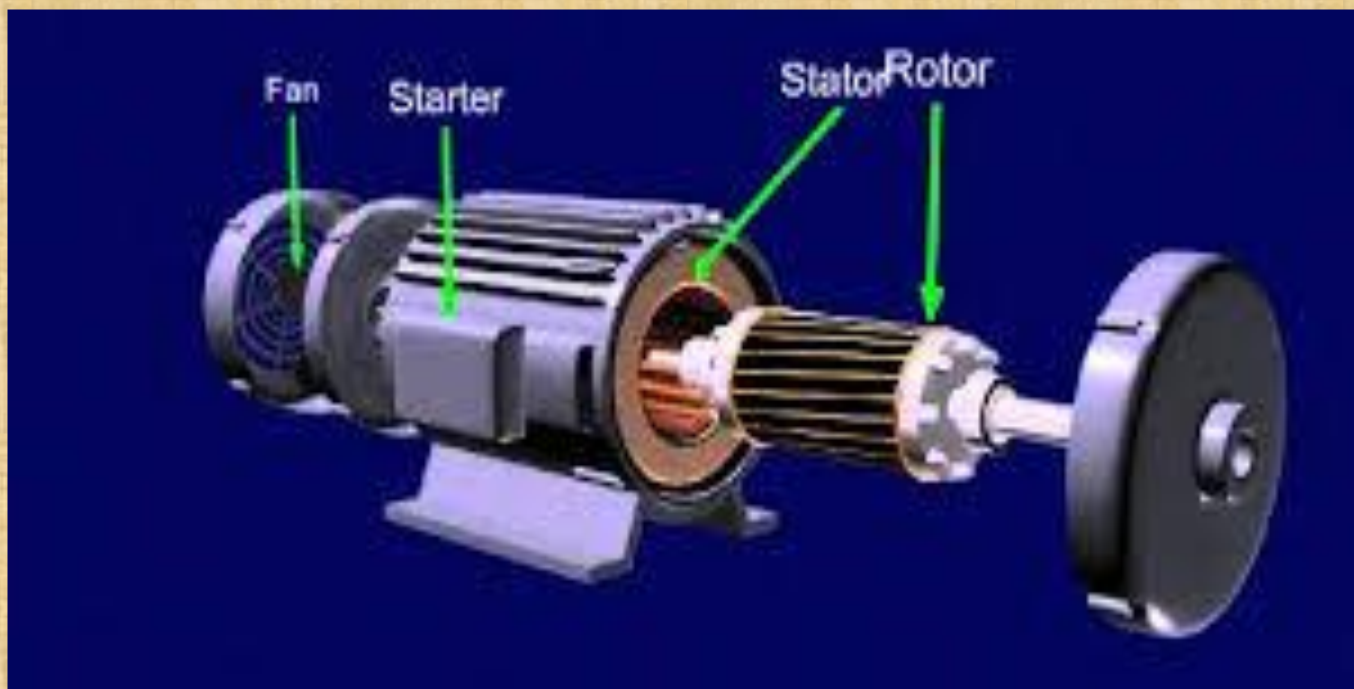
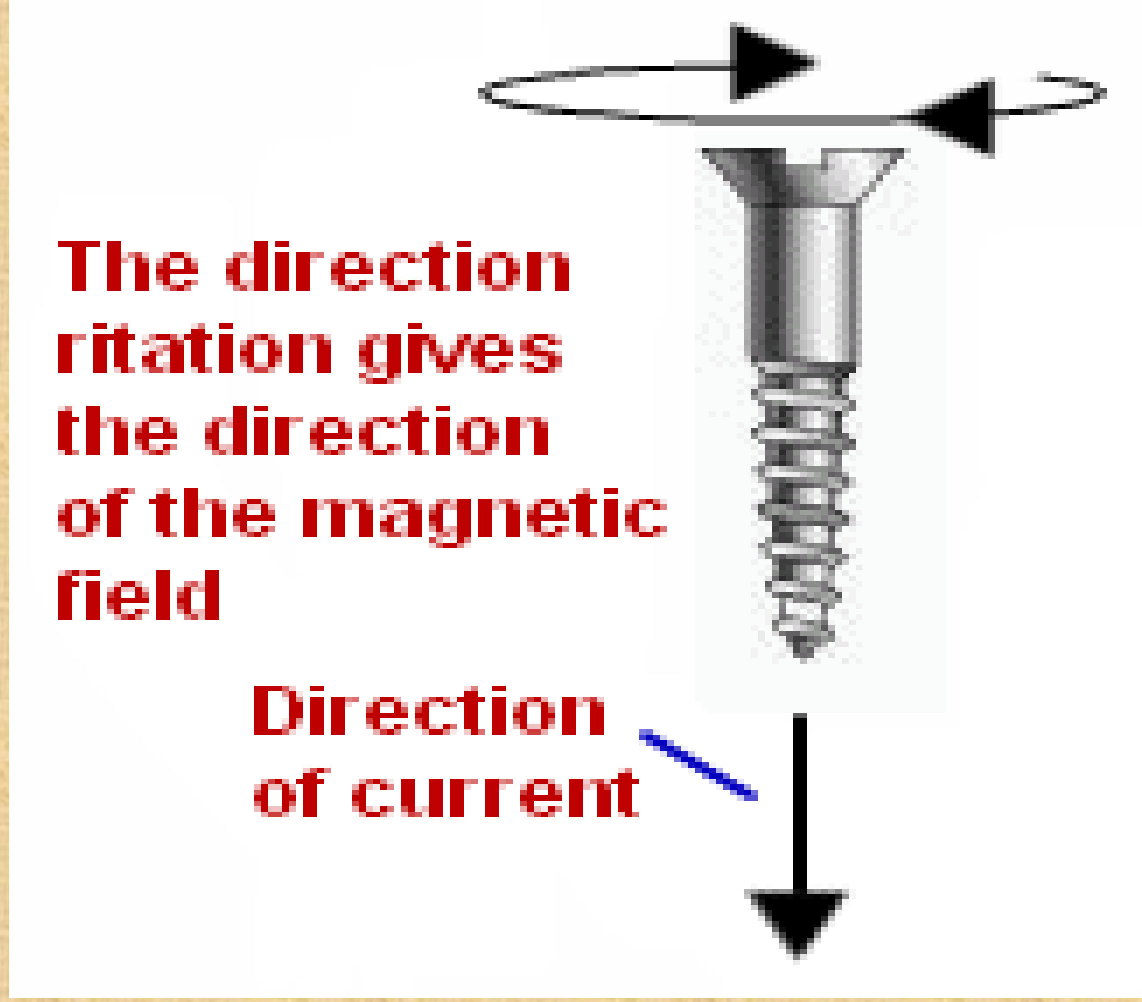
DC MACHINES



Prof. Subash Ranjan Kabat

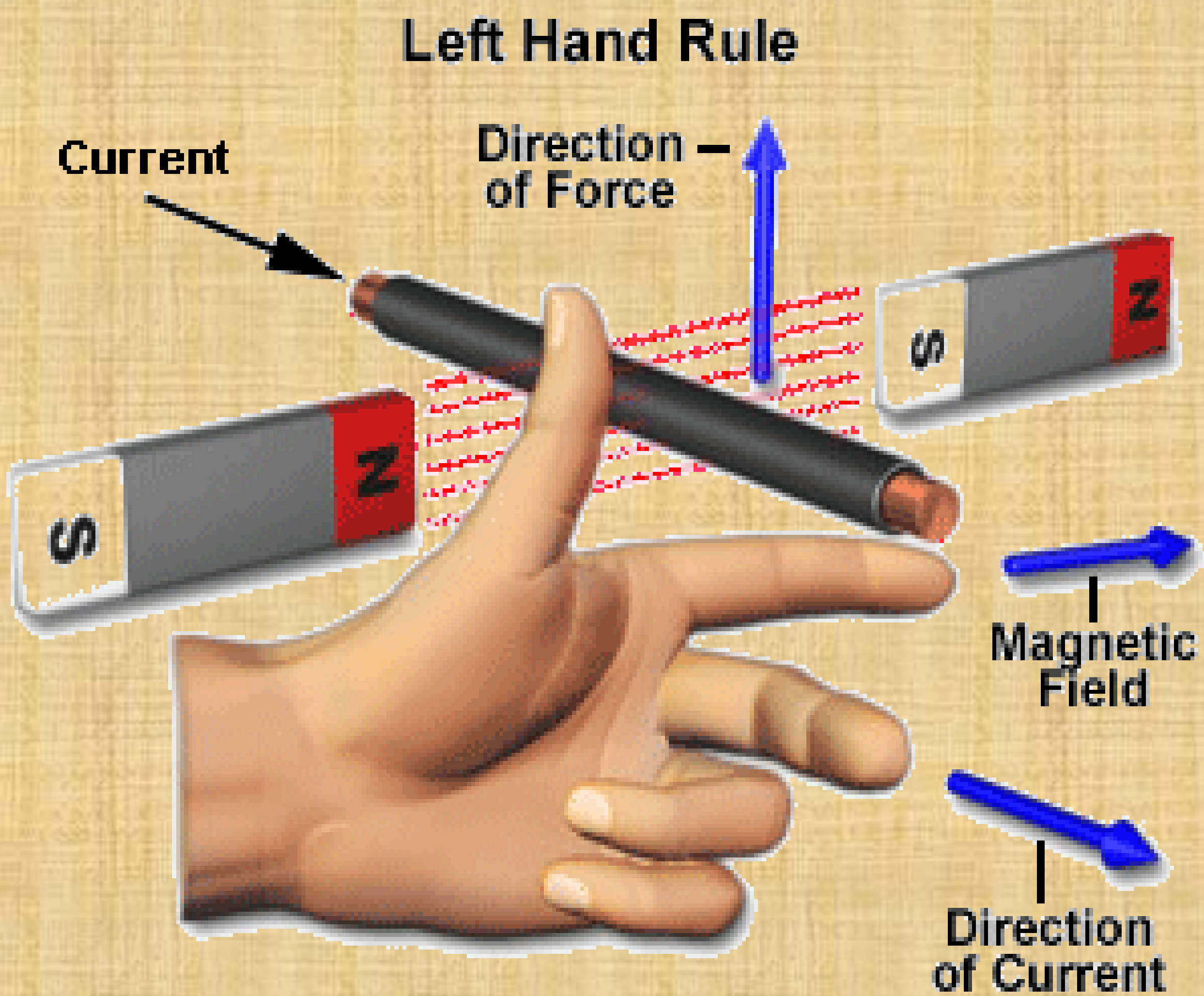
Maxwell's Cork screw Rule :



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

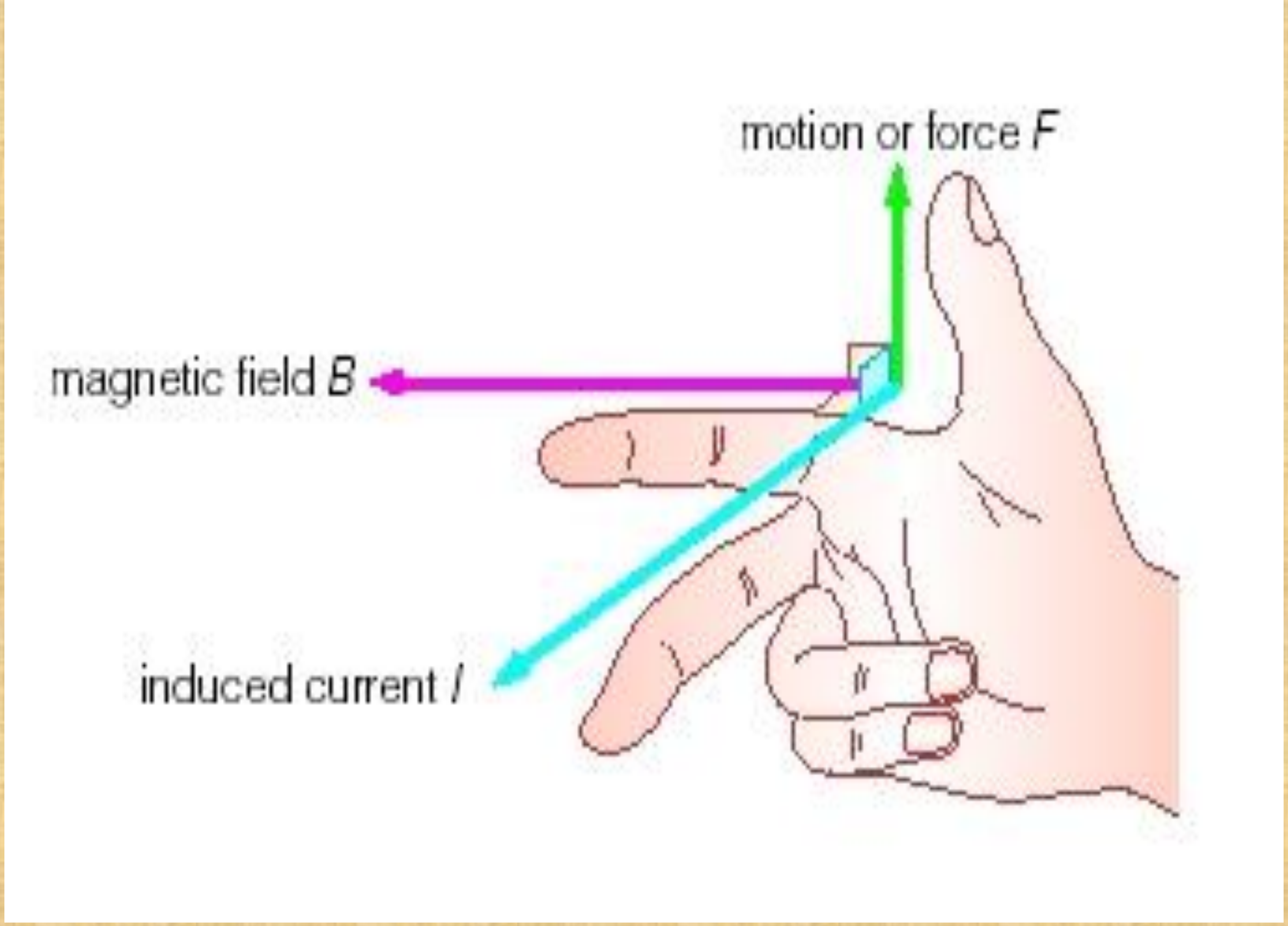


Fleming's left hand rule

- 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

Len'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 .

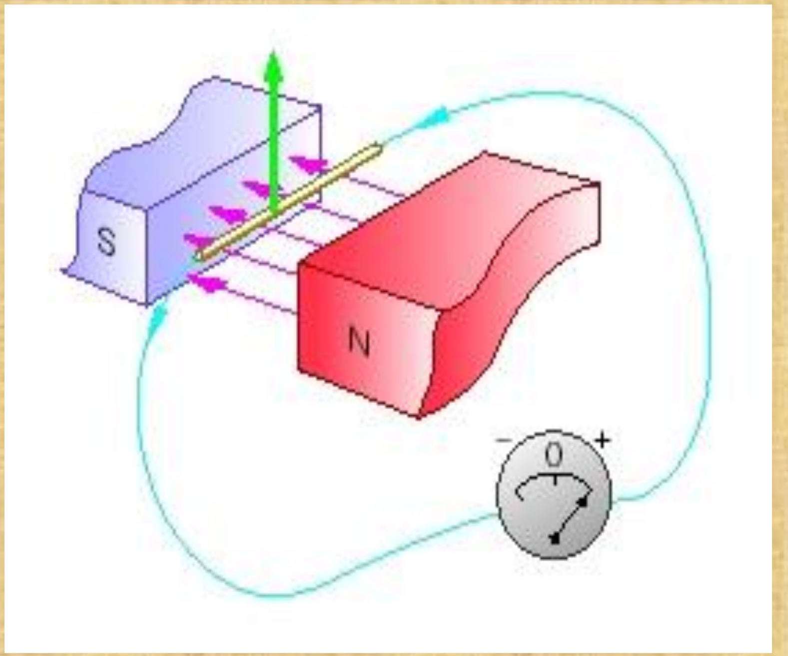
- $$e = -N\,(d\varnothing/dt)\ \text{volts}$$

DC Generator

Mechanical energy is converted to electrical energy

Three requirements are essential

1. Conductors
2. Magnetic field
3. Mechanical energy



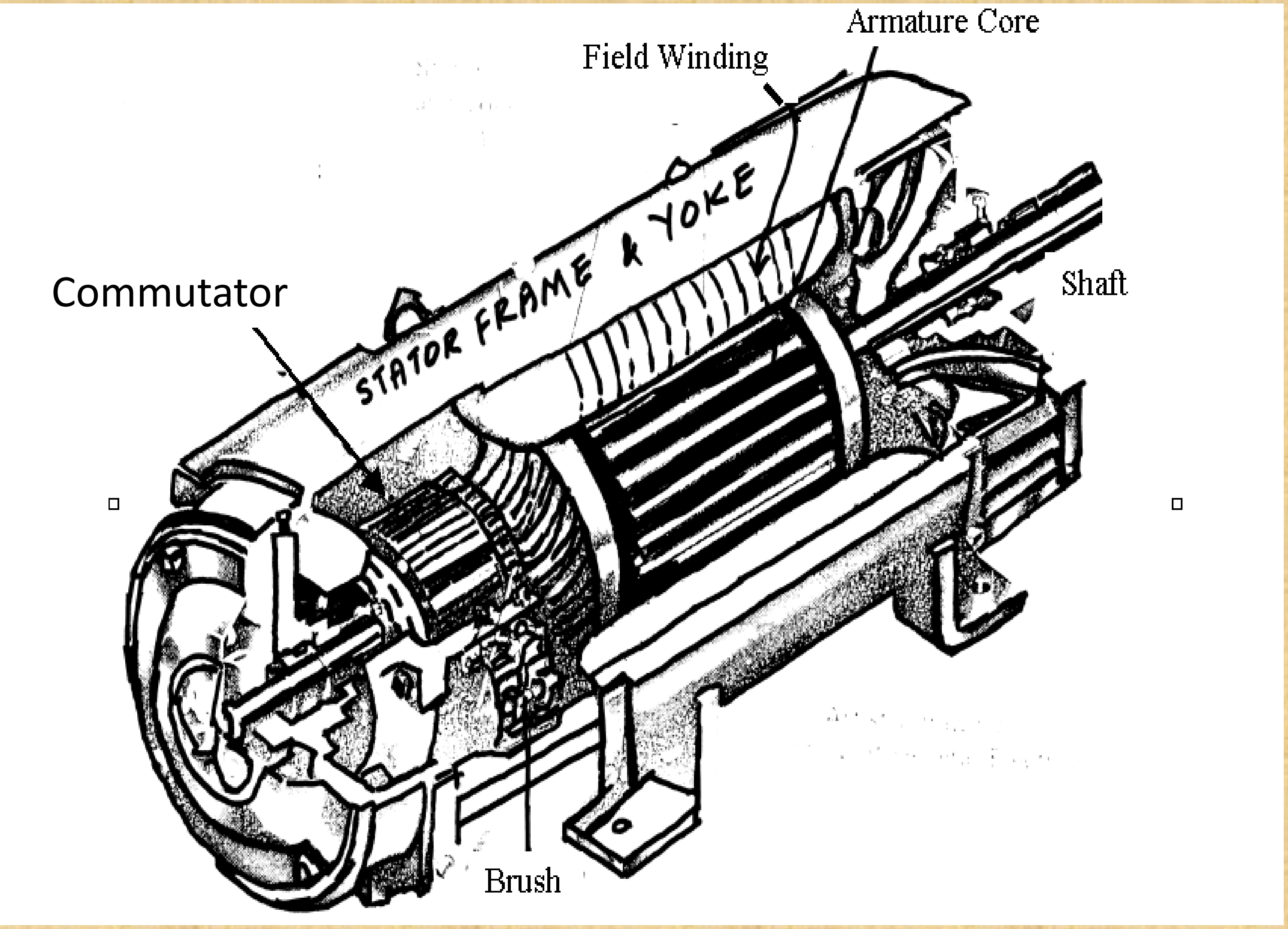
Working principle

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

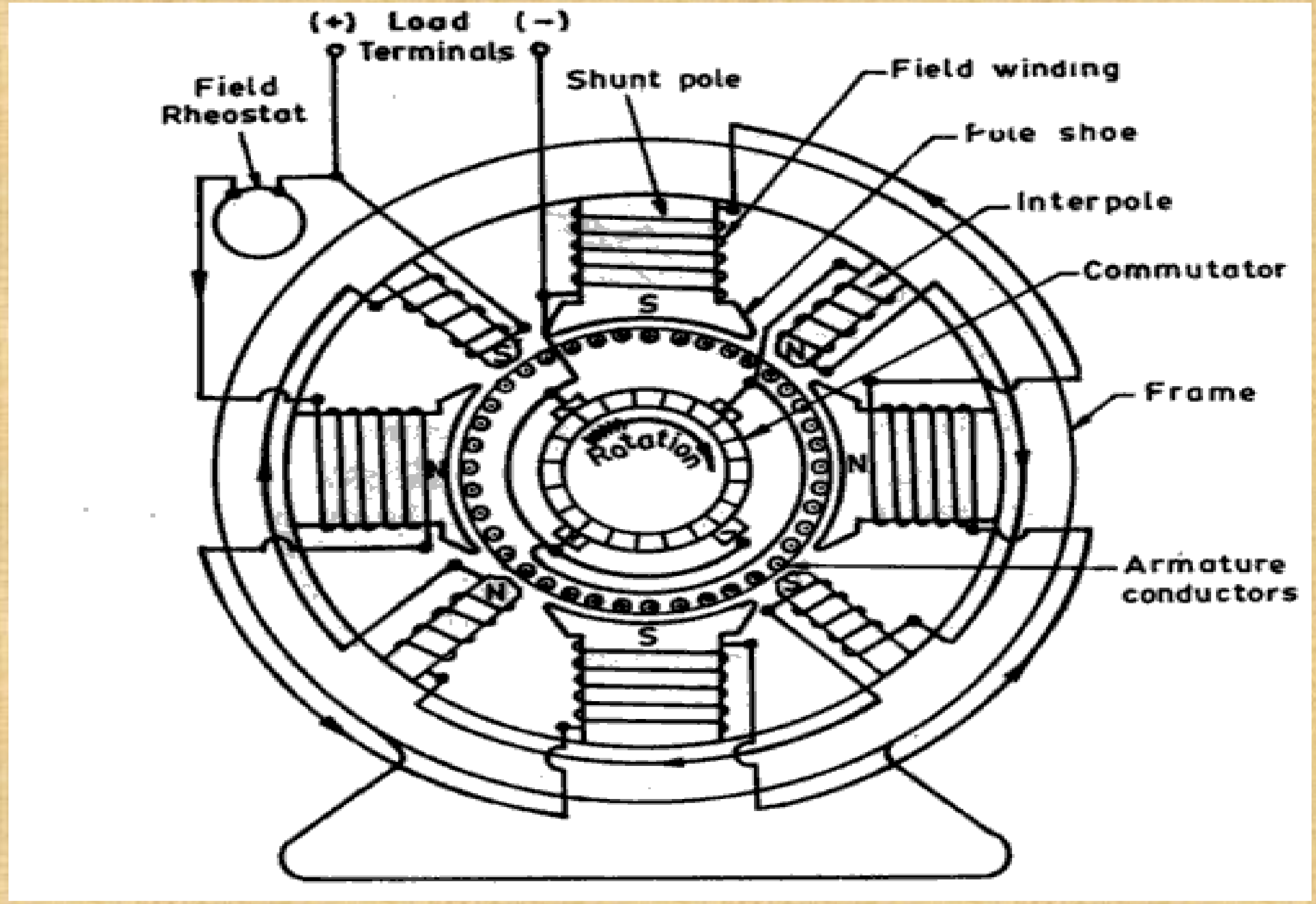
- Whenever a conductor is moved in the magnetic field , an emf is induced and the magnitude of the induced emf is directly proportional to the rate of change of flux linkage.

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

DC Machine

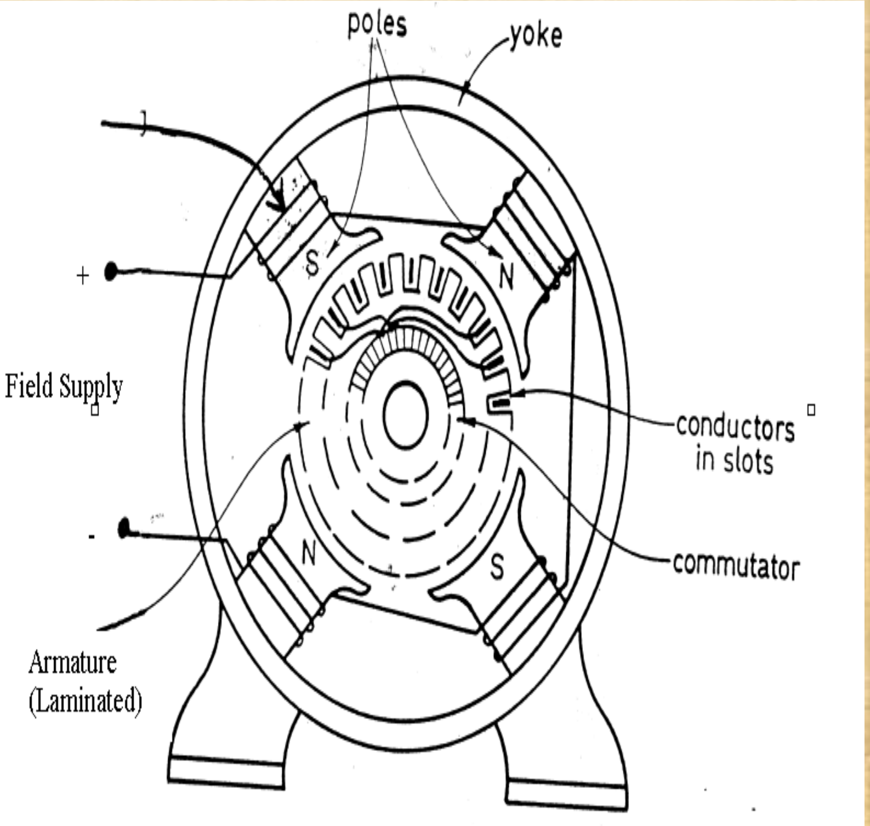

Armature Core
Field Winding
Commutator
STATOR FRAME & YOKE
Shaft
Brush

Sectional view of a DC machine

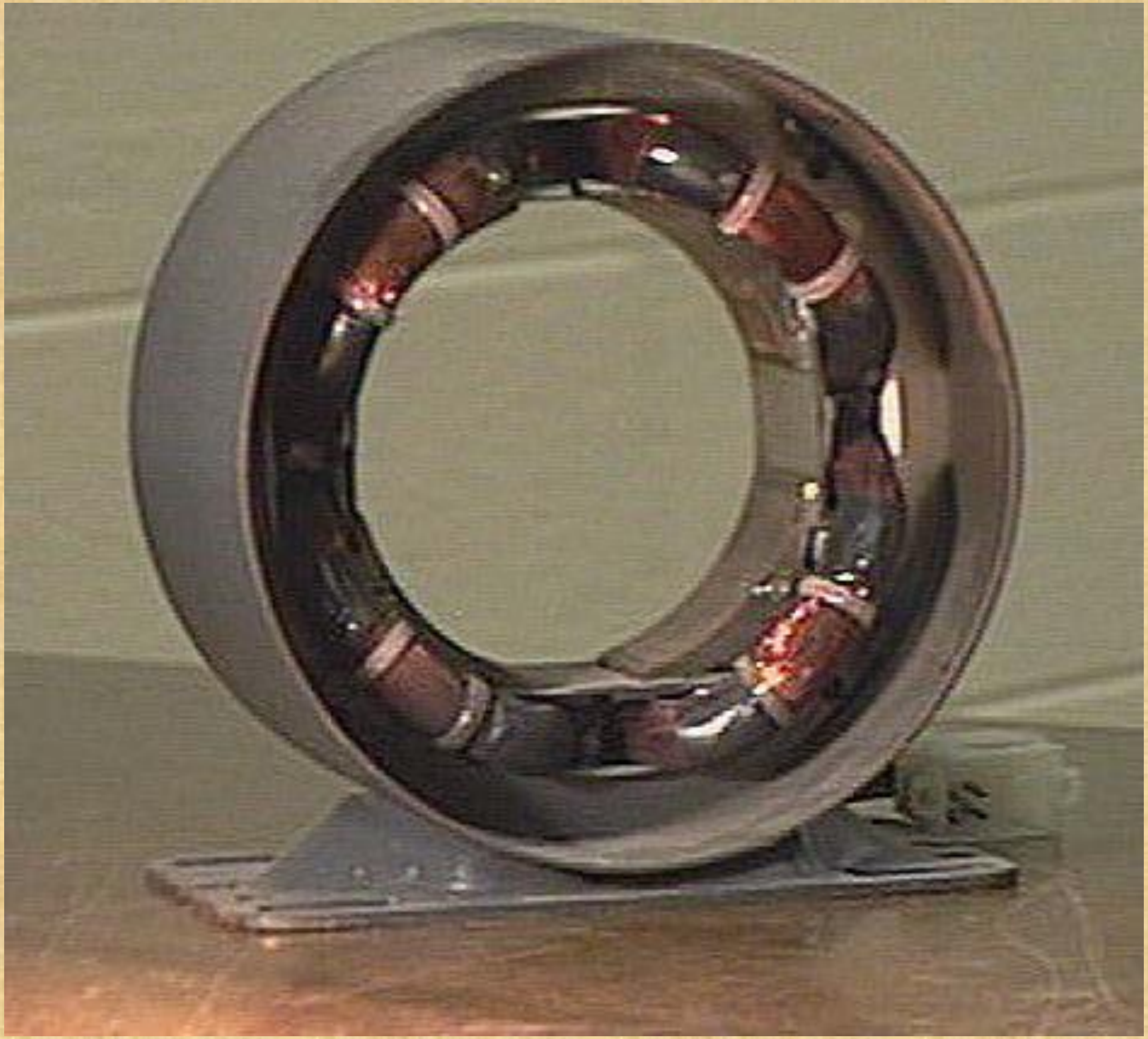


Construction of DC Generator

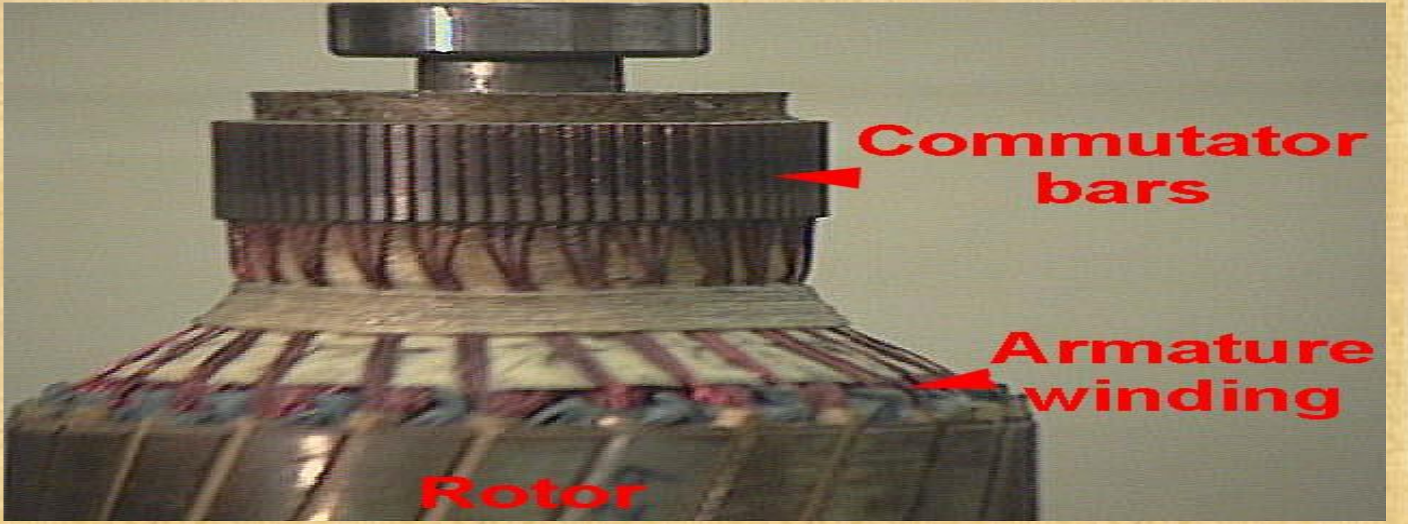
- Field system
- Armature core
- Armature winding
- Commutator
- Brushes



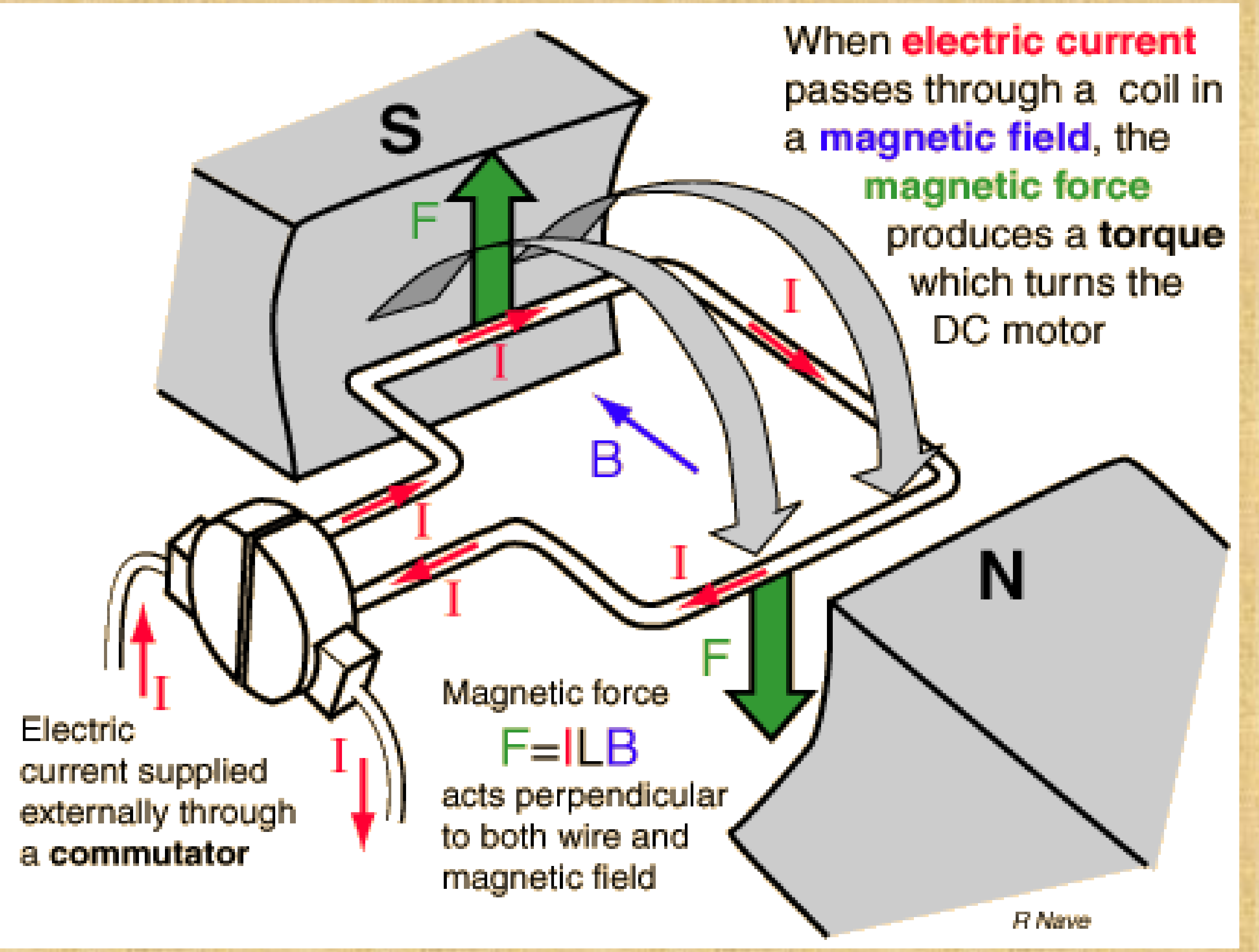
Field winding



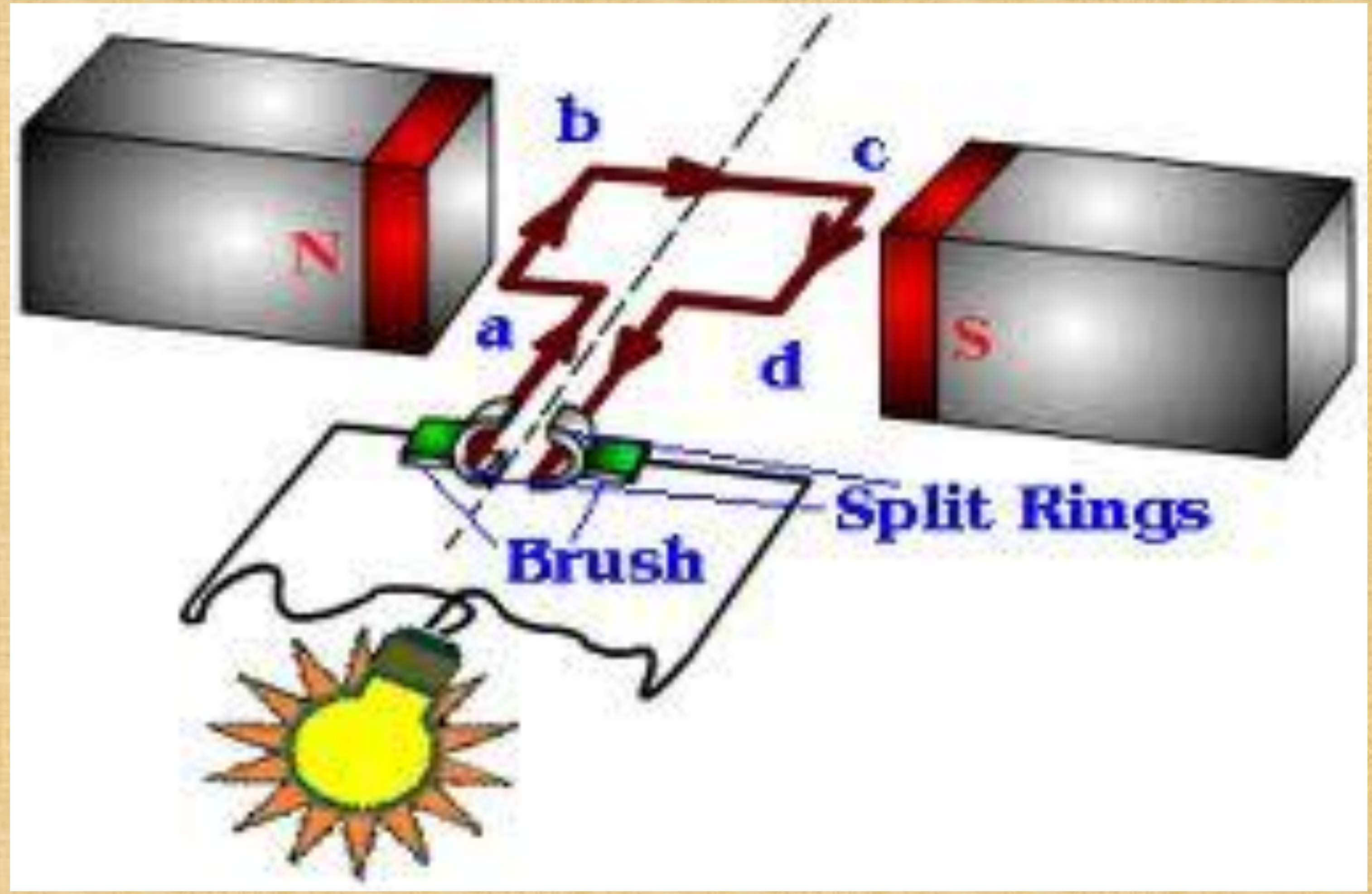
Rotor and rotor winding



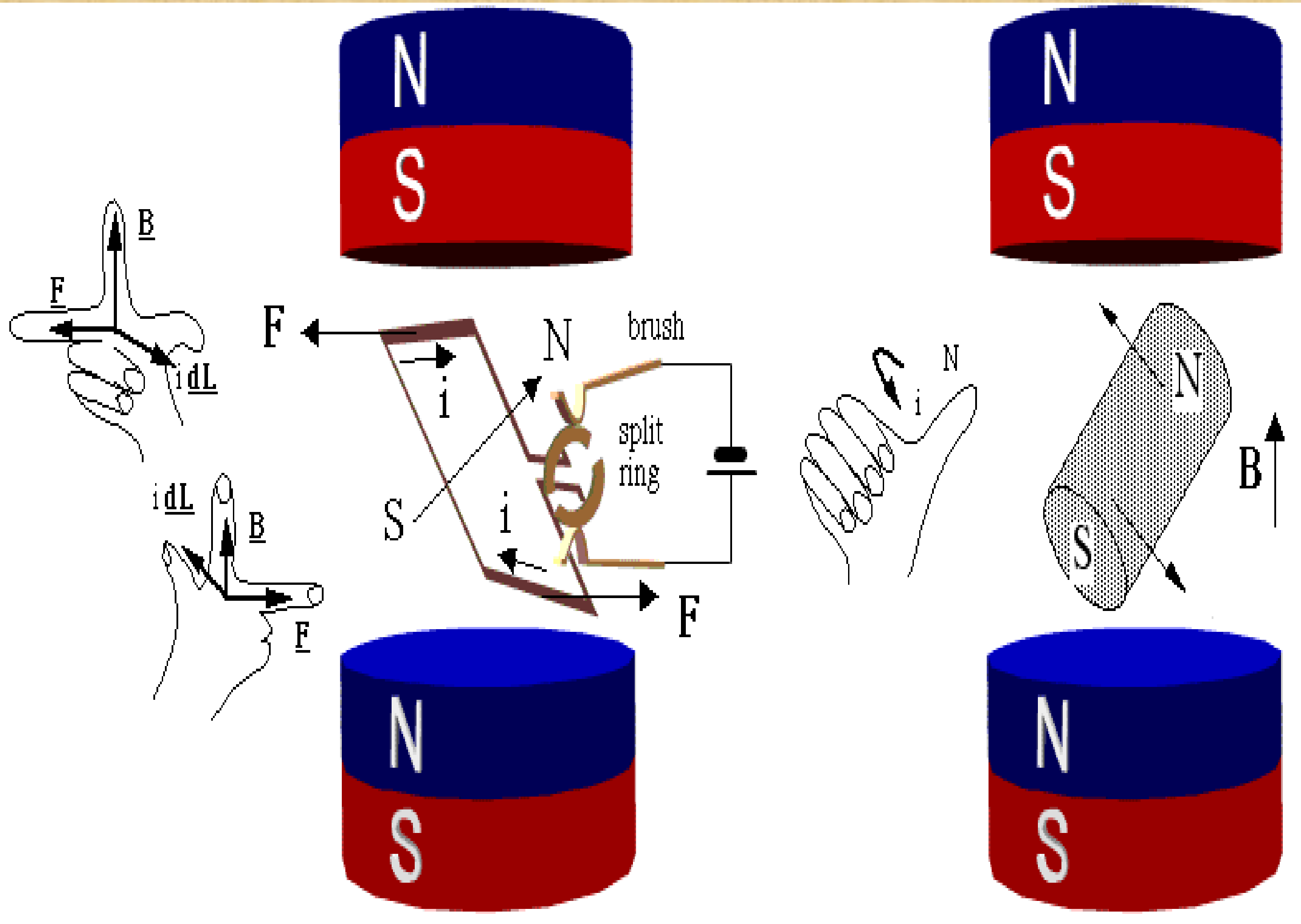
Working principle of DC motor



Working principle of DC motor



Force in DC motor



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

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 $= Z/A$

$E_g = P\phi NZ/60A$

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
  - compound

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

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

Torque

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

- $P = T * 2 \pi N / 60$
- $E_b I_a = T_a * 2 \pi N / 60$
- $T \propto \phi I_a$
- $T_a \propto I^2_a$

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

$$N \propto E_b/\phi$$

$$\propto V - I_a R_a/\phi$$

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

Potential divider control :

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

Needed to limit the starting current .

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

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 effficency , as a motor and as a Generator. In this method, efficiency is calculated by determining the losses .

Applications:

Shunt Motor:

- Blowers and fans
- Centrifugal and reciprocating pumps
- Lathe machines
- Machine tools
- Milling machines
- Drilling machines

Applications:

Series Motor:

- Cranes
- Hoists , Elevators
- Trolleys
- Conveyors
- Electric locomotives

Applications:

Cumulative compound Motor:

- Rolling mills
- Punches
- Shears
- Heavy planers
- Elevators

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