D.C Generator

An electrical Generator is a machine which converts mechanical energy (or power) into electrical energy (or power). The generator operates on the principle of the production of dynamically induced emf i.e., whenever flux is cut by the conductor, dynamically induced emf is produced in it according to the laws of electromagnetic induction, which will cause a flow of current in the conductor if the circuit is closed.

Hence, the basic essential parts of an electric generator are:

- A magnetic field and
- A conductor or conductors which can so move as to cut the flux

In dc generators the field is produced by the field magnets which are stationary. Permanent magnets are used for very small capacity machines and electromagnets are used for large machines to create magnetic flux. The conductors are situated on the periphery of the armature being rotated by the prime-mover.

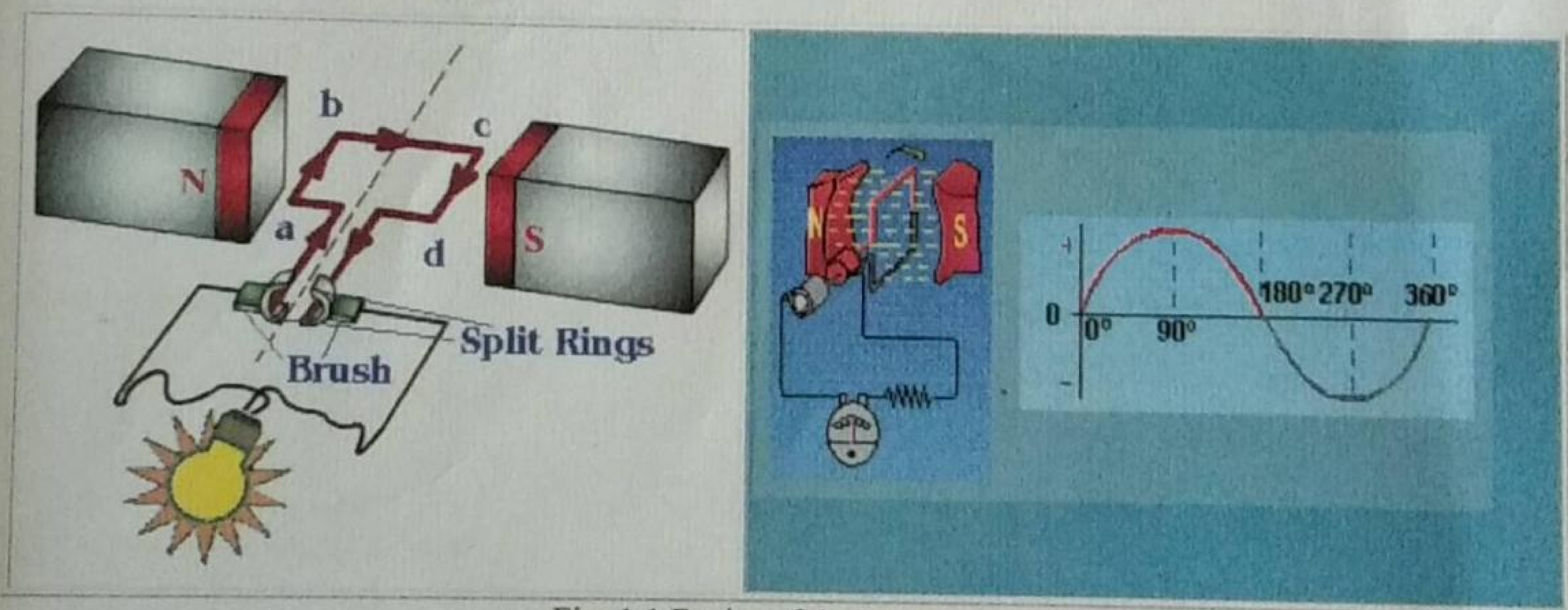

Fig. 1.1 Basics of dc generators

1.1 Practical DC generator construction

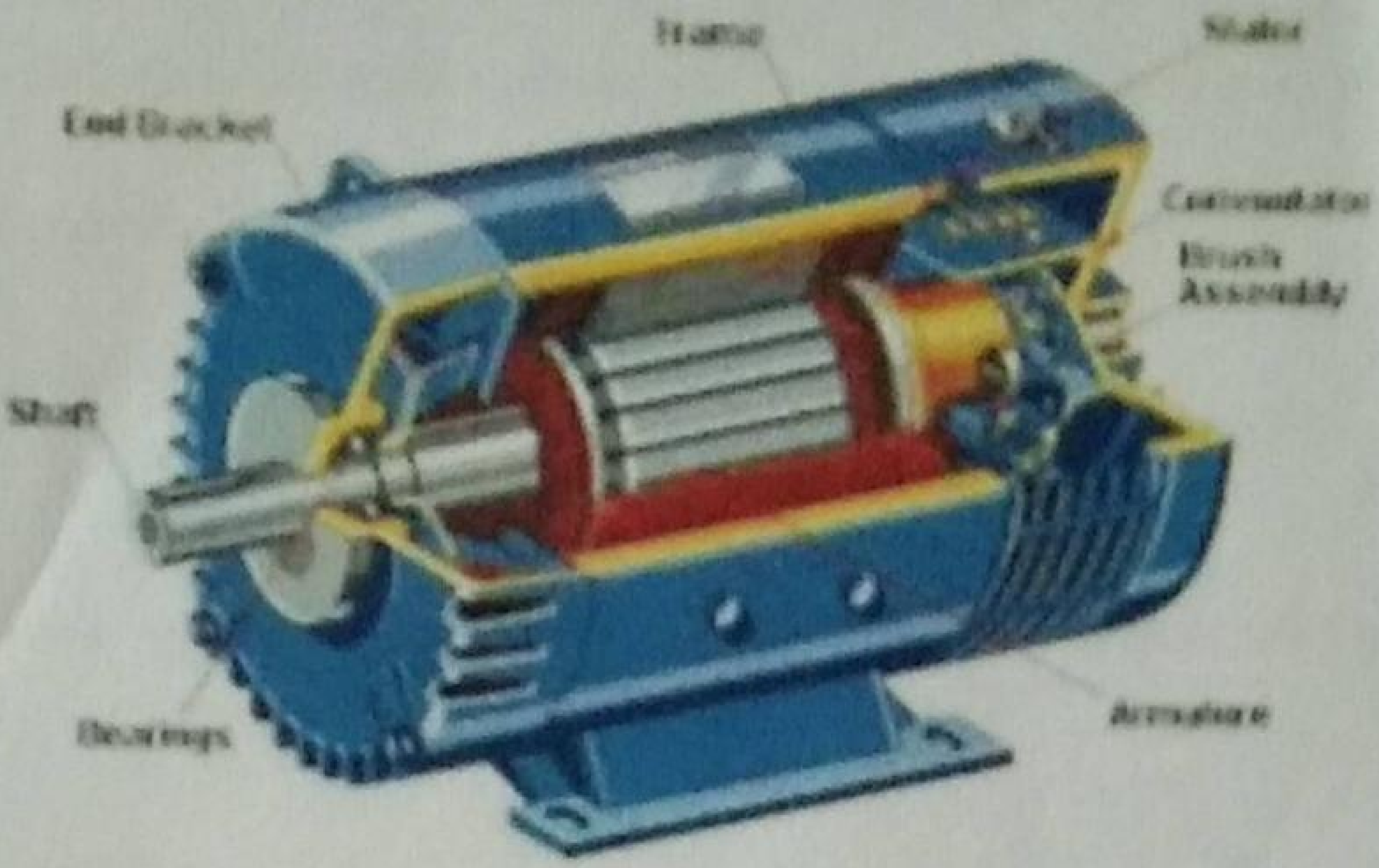

Fig. 1.2 Cut-away view of dc practical generators

The actual DC generator consists of the following essential parts:

- Magnetic frame or Yoke
- Pole Cores and Pole Shoes
- Pole Coils or Field Coils
- Armature Core
- Armature Windings or Conductors
- Commutator
- Brushes and Bearings

a) Magnetic frame or Yoke

Purpose of Yoke is

1. It act as a protecting cover for whole machine

2. It provides mechanical support for poles

3. It carries the magnetic flux produced by poles

b) Pole Cores and Pole Shoes

The field magnets consist of pole cores and pole shoes. The Pole shoes serve two purposes:

1. They spread out the flux in the air gap

2. They support the exciting coils

c) Armature

When current is passed through field coils, they electro-magnetize the poles which produce the necessary flux.

The Armature serves two purposes:

1. Armature houses the armature conductors or coils
2. It provides low reluctance path for flux

It is drum shaped and is built up of laminations made sheet steel to reduce eddy current loss. Slots are punched on the outer periphery of the disc. The Armature windings or conductors are wound in the form of flat rectangular coils and are placed in the slots of the Armature. The Armature windings are insulated from the armature body by insulating materials.

d) Commutator and brushes

The function of Commutator is to facilitate collection of current from the armature conductors and converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. The commutator is made up of insulated copper segments. Two brushes are pressed to the commutator to permit current flow. The Brushes are made of carbon or Graphite. Bearings are used for smooth running of the machine.

1.2 E.M.F. equation

Let, ϕ = flux per pole in weber

z = total number of armature conductors=no. of slots × no. of conductors/slot

P = no. of generator poles

A = no. of parallel paths in armature

N = armature rotation in revolutions per minute (rpm)

E = emf induced in any parallel path in armature

Generated emf, E_g = emf generated in any one of the parallel path i.e. E

Average emf generated/conductor = $\dfrac{d\phi}{dt}$ volts, $\because n = 1$

Now, flux cut per conductor in one revolution,

$d\phi = \phi P$ weber

No. of revolutions per second = $\dfrac{N}{60}$

Time for one revolution, $dt = \dfrac{60}{N}$ second

Hence, according to Faradays laws of Electromagnetic induction,

EMF generated/conductor = $\dfrac{d\phi}{dt} = \dfrac{\phi PN}{60}$ volts

For a simplex lap-wound generator:

No. of parallel paths = P

No. of conductors in one path = $\dfrac{z}{P}$

Hence, EMF generated/path = $\dfrac{\phi PN}{60} \times \dfrac{z}{P} = \dfrac{\phi zN}{60}$ volts

For a simplex wave-wound generator:

No. of parallel paths = 2

No. of conductors in one path $= \frac{z}{2}$

Hence, EMF generated/path $= \frac{\phi PN}{60} \times \frac{z}{2} = \frac{\phi zNP}{120}$ volts

In general generated EMF, $E_g = \frac{\phi zN}{60} \times \frac{P}{A}$

1.3 Types of generator

DC generators are usually classified according to the way in which their fields are excited. DC generators may be divided into, (a) separately excited dc generators, and (b) self excited dc generators.

a) separately excited dc generators

Separately excited generators are those whose field magnets are energized from an independent external source of dc current.

b) self excited dc generators

Self excited generators are those whose field magnets are energized by the current produced by the generators themselves. Due to residual magnetism, there is always present some flux in the poles. When the armature is rotated, some emf and hence some current flows which is partly or fully passed through the field coils thereby strengthening the residual pole flux.

There are three types of self excited dc generators named according to the manner in which their field coils (or windings) are connected to the armature. In shunt the two windings, field and armature are in parallel while in series type the two windings are in series. In compound type the part of the field winding is in parallel while other part in series with the armature winding.

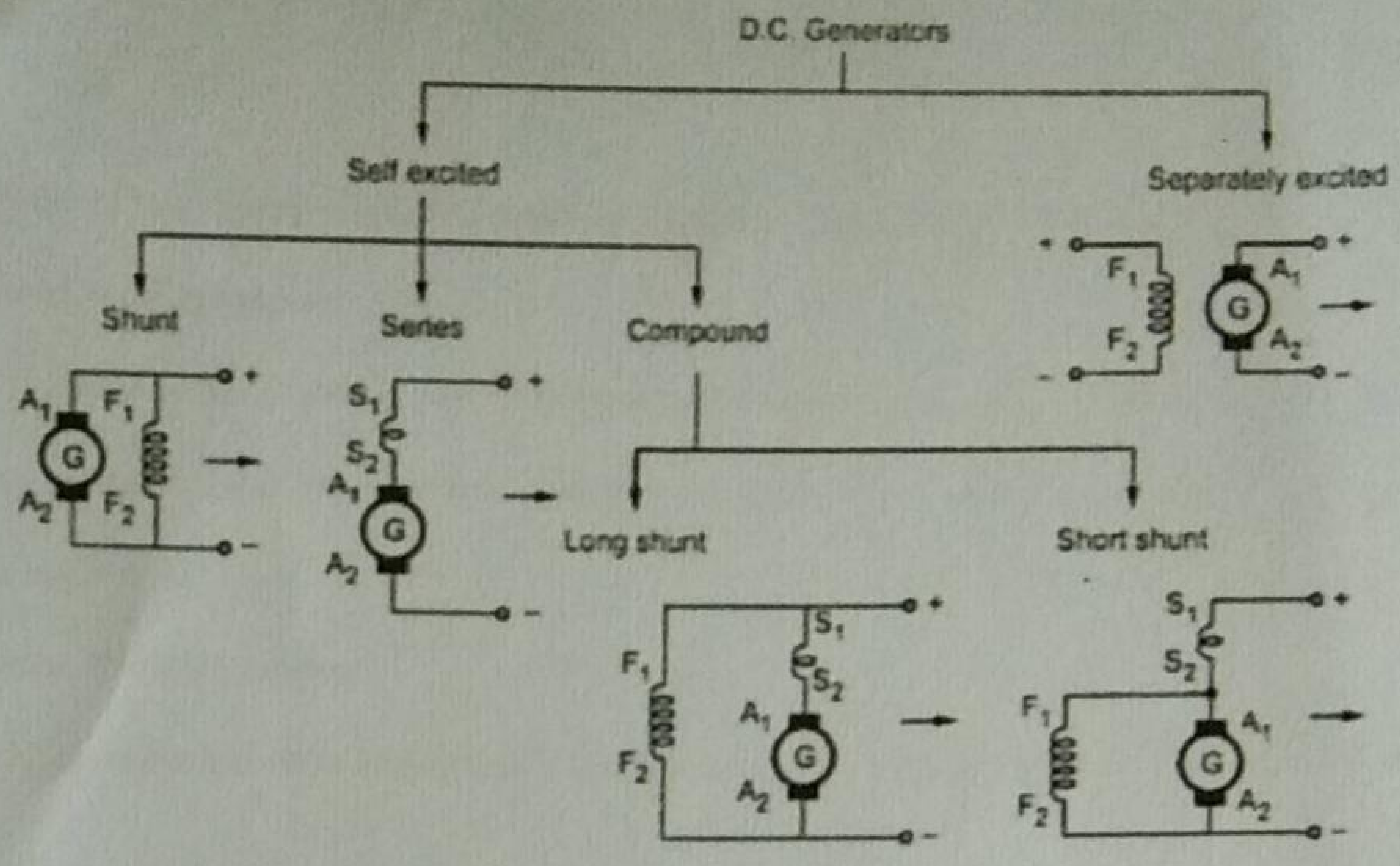

Fig.1.3 DC generators classification

D.C. Motor

An electric motor is a machine which converts electrical energy into mechanical energy.

2.1 Principle of operation

It is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's Left-hand rule and whose magnitude is given by

Force, **F = B I l** newton

Where B is the magnetic field in weber/m^2. I is the current in amperes and l is the length of the coil in meter.

Fleming's left hand rule says that if we extend the index finger, middle finger and thumb of our left hand in such a way that the current carrying conductor is placed in a magnetic field (represented by the index finger) is perpendicular to the direction of current (represented by the middle finger), then the conductor experiences a force in the direction (represented by the thumb) mutually perpendicular to both the direction of field and the current in the conductor.

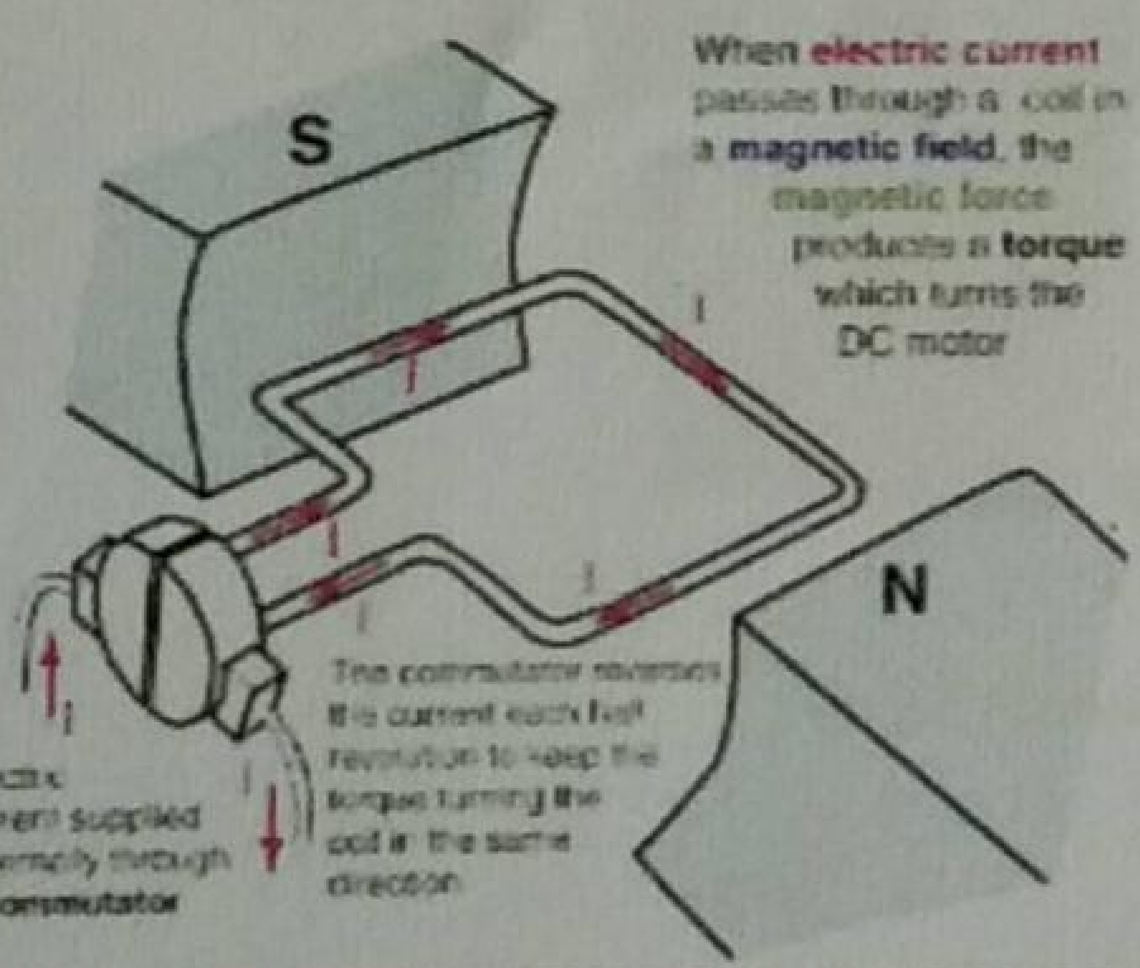

Figure 2.1: Force in DC Motor

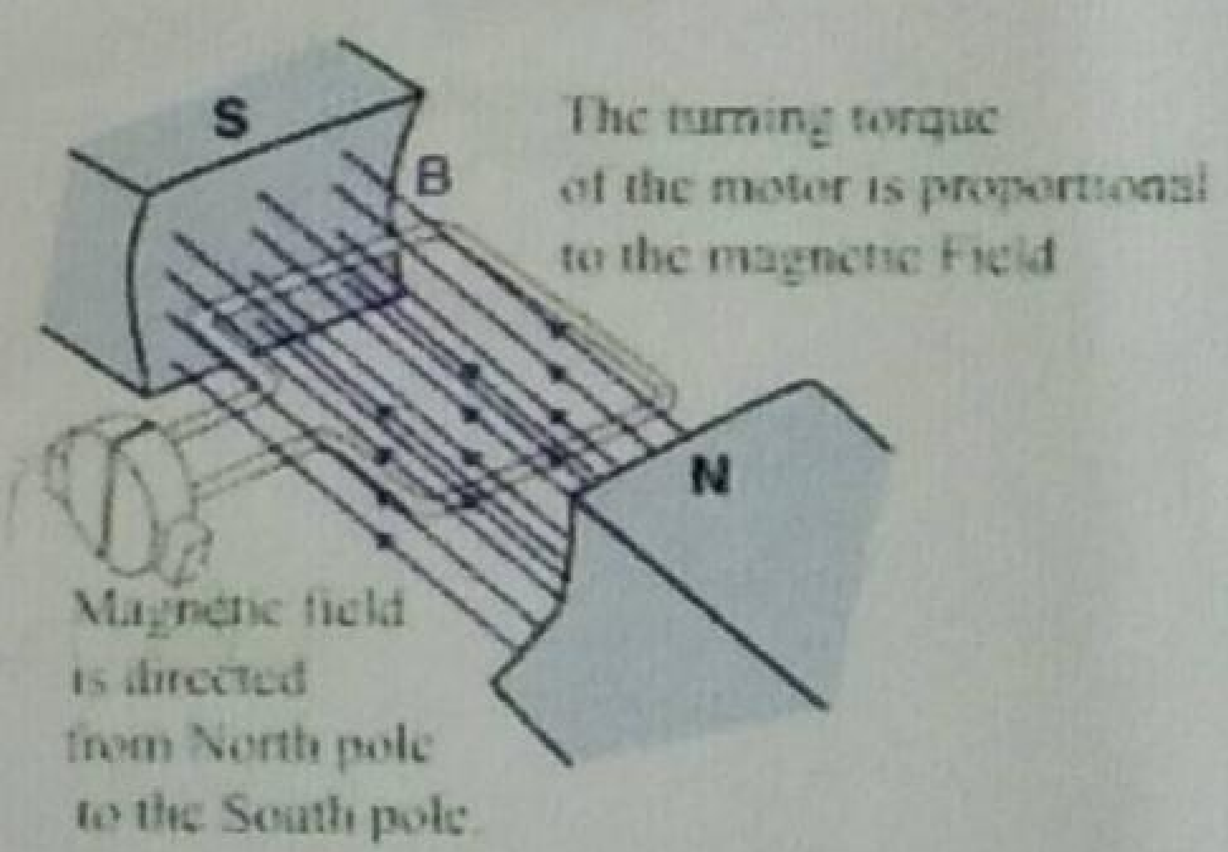

Figure 2.2 : Magnetic Field in DC Motor

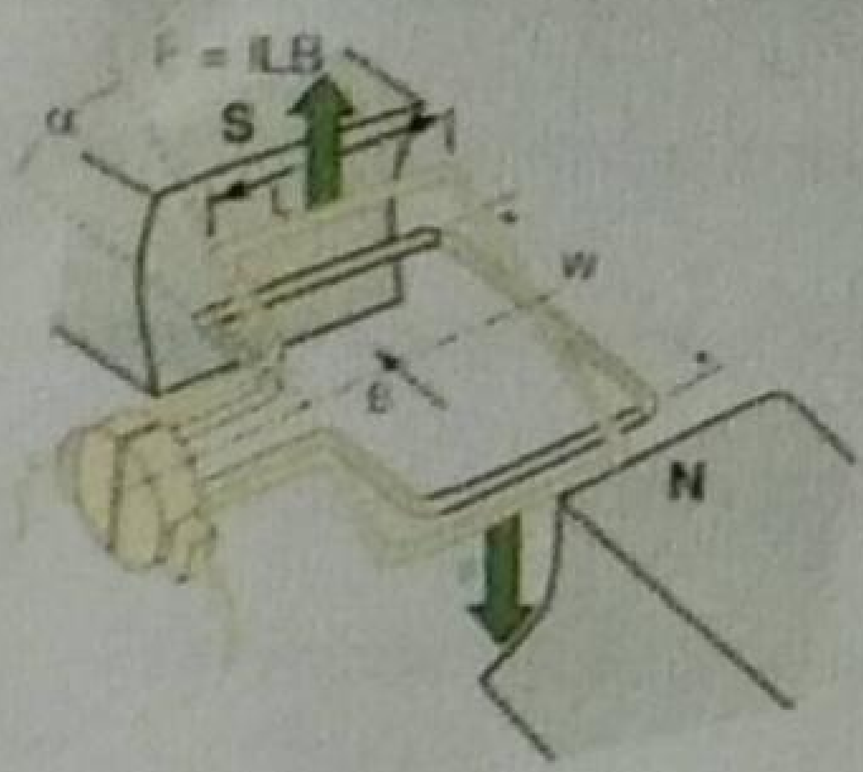

Figure 2.3 : Torque in DC Motor

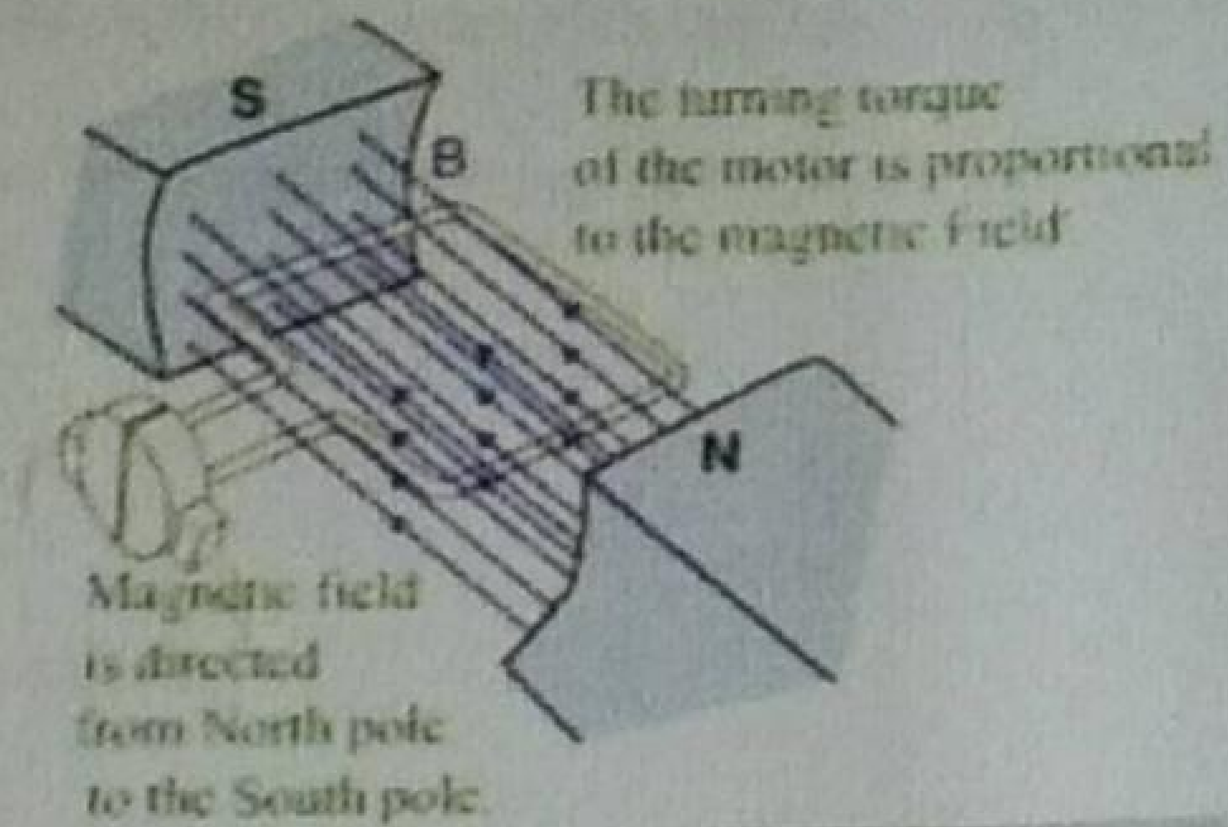

Figure 2.4 : Current Flow in DC Motor

Constructionally, there is no basic difference between a dc generator and motor. In fact, the same dc machine can be used interchangeably as a generator or as a motor. The basic construction of a dc motor contains a current carrying armature which is connected to the supply end through commutator segments and brushes and placed within the north south poles of a permanent or an electro-magnet.

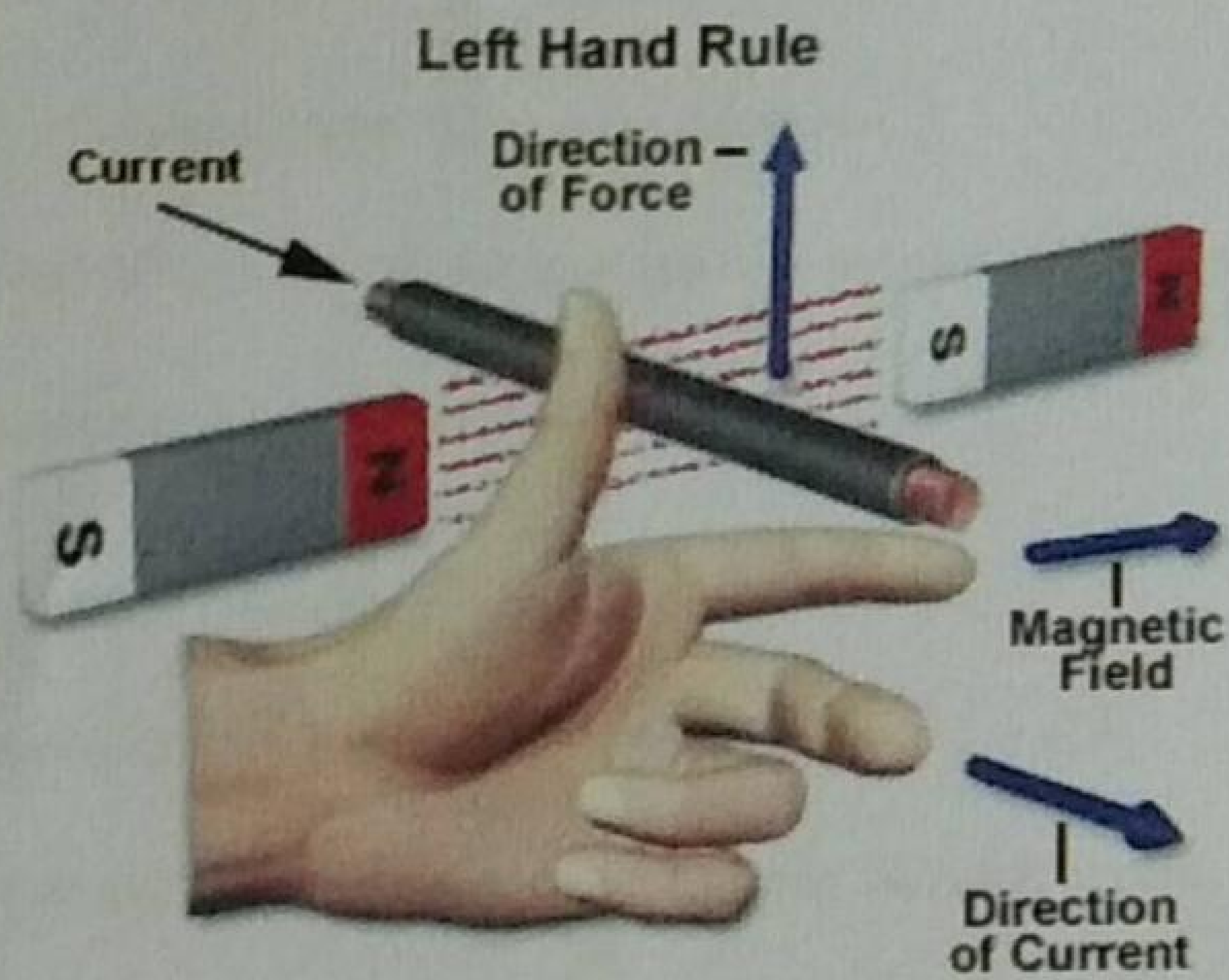

Fig. 2.5 Flemings Left hand rule

2.2 Back E.M.F

When the motor ārmature rotates, the conductors also rotate and hence cut the flux. In accordance with the laws of electromagnetic induction, emf is induced in them whose direction, as found by

Fleming's Right hand Rule, is in opposition to the applied voltage. Because of its opposing direction, it is referred to as counter emf of back emf E_b. V has to drive I_a against the opposition of E_b. The power required to overcome this opposition is $E_b I_a$.

2.3 Voltage Equation of a Motor

The voltage V applied across the motor armature has to,

(a) Overcome the back emf E_b, and

(b) Supply the armature ohmic drop $I_a R_a$

Hence, $V = E_b + I_a R_a$

This is known as voltage equation of a dc motor.

Now, multiplying both sides by I_a, we get

$$VI_a = E_b I_a + I_a^2 R_a$$

Where, VI_a = Electrical power input to the armature

$E_b I_a$ = Electrical equivalent of mechanical power developed in the armature

$I_a^2 R_a$ = copper loss in the armature

2.4 Condition for maximum efficiency

The gross mechanical power developed by motor is, $P_m = VI_a - I_a^2 R_a$

Differentiating both side with respect to I_a and equating the result to zero, we get

$$\frac{dP_m}{dI_a} = V - 2I_a R_a = 0$$

Hence, $I_a R_a = V/2$

As, $V = E_b + I_a R_a$ and $I_a R_a = V/2$

Hence, $E_b = V/2$

Thus gross mechanical power developed by a motor is maximum when back emf is equal to half the supply voltage. This condition is, however, not realized in practice, because in that case current would be much beyond the normal current of the motor. Moreover, half the input would be wasted in the form of heat and taking other losses (mechanical and magnetic) into consideration, the motor efficiency will be well below 50 percent.

2.5 Torque

The turning or twisting moment of a force about an axis is called torque. It is measured by the product of the force and the radius at which this force acts.

Consider a pulley of radius r meter acted upon by a circumferential force of F newton which causes it to rotate at N rpm.

Then torque $T = F \times r$ newton-metre(N-m

Work done by this force in one revolution

=Force × distance

$= F \times 2\pi r$ joule

Power developed $= F \times 2\pi r \times N$ joule/second or watt $= (F \times r) \times 2\pi N$ watt

Now, $2\pi N$ = angular velocity ω in radian per second and $F \times r$ =torque T

Hence, power developed $= T \times \omega$ watt or $P = T\omega$ watt

Moreover, if N is in rpm, then

$\omega = 2\pi N / 60$ rad/s

Hence, $P = \frac{2\pi N}{60} \times T$ or $P = \frac{2\pi}{60} NT = \frac{NT}{9.55}$

2.5.1 Armature torque of a motor

Let T_a be the torque developed by the armature of a motor running at N rps. If T_a is in N-m, then power developed $= T_a \times 2\pi N$ watt