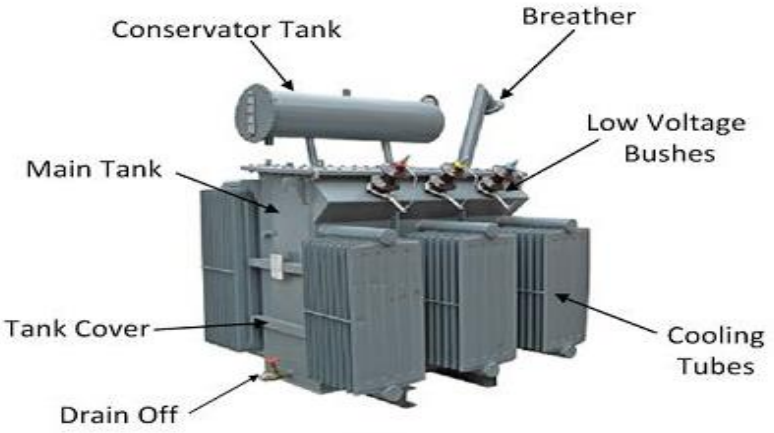
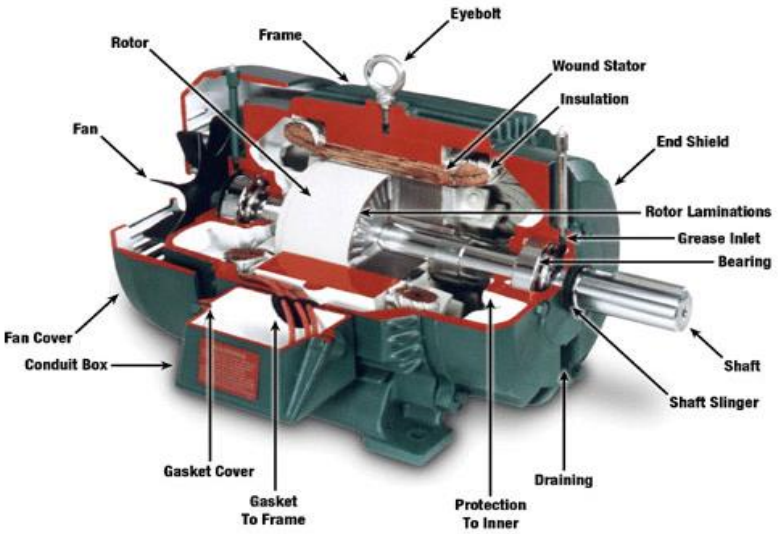
UNIT-III: Fundamentals of Electrical Machines

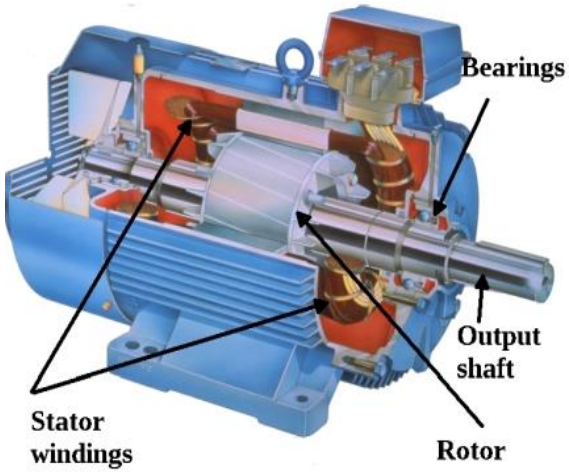
TRANSFOREMR



DC MACHINE



INDUCTION MOTOR

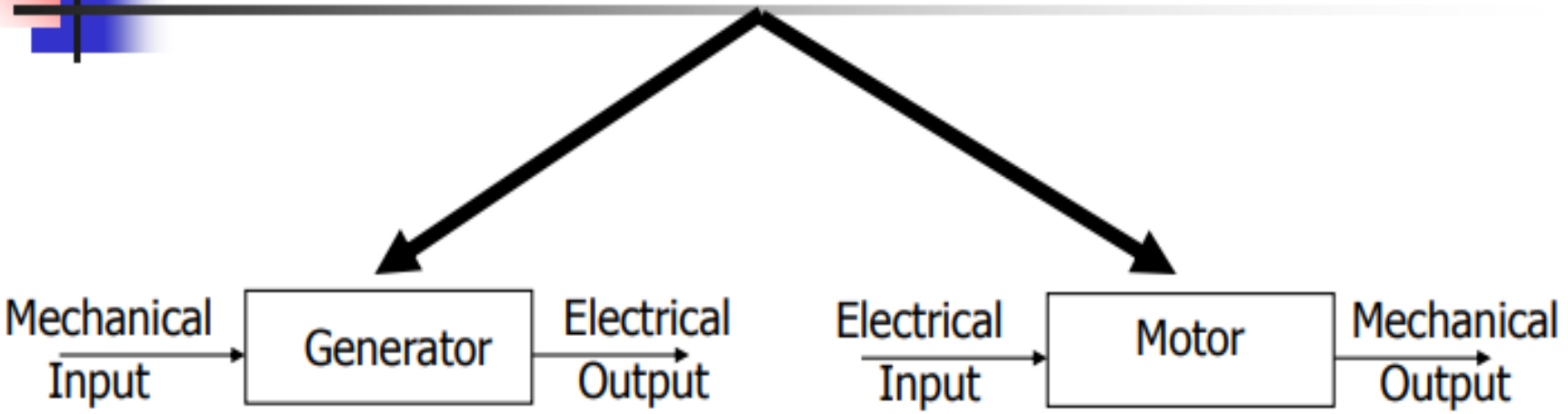


DC MACHINES

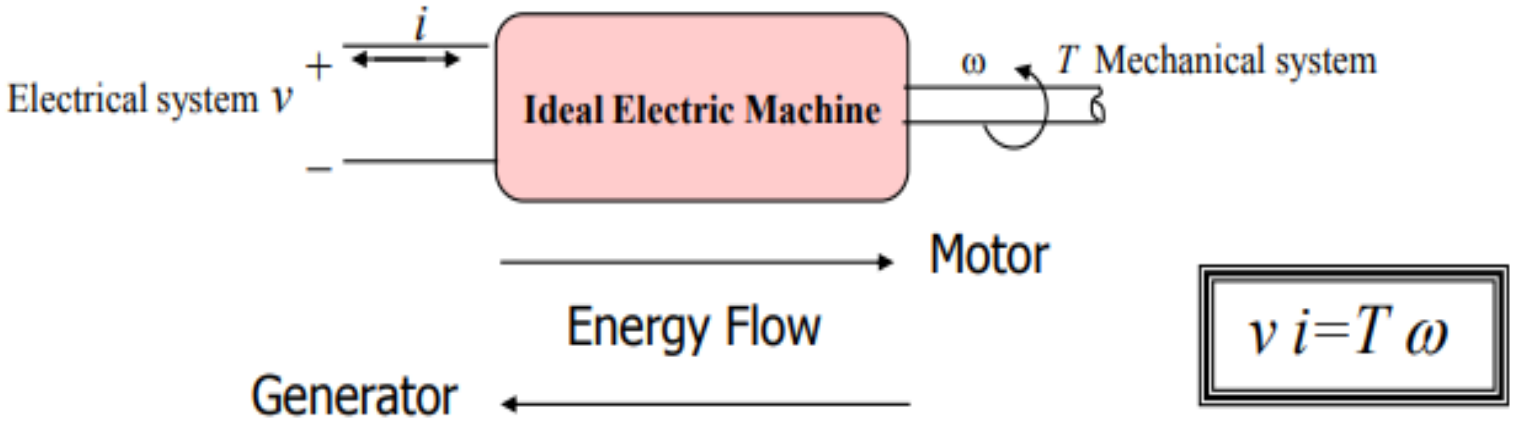
- **DC MOTOR**
- **DC GENERATOR**

- ❑ Construction
- ❑ Working principles
- ❑ Classification
- ❑ Speed control of DC Motor
- ❑ Applications of dc motors

Electric Machine



Electromechanical Energy Conversion



$$v\,i = T\,\omega$$

DC MOTOR

- When a current carrying conductor is places in a magnetic field, it experiences a mechanical force. The direction of is determined by fleming's left hand rule and magnitude is given by

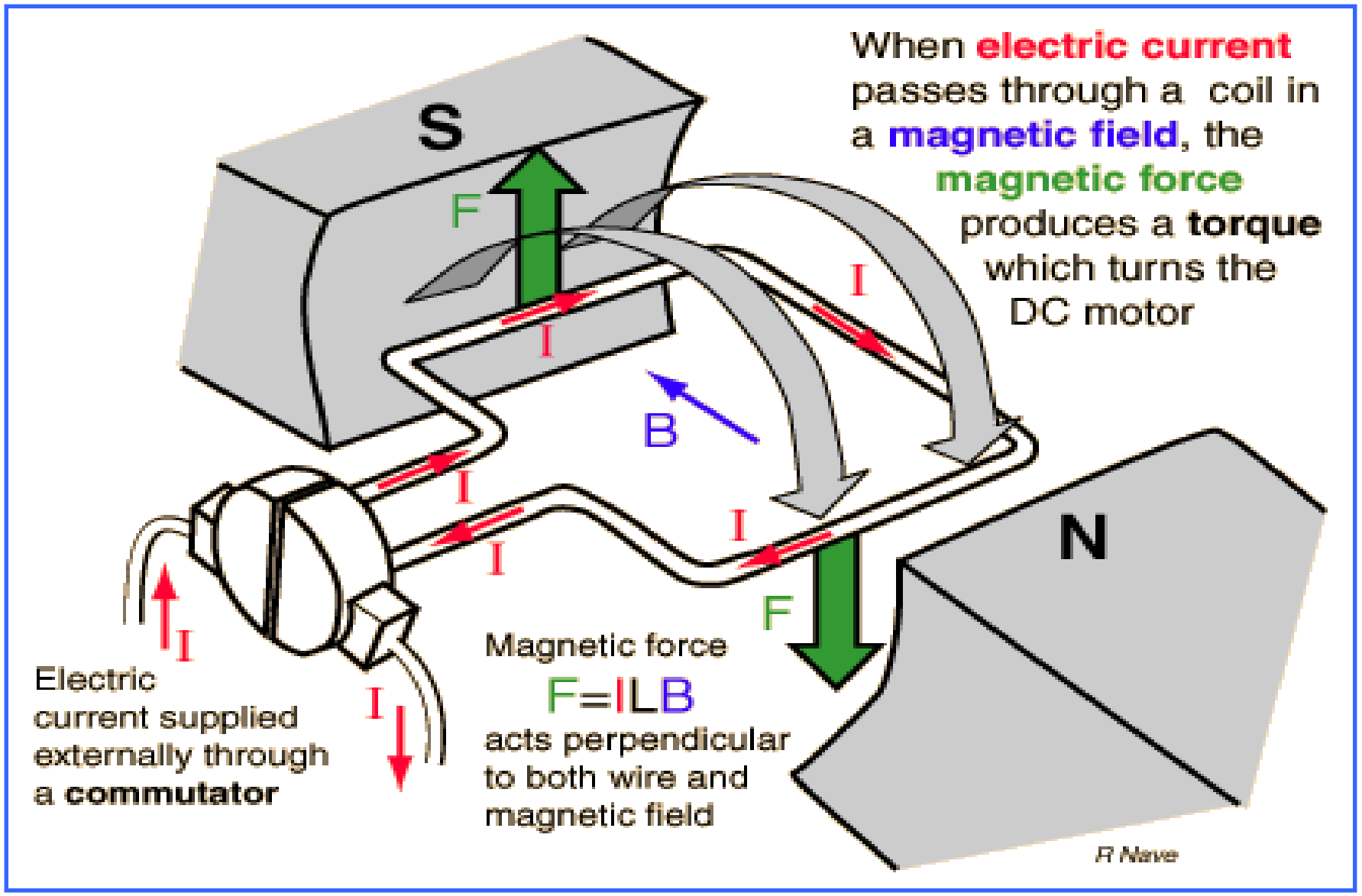
$$F=BIL$$

- DC motors are found in many special industrial environments Motors drive, many types of loads from fans and pumps to presses and conveyors.

- The major advantages of dc machines over generators are easy to control speed and torque regulation.

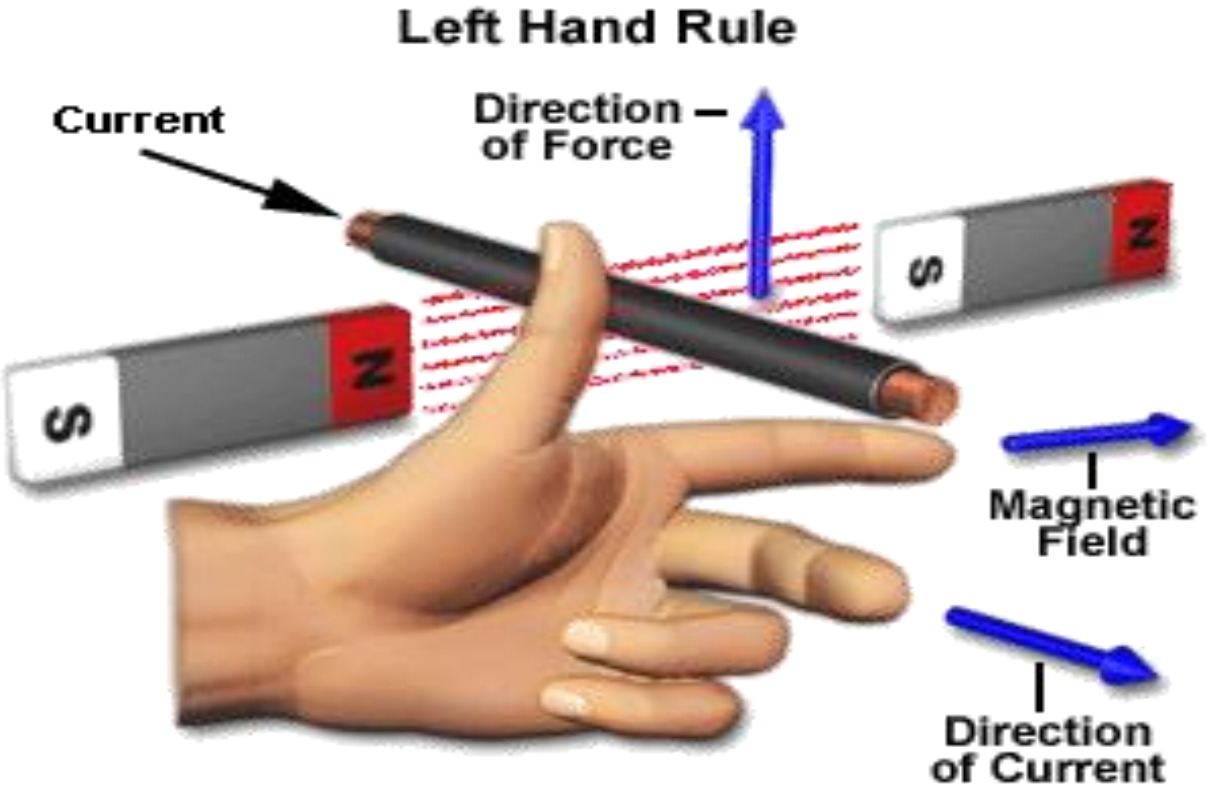
- In the past, automobiles were equipped with dc dynamos to charge their batteries, but now dynamos are replaced by alternators.

WORKING OF DC MOTOR



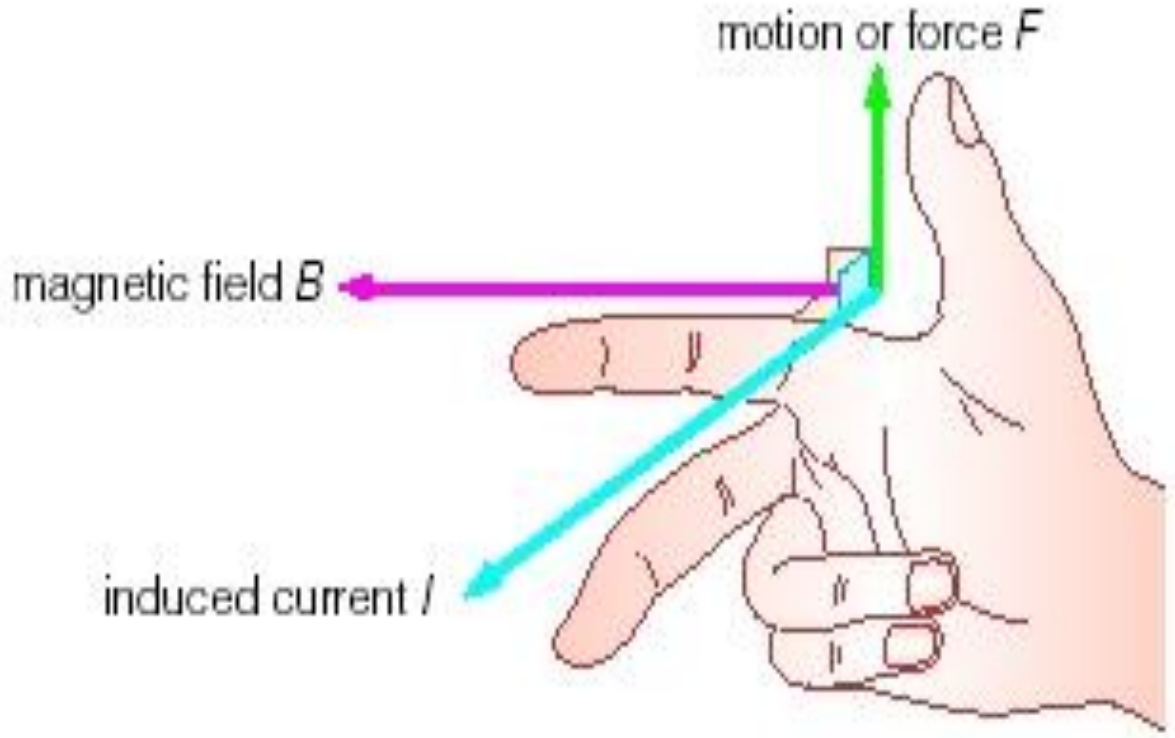
Fleming's left hand rule

- Used to determine the direction of force acting on a current carrying conductor placed in a magnetic field .



This rule is used **in motors.**

Fleming's Right hand rule



MCQ

Fleming's right-hand rule regarding direction of induced e.m.f., correlates:

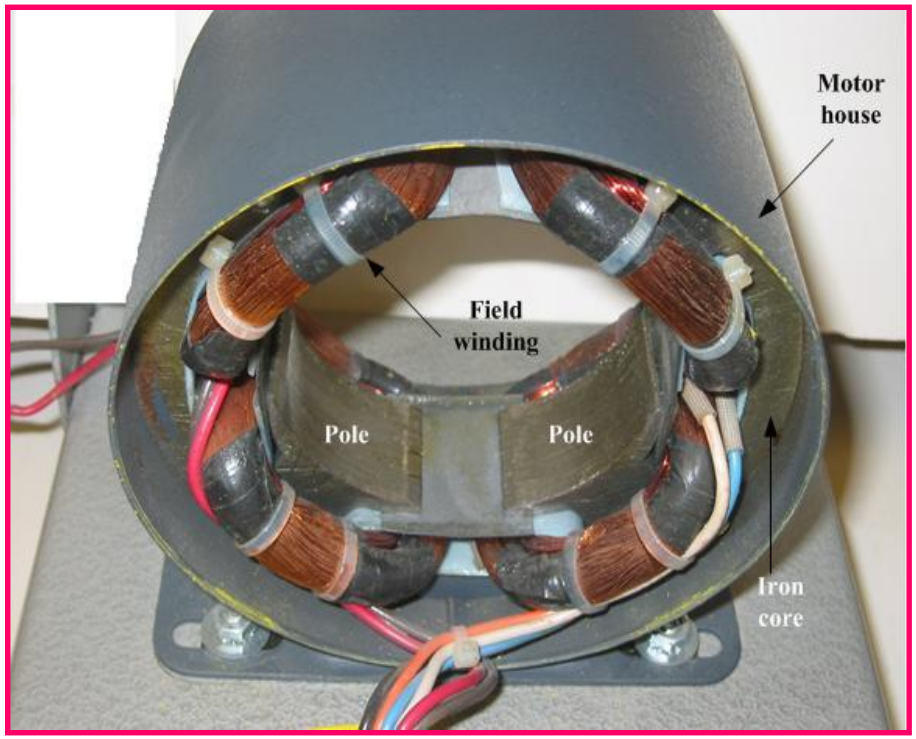
(a) magnetic flux, direction of current flow and resultant force

(b) magnetic flux, direction of motion and the direction of e.m.f. induced

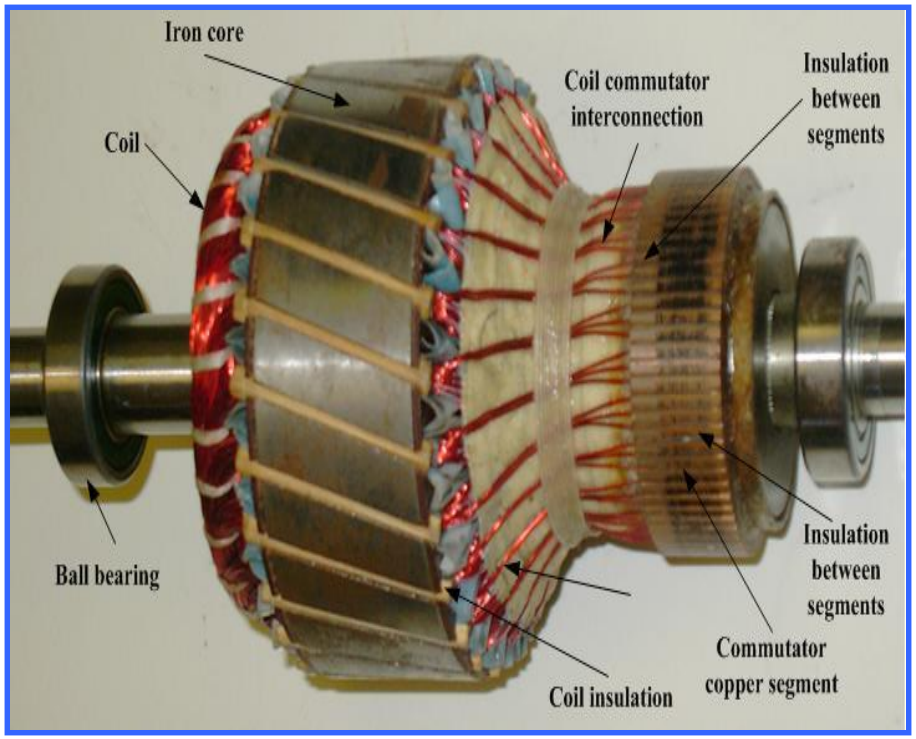
(c) magnetic field strength, induced voltage and current

(d) magnetic flux, direction of force and direction of motion of conductor

CONSTRUCTION OF DC MACHINES



DC motor stator

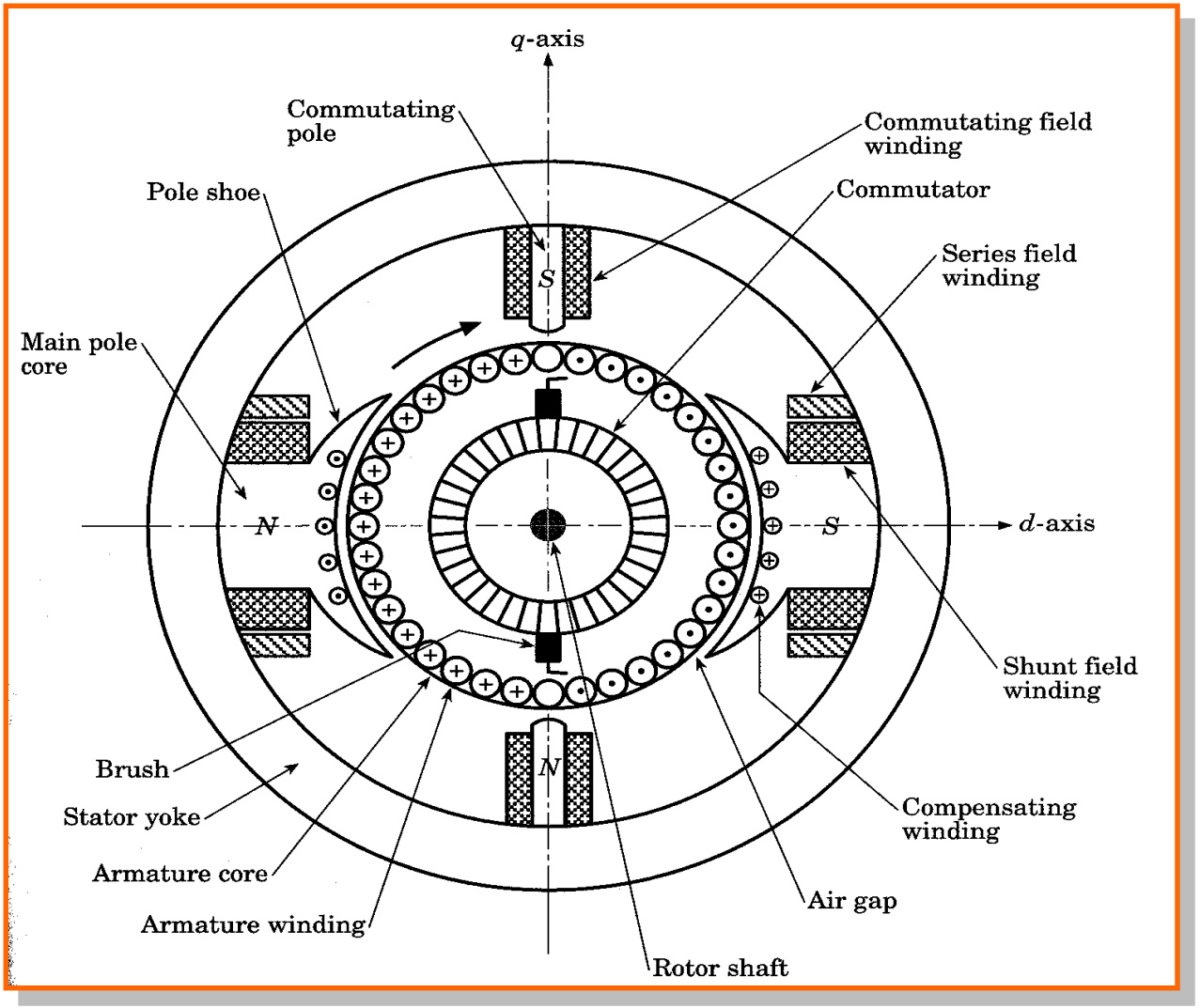


Rotor of a dc motor

DC Machines Construction

two sets of electrical windings

- Field windings - on stator
- Armature windings - on the rotor.

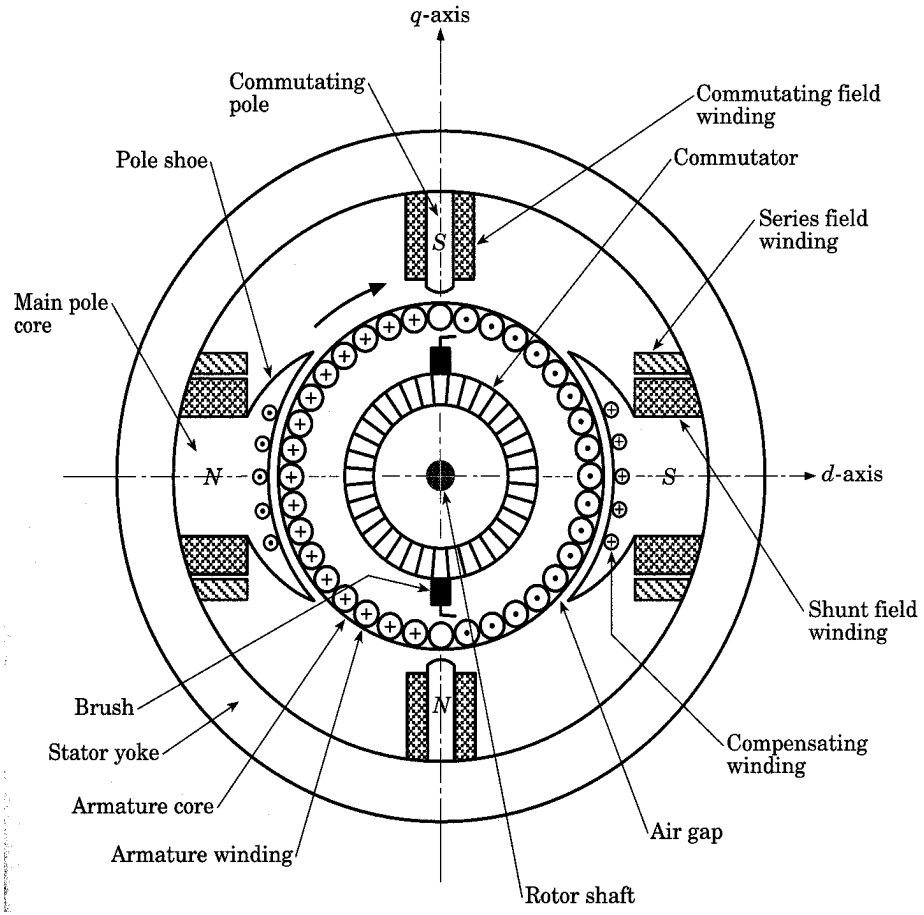


DC Machines Construction

- Stator of dc motor has poles, which are excited by dc current to produce magnetic fields.

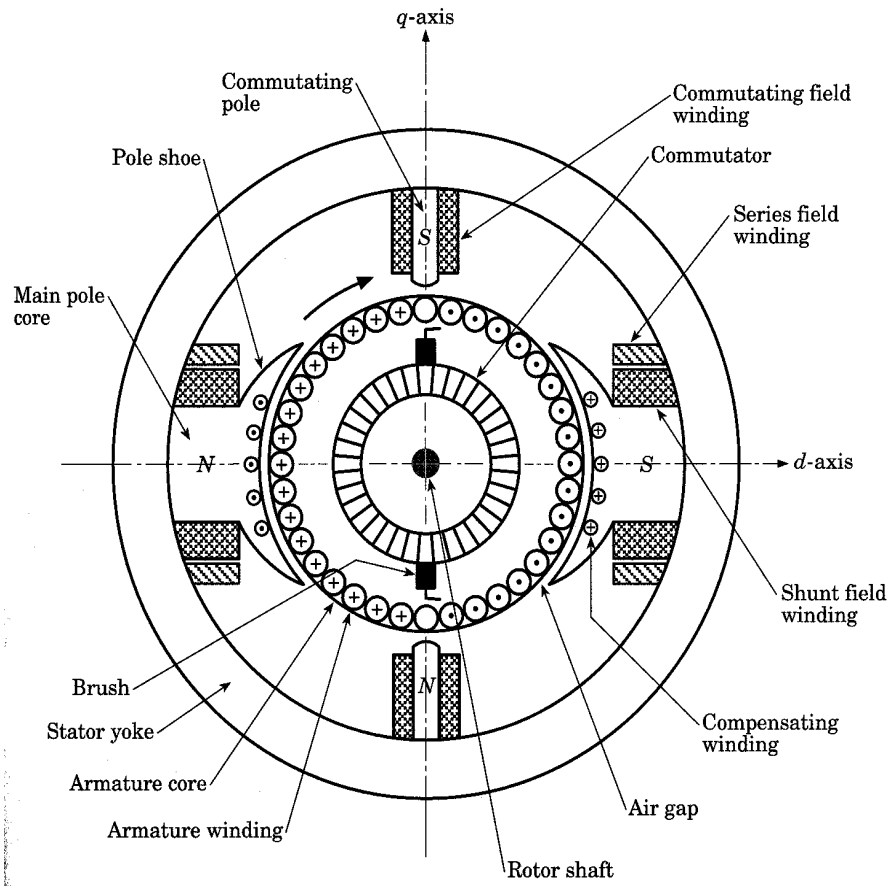
- In the neutral zone, in the middle between the poles, commutating poles are placed to reduce sparking of the commutator.

- Compensating windings are mounted on the main poles. These short-circuited windings damp rotor oscillations.



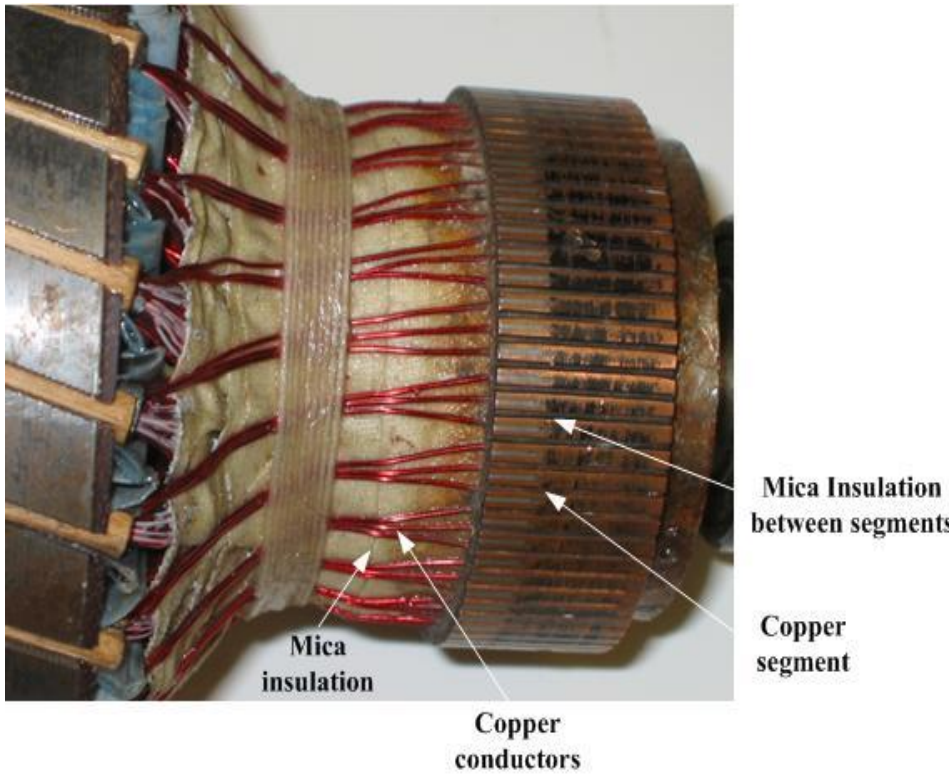
DC Machines Construction

- The poles are mounted on an iron core that provides a closed magnetic circuit.
- The motor housing supports the iron core, the brushes and the bearings.
- The rotor has a ring-shaped laminated iron core with slots.
- Coils with several turns are placed in the slots.



DC Machines Construction

- The coils are connected in series through the commutator segments.
- The ends of each coil are connected to a commutator segment.
- The commutator consists of insulated copper segments mounted on an insulated tube.
- The *commutator* switches the current from one rotor coil to the adjacent coil.
- Two brushes are pressed to the commutator to permit current flow.
- The brushes are placed in the neutral zone, where the magnetic field is close to zero, to reduce arcing.



MCQ

The insulating material used between the commutator segments is normally

(a) graphite

(b) paper

(c) mica

(d) insulating varnish

Principle of Operation

The generated voltage of a DC machines having (*p)* poles and *(Z)* conductors on the armature with (*a*) parallel path between brushes as below :

$$E_A = \frac{pZ\Phi\omega}{2\pi a} = K\Phi\omega$$

where K = pZ /(2πa) = machine constant

The mechanical torque which also equal to electromagnetic torque, is found as follows:

$$\tau_e = \tau_m = \frac{E_A I_A}{\omega} = K\Phi I_A$$

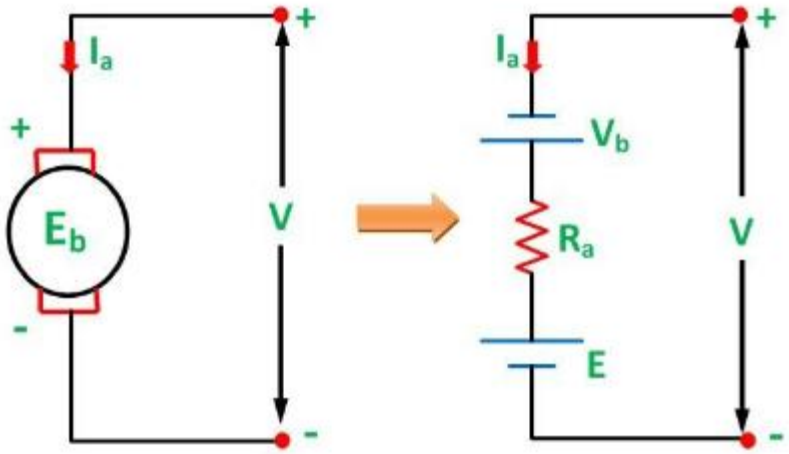
In the case of a generator, τ_m is the input mechanical torque, which is converted to electrical power. For the motor, τ_e is developed electromagnetic torque, which used to drive the mechanical load.

Speed Control of DC motors

According to the speed equation of a dc motor

$$N \propto Eb/\varphi$$

$$\propto V- Ia\ Ra/\ \varphi$$



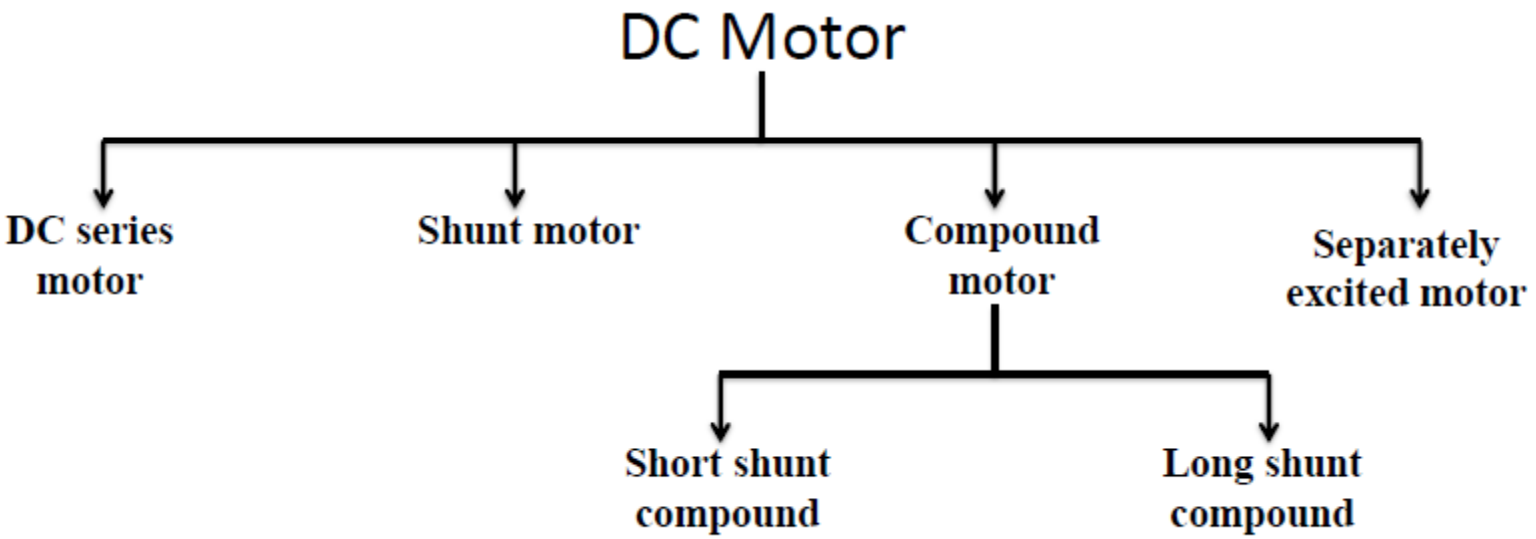
Thus speed can be controlled by:

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.

Types of DC Motors

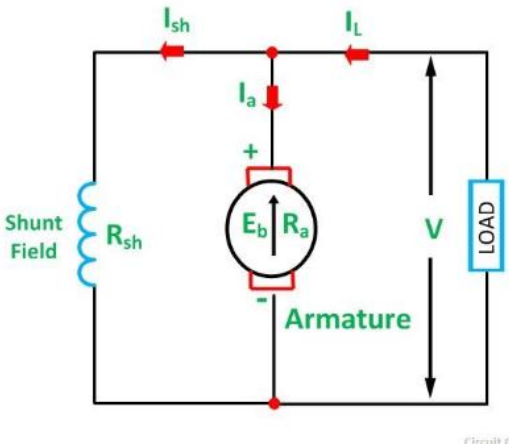
- DC motors are classified according to electrical connections of armature windings and field windings.

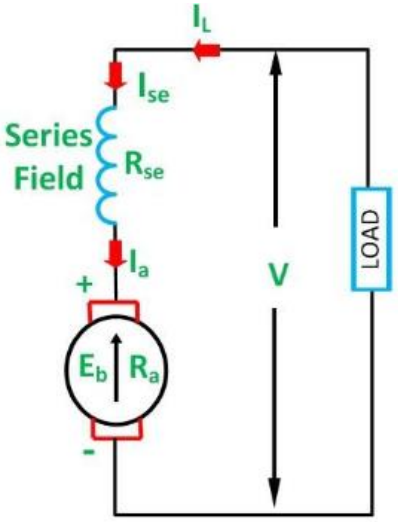


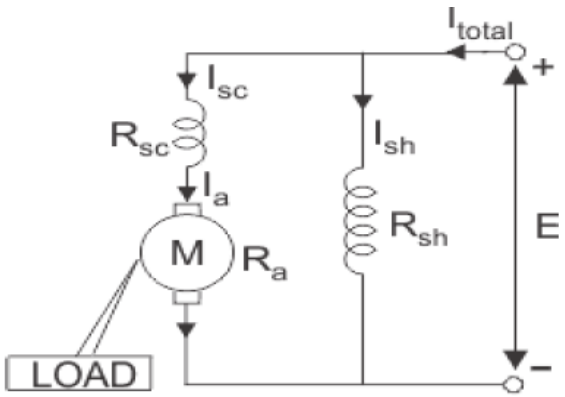
Shunt Machine: armature and field circuits are connected in parallel.

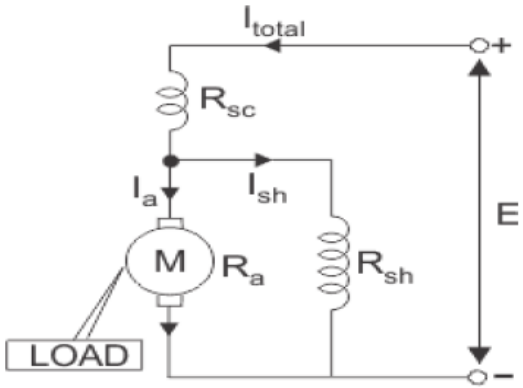
Series Machine: armature and field circuits are connected in series.

Separately-excited DC machine: The field windings may be separately excited from an eternal DC source.









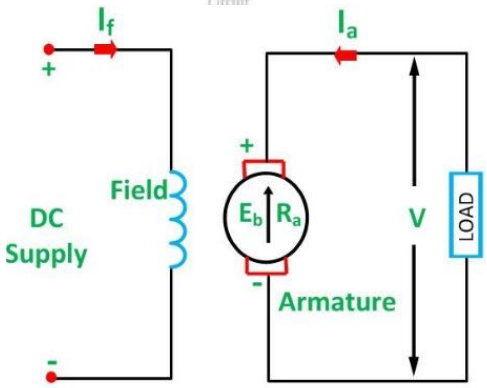


Fig.(1): Long shunt compound dc motor

fig.(2):Short shunt compound dc motor

Applications of DC Motors

Shunt Motor:

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

Series Motor:

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

Cumulative compound Motor:

- Rolling mills
- Punches
- Elevators

MCQ

The field coils of D.C. generator are usually made of

(a) mica

(b) copper

(c) cast iron

(d) carbon

MCQ

Brushes of D.C. machines are made of

(a) carbon

(b) soft copper

(c) hard copper

(d) all of above

Induction Motor
(Asynchronous Motor)

BASIS OF DIFFERENCE	SYNCHRONOUS MOTOR	INDUCTION MOTOR
Type of Excitation	A synchronous motor is a doubly excited machine.	An induction motor is a single excited machine.
Supply System	Its armature winding is energized from an AC source and its field winding from a DC source.	Its stator winding is energized from an AC source.
Speed	It always runs at synchronous speed. The speed is independent of load.	If the load increased the speed of the induction motor decreases. It is always less than the synchronous speed.
Starting	It is not self starting. It has to be run up to synchronous speed by any means before it	Induction motor has self starting torque.
Cost	A synchronous motor is costlier than an induction motor of the same output and voltage rating	An induction motor is cheaper than the synchronous motor of the same output and voltage rating.

INDUCTION MOTORS

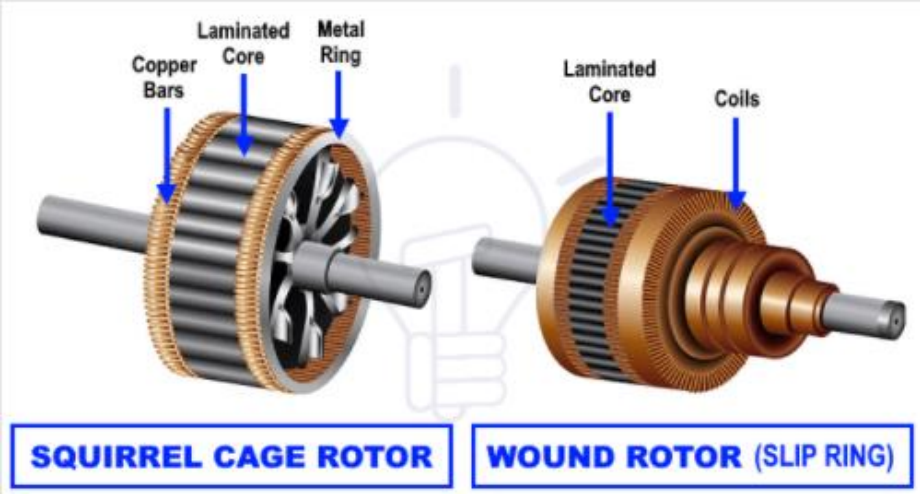
It is an AC electric motor in which the electric current in the rotor needed to produce torque and is obtained by electromagnetic induction from the magnetic field of the stator winding.

Depending on the rotor construction, induction motor can be classified into two categories:

- Squirrel-cage induction motor.
- Slip-ring induction motor or wound rotor induction motor.

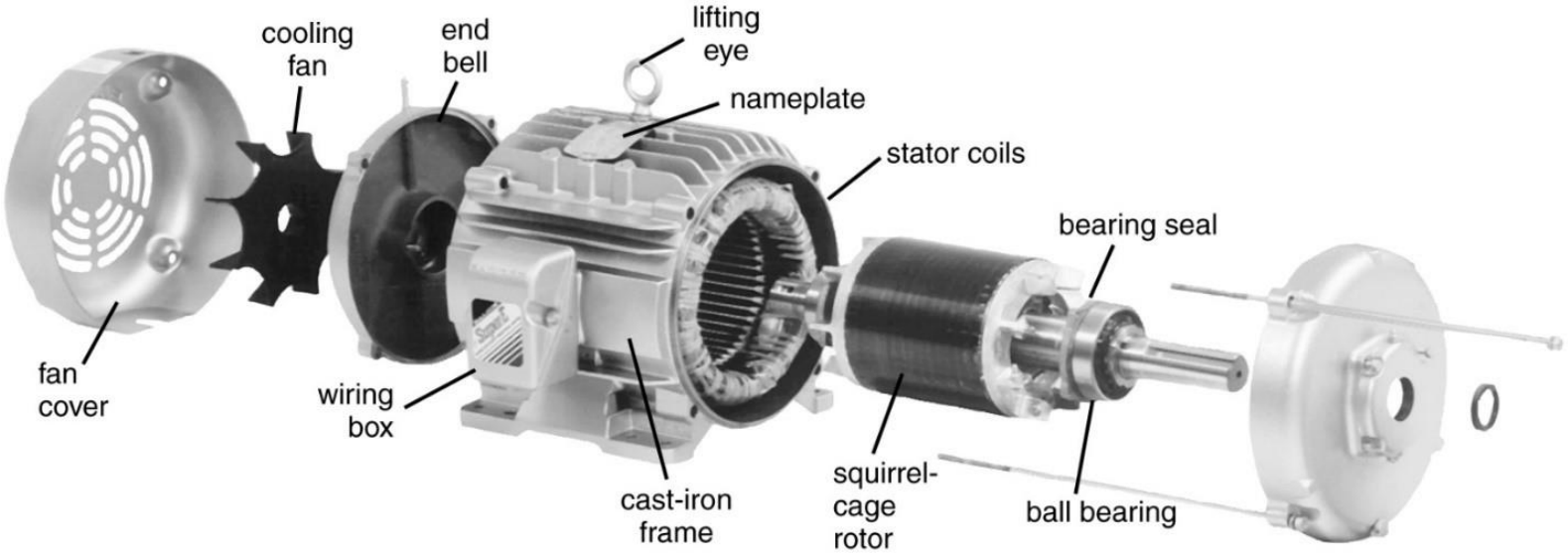
Depending on the number of phases it can be classified as:

- Single-phase induction motor
- Three-phase induction motor



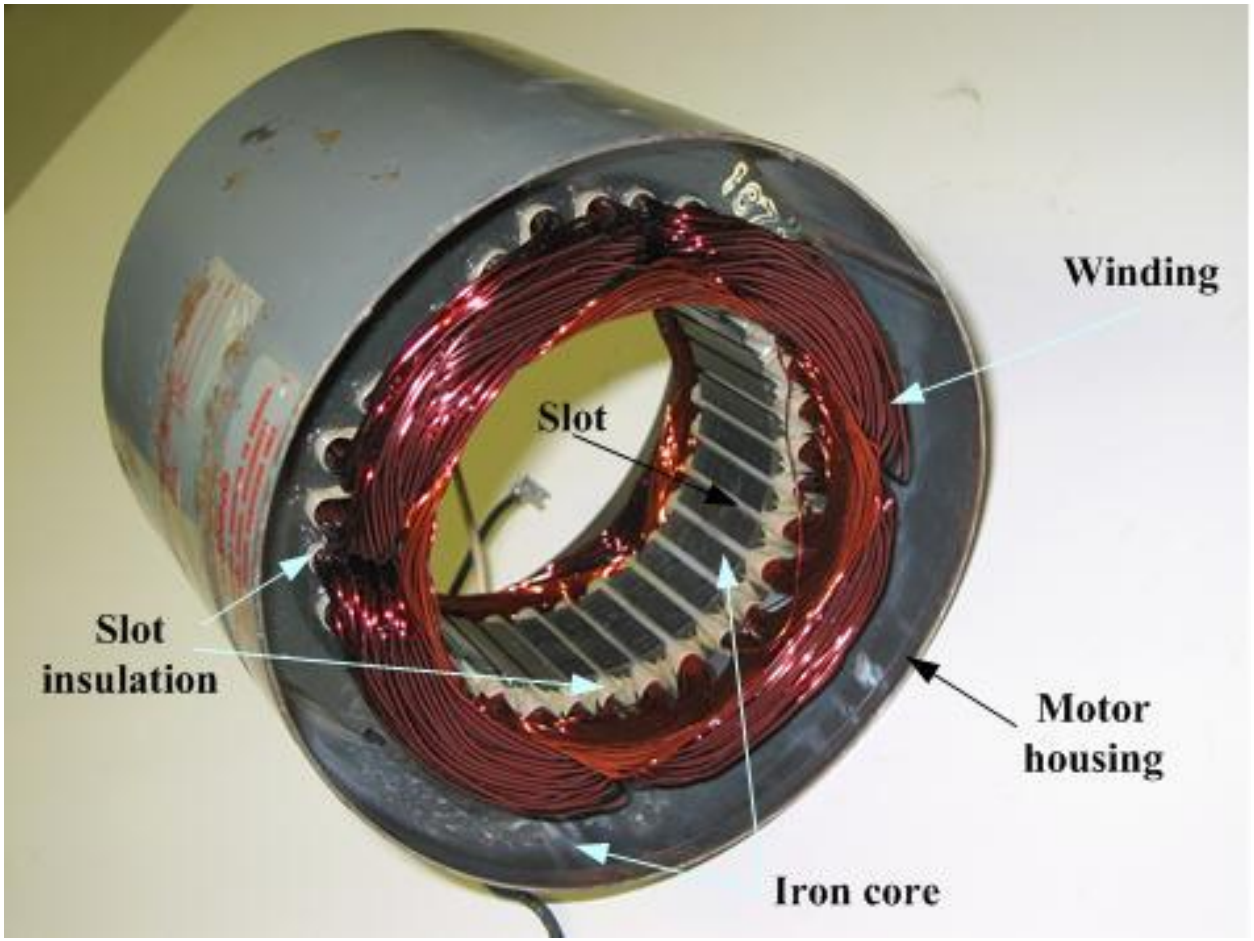
Single Phase Induction Motor

- Single-phase induction machine is most frequently used motor for vacuum cleaners, washing machines, drills, compressors, pumps, and so forth.
- The single-phase motor stator has a laminated iron core with two windings arranged perpendicularly.
  - One is the main winding and
  - Other is the auxiliary winding or *starting winding*

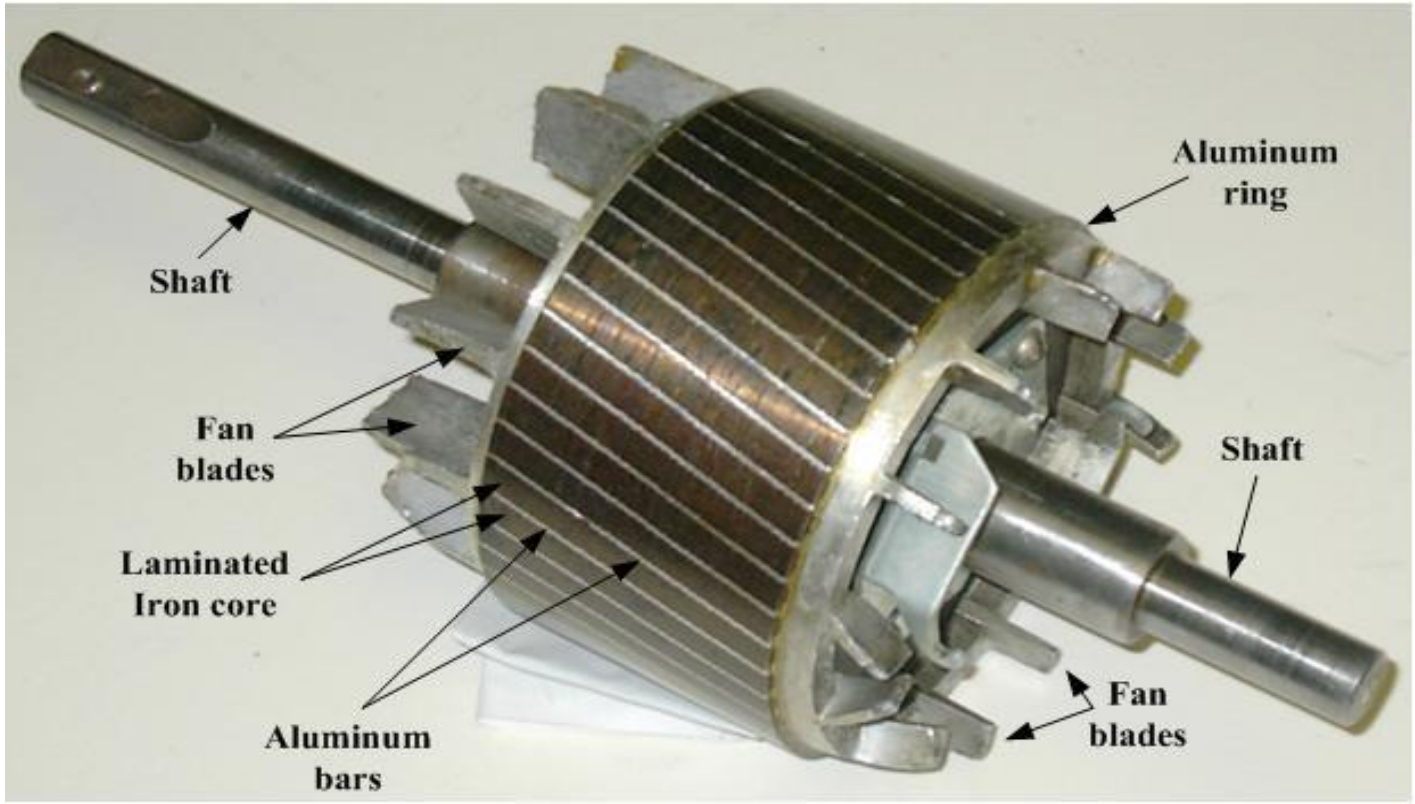


https://www.youtube.com/watch?v=awrUxv7B-a8

Construction of Single Phase Induction Motor



Single Phase Induction Motor



Squirrel cage rotor

Operating principle

- Apply a single phase AC supply to the stator winding, the alternating current starts flowing through the stator or main winding.

- This alternating current produces an alternating flux called main flux.

- This main flux also links with the rotor conductors and hence cut the rotor conductors.

- According to the Faraday law of EMI , emf gets induced in the rotor.

Cont..

- As rotor circuit is closed one so, the current starts flowing in the rotor. This current is called the rotor current.

- This rotor current produces its flux called rotor flux. Since this flux is produced due to induction principle. so, motor working on this principle called Induction Motor.

- Now there are two fluxes one is main flux, and another is called rotor flux.

These two fluxes produce desired torque which is required by motor to rotate.

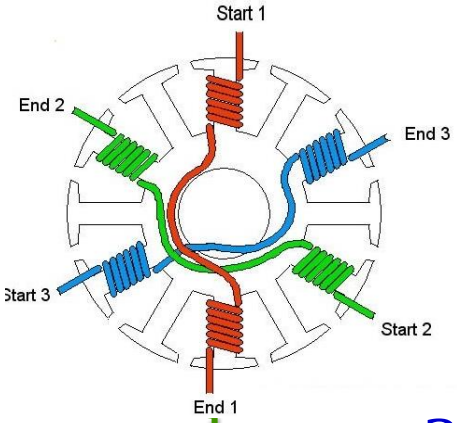
APPLICATIONS

- Fans, Compressor, Pumps, blowers, machine tools like lathe, drilling machine, lifts, conveyer belts etc.

Three Phase Induction Motor

- Three-phase induction motors are the most common and frequently encountered machines in industry
- It can be considered to be the cheapest motor.
- It is rugged and requires less maintenance.
- It is simple in design.
- It gives reliable operation.
- Its efficiency is very high.
- It is easy to control
- It runs at constant speed from zero to full load

Principle of Operation



- **Torque producing mechanism**
  - When a 3 phase stator winding is connected to a 3 phase voltage supply, 3 phase current will flow in the windings, hence the stator is energized.
  - A rotating flux Φ is produced in the air gap. The flux Φ induces a voltage E_a in the rotor winding (like a transformer).
  - The induced voltage produces rotor current, if rotor circuit is closed.
  - The rotor current interacts with the flux Φ, producing torque. The rotor rotates in the direction of the rotating flux.

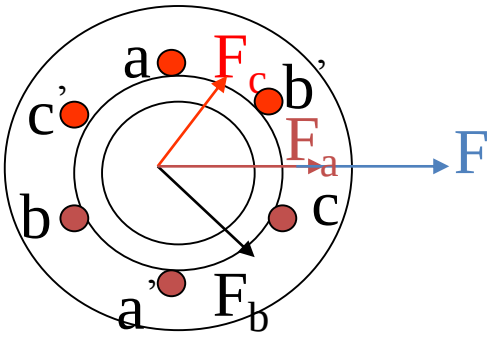
Rotating Magnetic Field

- When a 3 phase stator winding is connected to a 3 phase voltage supply, 3 phase current will flow in the windings, which also will induced 3 phase flux in the stator.
- These flux will rotate at a speed called a Synchronous Speed, n_s. The flux is called as Rotating magnetic Field.
- Synchronous speed: speed of rotating flux.

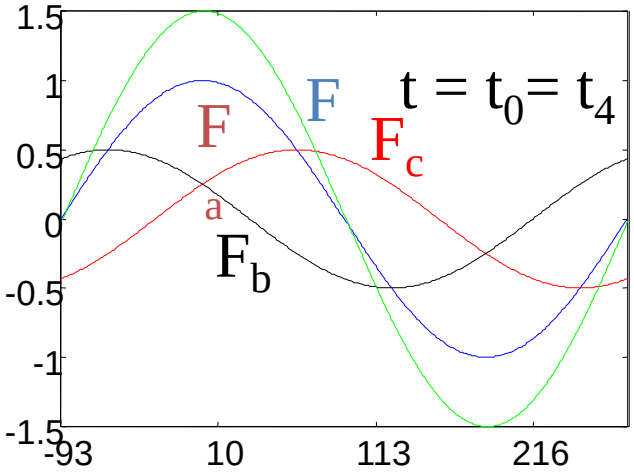
$$n_s = \frac{120f}{p}$$

- Where; p = is the number of poles, and
  f = the frequency of supply

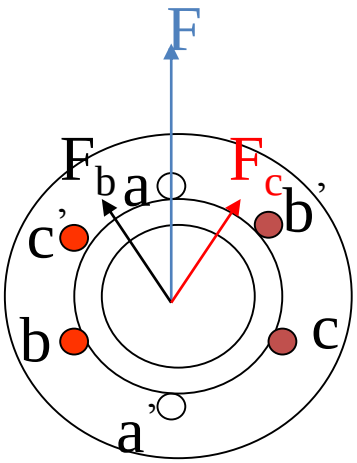
RMF(Rotating Magnetic Field)



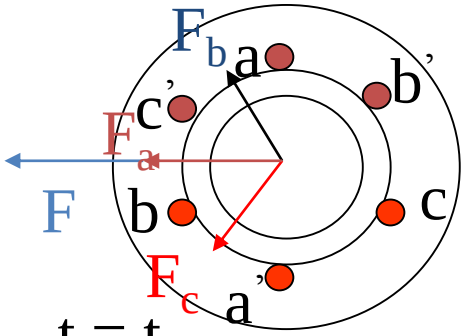
$t = t_0 = t_4$



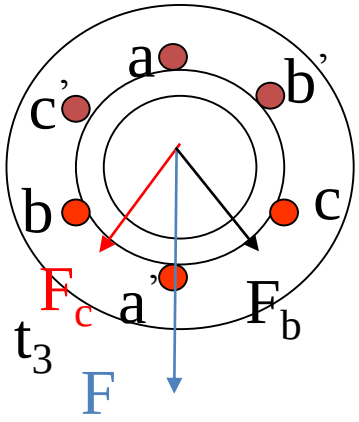
Space angle (θ) in degrees



$t = t_1$



$t = t_2$



$t = t_3$

Slip and Rotor Speed

- **Rotor Speed**
  - When the rotor move at rotor speed, $n_{r\,(rps)}$, the stator flux will circulate the rotor conductor at a speed of $(n_s\text{-}n_r)$ per second. Hence, the frequency of the rotor is written as:

Note:

At stator: $n_s = \frac{120f}{p}$

$$\therefore f = \frac{n_s p}{120} \qquad .....(i)$$

At Rotor: $n_s - n_r = \frac{120f}{p}$

$$\therefore f_r = \frac{(n_s - n_r)p}{120} \qquad .....(ii)$$

$(ii) \div (i)$: $f_r = s.f$

- Where, s = slip

  f = supply frequency

- **Advantages of Three-Phase Induction Motor**: These **motors** are self-starting and use no capacitor, start winding, centrifugal switch or other starting device.

APPLICATIONS

- **Three-phase** AC **induction motors** are widely used in industrial and Commercial **applications**.

APPLICATION OF three phase INDUCTION MOTOR

- **Squirrel cage induction motor**
- Squirrel cage induction motors are simple and rugged in construction, are relatively cheap and require little maintenance. Hence, squirrel cage induction motors are preferred in most of the industrial applications such as in
- Lathes
- Drilling machines
- Agricultural and industrial pumps
- Industrial drives.

MCQ

An induction motor is identical to

(a) D.C. compound motor

(b) D.C. series motor

(c) synchronous motor

(d) asynchronous motor

MCQ

Which type of bearing is provided in small induction motors to support the rotor shaft?

(a) Ball bearings

(b) Cast iron bearings

(c) Bush bearings

(d) None of the above

https://www.youtube.com/watch?v=awrUxv7B-a8