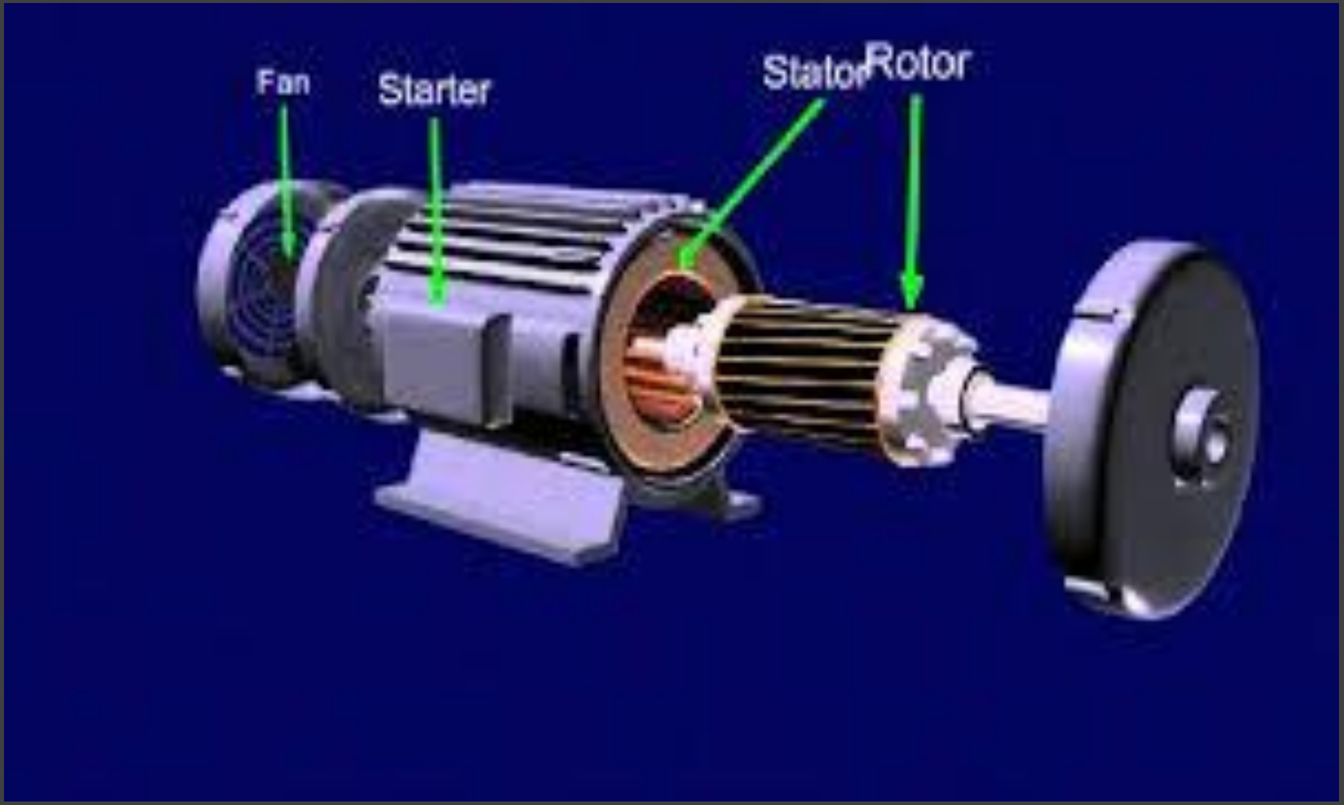
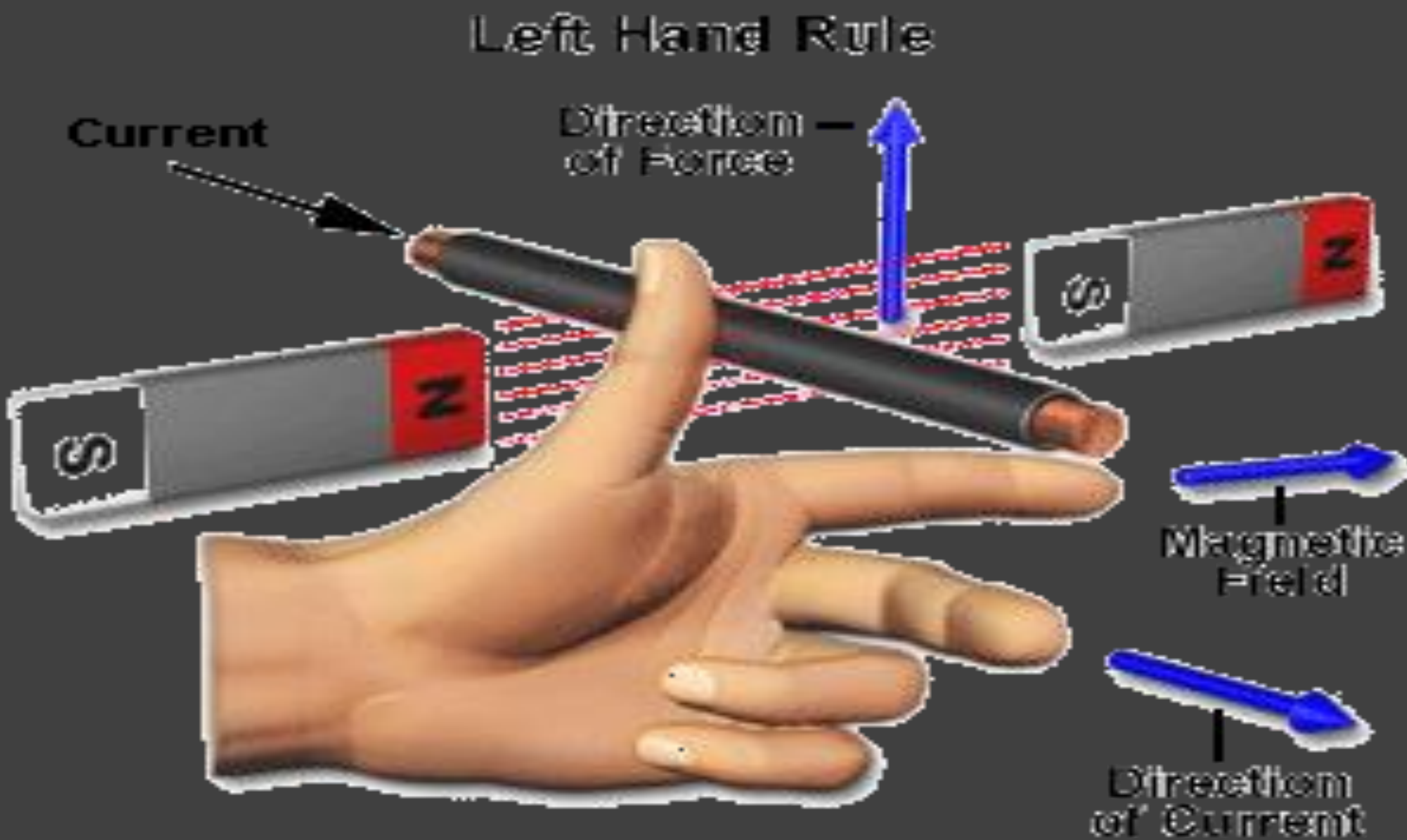
DC MACHINES



DC Motors

- The most common actuator in mobile robotics.
- Simple, cheap, and easy to use.
- Come in a great variety of sizes, to accommodate different robots and tasks.

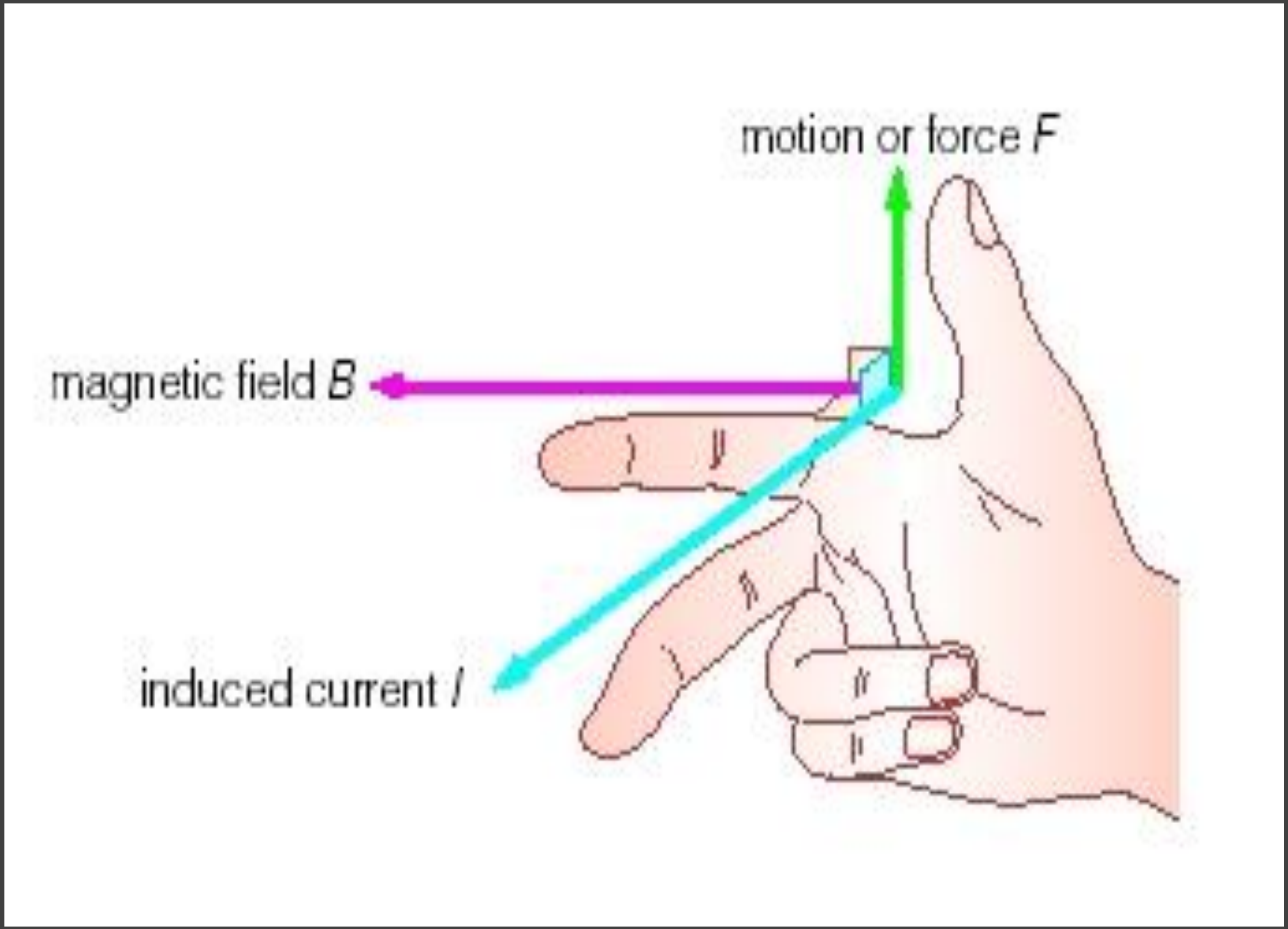
Fleming’s left hand rule



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 .

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

Principles of Operation

- *DC motors convert electrical into mechanical energy.*
- They consist of permanent magnets and loops of wire inside.
- When current is applied, the wire loops generate a magnetic field, which reacts against the outside field of the static magnets.
- The interaction of the fields produces the movement of the shaft/armature.
- Thus, electromagnetic energy becomes motion.

How do magnets arise?

There are two main sources of magnetic fields:

- Magnetic fields due to electric currents in conducting materials.
- Fields arising from **magnetic materials**. In these, electron motion (**orbital** or **spin**) can lead to a net ‘magnetic moment’ and a resulting **magnetization**.

Electromagnets

When a current flows through a conductor, a magnetic field surrounds the conductor. As current flow increases, so does the number of lines of force in the magnetic field.

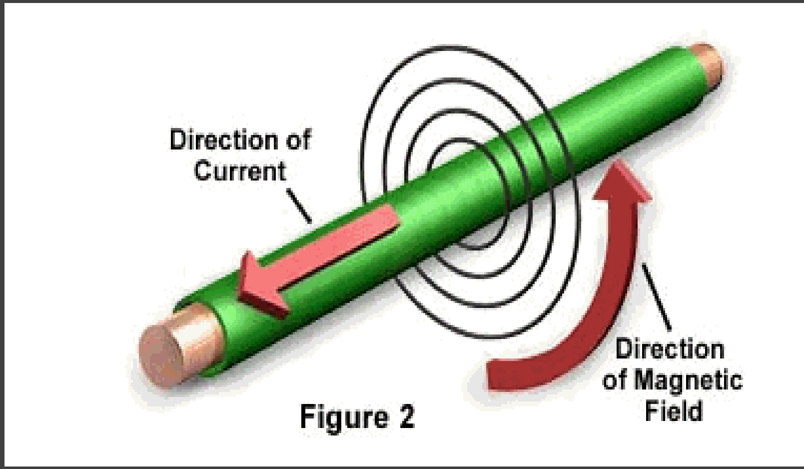
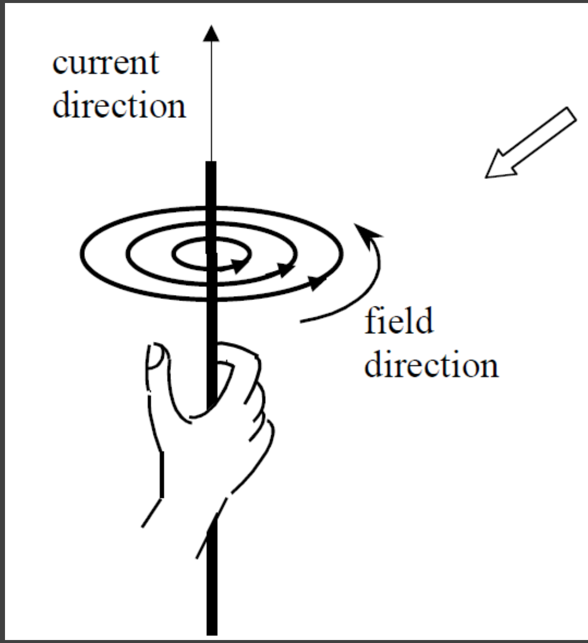
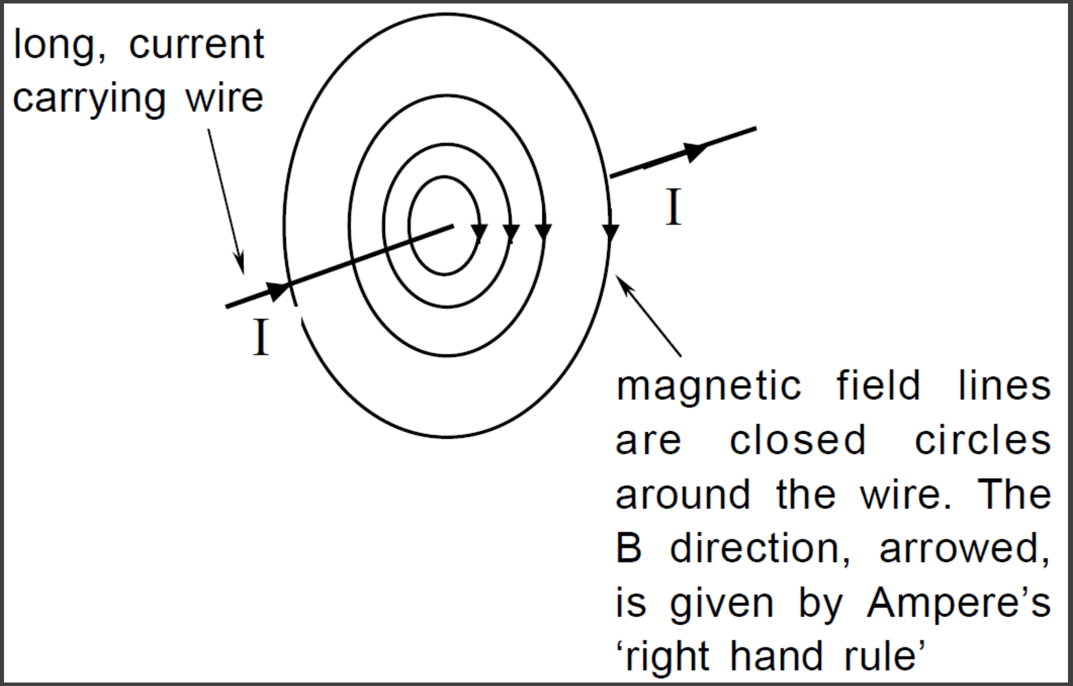


Figure 2

We can see that the field is perpendicular to the wire and that the field's direction depends on which direction the current is flowing in the wire.

Andre Ampere (1775-1836) formulated the right hand rule in the early 1820s. Ampere's essential contribution was to show that electricity and magnetism were part of the same phenomenon.



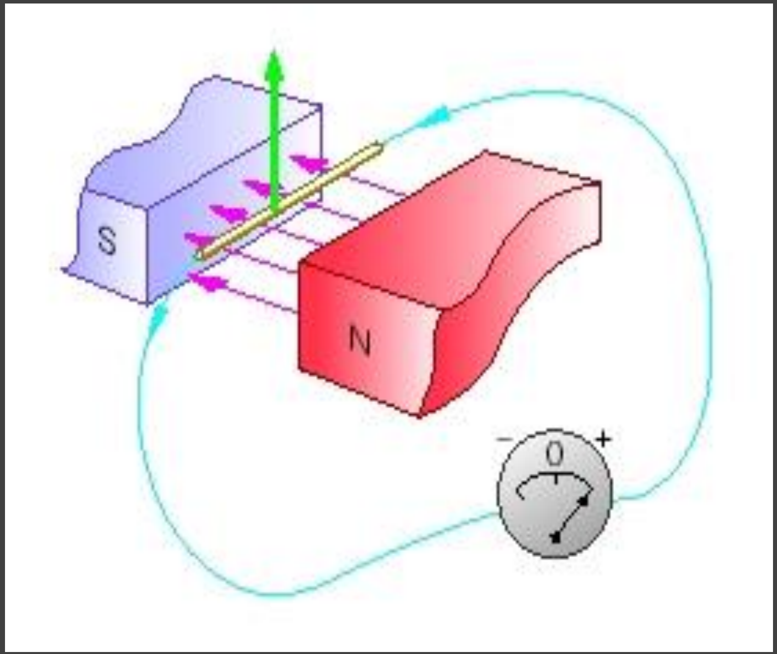


DC Generator

Mechanical energy is converted to electrical energy

Three requirements are essential

1. Conductors
2. Magnetic field
3. Mechanical energy



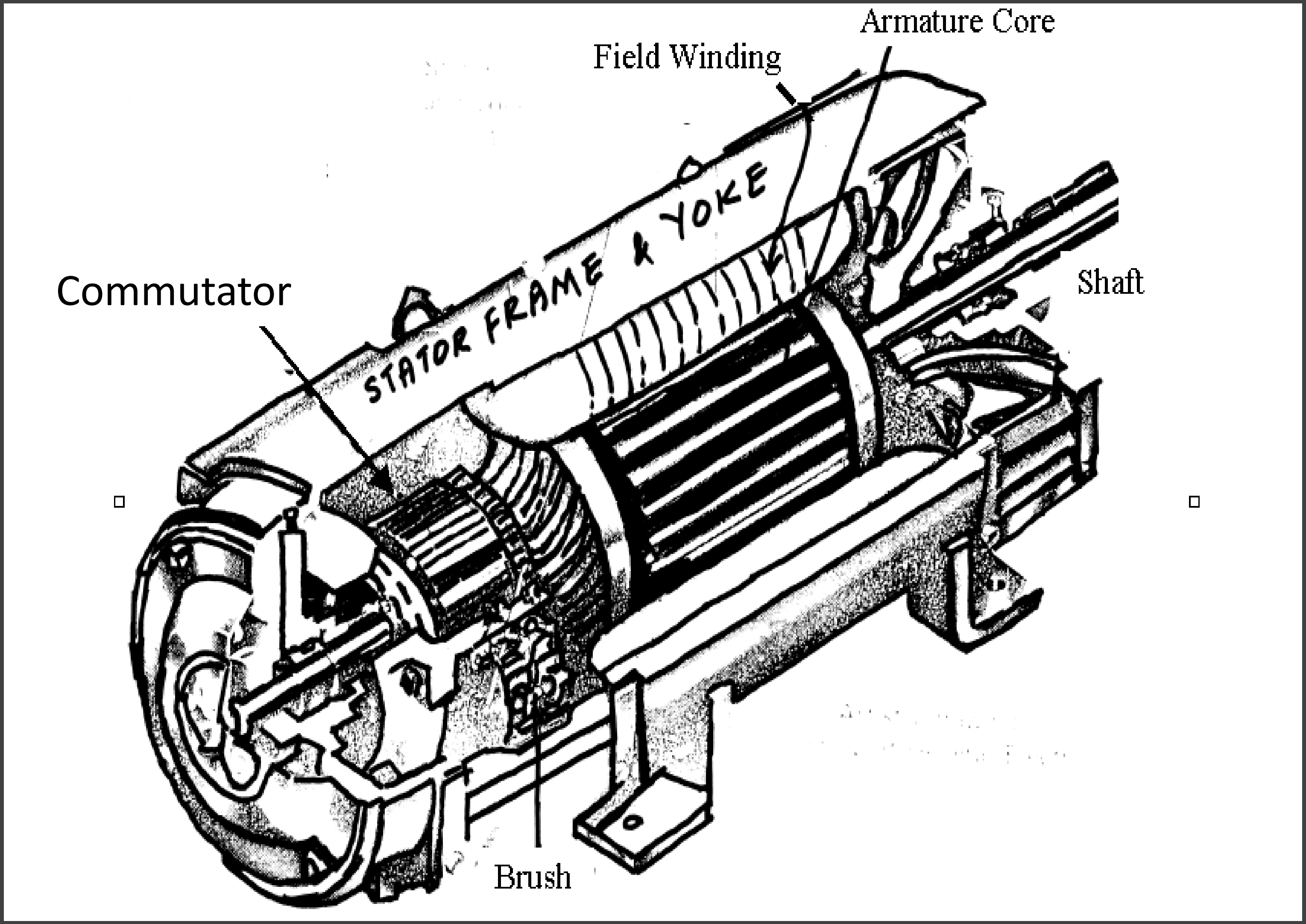
Working principle

- 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
STATOR FRAME & YOKE
Commutator
Shaft
Brush

Basics of a Electric Motor

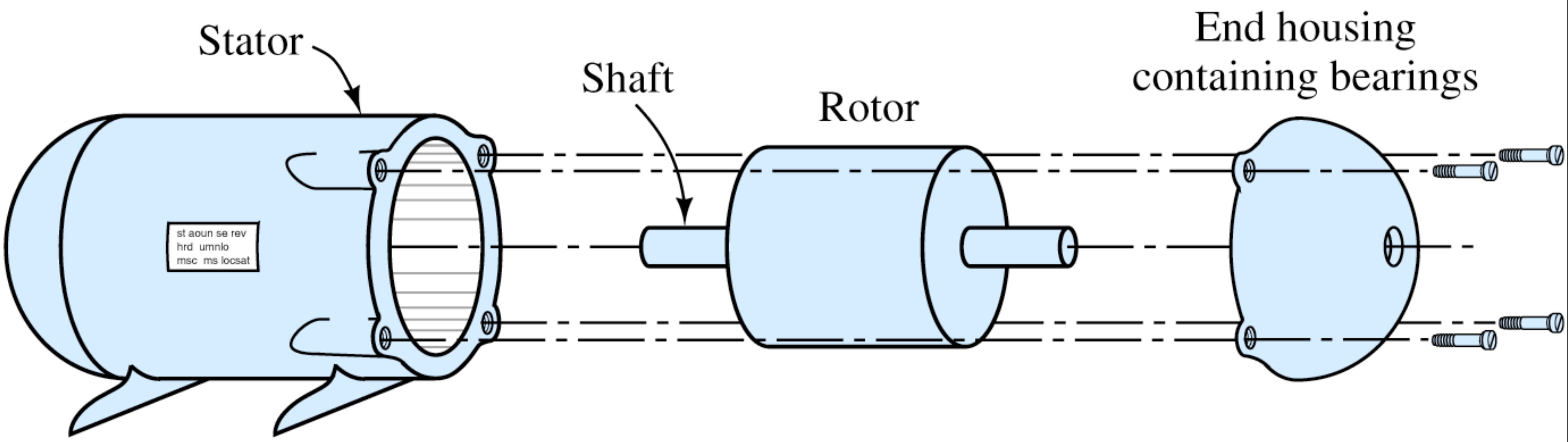
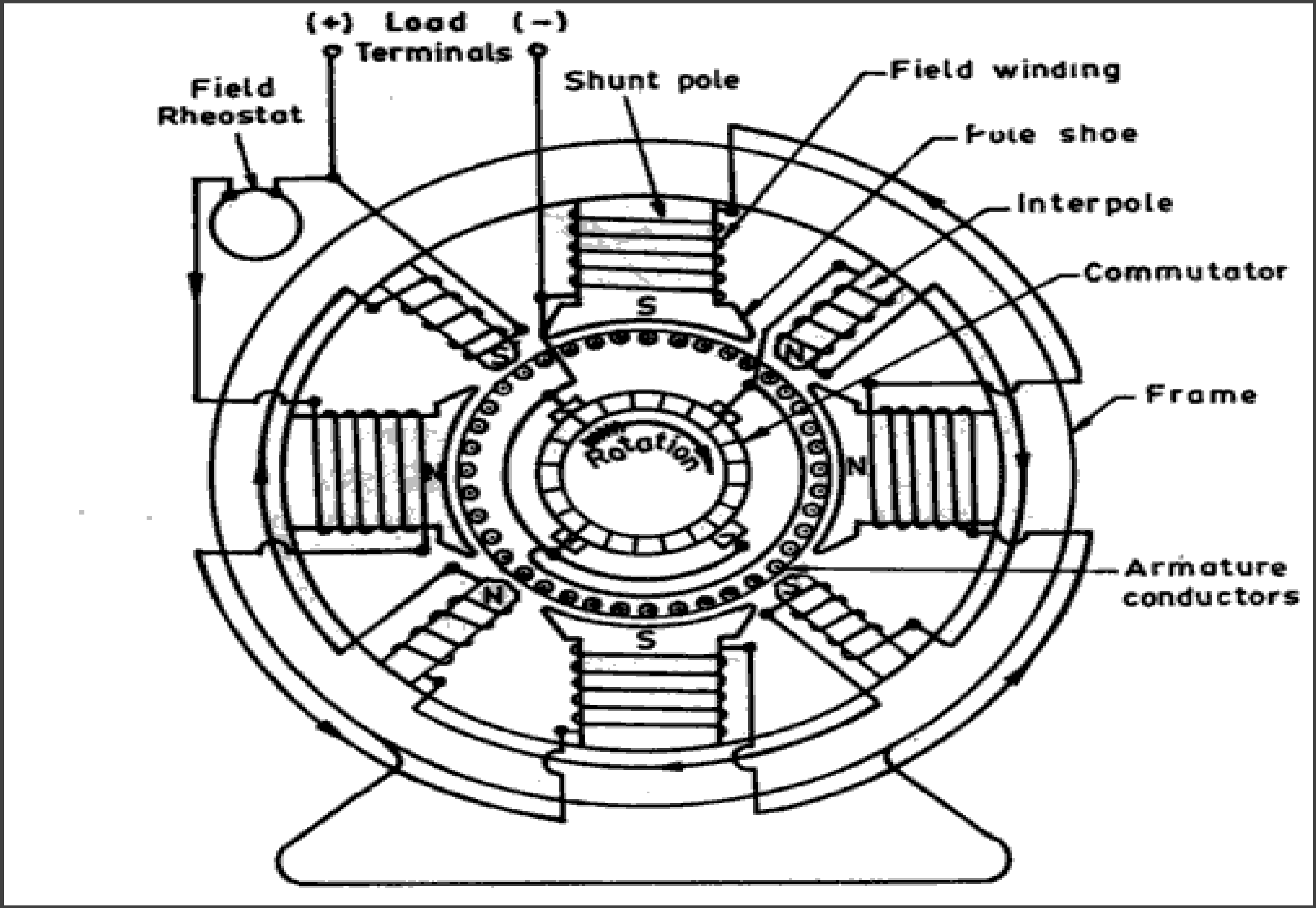


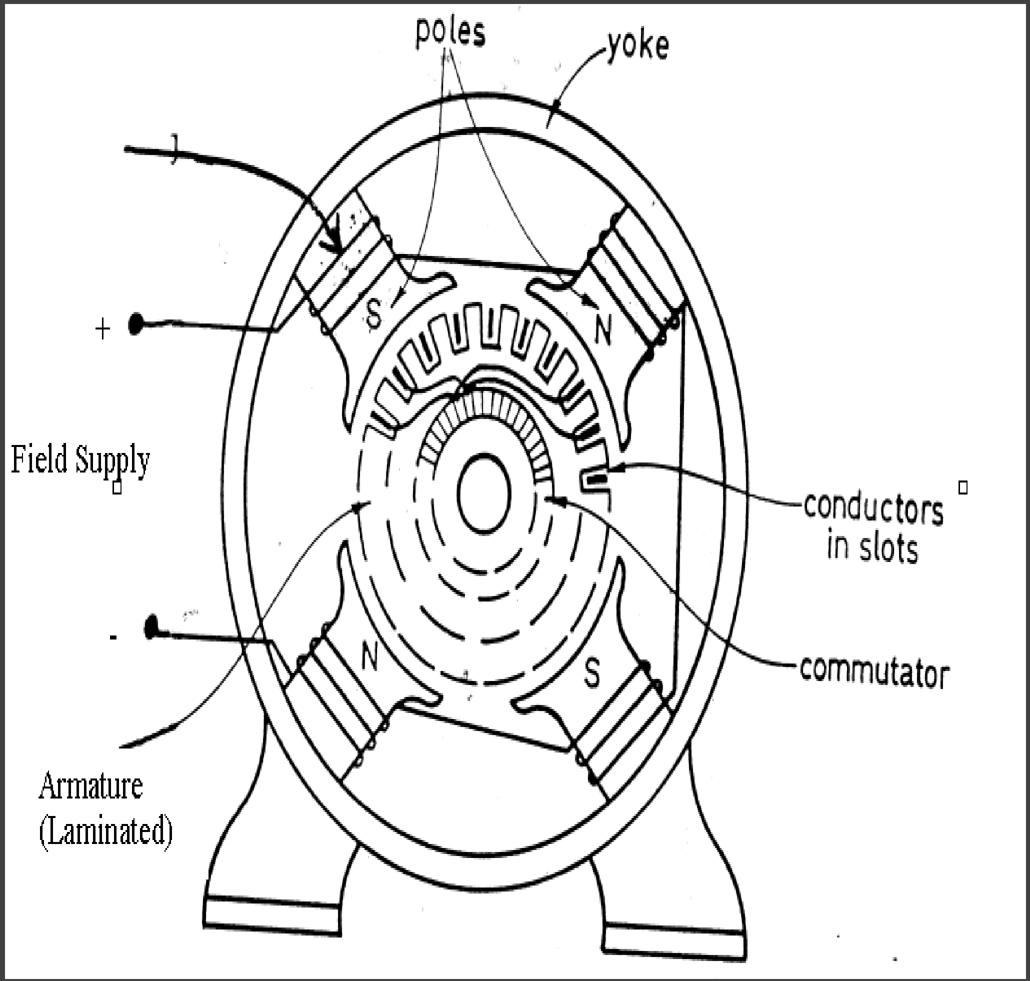
Figure 16.1 An electrical motor consists of a cylindrical rotor that spins inside a stator.

Sectional view of a DC machine



Construction of DC Generator

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



Armature of a DC Motor

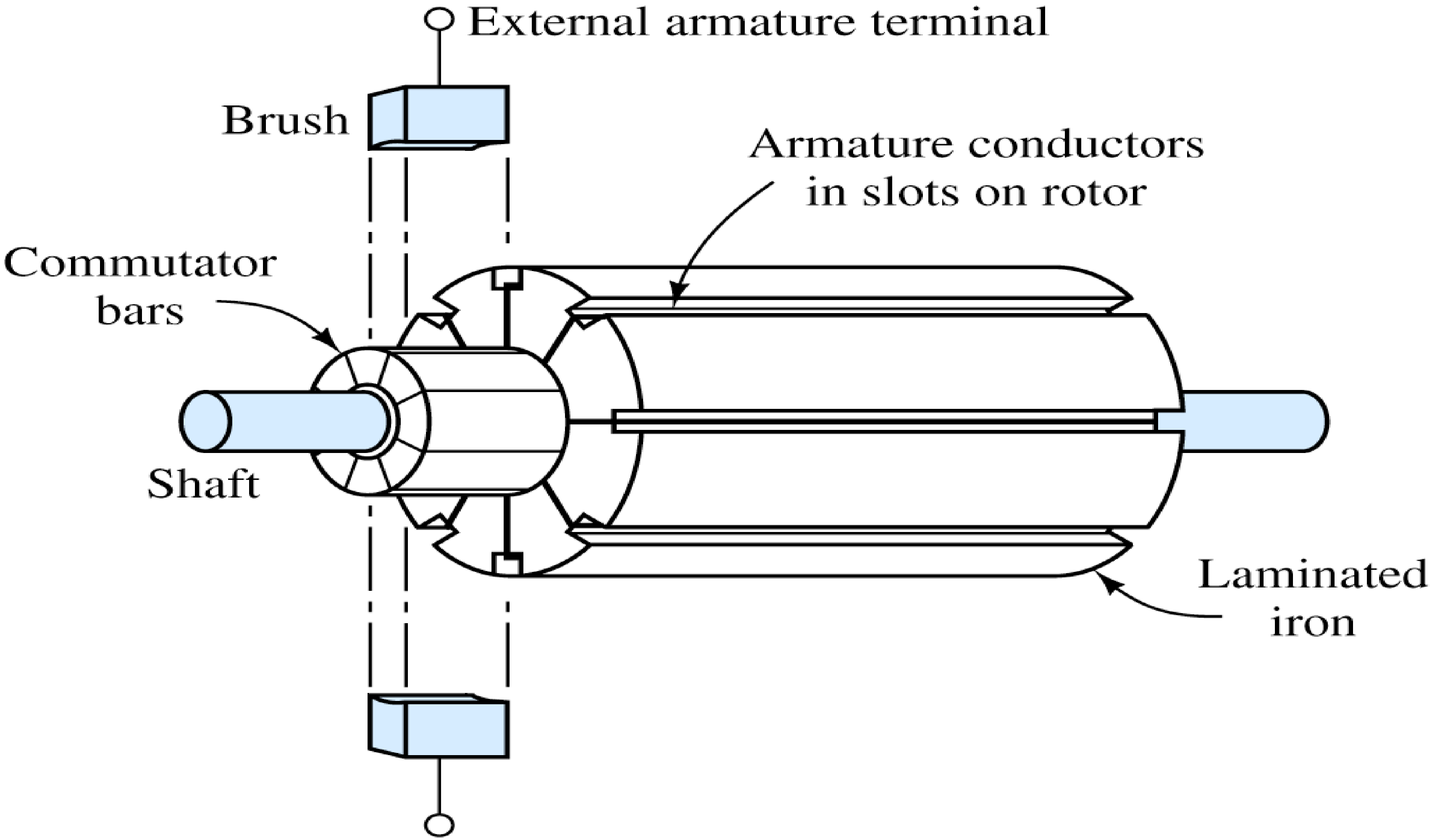
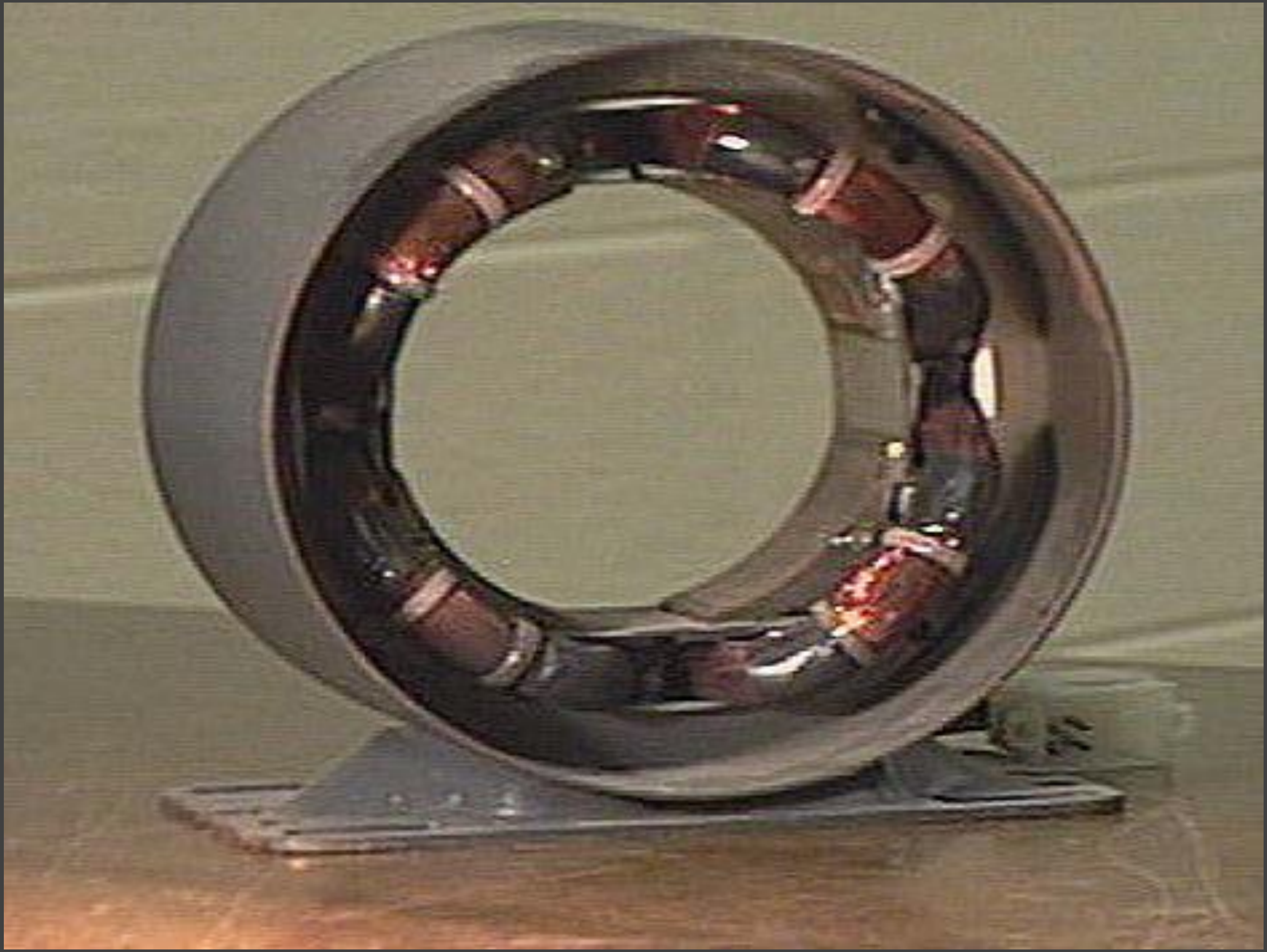
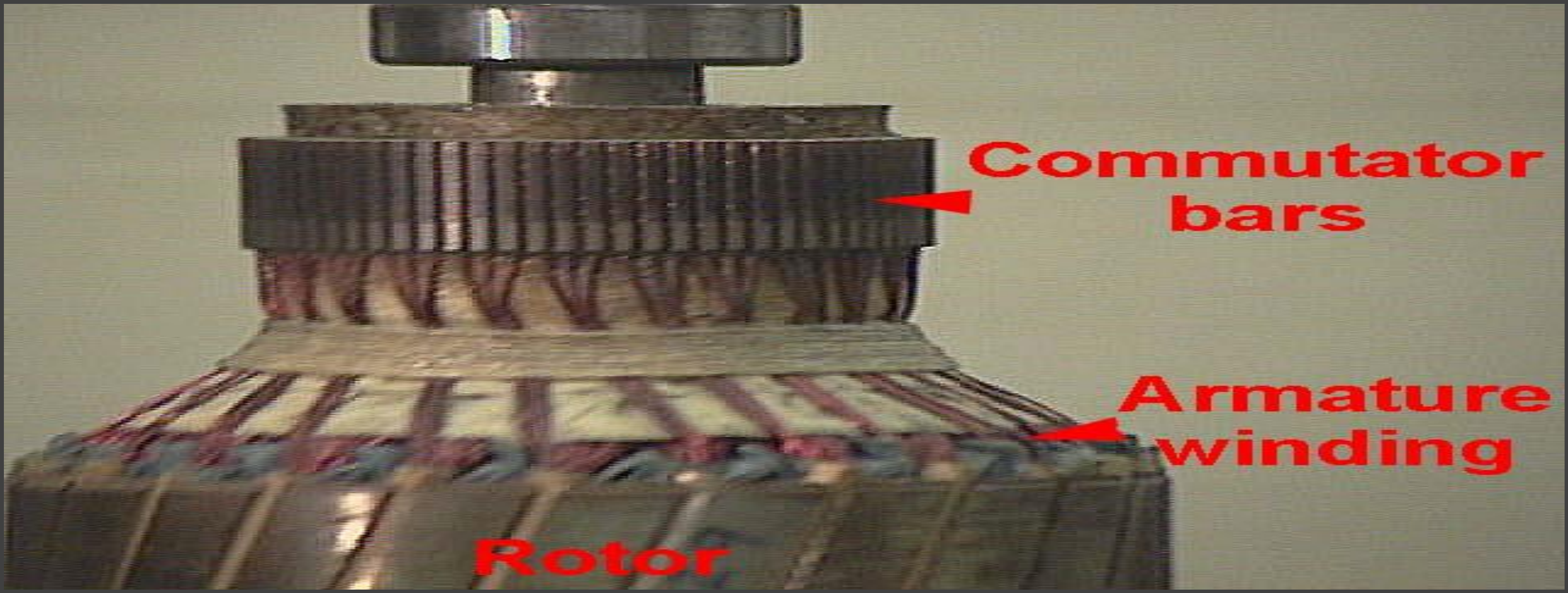


Figure 16.9 Rotor assembly of a dc machine.

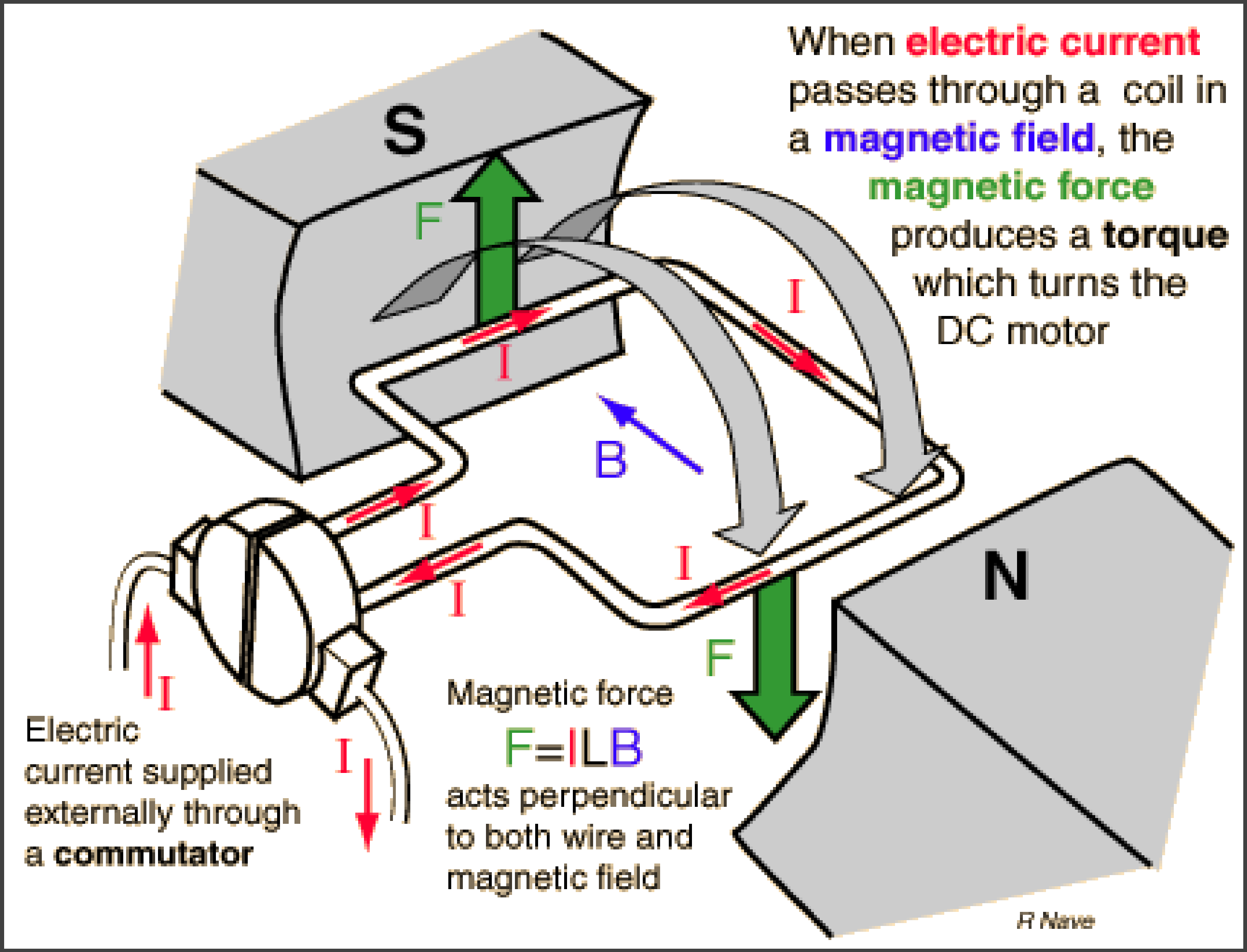
Field winding



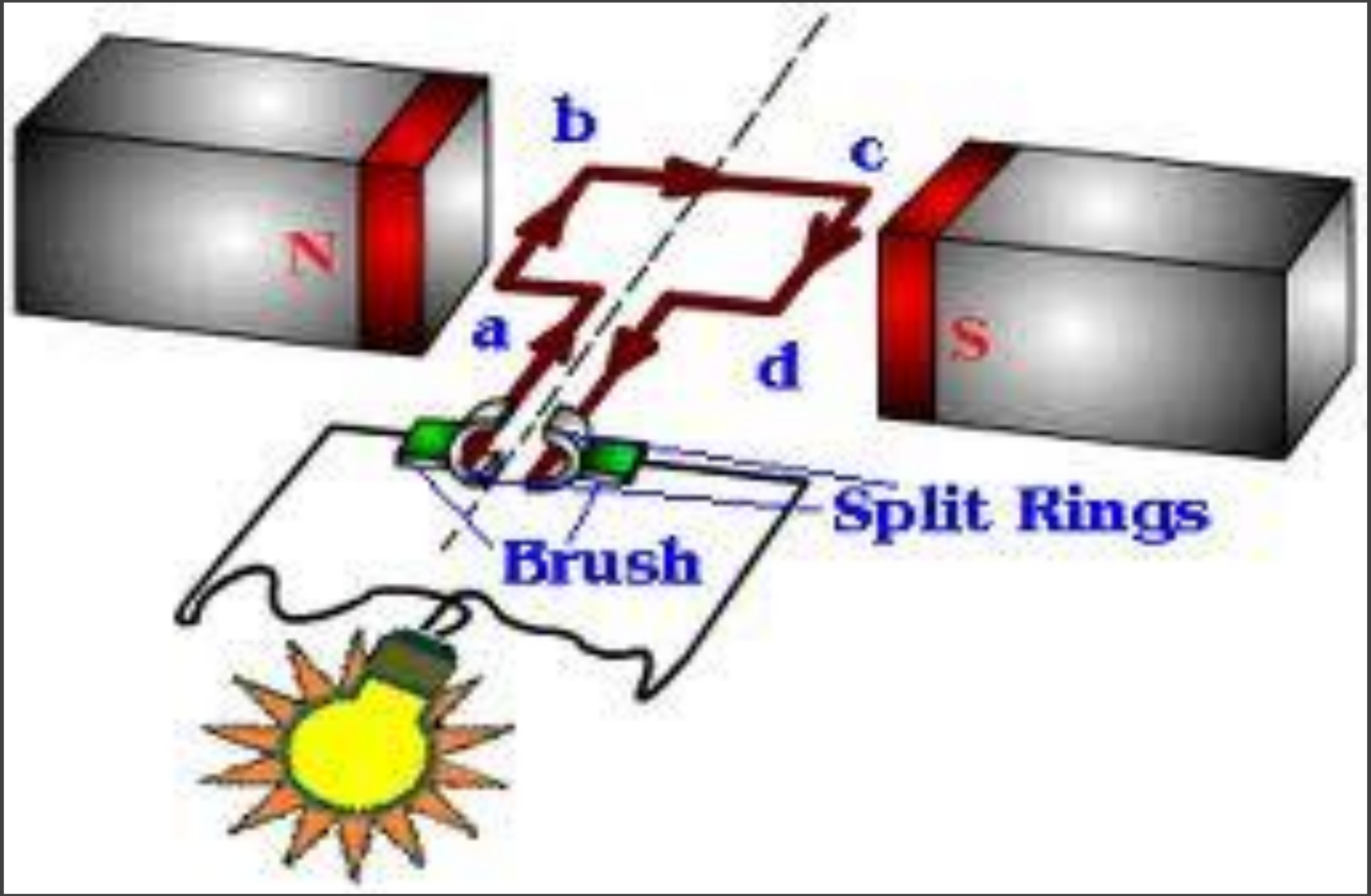
Rotor and rotor winding



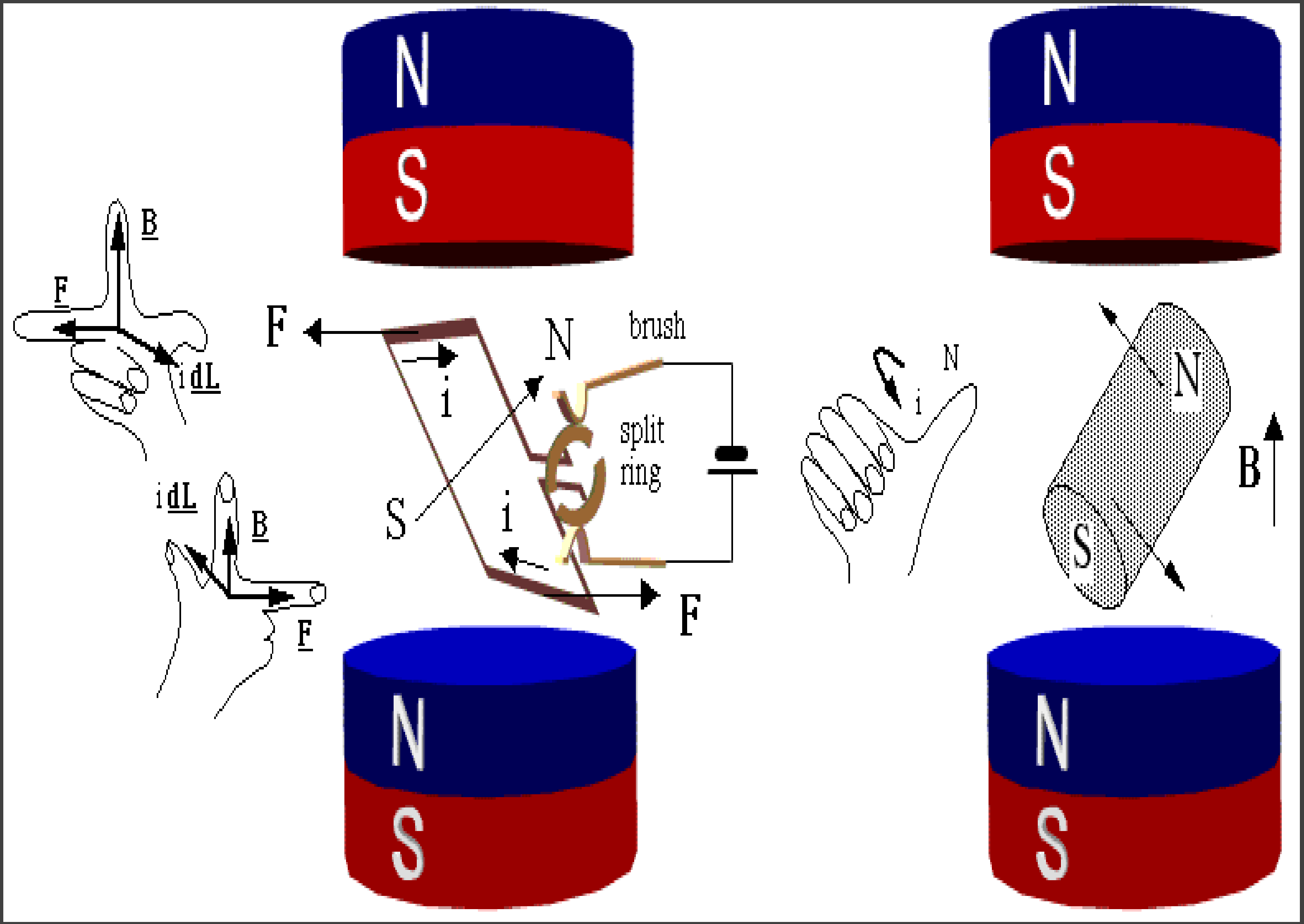
Working principle of DC motor



Working principle of DC motor



Force in DC motor



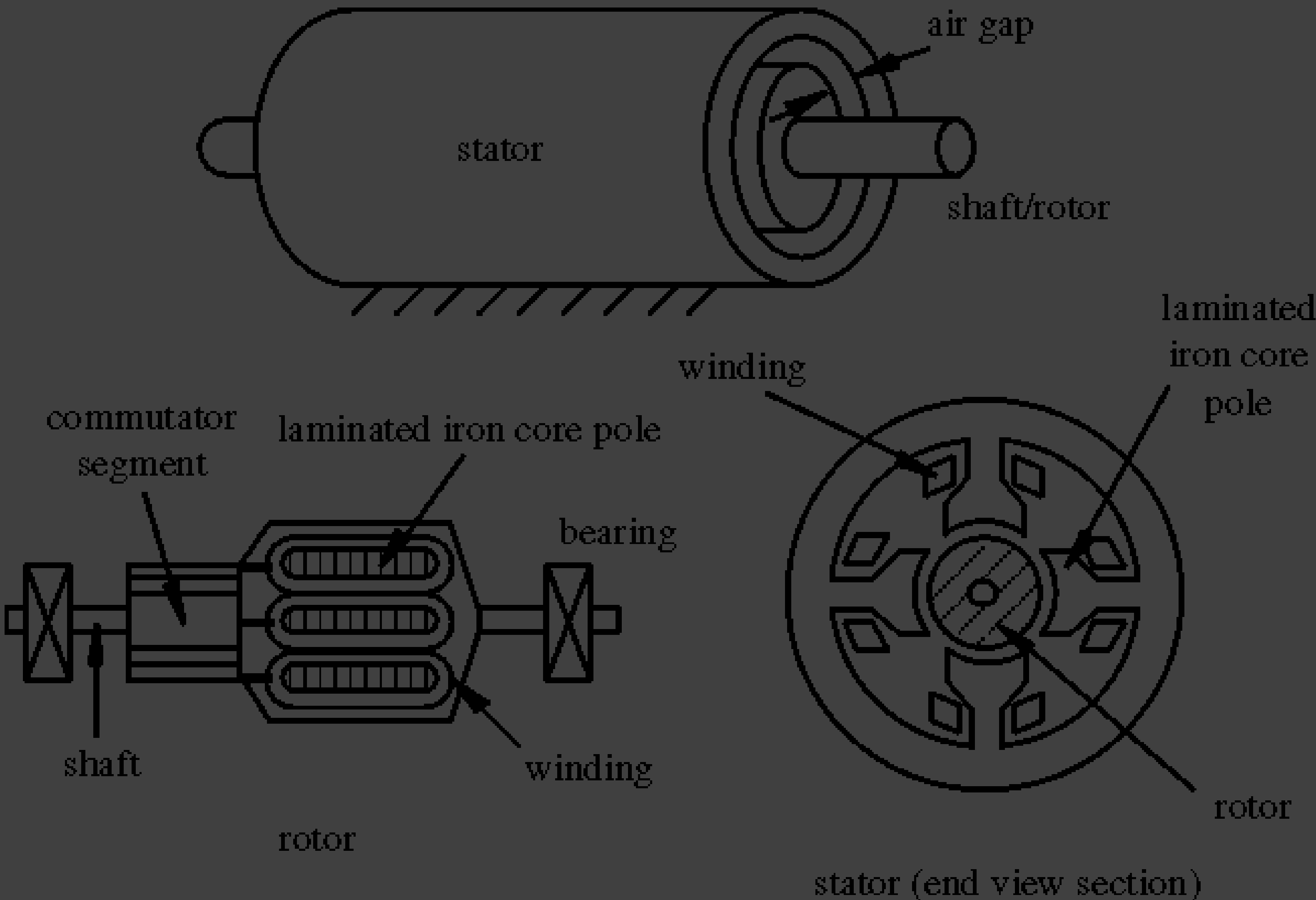
Electric and magnetic fields: Lorentz force

- A current-carrying wire in a magnetic field experiences a force.
- The magnitude and direction of this force depend on four variables: the magnitude and direction of the current (I), the length of the wire (L), the strength and direction of the magnetic field (B), and the angle between the field and the wire (Θ).

$F = I\,(L \times B)$ Or in scalar terms: $F = I\,L\,B\,\sin\Theta$

- When current is in amperes, length in meters, and magnetic field in teslas, the force is in newtons.
- The direction of the force is perpendicular to both the current and the magnetic field, and is predicted by the right-hand cross-product rule.

A Real 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

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
- 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

EMF equation

Let,

- Ø= flux per pole in webber
- Z = Total number of conductor
- P = Number of poles
- A = Number of parallel paths
- N =armature speed in rpm
- Eg = 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 $= Z / A$

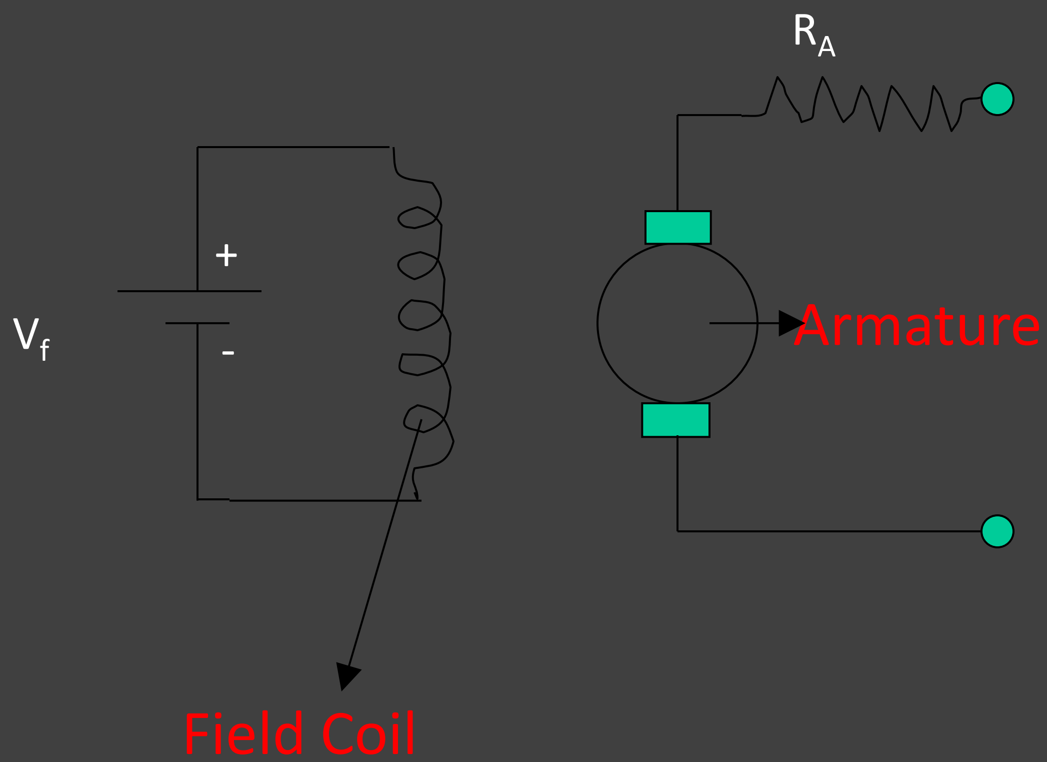
$$= P\phi NZ/60A$$

Types of DC Generator

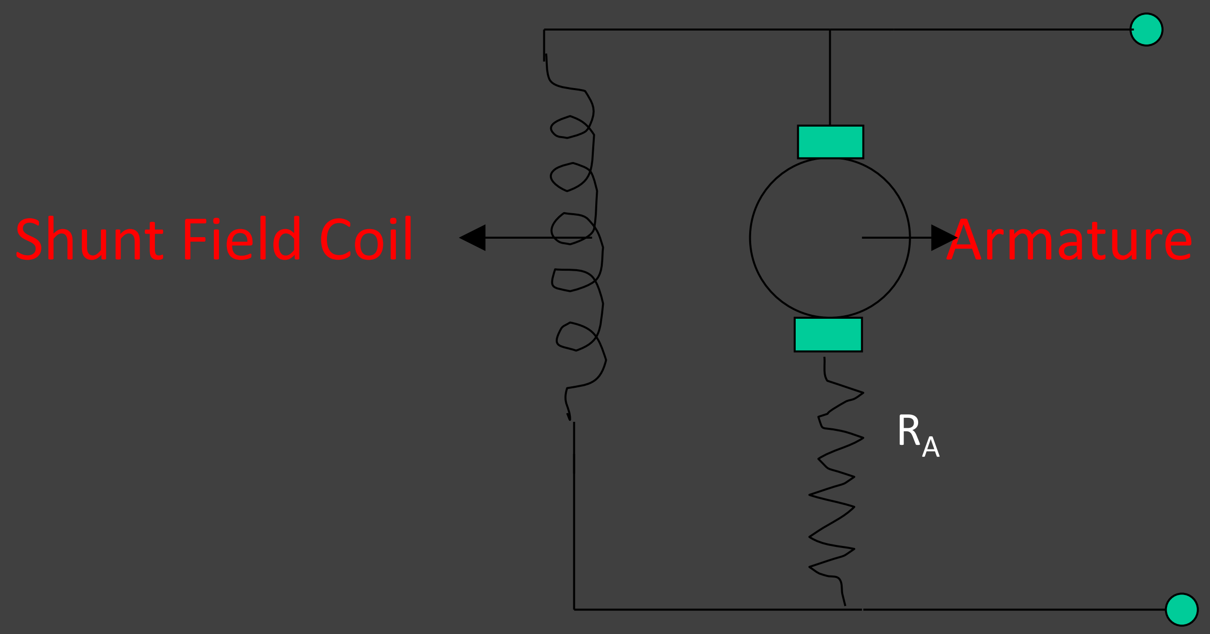
DC generators are generally classified according to their method of excitation .

- Separately excited DC generator
- Self excited DC generator

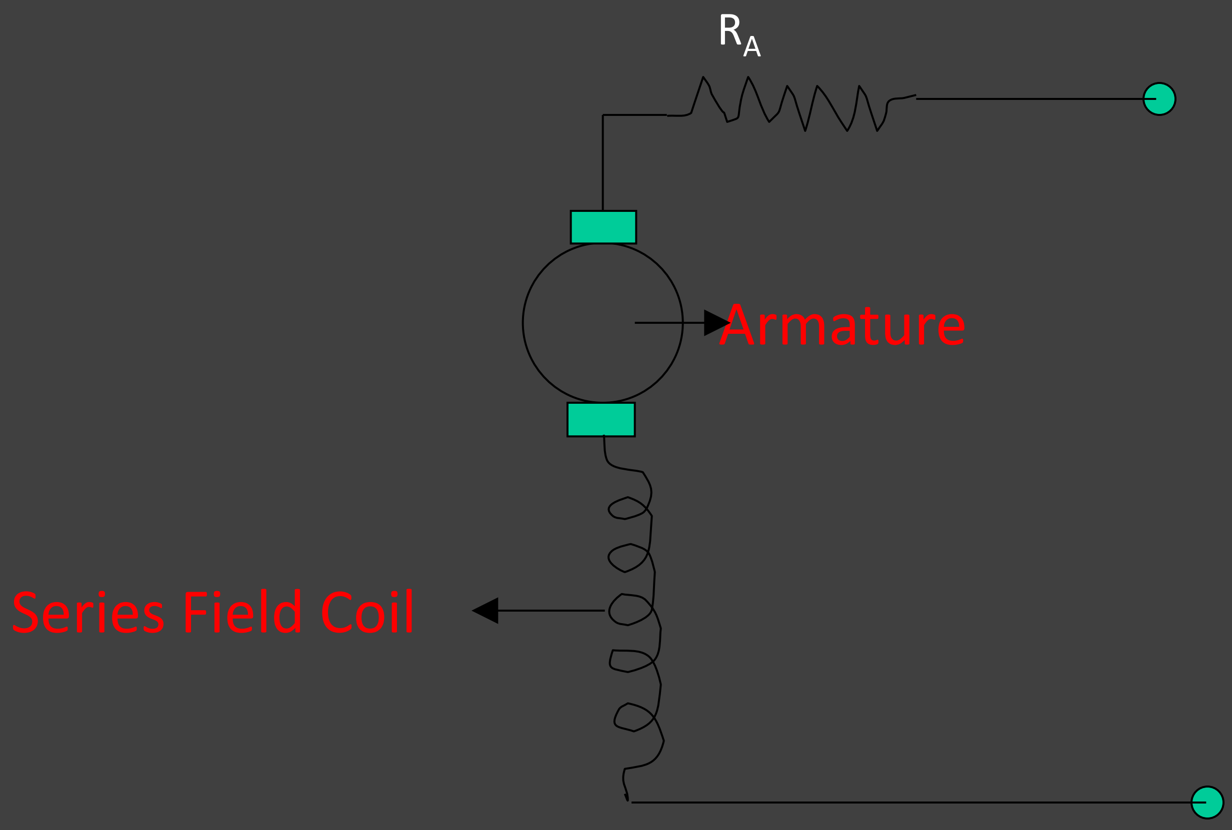
Separately Excited DC Machine



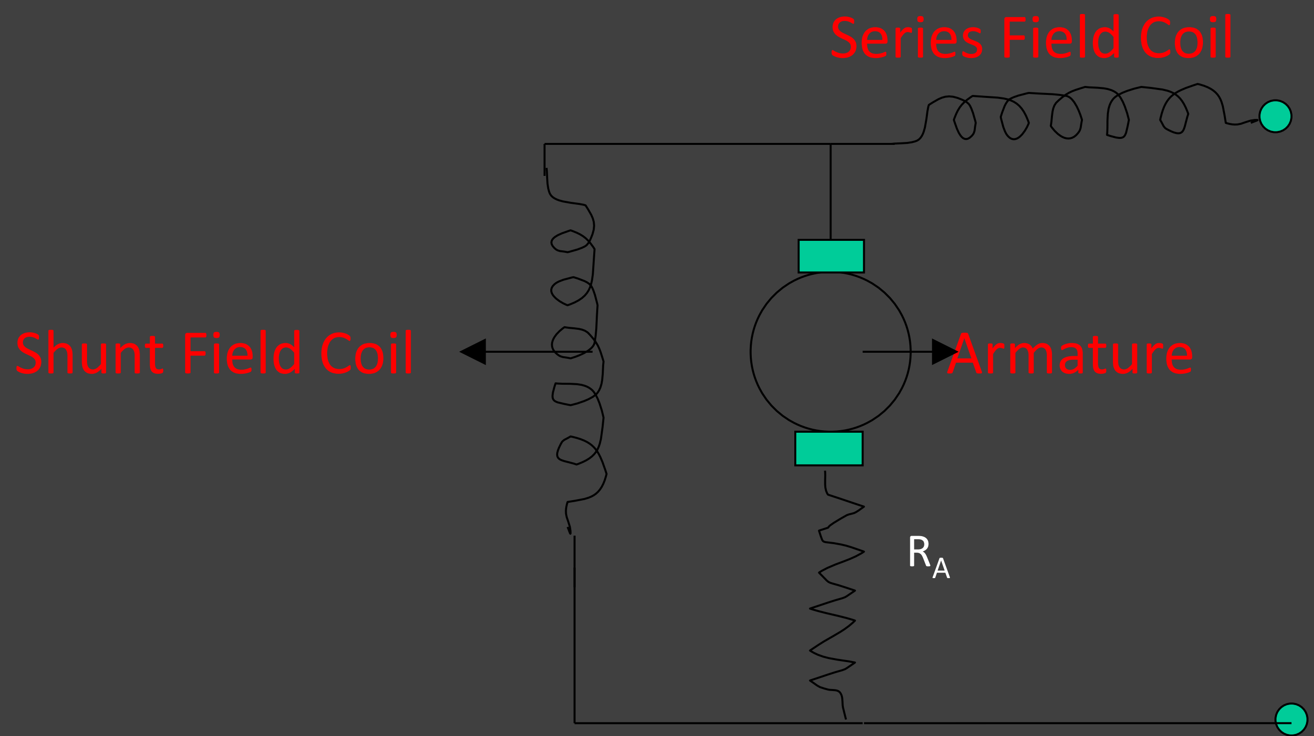
Shunt Excited DC Machine



Series Excited DC Machine

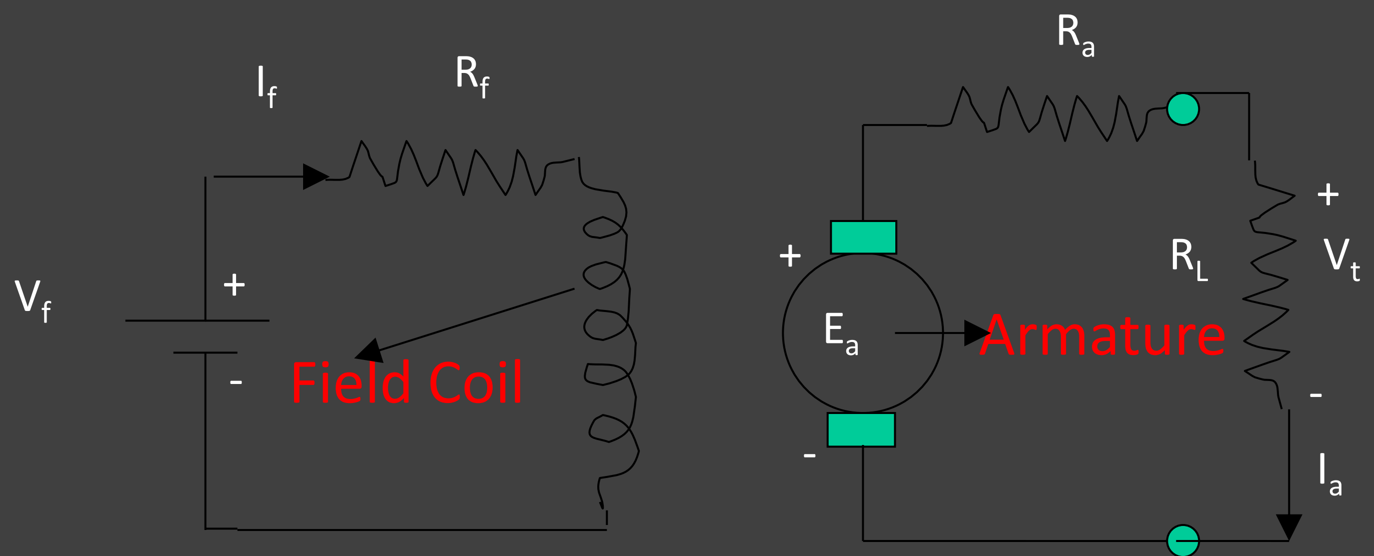


Compound Excited DC Machine



- If the shunt and series field aid each other it is called a cumulatively excited machine.
- If the shunt and series field oppose each other it is called a differentially excited machine.

Separately Excited DC Generator

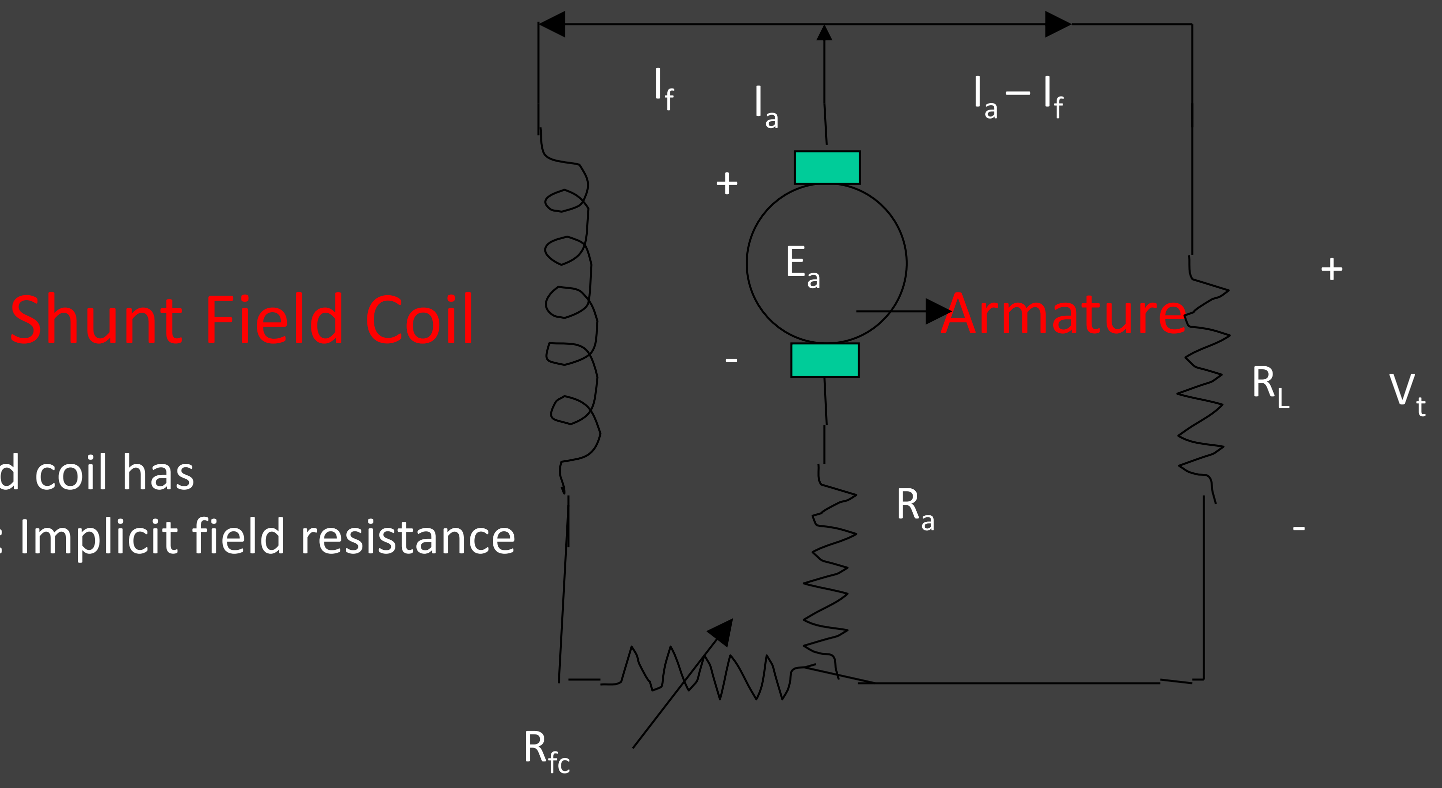


Field equation: $V_f = R_f I_f$

Armature equation: $V_t = E_a - I_a R_a$

$V_t = I_a R_L$, $E_a = K_a \Phi \omega_m$

Shunt Generators



Field coil has
R_{fw} : Implicit field resistance

Field equation: $V_t = R_f I_f$

$R_f = R_{fw} + R_{fc}$

Armature equation: $V_t = E_a - I_a R_a$

$V_t = (I_a - I_f) R_L$, $E_a = K_a \Phi \omega_m$

Further classification of DC Generator

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

&

Differentially compound

Applications

Shunt Generators:

- In electro plating
- For battery recharging
- As exciters for AC generators.

Series Generators :

- As boosters
- 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

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