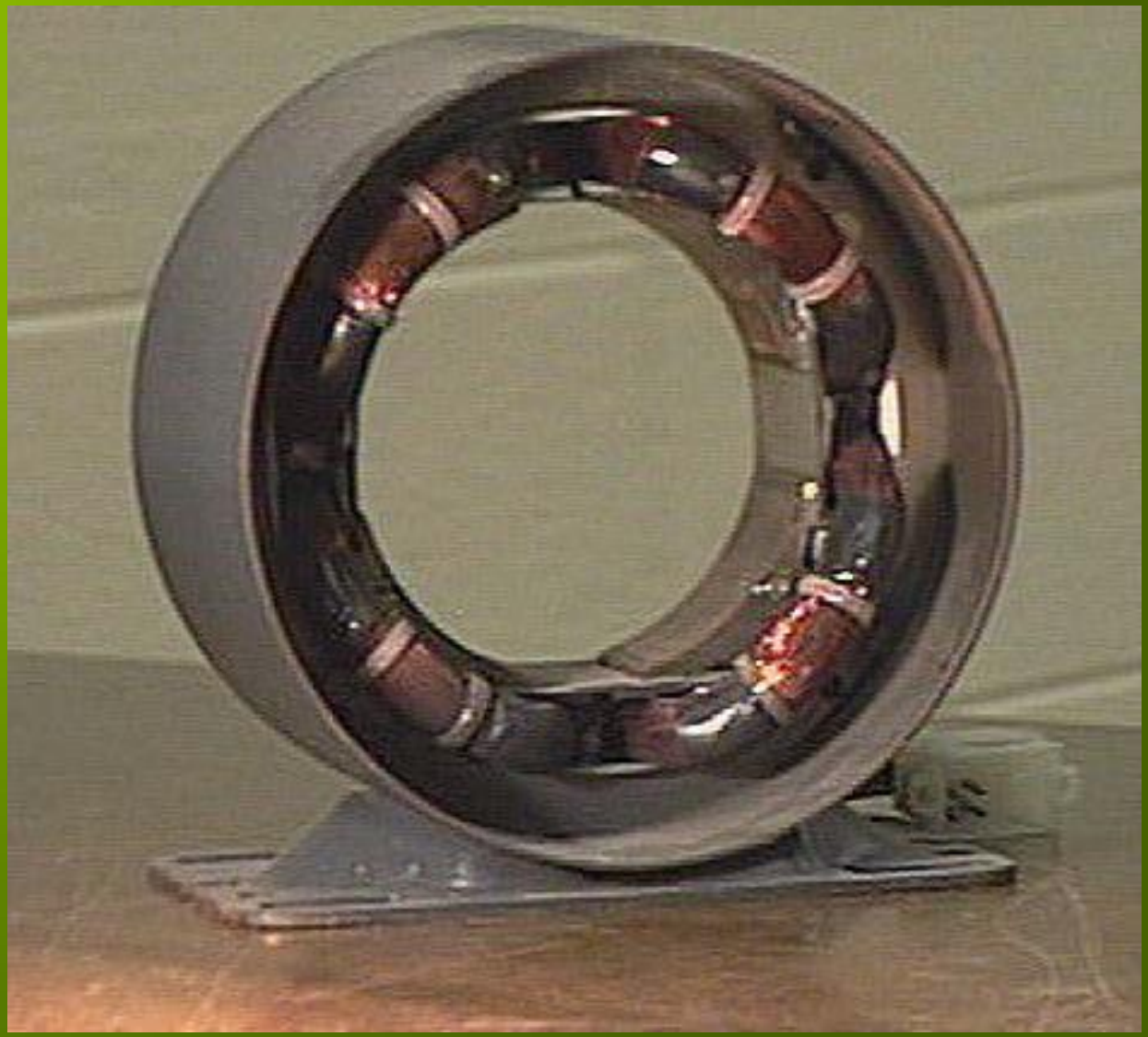


Construction of DC Generator

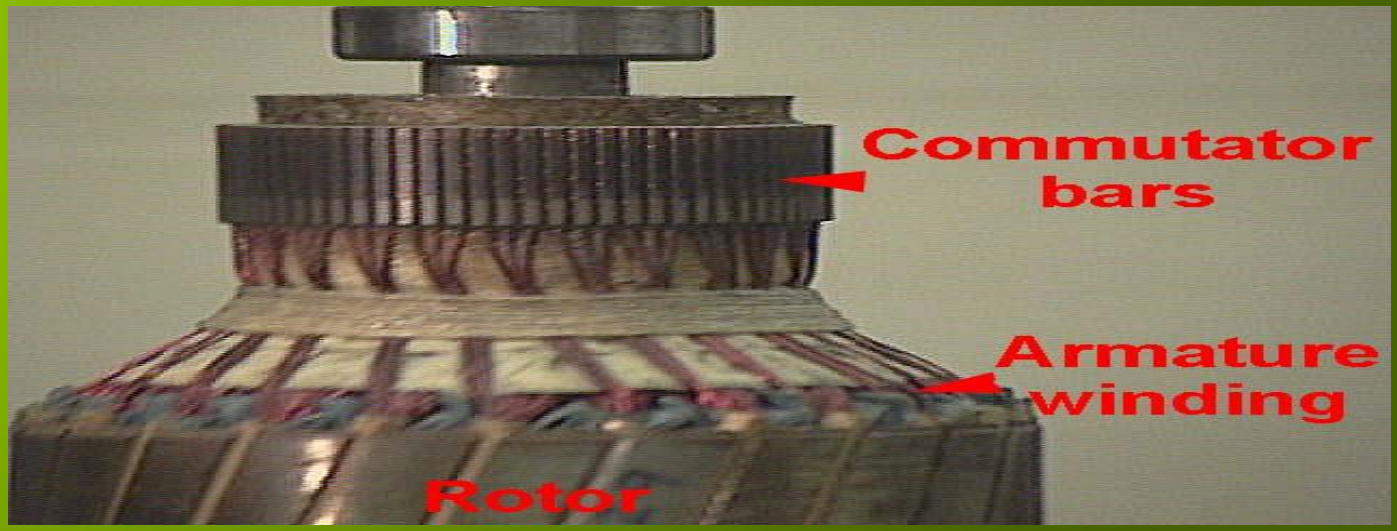
- Field system
- Armature core
- Armature winding
- Commutator
- Brushes

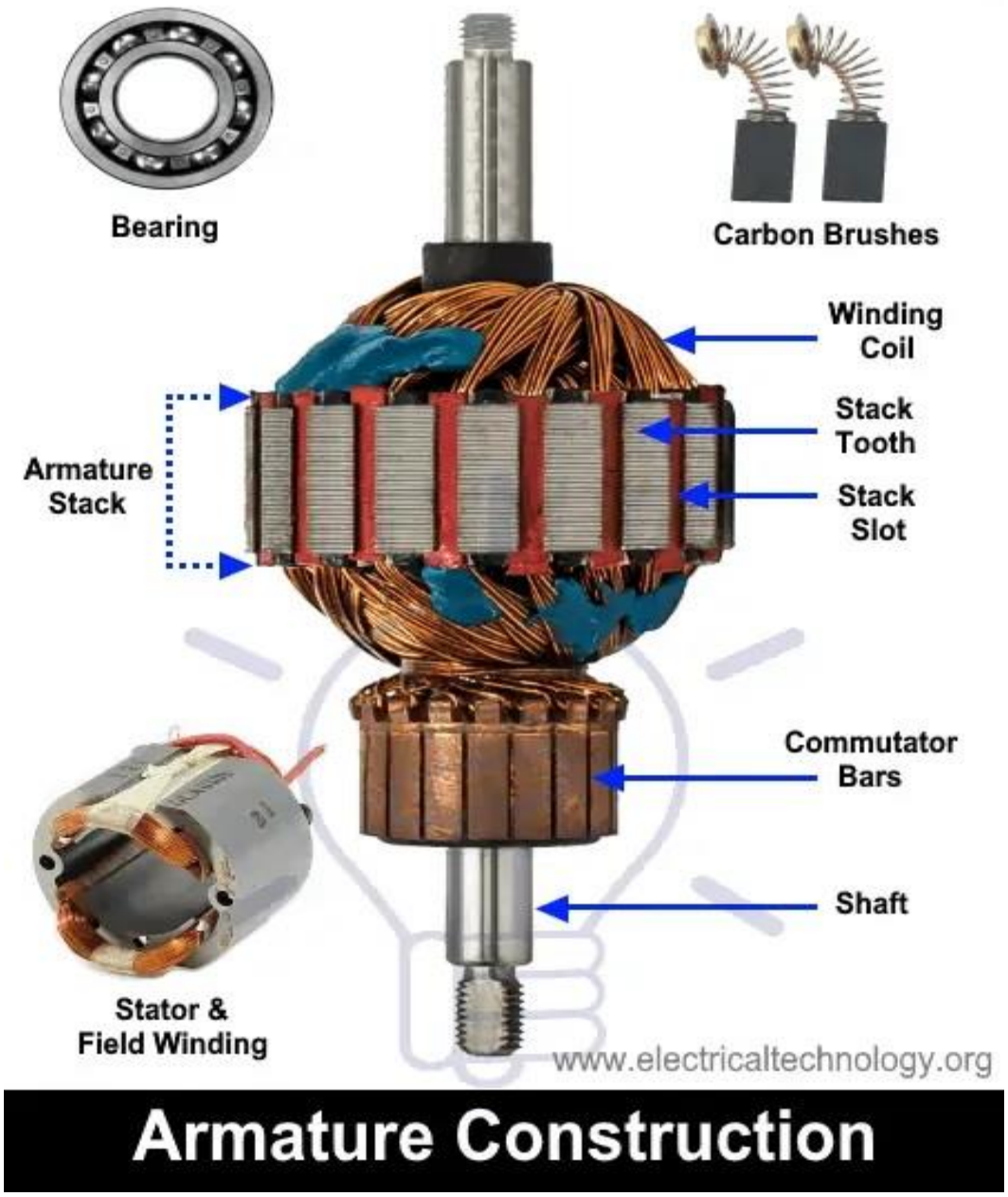


Field winding

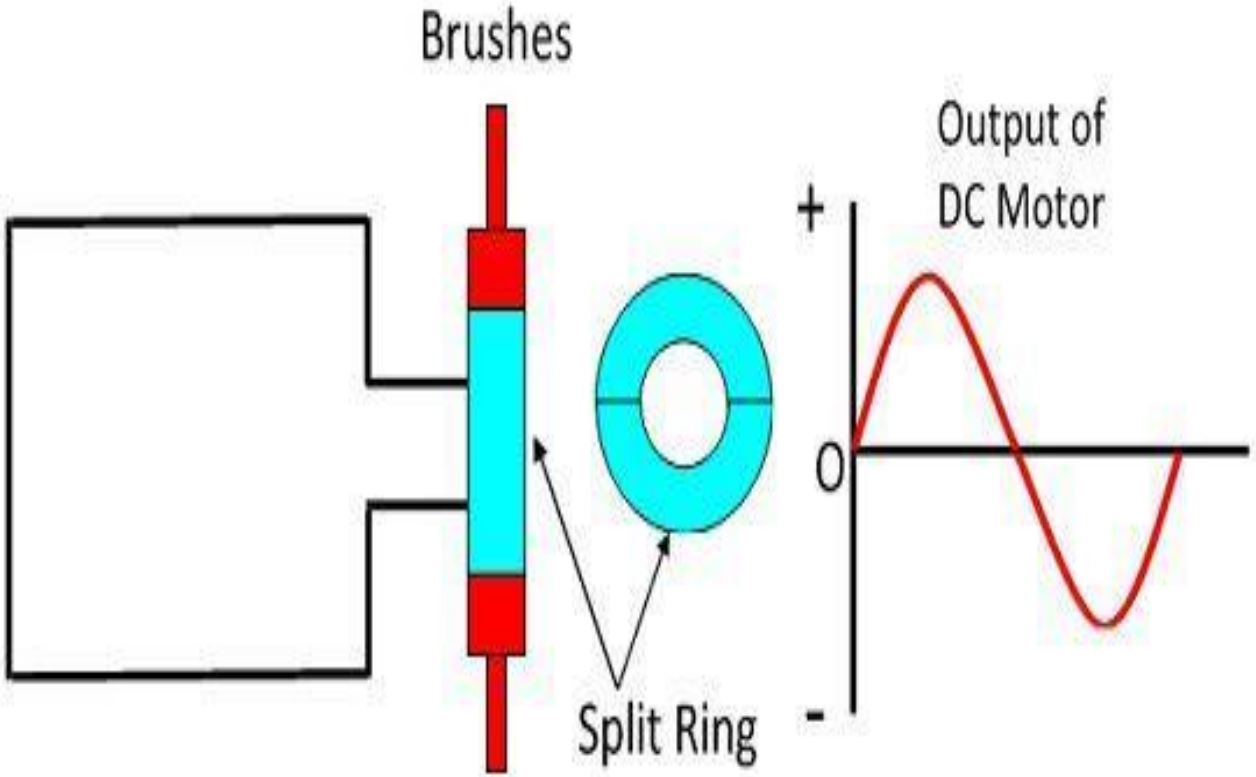


Rotor and rotor winding

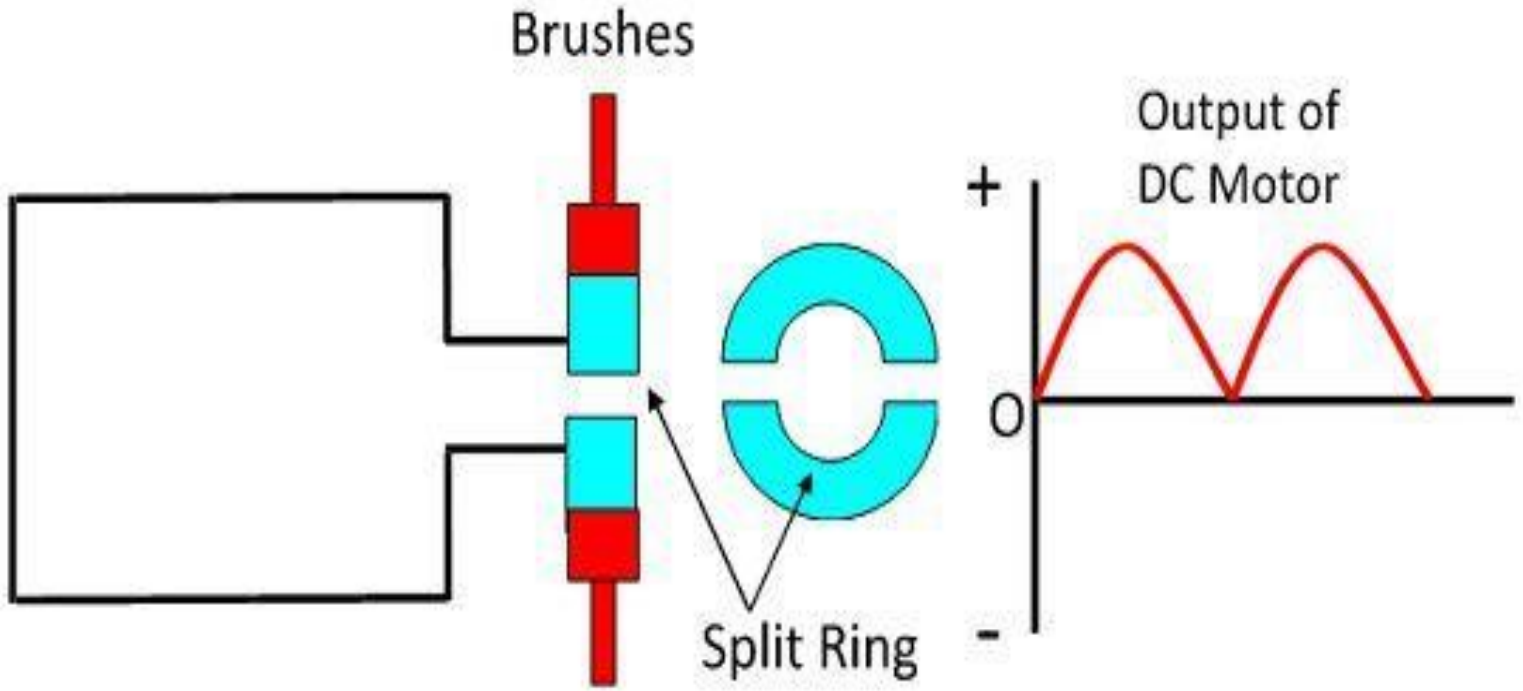




Armature Construction



AC with Slip Ring



DC with Split Ring Commutator

EMF equation

Let,

- Ø= flux per pole in weber
- Z = Total number of conductor
- P = Number of poles
- A = Number of parallel paths
- N =armature speed in rpm
- Eg = emf generated in any on of the parallel path

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

Eg = $P\phi NZ/60A$

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

Types of DC Generator

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

- Separately excited DC generator
- Self excited D C generator

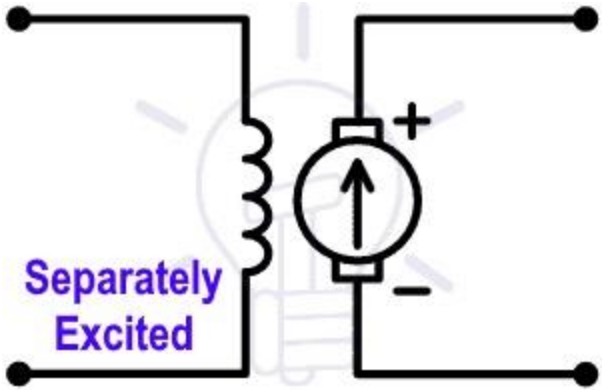
Further classification of DC Generator

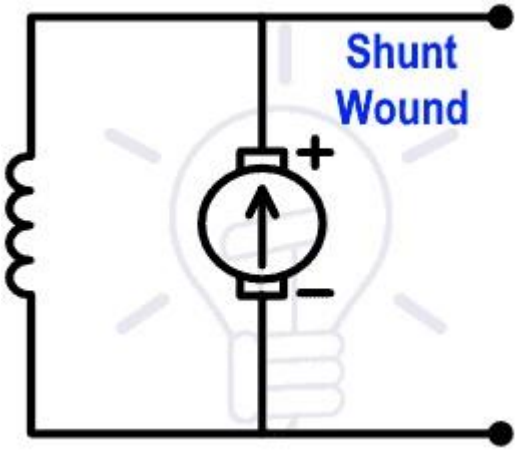
- Series wound generator
- Shunt wound generator
- Compound wound generator
  - Short shunt & Long shunt
  - Cumulatively compound

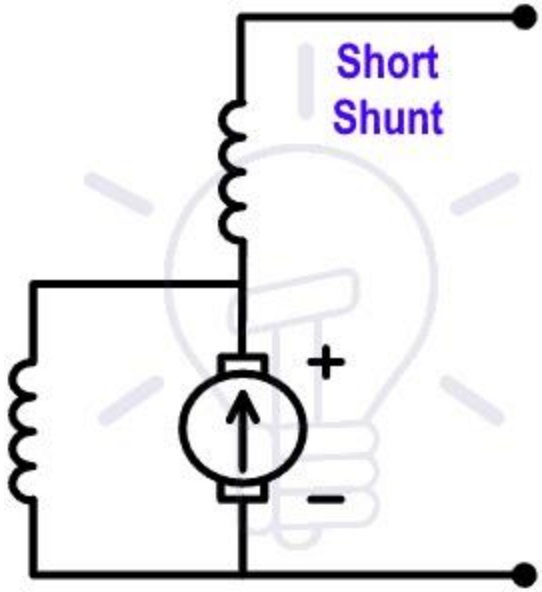
    &

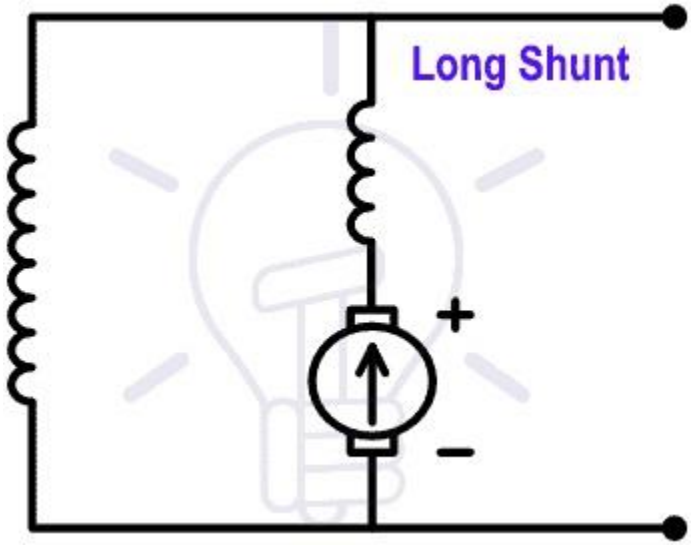
    Differentially compound

Classifications of DC Generator



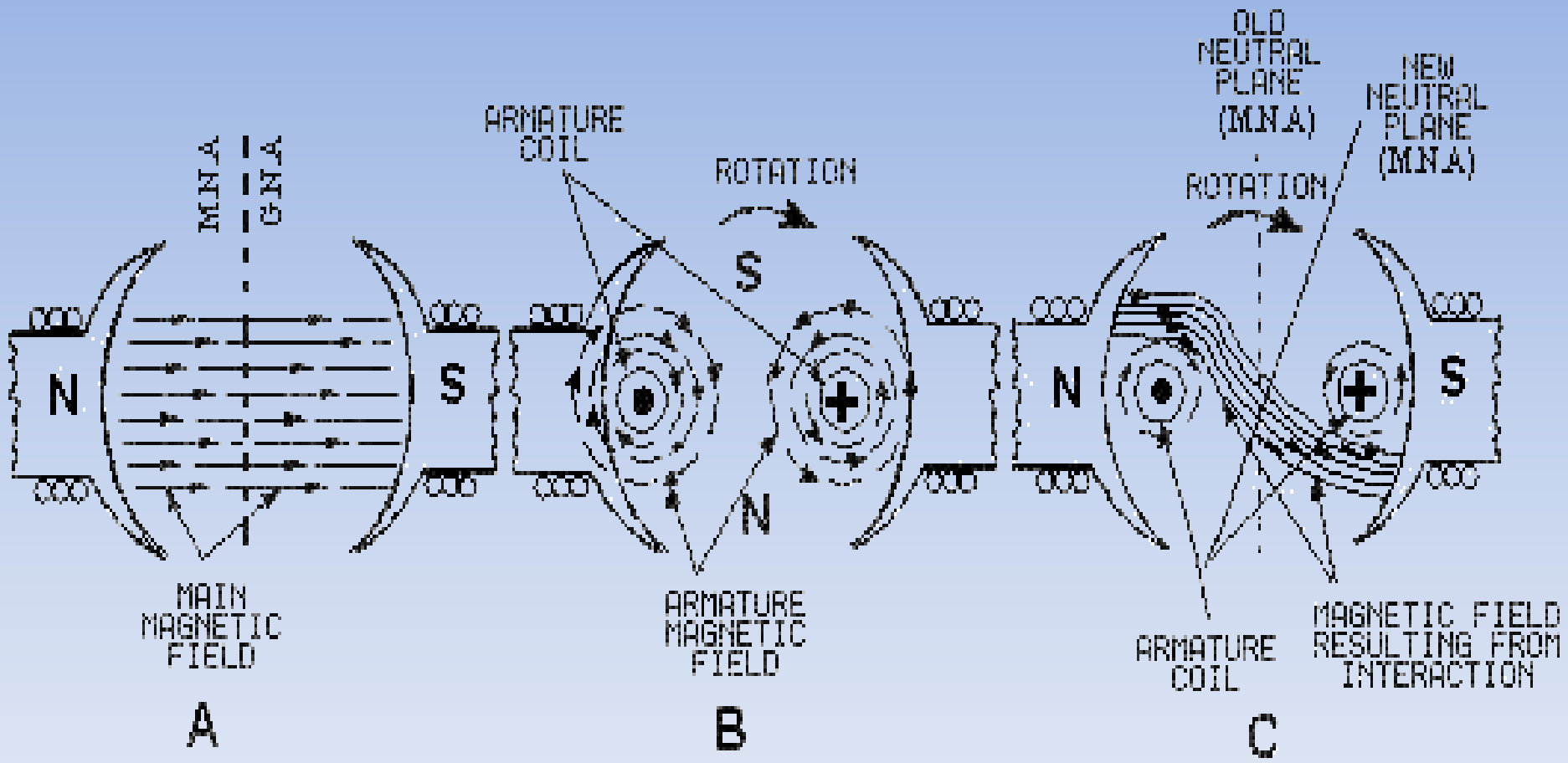






Armature Reaction

Interaction of Main field flux with Armature field flux



Effects of Armature Reaction

- It decreases the efficiency of the machine
- It produces sparking at the brushes
- It produces a demagnetising effect on the main poles
- It reduces the emf induced
- Self excited generators some times fail to build up emf

General terms used in Armature reaction

Magnetic neutral axis :

It is perpendicular to the lines of force between the two opposite adjacent poles.

Leading pole Tip (LPT) :

It is the end of the pole which first comes in contact with the armature.

Trailing pole tip :

It is the end of the pole which comes in contact later with the armature.

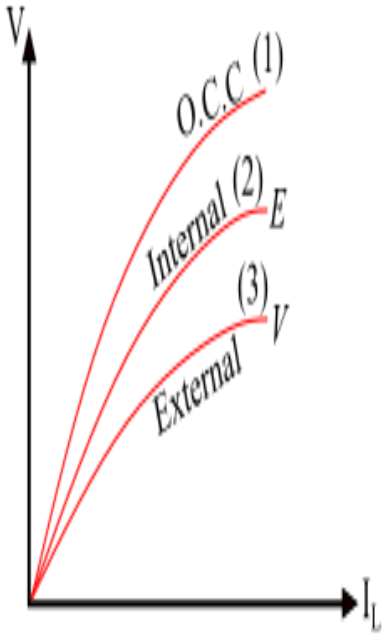
Armature reaction remedies

1. Brushes must be shifted to the new position of the MNA
2. Extra turns in the field winding
3. Slots are made on the tips to increase the reluctance
4. The laminated cores of the shoe are staggered
5. In big machines the compensating winding at pole shoes produces a flux which just opposes the armature mmf flux automatically.

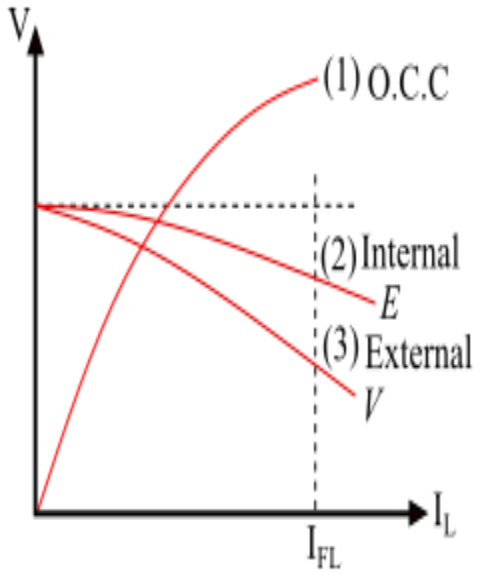
Characteristics

- No load saturation characteristic (Eo/If) : Open Circuit Characteristics or Magnetization Curve
- Internal or Total characteristic (E/ Ia)
- External characteristic (V/I)

Characteristics

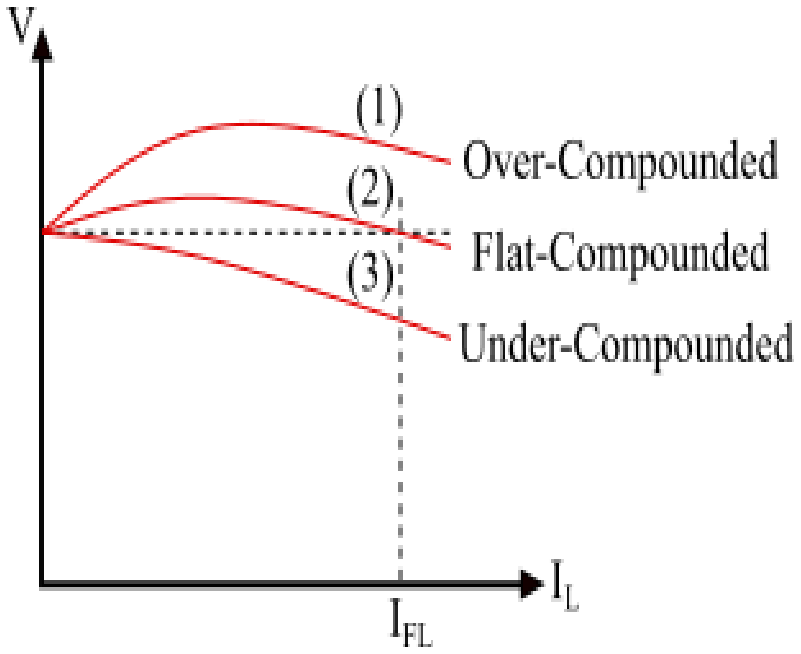


DC Series Generator



DC Shunt Generator

Characteristics



DC Compound Generator

Critical field resistance

For appreciable generation of emf, the field resistance must be always less certain resistance, that resistance is called as the critical resistance of the machine .

Commutation

The change in direction of current takes place when the conductors are along the brush axis .

During this reverse process brushes short circuit that coil and undergone commutation

Due to this sparking is produced and the brushes will be damaged and also causes voltage dropping.

Losses in DC Generators

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

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

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

Hysteresis loss 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

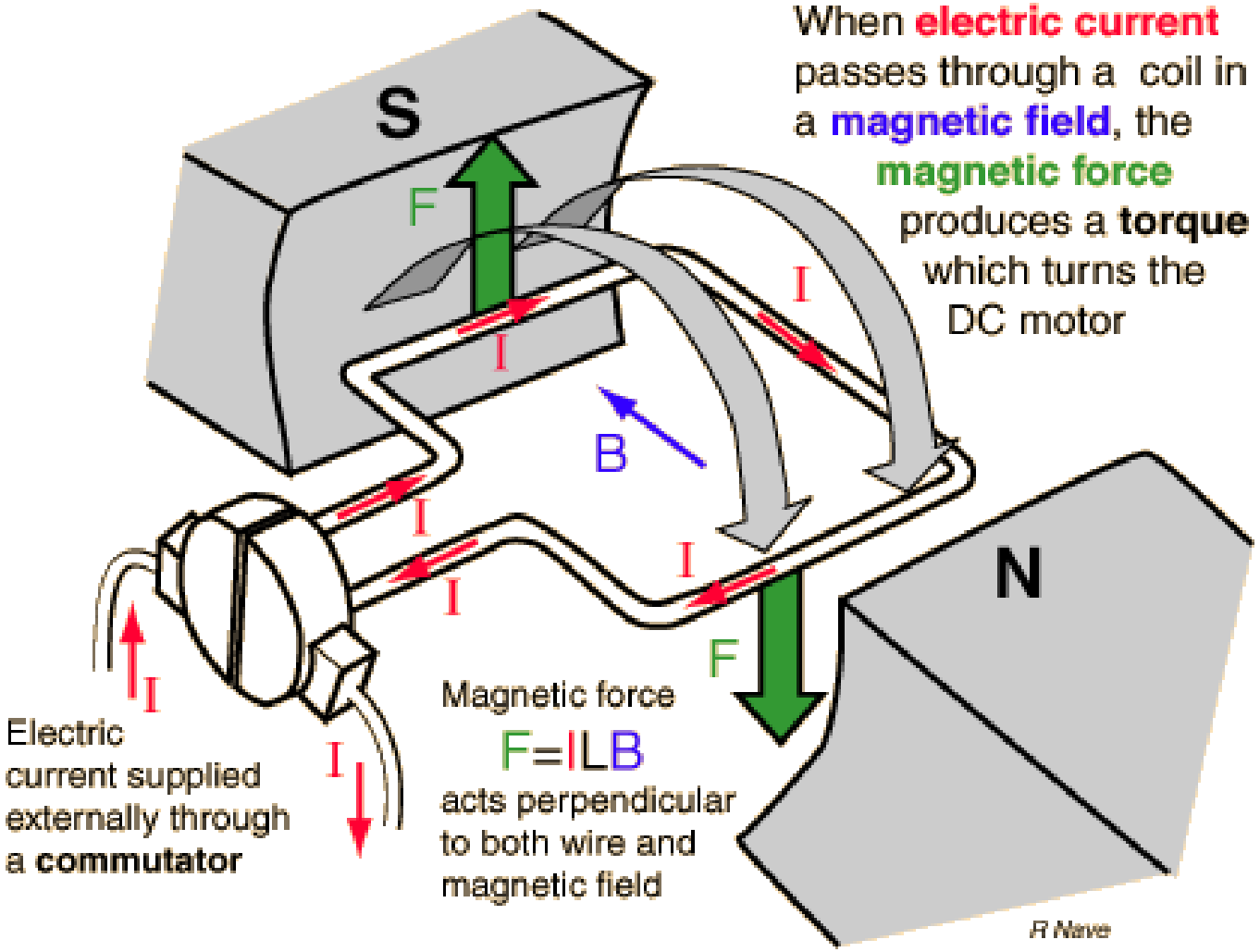
c. as exciters for AC generators.

Series Generators :

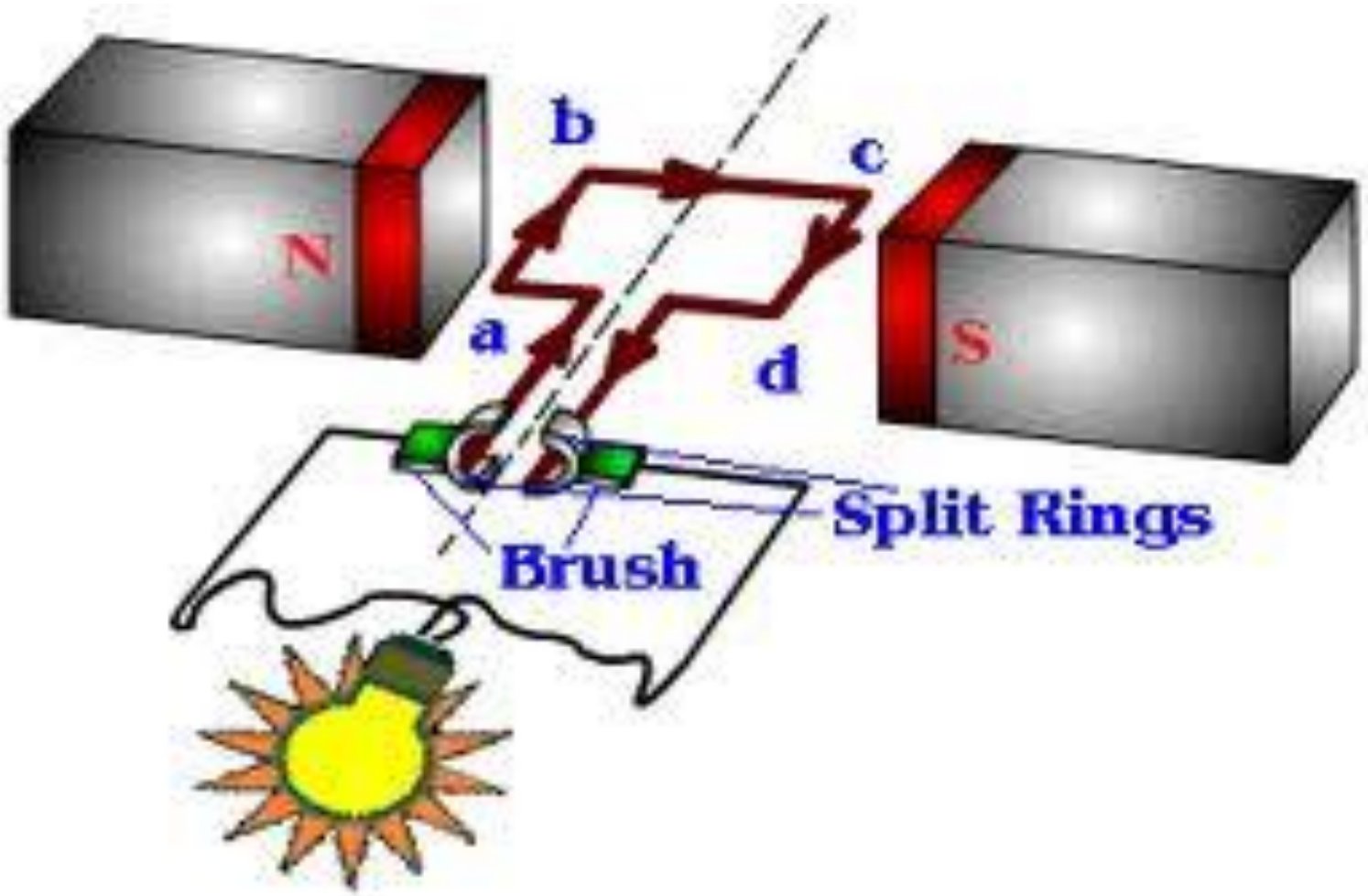
A. As boosters

B. As lighting arc lamps

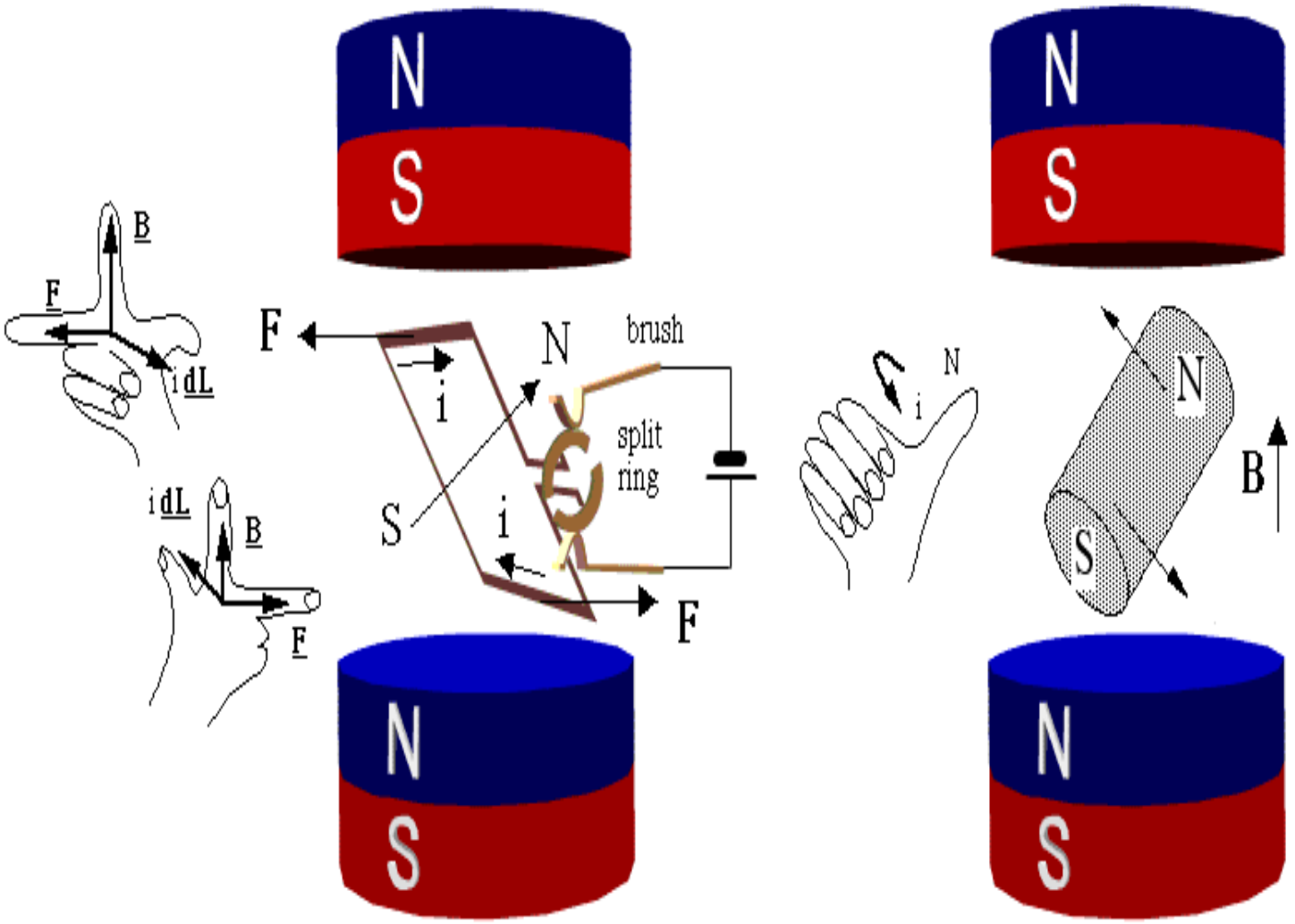
Working principle of DC motor



Working principle of DC Generator



Force in DC motor



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 .

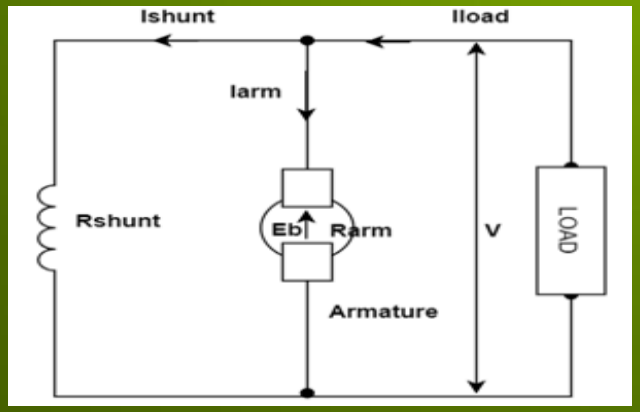
According to the Lenz's law, the direction of the induced emf is always so as to oppose the cause producing it .

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

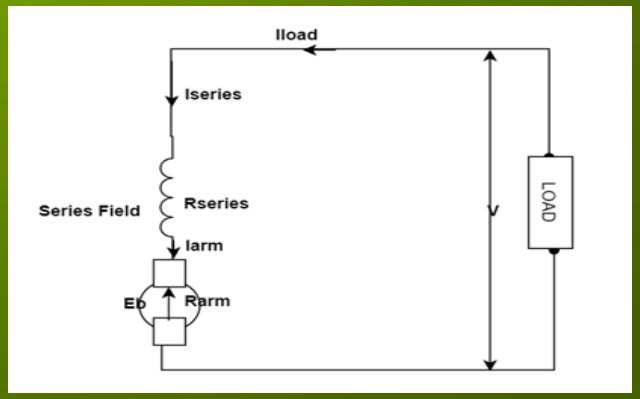
Classification of DC motors

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

- Shunt motor



Series motor



- Compound motor
  - Differential compound
  - Cumulative compound

Comparison

Type	DC Series Motor	DC Shunt Motor
Features	Variable speed and initial torque value will be high	Approximately constant speed value and initial torque value will be medium up to the range of 1.5 F.L.
Applications	Blowers/fans, machine components, centrifugal type of pumps, lathes and in reciprocating pumps	These are mostly implemented for traction work means for a trolley, conveyors, cars, rapid transit machines, and electric locomotive systems.

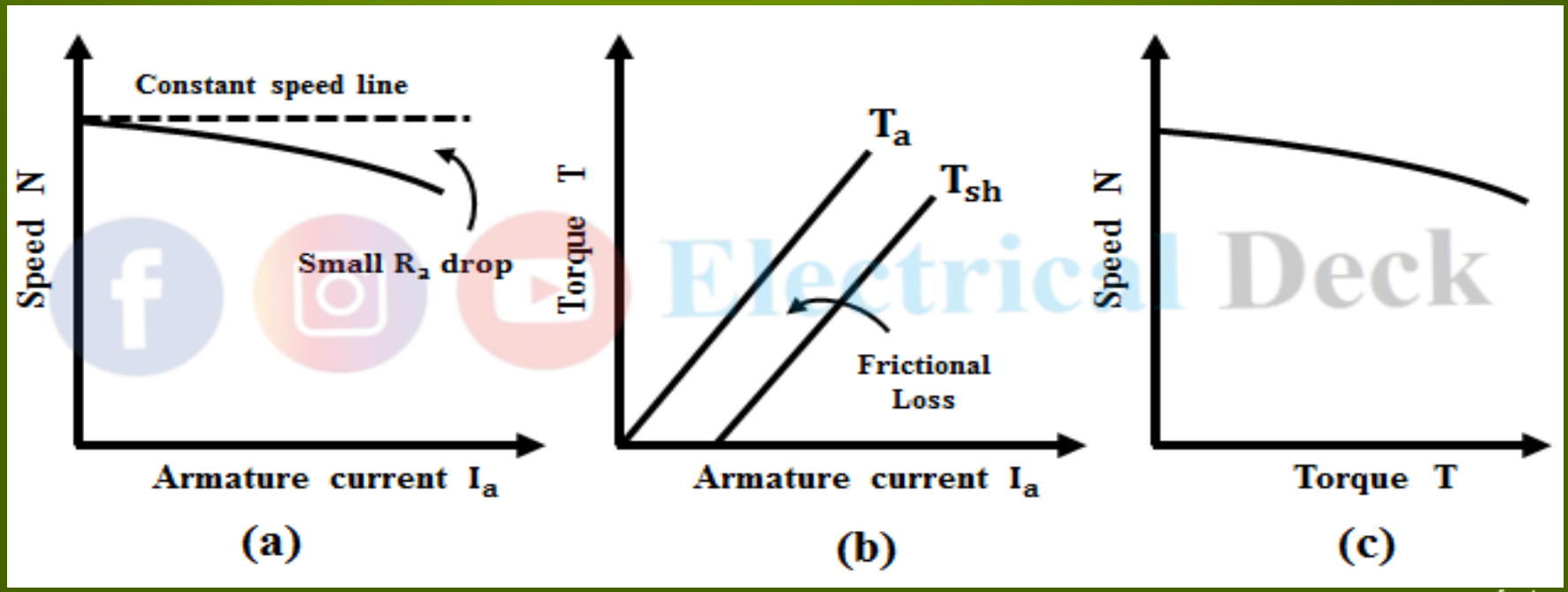
Torque

The turning or twisting force about an axis is called torque .

- $P = T * 2 \pi N / 60$
- $Eb\ Ia = Ta * 2 \pi N / 60$
- $T \propto \phi\ I\ a$
- $Ta \propto I2a$

Characteristic of DC motors

- T/ Ia characteristic
- N/ I a characteristic
- N/T characteristic



Speed control of DC motors

According to the speed equation of a dc motor

$$N \propto Eb/\phi$$

$$\propto V - Ia\,Ra/\phi$$

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

<u>Potential divider control :</u>

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 .

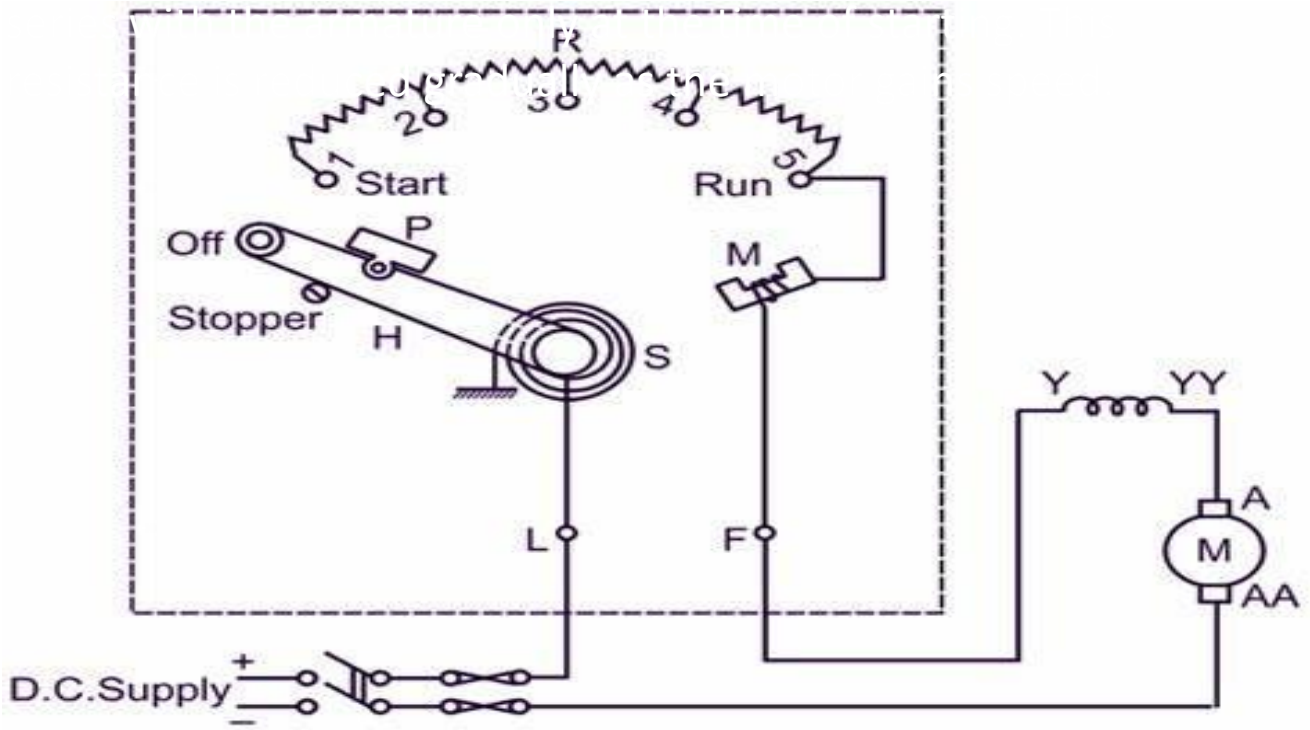
Starters for DC motors

While starting a DC motor huge amount of current can be driven to the windings due to the absence of the back emf. The current may rise about 4-6 times higher than the rated load current of the winding wire. So, it can damage the winding of the motor at the starting itself. To prevent such high current rush, starters are used in DC motors.

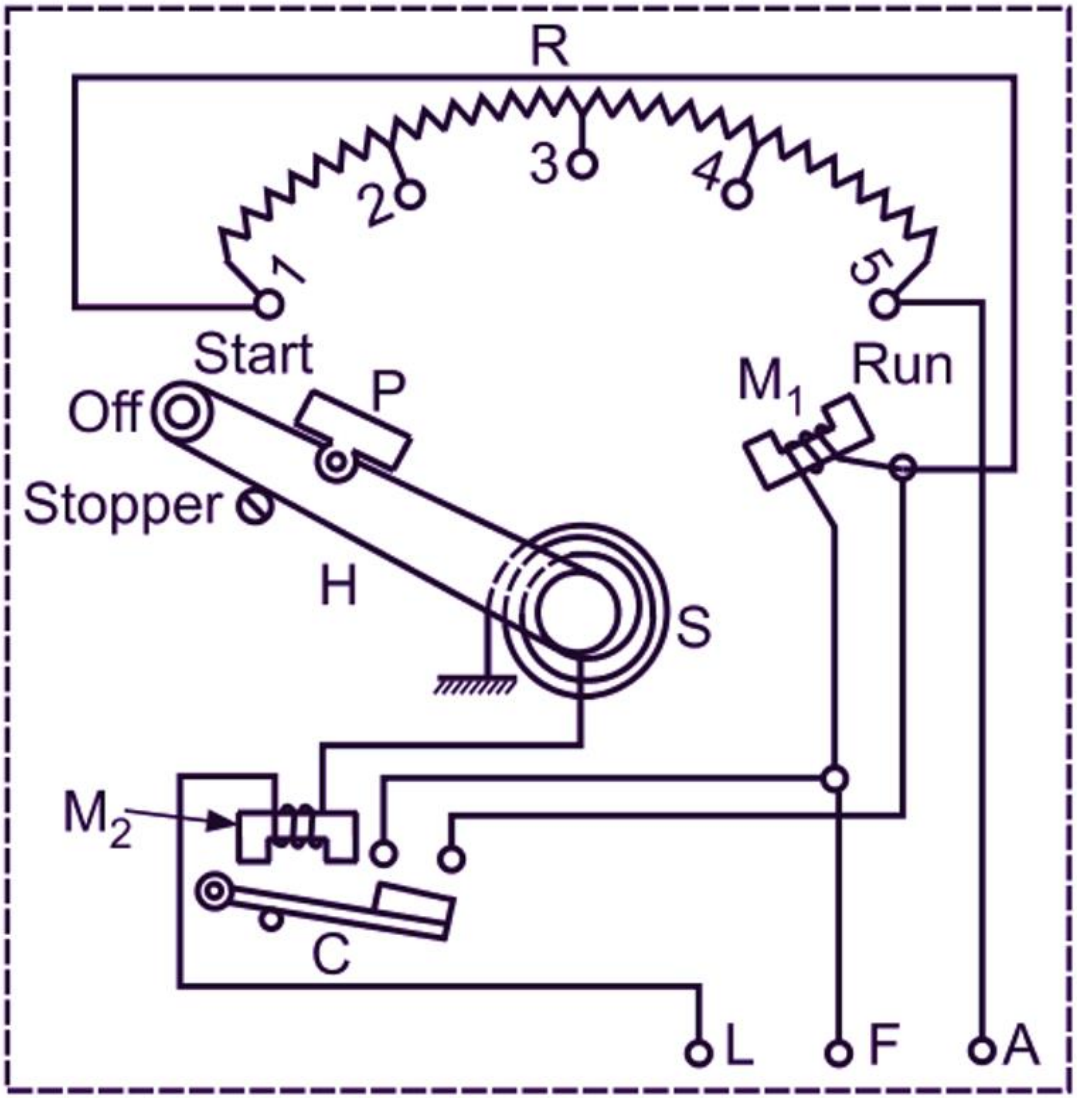
1. Two point starter
2. Three point starter
3. Four point starter

Two point starter

The basic function of a two point starter is to **protect DC series motor from high starting current**. It does so by limiting the high starting armature current to a safe value by connecting a resistance in series with the armature only at the time of starting. This resistance is reduced gradually as the motor gains speed .
basic function of a two point starter is to **protect DC series motor from high starting current**. It

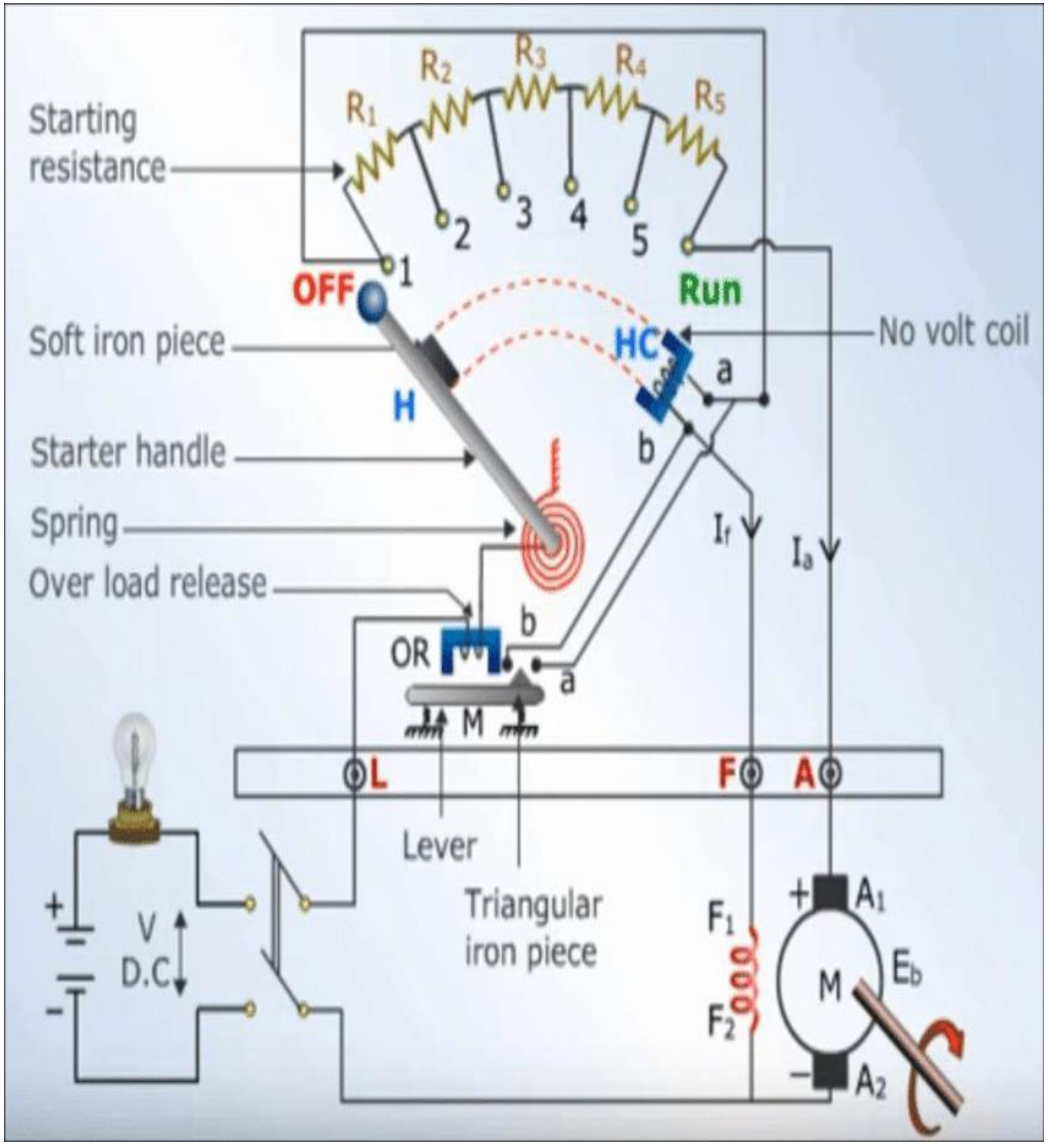


Three point starter



3 Point Starter is a device whose main function is starting and maintaining the speed of the DC shunt motor. The 3 point starter connects the resistance in series with the circuit which reduces the high starting current and hence protects the machines from damage.

Four Point point starter



A **4** point starter protects the armature of a DC shunt motor or compound wound DC motor against the initially high starting current of the DC motor. The 4 point starter has a lot of constructional and functional similarity to a 3 point starter, but this special device has an additional point and coil in its construction (as the name suggests). This brings about some difference in its functionality, though the basic operational characteristic remains the same.

Testing of DC machines

To determine the efficiency of as DC motor , the output and input should be known.

There are two methods.

- The load test or The direct method
- The indirect method

Direct method: In this method , the efficiency is determined by knowing the input and output power of the motor.

Indirect method: Swinburne's test is an indirect method of testing DC shunt machines to predetermine the efficency , as a motor and as a Generator. In this method, efficiency is calculated by determining the losses .