

UNIT-5



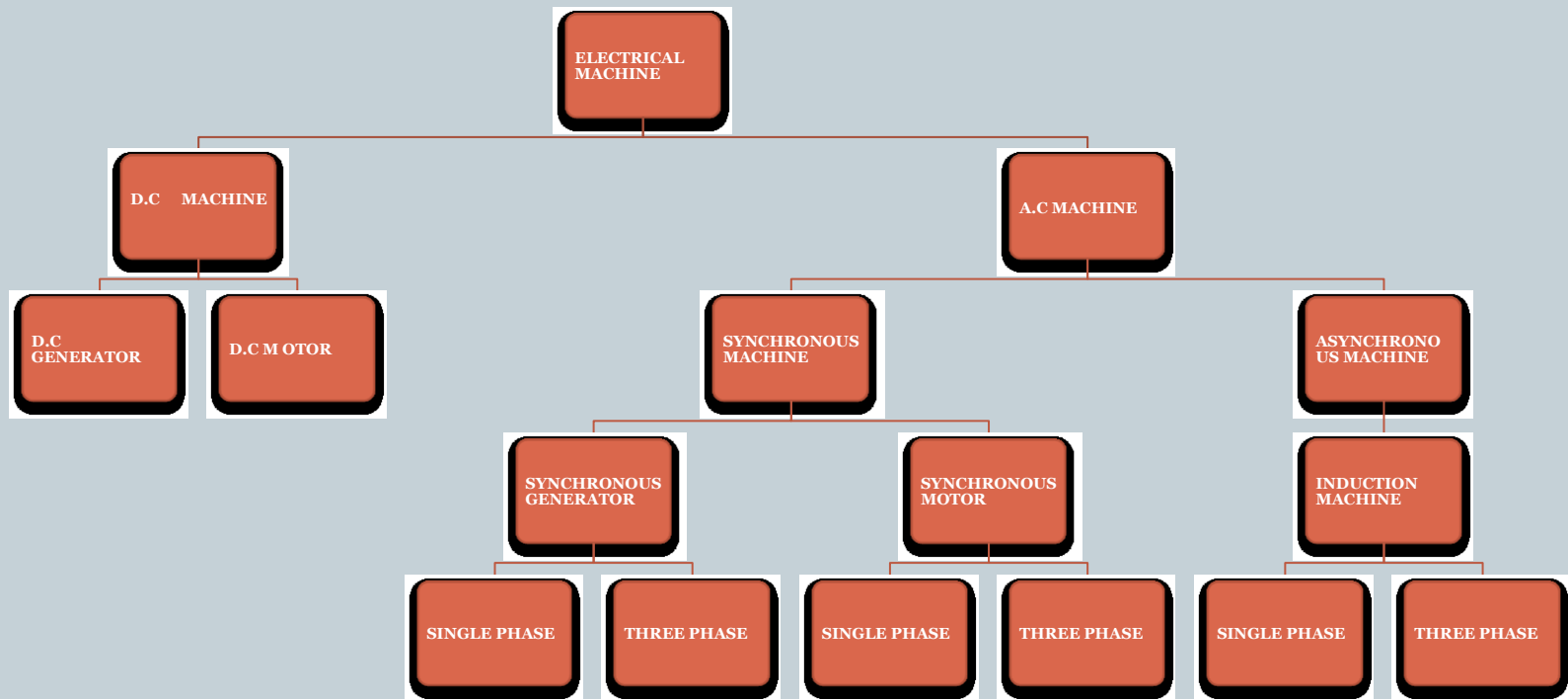
- **Electrical Machines:**
- **DC machines:** Construction, e.m.f. equation of generator and torque equation of motor. Types
- and DG machines, characteristics and applications of dc motors (simple numerical problems).
- **Three Phase Induction Motor:** Constructions types, rotating magnetic field. Principle of
- operation, slip-torque characteristics, applications (numerical problems related to slip only).
- **Single Phase Induction motor:** Principle of operation phase splitting methods of starting,
- applications.
- **Three Phase Synchronous Machines:** Principle of operation of alternator and synchronous
- motor and their applications.

Electrical Machine

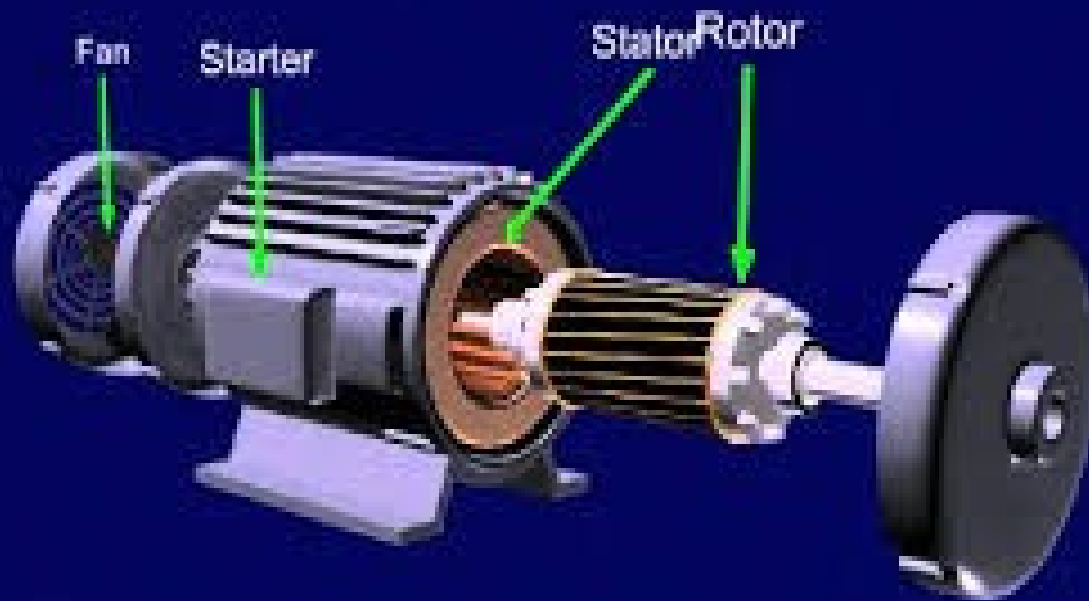


- An electrical machine is the apparatus that converts energy in three categories:
 - Generators which convert mechanical energy to electrical energy.
- Motors which convert electrical energy to mechanical energy, and
- Transformers which changes the voltage level of an alternating current.

Types of electrical machine



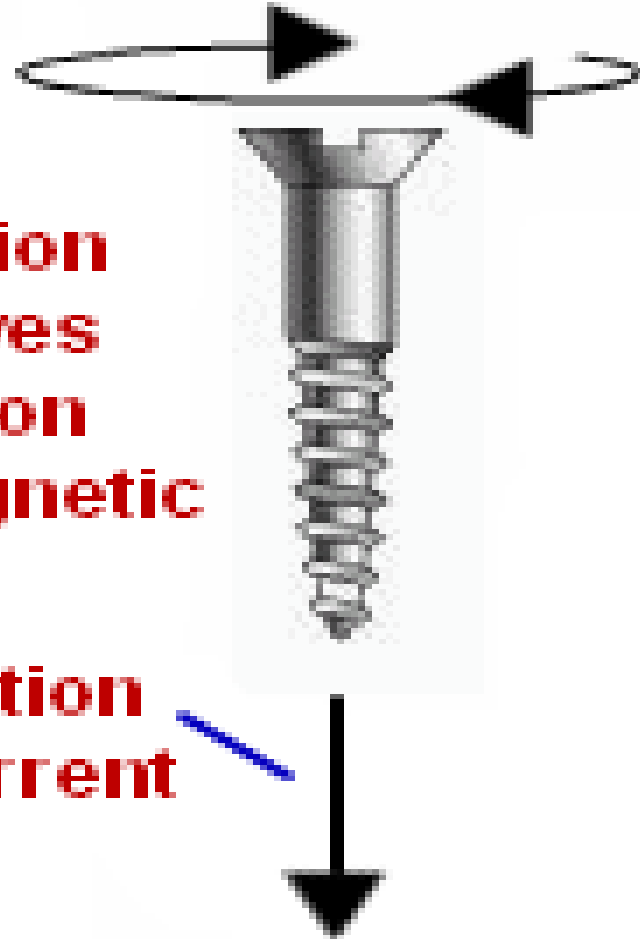
DC MACHINES



Maxwell's Cork screw Rule :

The direction of rotation gives the direction of the magnetic field

Direction of current

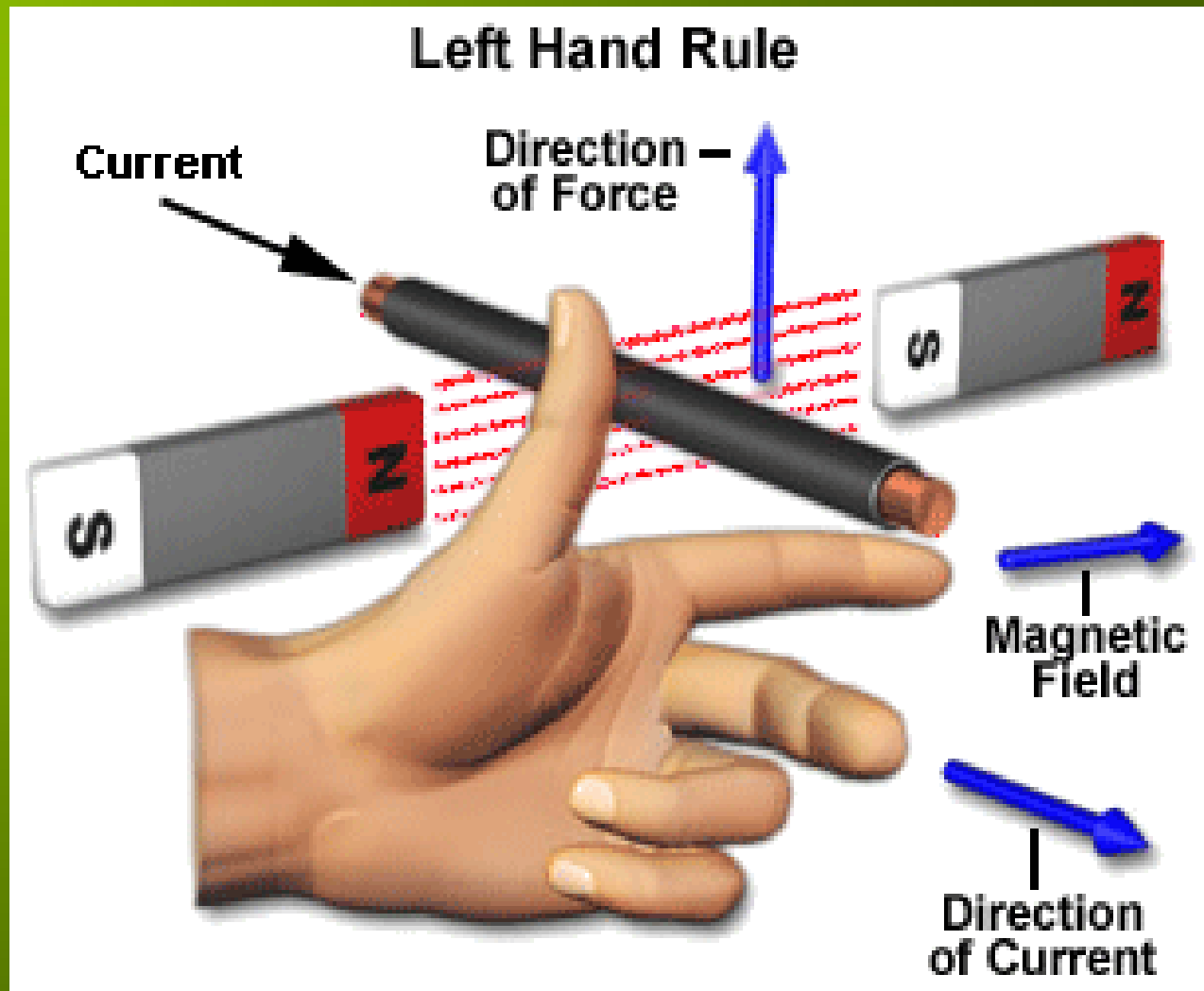




Maxwell's Cork screw Rule :

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

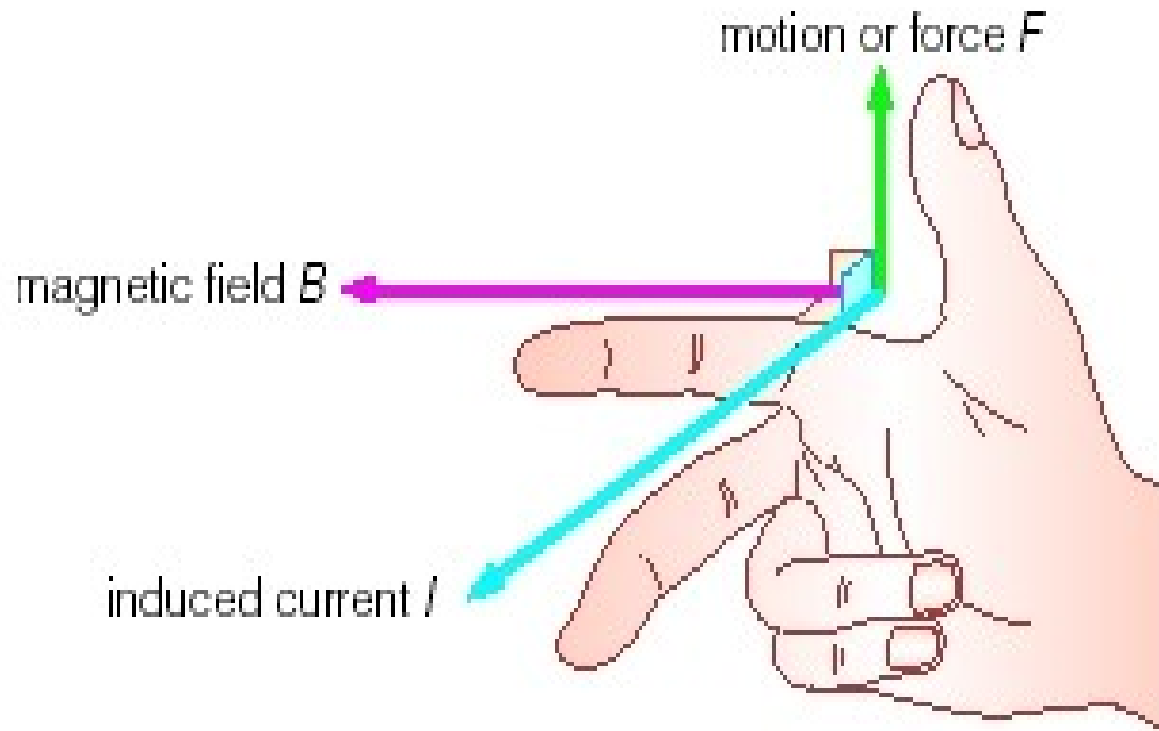


Fleming's left hand rule

- ▀ 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 .

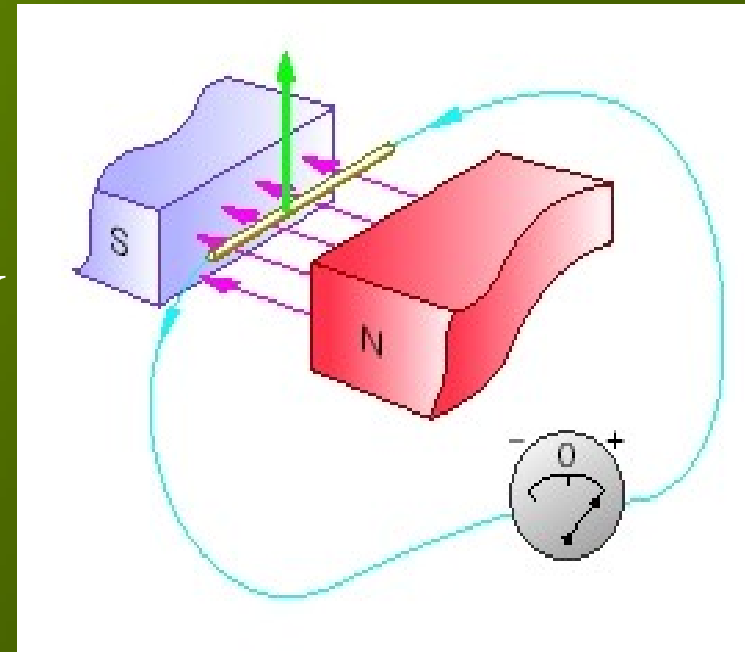
▀
$$e = -N (d\Phi/dt) \text{ volts}$$

DC Generator

Mechanical energy is converted to electrical energy

Three requirements are essential

1. Conductors
2. Magnetic field
3. Mechanical energy

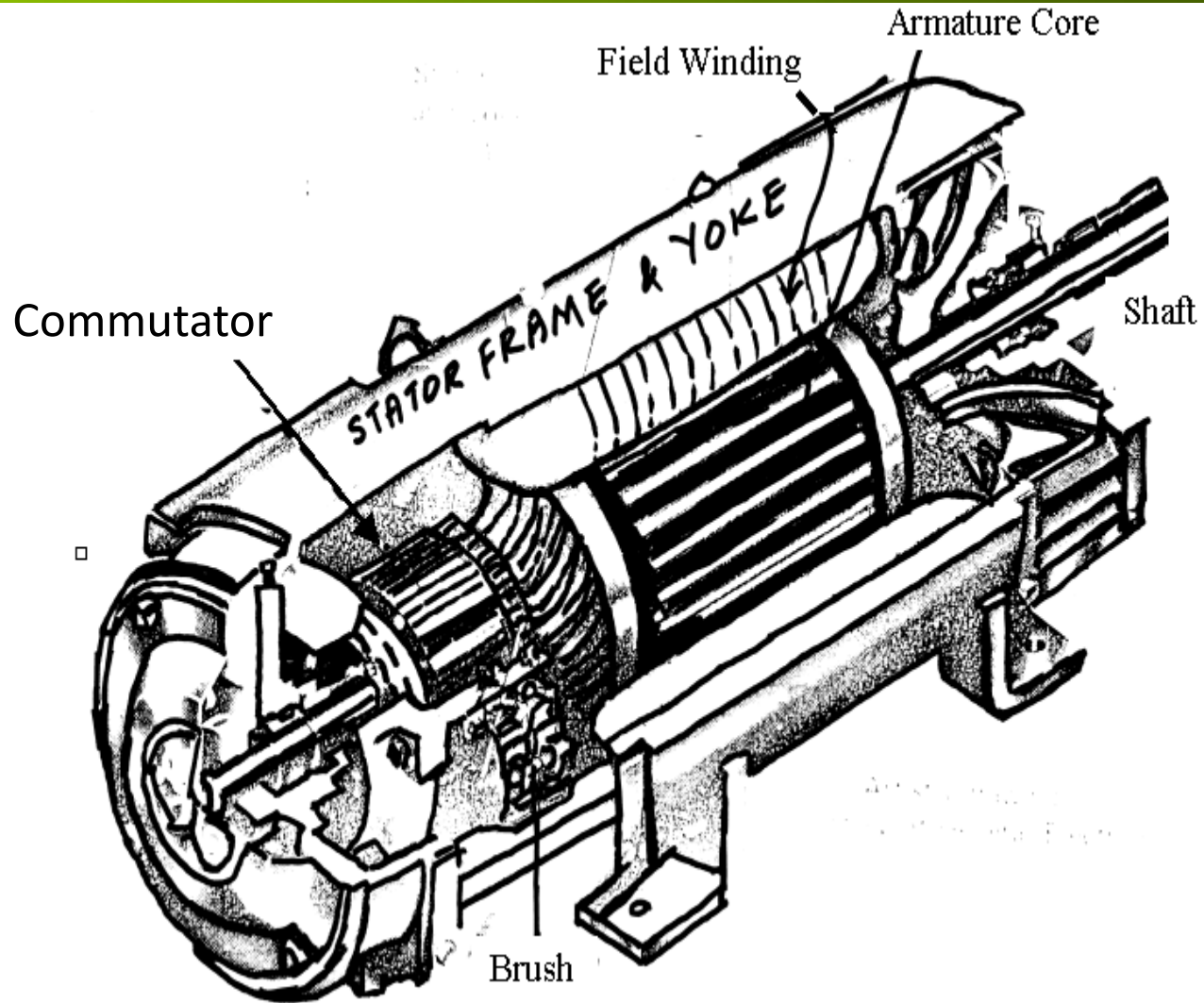


Working principle

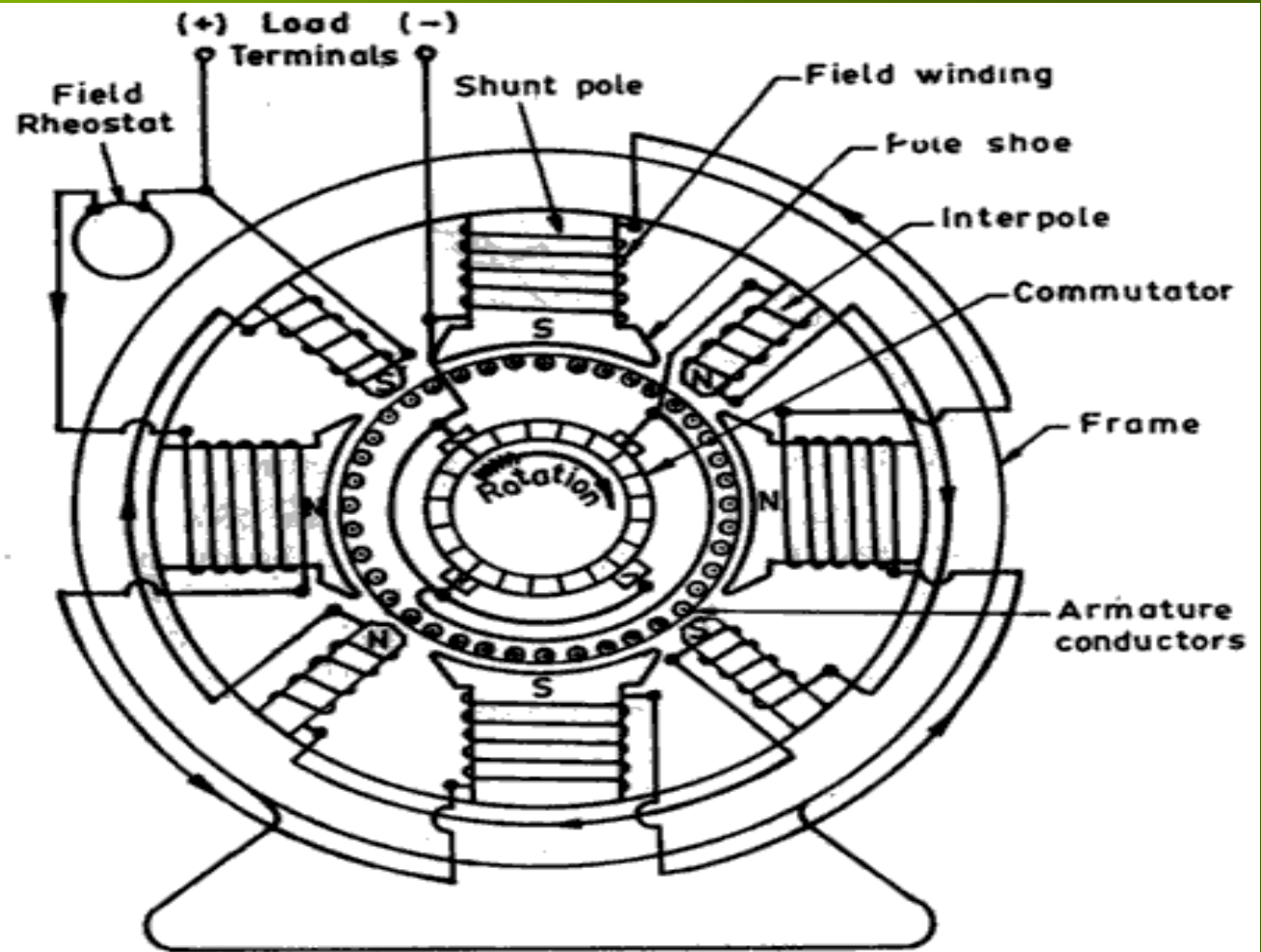
- ▶ A generator works on the principles of Faraday's law of electromagnetic induction
- ▶ Whenever a conductor is moved in the magnetic field, an emf is induced and the magnitude of the induced emf is directly proportional to the rate of change of flux linkage.
- ▶ This emf causes a current flow if the conductor circuit is closed.



DC Machine

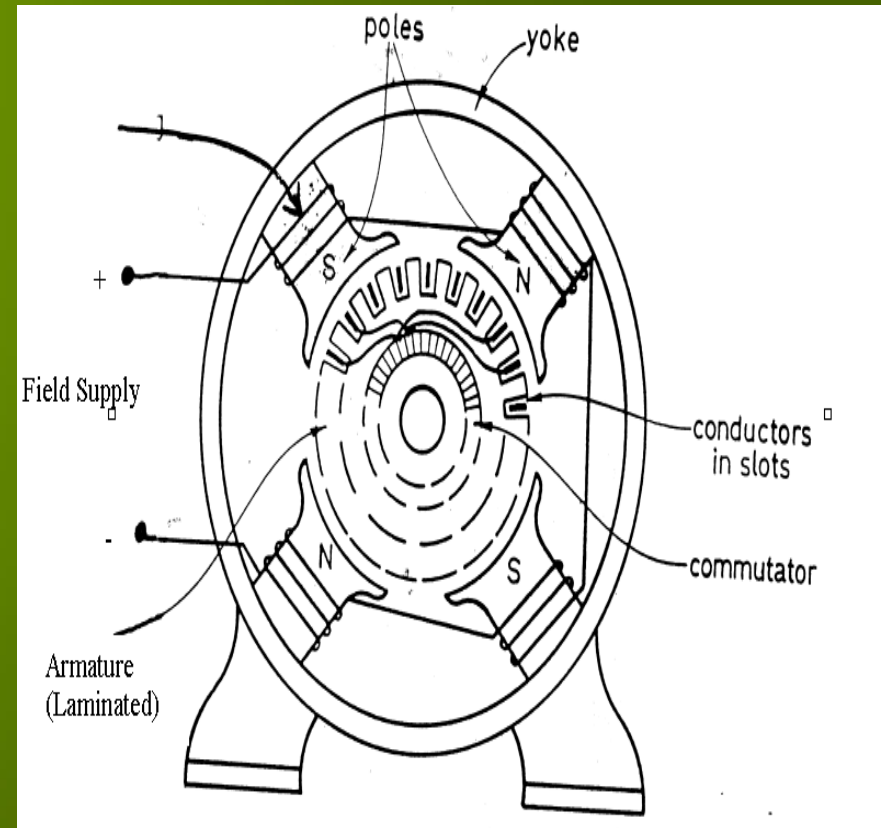


Sectional view of a DC machine

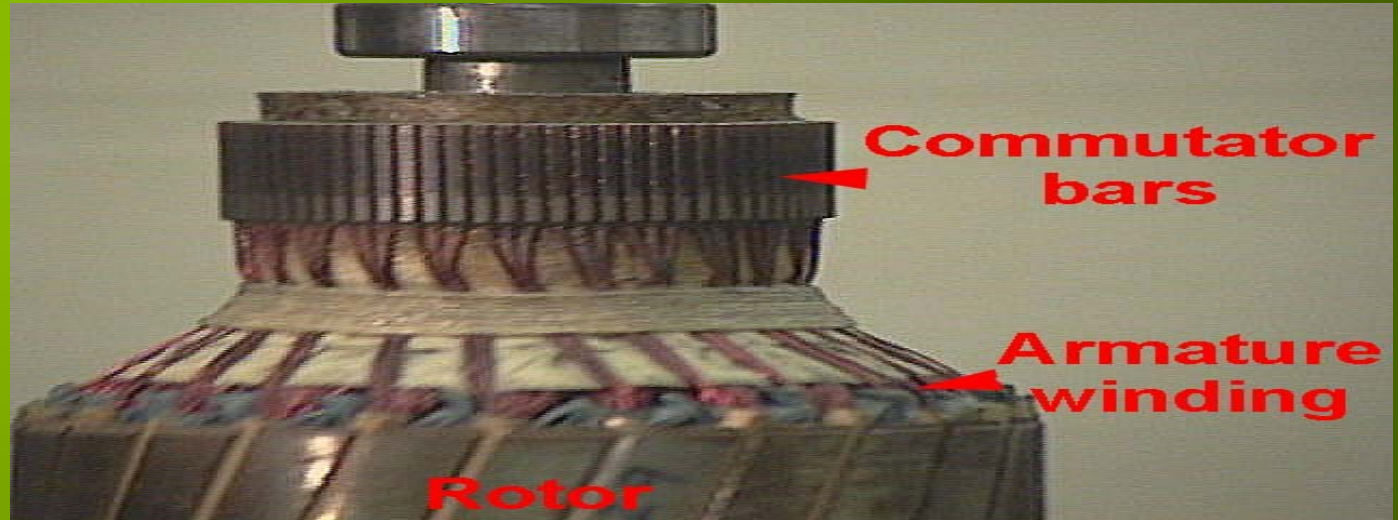


Construction of DC Generator

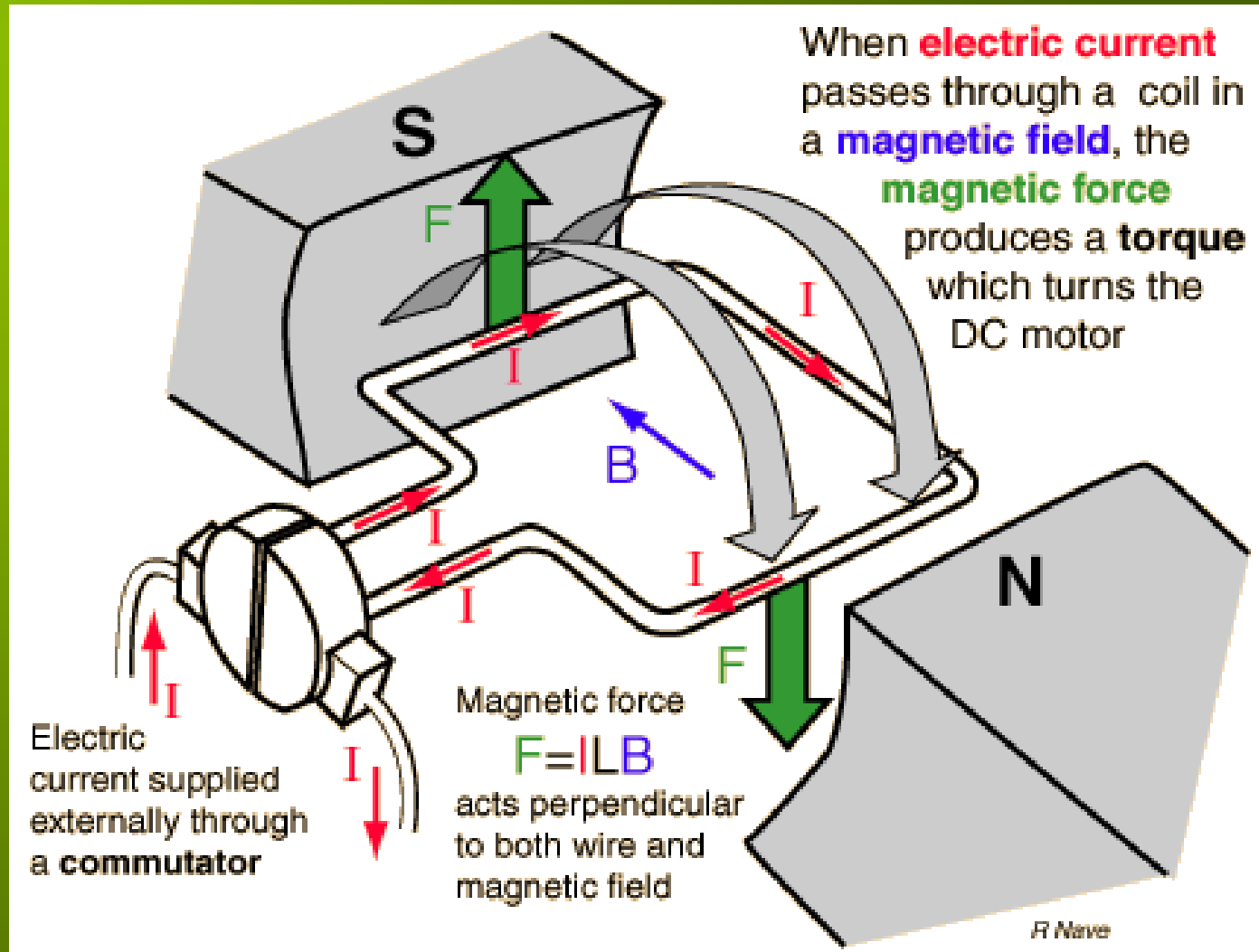
- ▣ Field system
- ▣ Armature core
- ▣ Armature winding
- ▣ Commutator
- ▣ Brushes



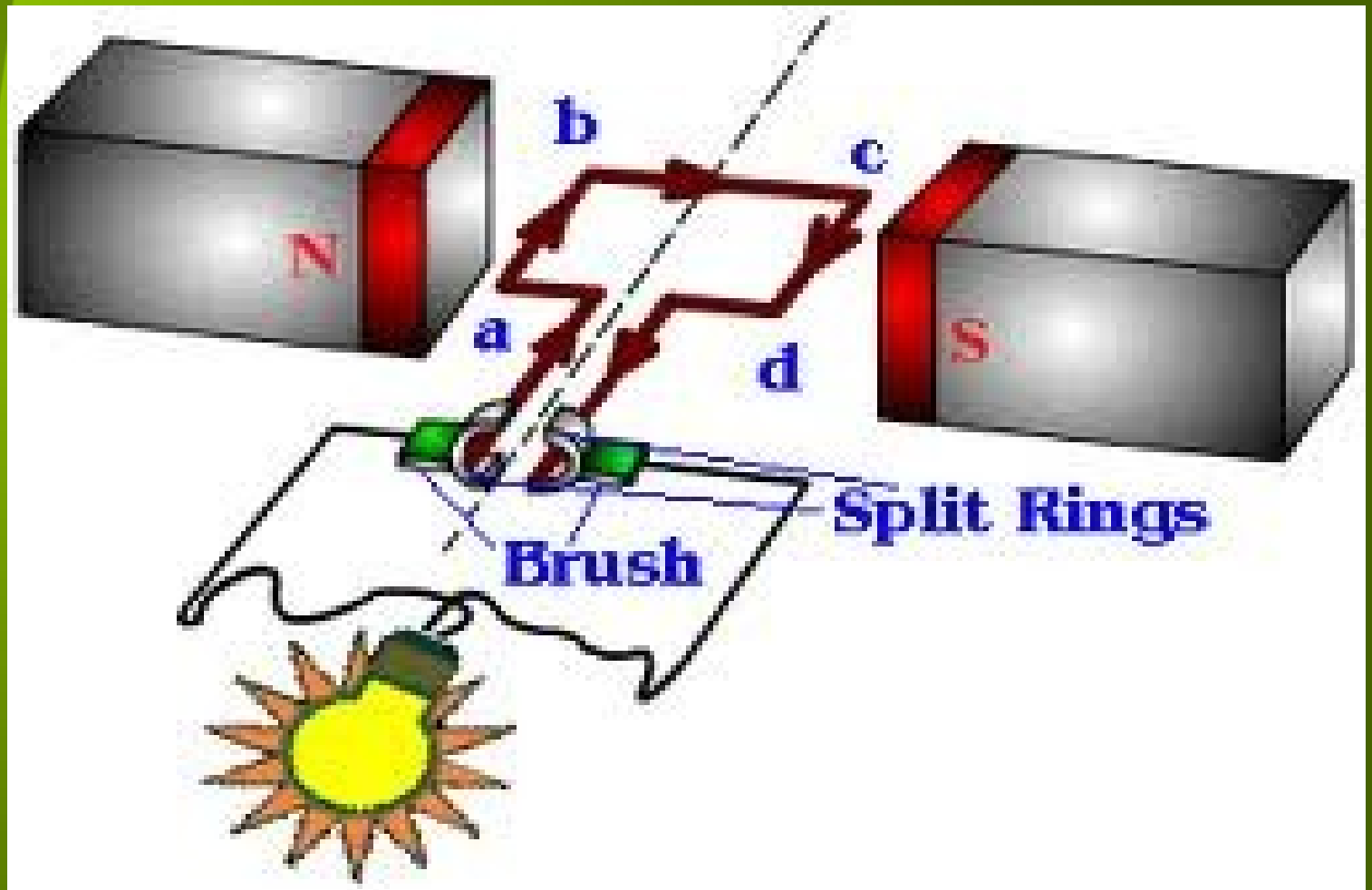
Rotor and rotor winding



Working principle of DC motor



Working principle of 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

EMF equation

Let,

▶ Φ = flux per pole in weber

▶ Z = Total number of conductor

▶ P = Number of poles

▶ A = Number of parallel paths

▶ N = armature speed in rpm

▶ E_g = emf generated in any one 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
 - Cumulatively compound
&
Differentially compound



Characteristics

- ▶ No load saturation characteristic (E_o/I_f)
- ▶ Internal or Total characteristic (E/ I_a)
- ▶ External characteristic (V/I)

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 .

$$\blacksquare P = T * 2 \pi N / 60$$

$$\blacksquare E_b I_a = T_a * 2 \pi N / 60$$

$$\blacksquare T \propto \phi I_a$$

$$\blacksquare T_a \propto I_{2a}$$

Characteristic of DC motors



- T/ I_a 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

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

Three phase induction motor



- Three phase induction motors are the workhorse of industry. It has been estimated that 70% to 80% of all electricity in the world is consumed by these motors. They are truly elegant machines in that there are no moving parts except the rotor, and there are no brushes, commutators, or slip rings to wear out.