# Electrical Engineering and Measurement (EE1101) (Transformer)

Presented

by

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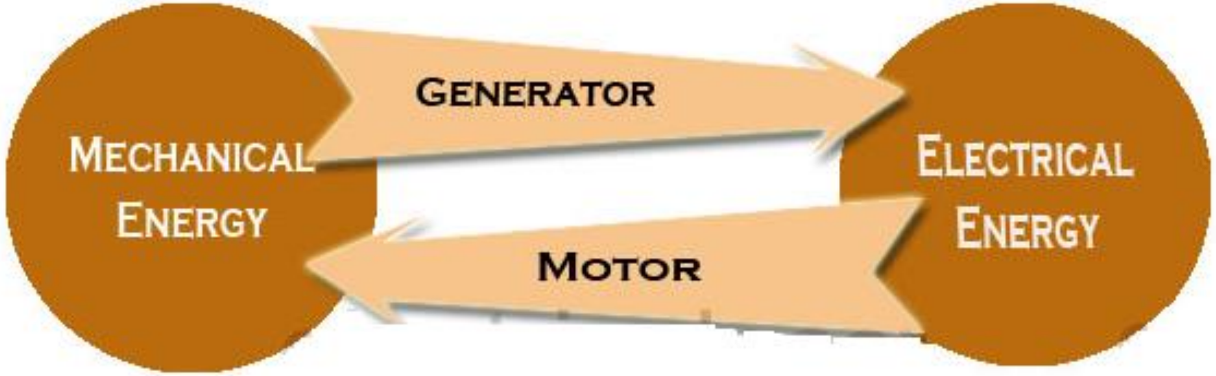
# Introduction

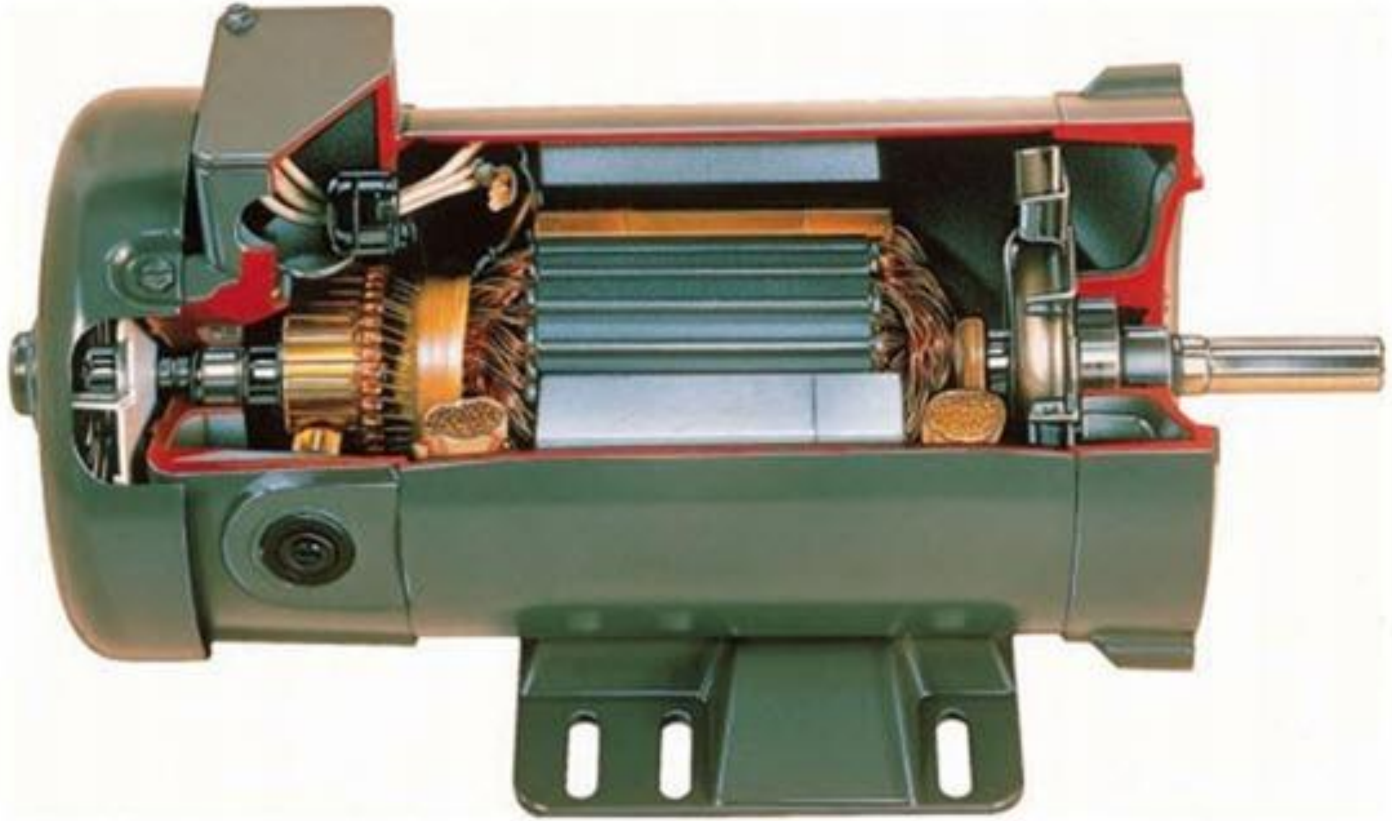
- Electrical Machine:

  An electrical machine is a device which converts mechanical energy into electrical energy or vice versa.

- When the input to an electrical machine is electrical energy, and the output is mechanical energy, the machine is called an electric motor.
- Thus an electric motor converts electrical energy into mechanical energy.
- When the input to an electrical machine is mechanical energy, and the output is electrical energy, the machine is called a generator.
- Thus, a generator converts mechanical energy to electrical energy.



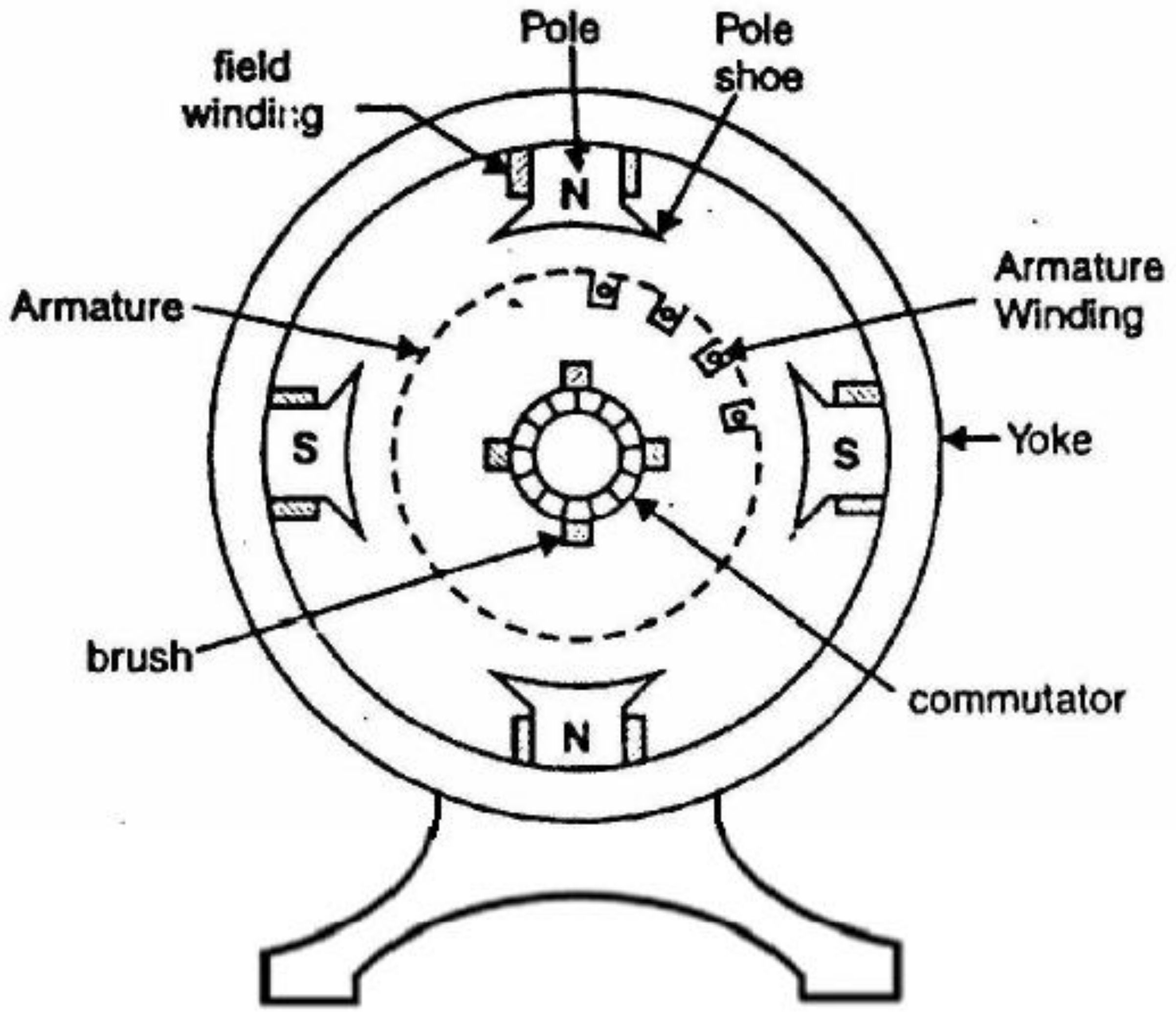
# Construction of DC Machine



# Construction of DC Machine

- The main parts of DC Machine (motor or generator) are as follows:

1. Yoke
2. Pole core
3. Pole shoes
4. Field winding
5. Armature core
6. Armature winding or conductor
7. Commutator
8. Brushes and bearings

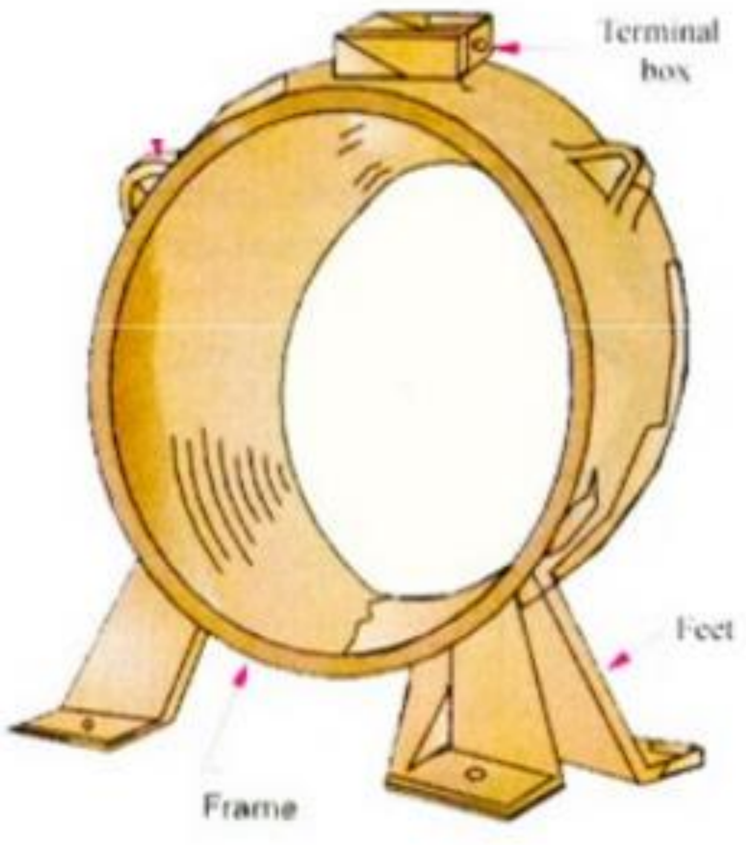


# Construction of DC Machine

## 1. Yoke

### Function

- It provide mechanical Support for poles
- It also provide protection to whole machine from dust, moisture etc.
- Yoke is also called as frame.




### Material used

- For small M/C yoke is made of cast iron.
- For large M/C it is made of cast steel or rolled steel.

# Construction of DC Machine

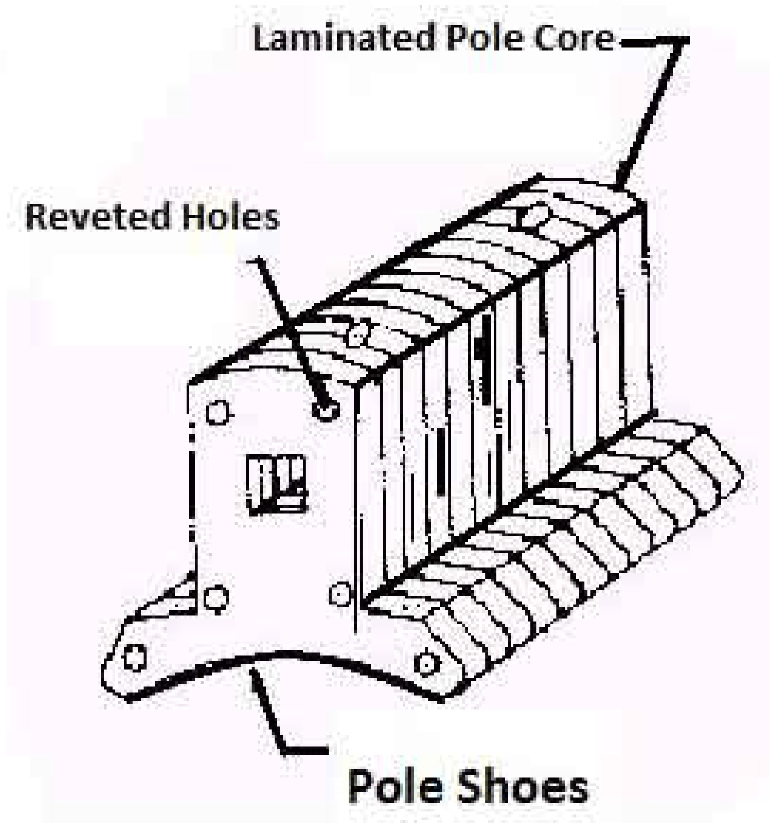
## 2. Pole & Pole core

### Function

- Pole of a generator is an electromagnet.
- The field winding is wounded over pole.
- Pole provides magnetic flux when field winding is excited.

### Material used

- Pole core or pole made of cast iron or cast steel.
- It built of these laminations of annealed steel. The laminations is done to reduce the power lose due to eddy currents.



# Construction of DC Machine

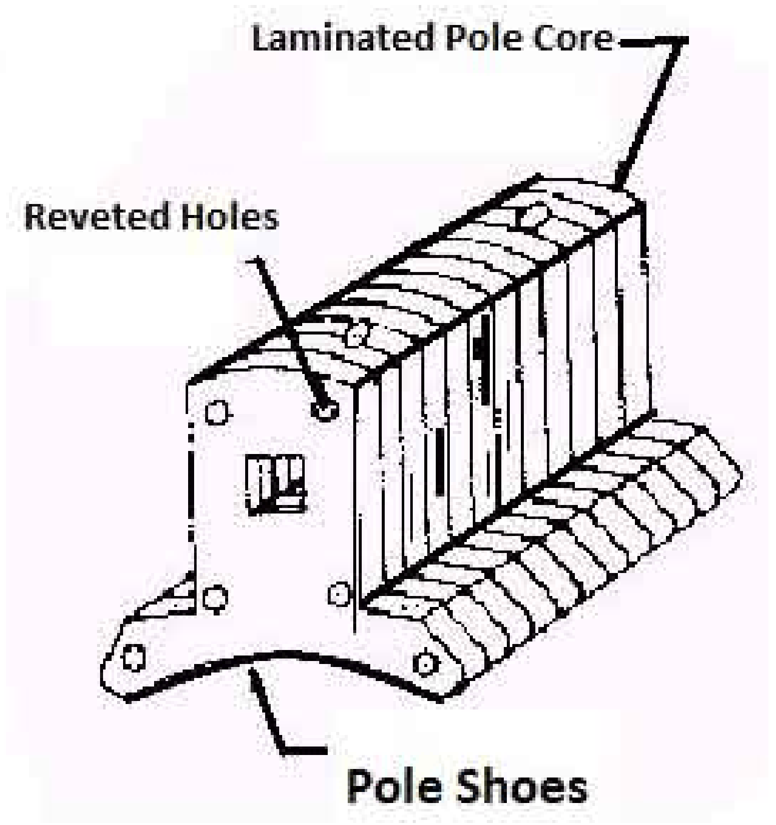
## 3. Pole Shoe

### Function

- It is extended part of pole. It enlarge area of pole
- Due to this enlarged area, flux is spread out in the air gap and more flux can pass through the air gap to armature.

### Material used

- It is made of cast iron or cast steel.

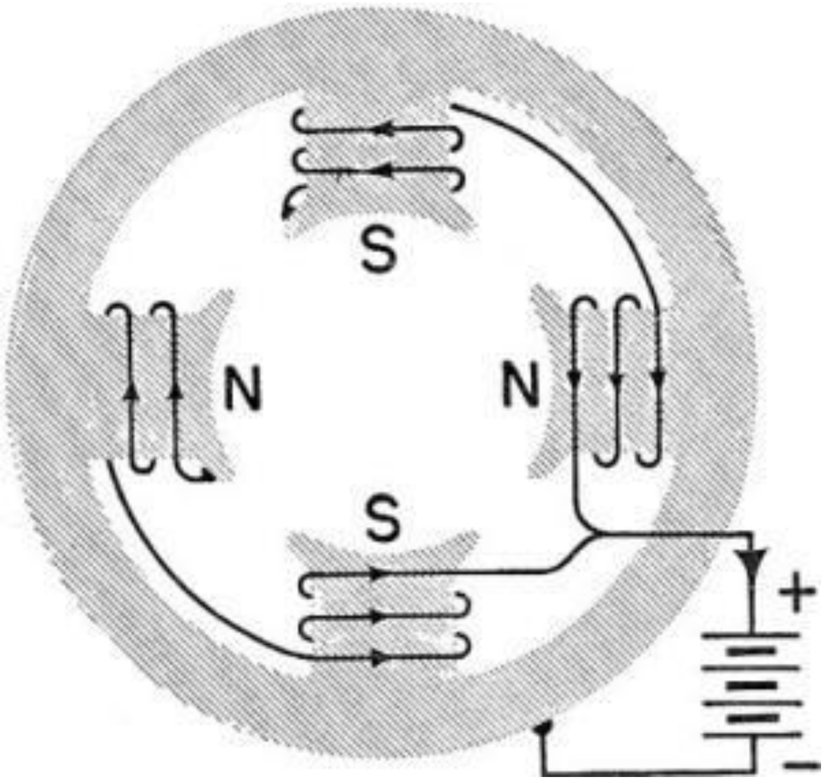


# Construction of DC Machine

## 4. Field windings

### Function

- It is wound around pole core and called as field winding
- When Current is passed through field winding it electro magnetize the poles which produce necessary flux.




### Material used

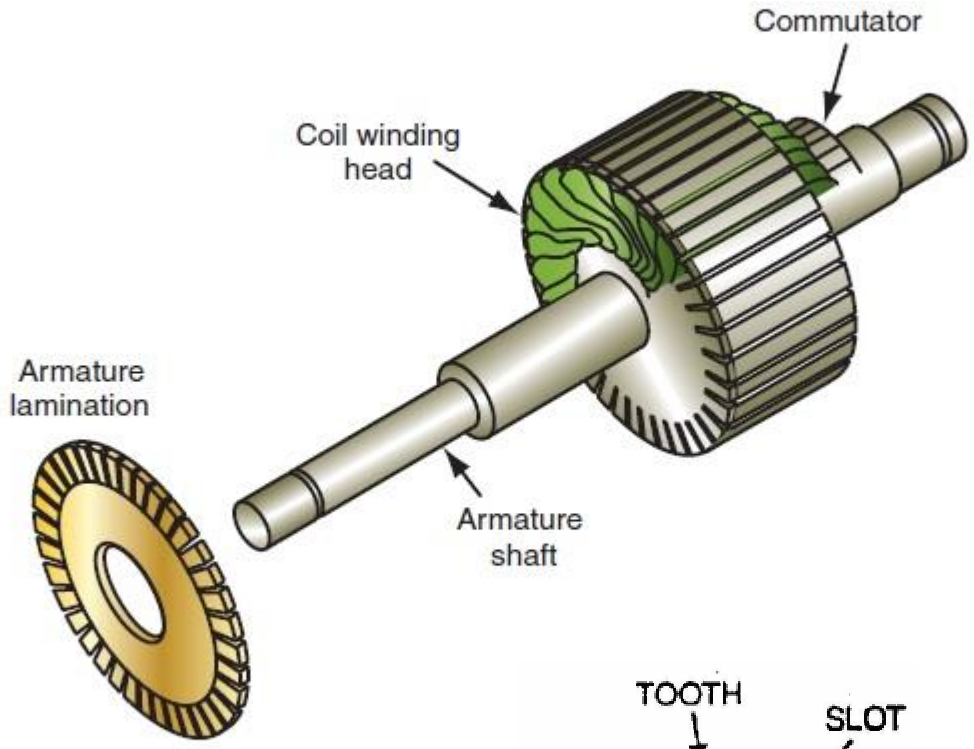
- The material used for field conductor is copper.

# Construction of DC Machine

## 5. Armature Core

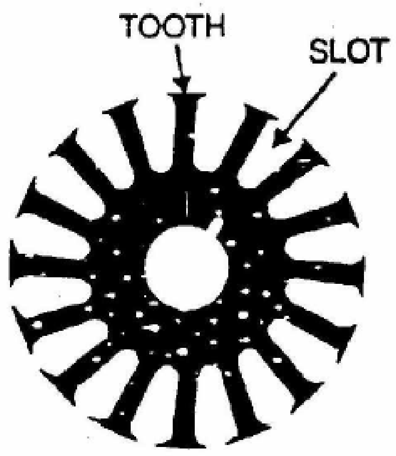
### Function

- It has large number of slots in its periphery
- Armature conductors are placed in this slots
- It is also provide path of low reluctance to the flux produced by field winding




### Material used

- High permeability low reluctance materials such as cast iron are used for armature core.
- The lamination is provided so as to reduce the loss due to eddy current.



# Construction of DC Machine

## 6. Armature Winding

### Function

- Armature conductor are inter connected to form armature Winding
- When armature winding is rotated using prime mover. The magnetic flux and voltage gets induced in it
- Armature winding is connected to external circuit

### Material used

- It is made of conducting material such as copper.

# 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**
- ɪt is used in low current output and high voltage.
- 2 brushes

# Construction of DC Machine

## 7. Commutator

### Function

- It Convert alternating current induce in the armature winding to unidirectional current in dc generator and vice versa for dc motor.
- It collects the current from armature conductor and pass it load with the help of brushes

### Material used

- Hard drawn copper and mica

# Construction of DC Machine

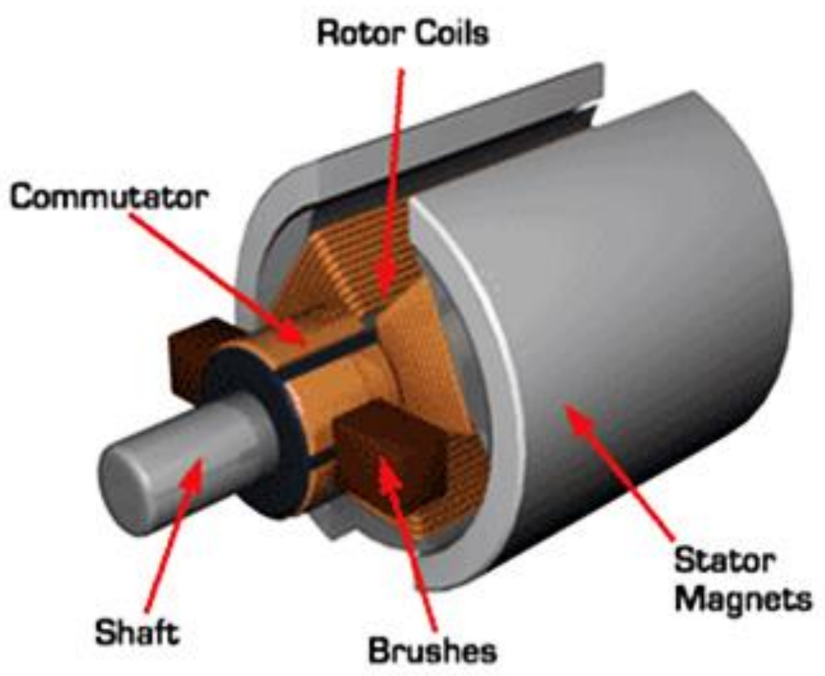
## 8. Brushes

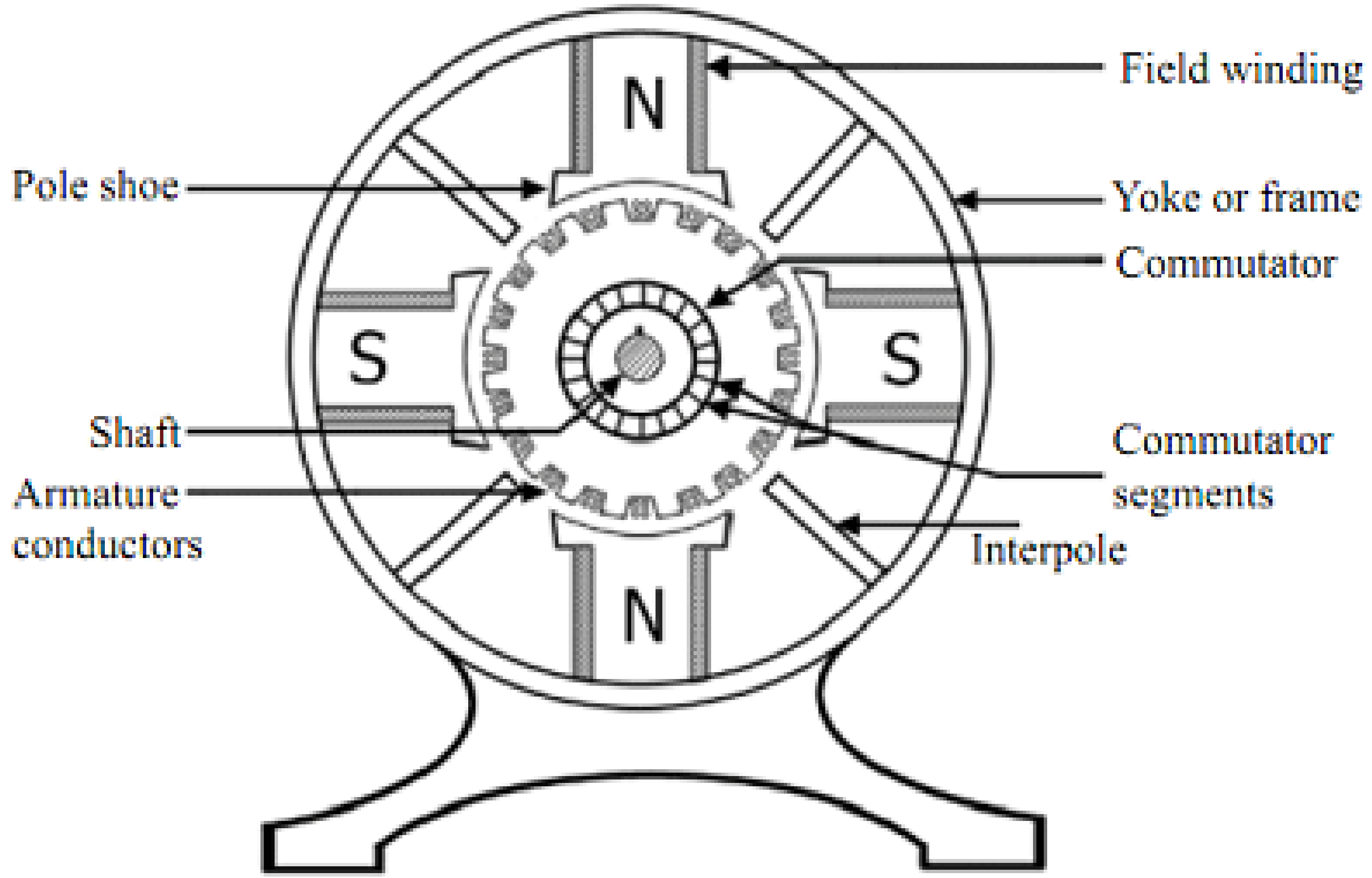
### Function

- Brushes collect the current from commutator and apply it to external load.
- Brushes wear with time and it is should be inspected regularly.

### Material used

- Brushes are made of carbon or graphite it is rectangular in shape.





Field winding
N
Pole shoe
Yoke or frame
Commutator
S
S
Shaft
Commutator
segments
Armature
conductors
Interpole
N

# 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

# Generator Working Principle

- An electric generator is a machine that converts mechanical energy into electrical energy.
- When ever a conductor cuts magnetic flux, dynamically induced EMF is produced according to Faraday's law of electromagnetic induction.
- The direction of induced EMF (and hence current) is given by Fleming's right hand rule.
- Therefore, the essential components of a generator are:

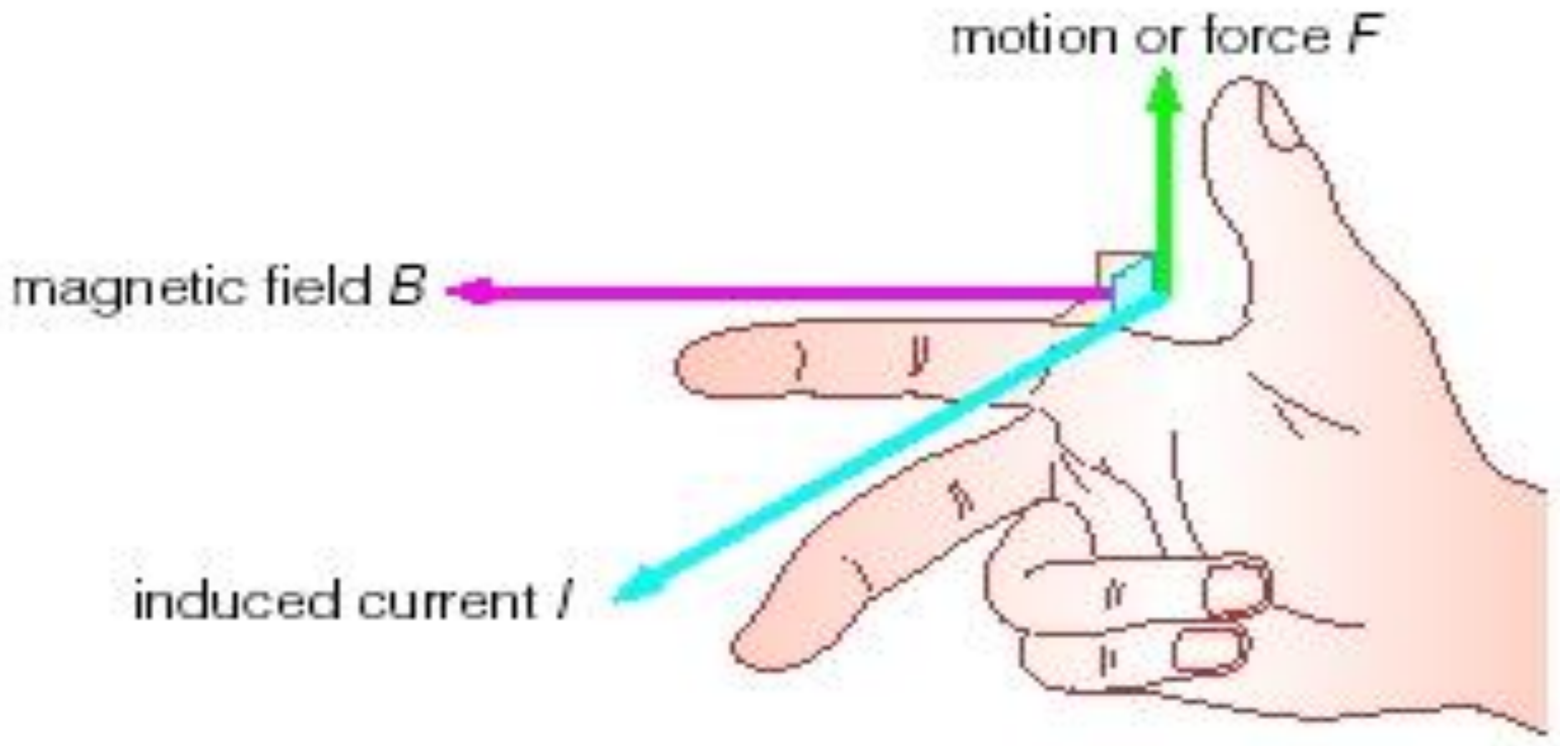
    (a) a magnetic field

    (b) moving conductor or conductors as to cut the flux

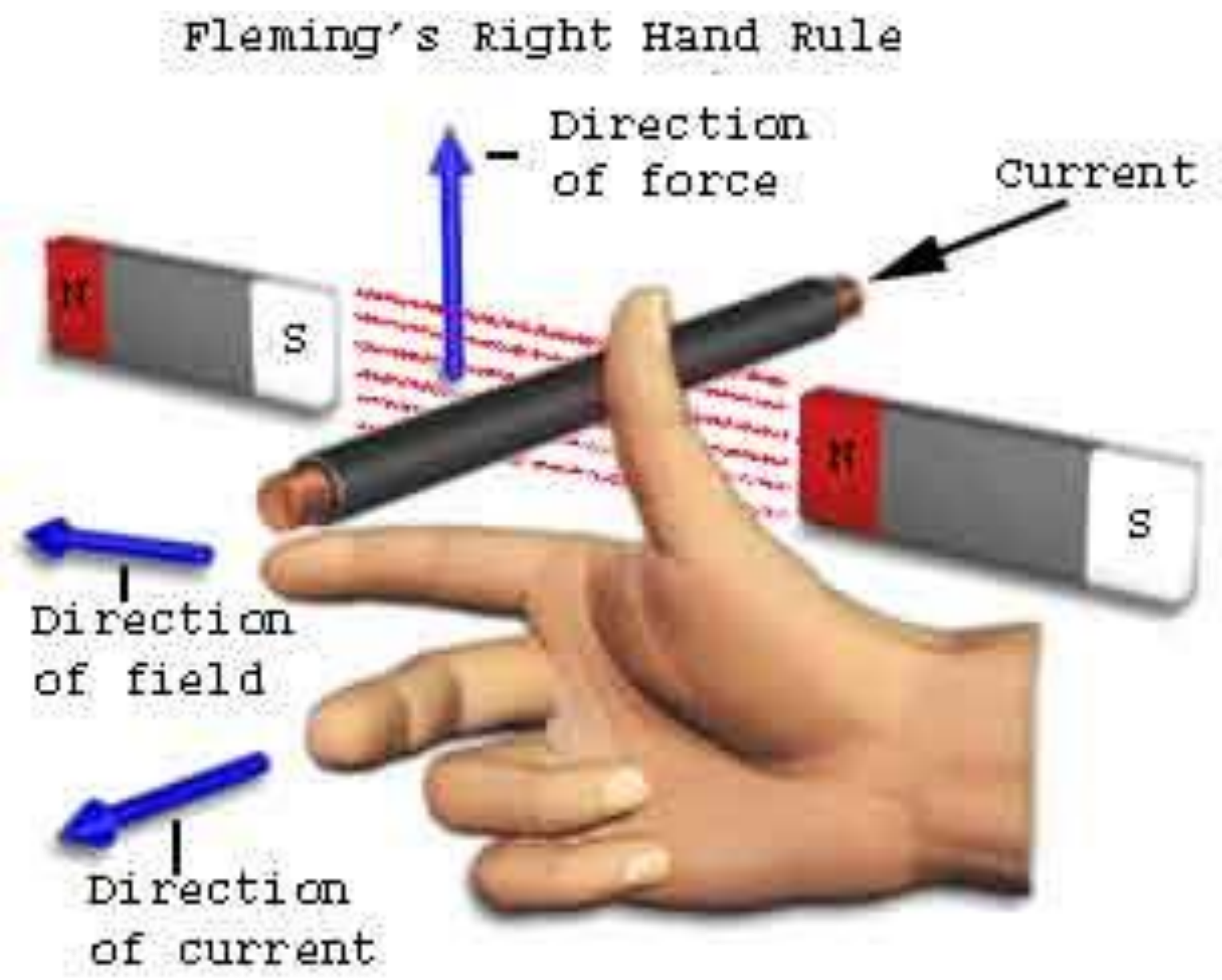
    Let's see the animation of a Generator (click on following link)

    Operating Principal of Generator.mp4

# Fleming's Right  hand rule



# 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

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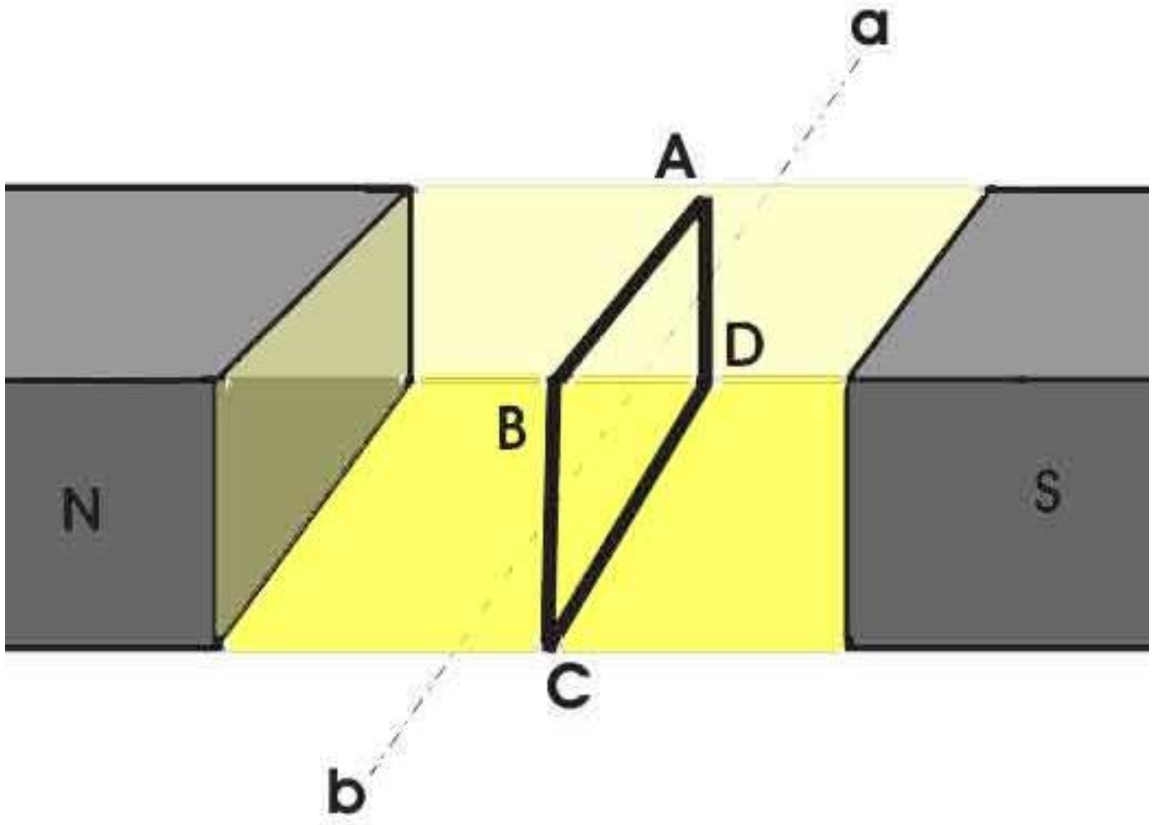
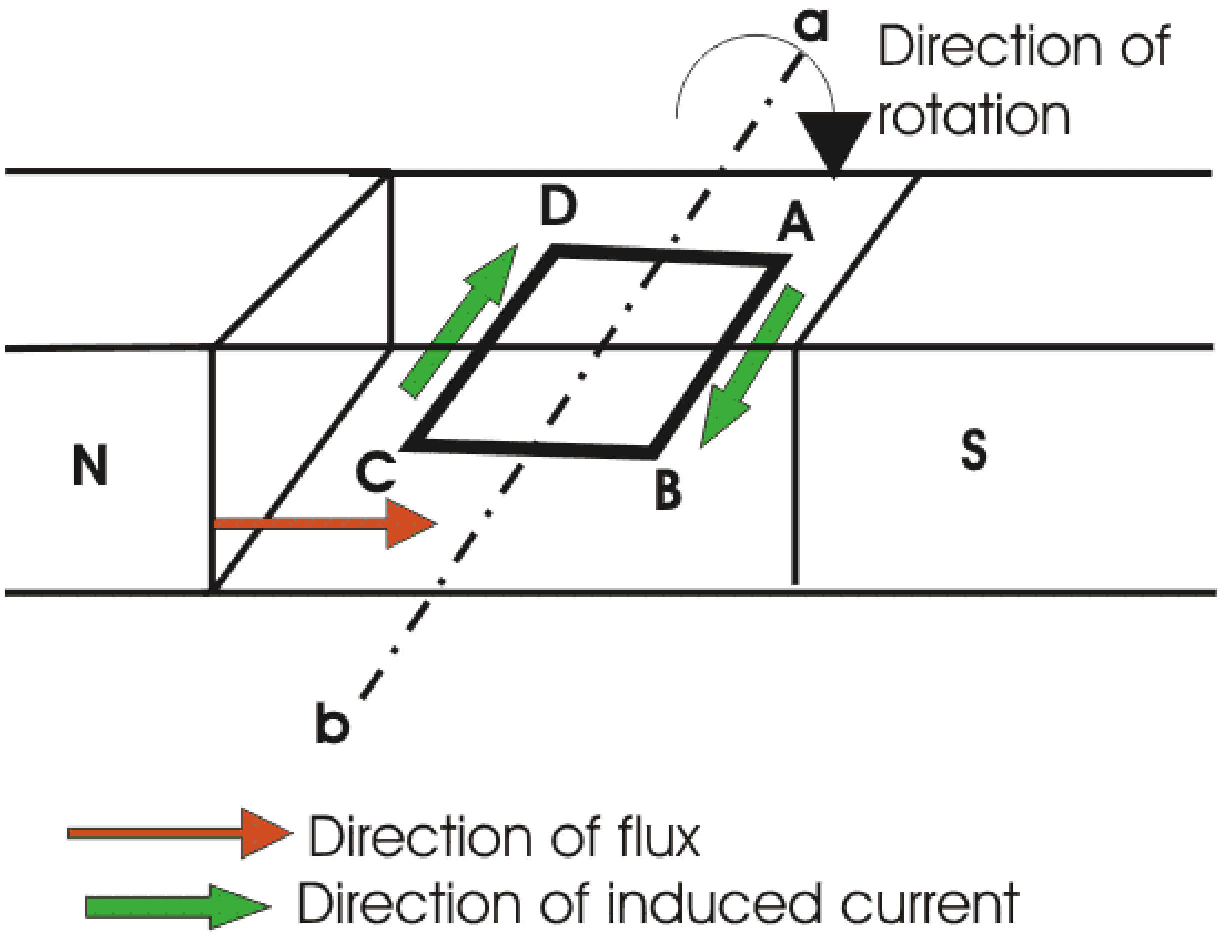
This rule is used in DC Generators

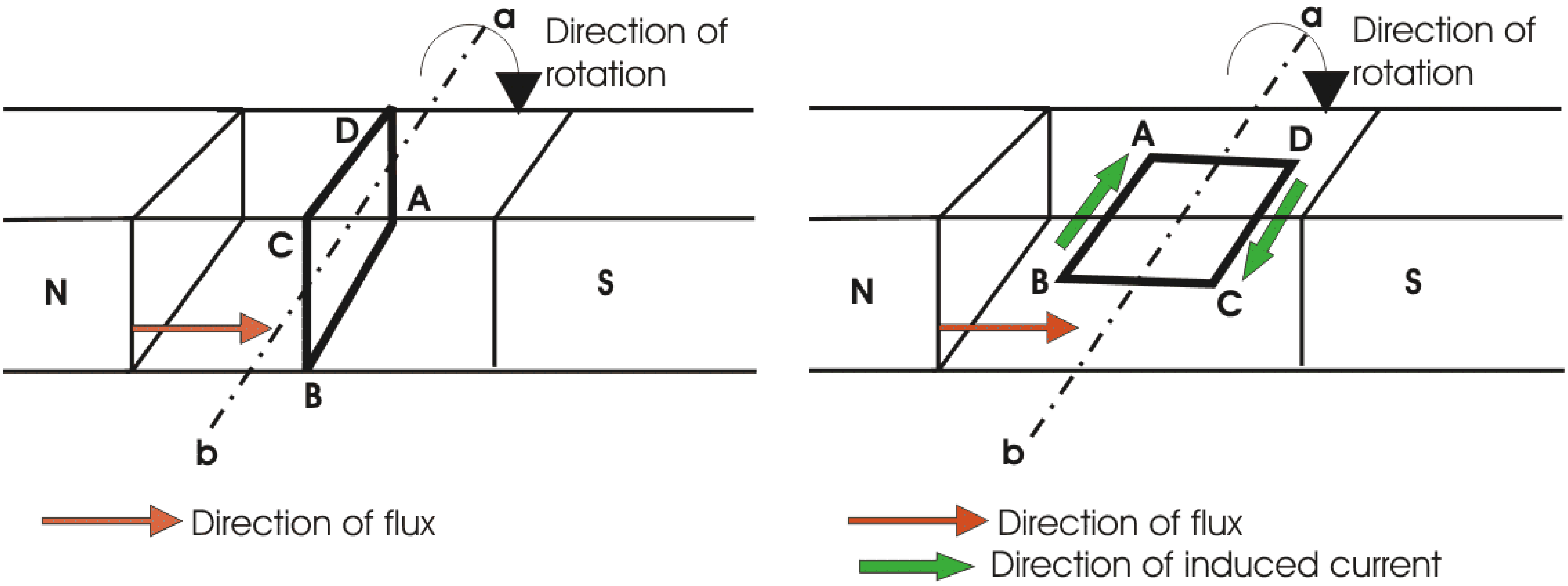
# Generator Working Principle

- Working principle of dc generator can be explained with single loop generator concept.

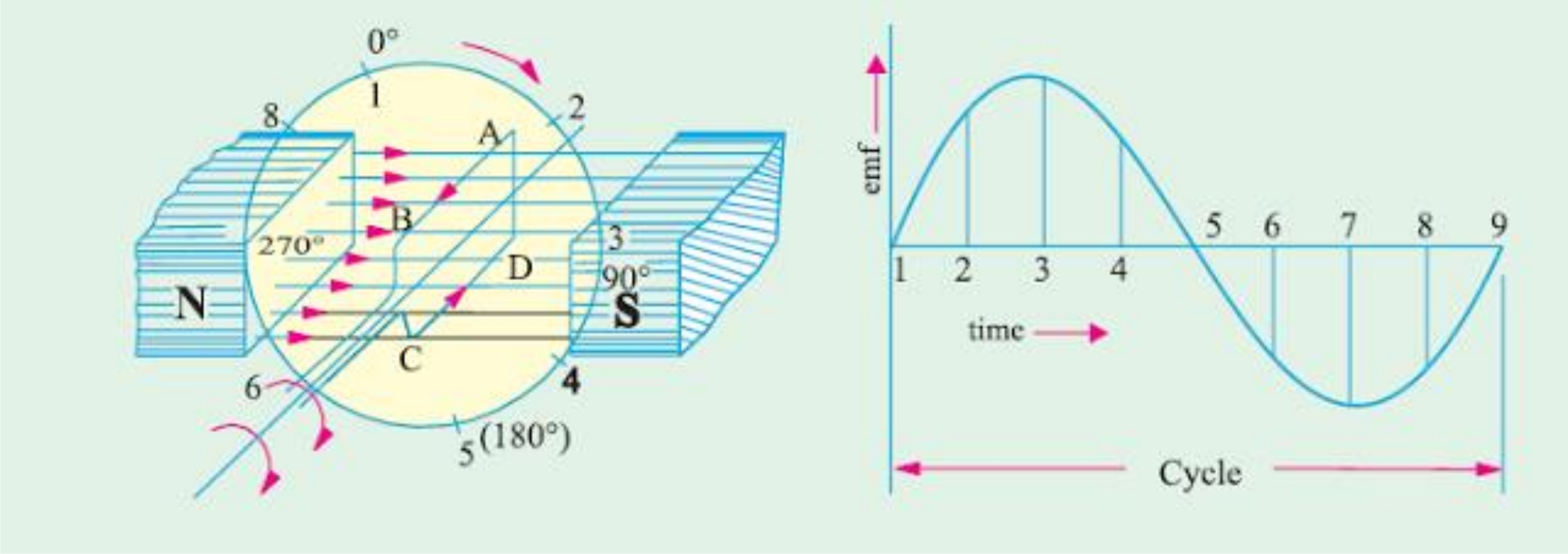


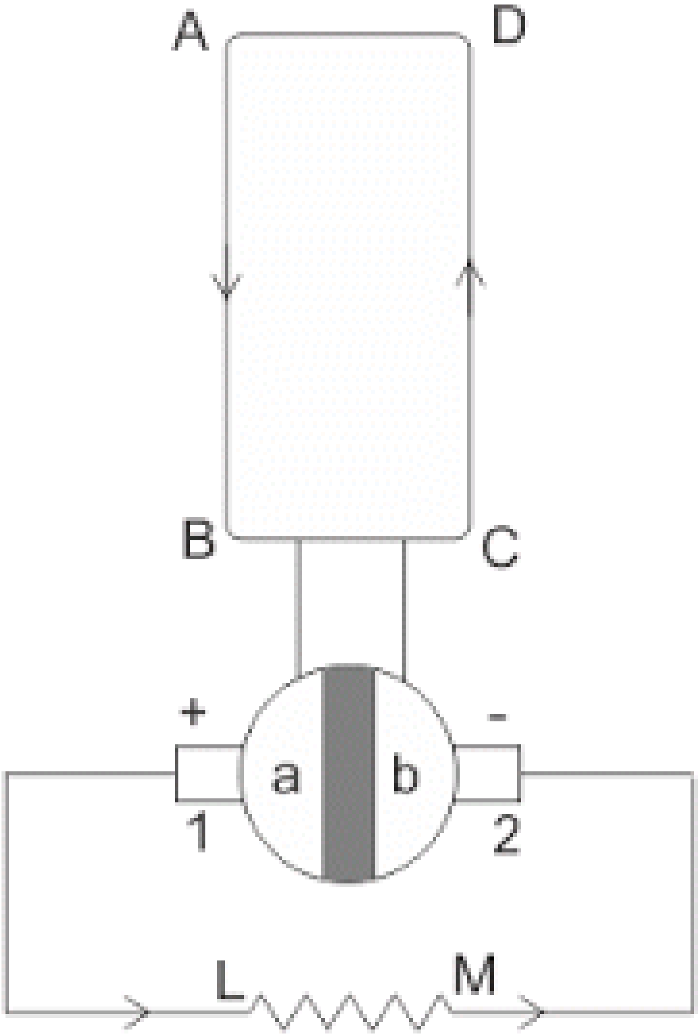
# Generator Working Principle

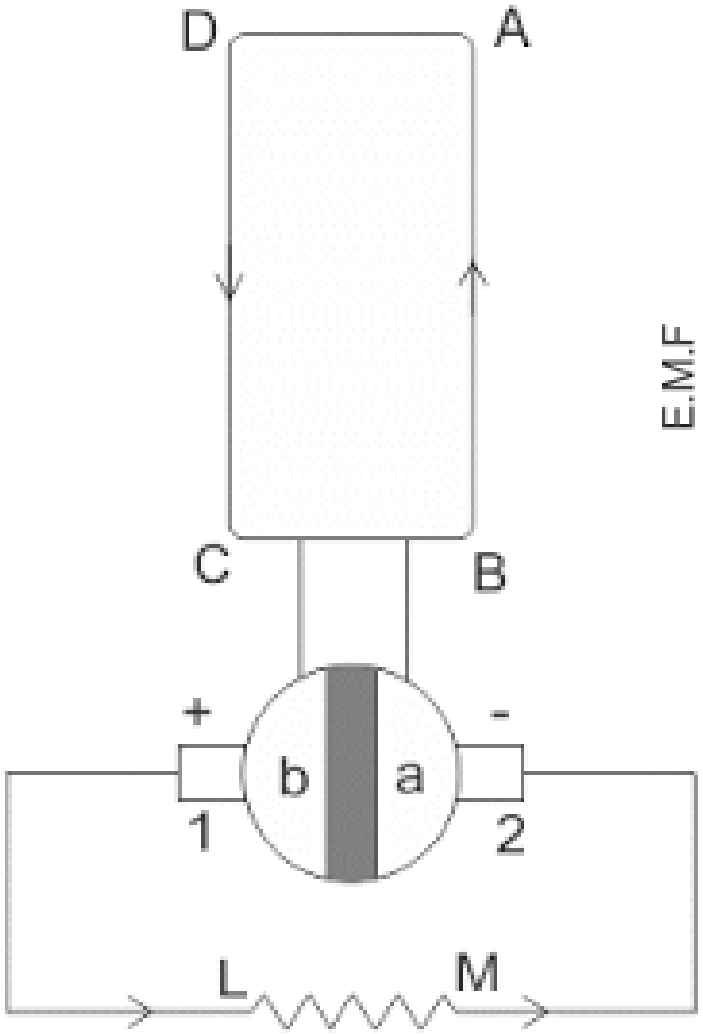


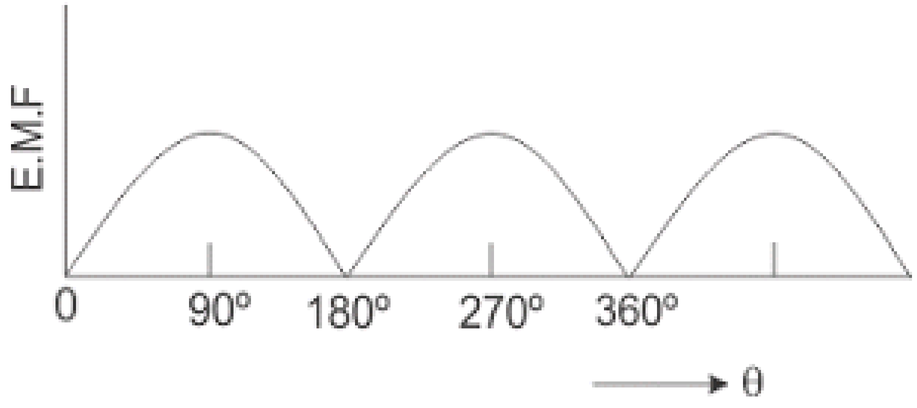
# Generator Working Principle



# Action of Commutator



# E.M.F. Equation of a D.C. Generator

- To derive an expression for the e.m.f. generated in a d.c. generator let us consider:

  $\Phi$ = flux/pole in Wb

  Z = total number of armature conductors

  P = number of poles

  A = number of parallel paths = 2 ... for wave winding

  = P ... for lap winding

  N = speed of armature in r.p.m.

  $E_g$ = e.m.f. of the generator

- Flux cut by one conductor in one revolution of the armature,

  $$d\Phi = P\Phi \text{ webers}$$

- Time taken to complete one revolution,

  $$dt = 60/N \text{ second}$$

# E.M.F. Equation of a D.C. Generator

- E.M.F generated/conductor = $\dfrac{d\phi}{dt} = \dfrac{P\phi}{60/N} = \dfrac{\phi NP}{60}$ volts

- E.M.F. of generator,

$$E_g = (\text{emf/conductor}) \times \text{no. of conductors in series per parallel path}$$

$$= \frac{\phi NP}{60} \times \frac{Z}{A}$$

$$= \frac{\phi ZNP}{60A}$$

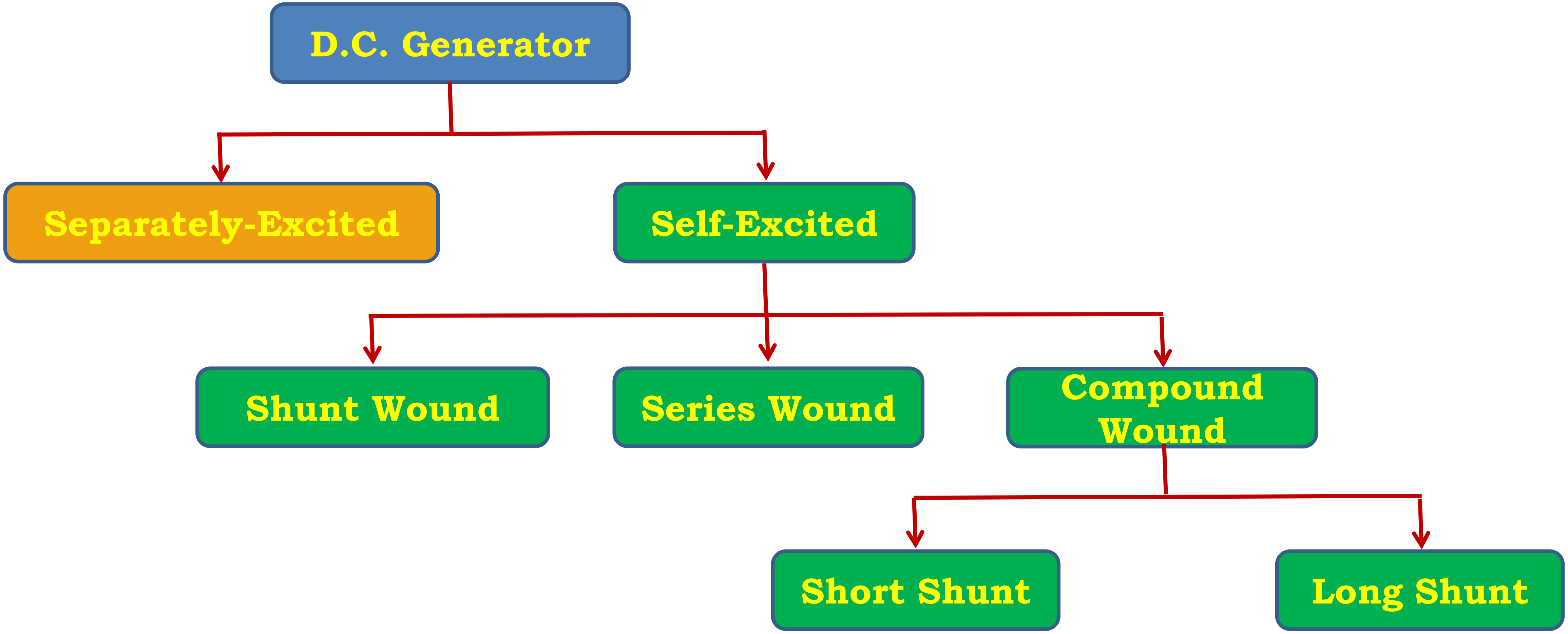
where A = 2 for wave winding

= P for lap winding

# Problems

1. An 8-pole, wave-connected armature has 600 conductors and is driven at 625rev/min. If the flux per pole is 20mWb, determine the generated e.m.f.
2. A 4-pole generator has a lap-wound armature with 50 slots with 16 conductors per slot. The useful flux per pole is 30mWb. Determine the speed at which the machine must be driven to generate an e.m.f. of 240V.
3. An 8-pole, lap-wound armature has 1200 conductors and a flux per pole of 0.03Wb. Determine the e.m.f. generated when running at 500rev/min.
4. A D.C. generator running at 30rev/s generates an e.m.f. of 200V. Determine the percentage increase in the flux per pole required to generate 250 V at 20 rev/s.

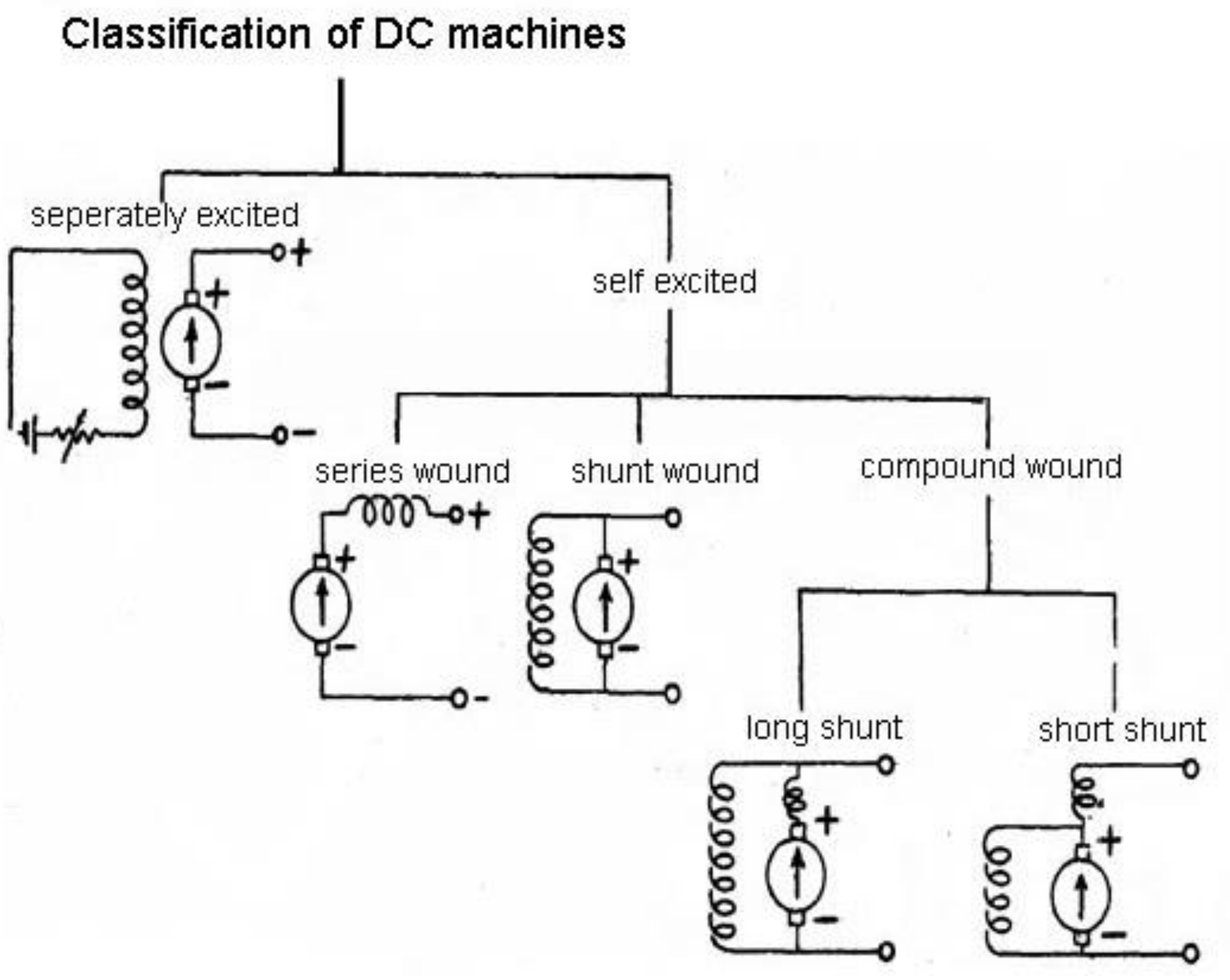
# Types of D.C. Generator



# Types of D.C. Generator

- D.C. generators are classified according to the method of their field excitation.
- These groupings are:
  1. Separately-excited generators
  2. Self-excited generators
     a. Series Wound Generator
     b. Shunt Wound Generator
     c. Compound Wound Generator
        i. Short shunt
        ii. Long shunt

# Types of D.C. Generators



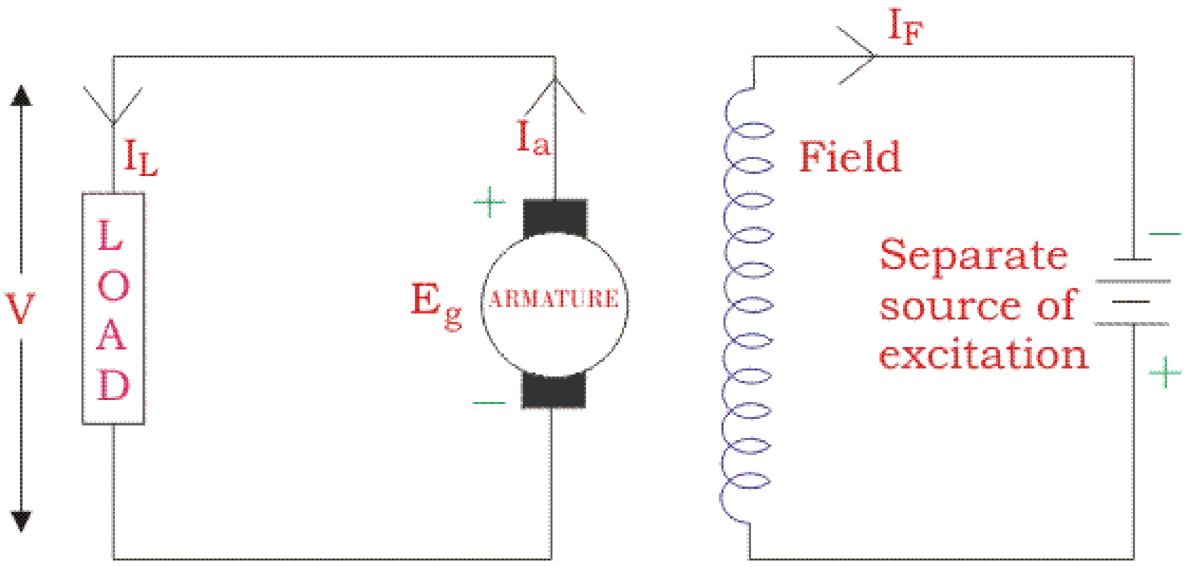
# Types of D.C. Generator

1. Separately-excited generator

**In these types of machines, the field winding is connected to an external source of supply**

Terminal voltage, $V = E_g - I_a R_a$

Generated EMF, $E_g = V + I_a R_a$




Separately Excited DC Generator

# Types of D.C. Generator

2. Self-excited DC Generators

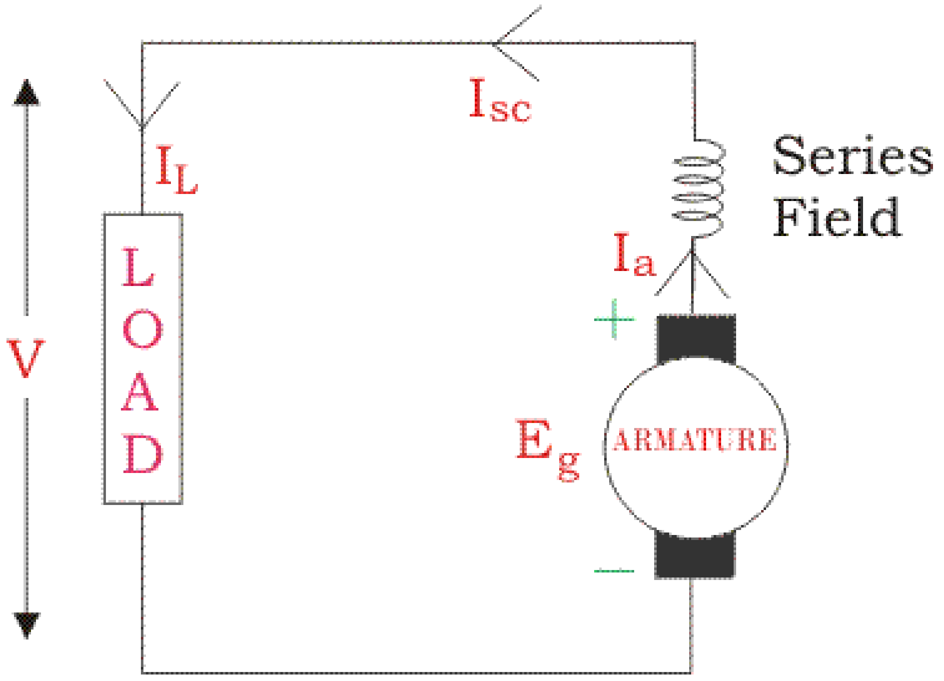
**In these types of machines, the field winding receives its supply (excitation) from the armature of its own machine**

a. Series wound generators

Here, $I_a = I_{sc} = I_L$

Terminal voltage, $V = E_g - I_a(R_a + R_{sc})$

Generated EMF, $E_g = V + I_a(R_a + R_{sc})$




Series Wound Generator

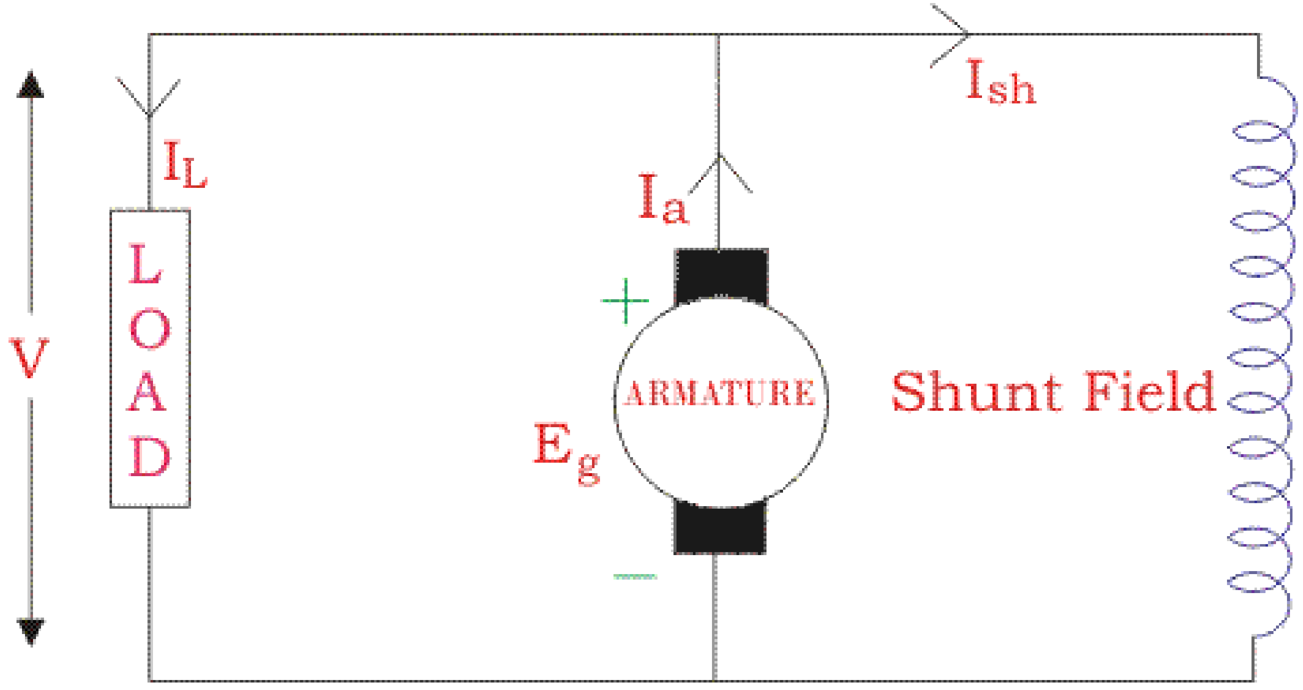
# Types of D.C. Generator

b. Shunt wound generators

Here, $I_a = I_L + I_{sh}$

Terminal voltage, $V = E_g - I_a R_a$

Generated EMF, $E_g = V + I_a R_a$




Shunt Wound Generator

# Types of D.C. Generator

## c. Compound Wound DC Generator

### i. Short Shunt Compound Wound DC Generator

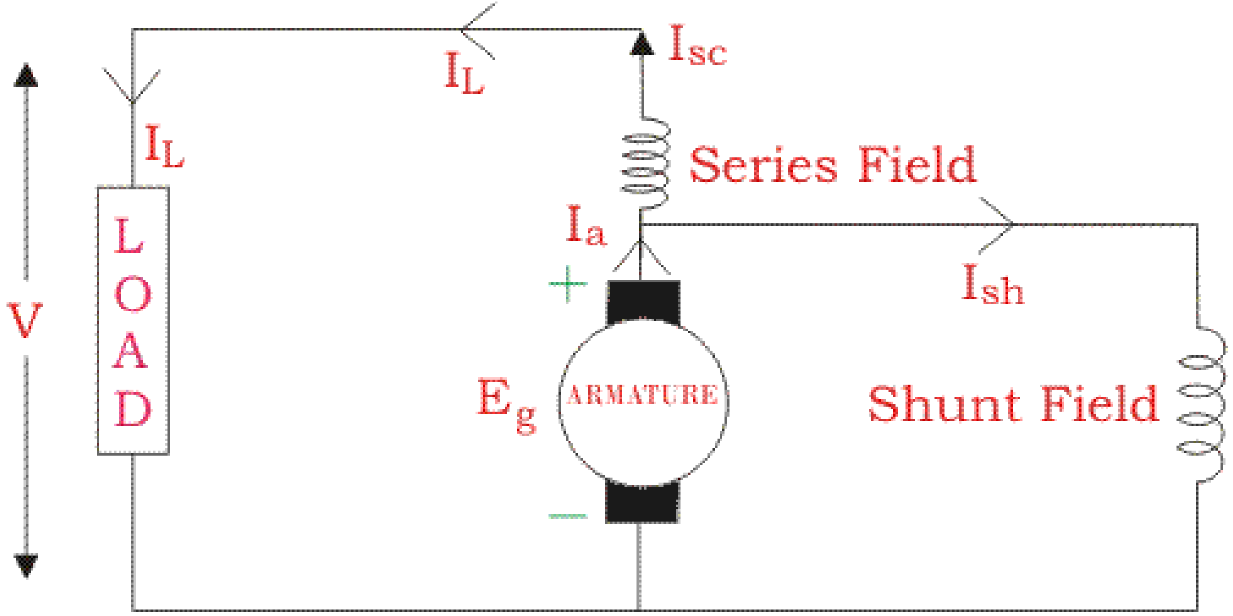
Here, $I_a = I_{sc} + I_{sh}$

Terminal voltage,

$$V = E_g - I_a R_a - I_{sc} R_{sc}$$

Generated EMF,

$$E_g = V + I_a R_a + I_{sc} R_{sc}$$




Short Shunt Compound Wound Generator

# Types of D.C. Generator

ii. Long Shunt Compound Wound DC Generator

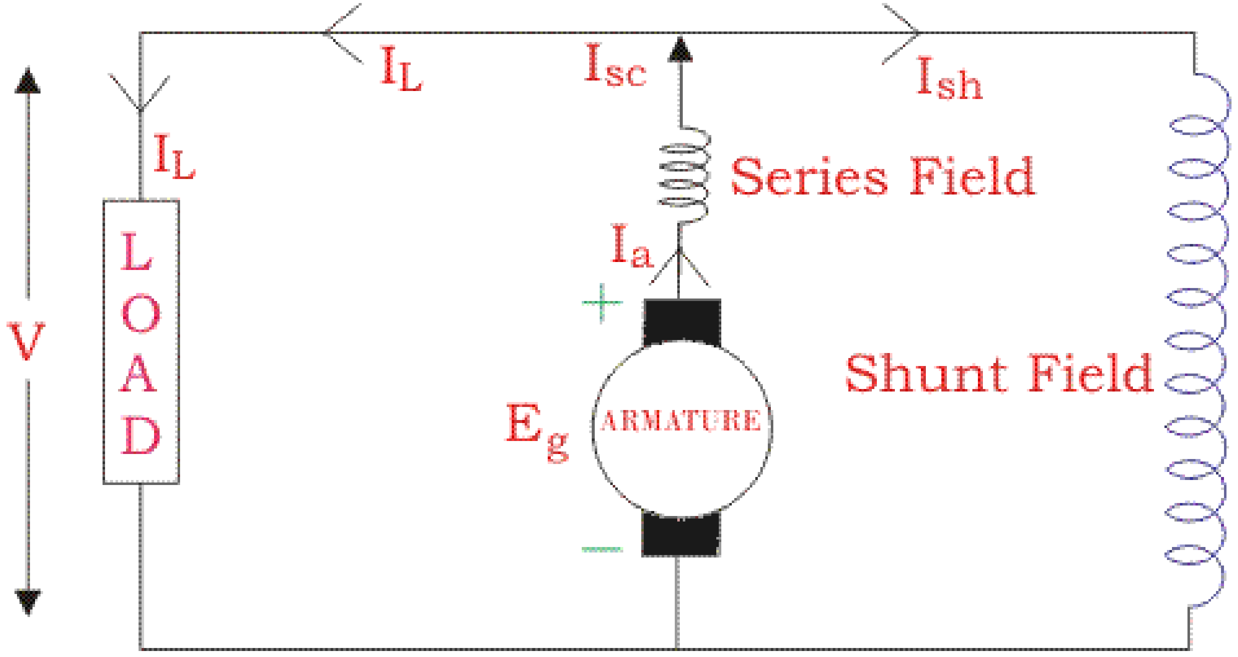
Here, $I_a = I_{sc} = I_L + I_{sh}$

Terminal voltage,

$$V = E_g - I_a R_a - I_{sc} R_{sc}$$
$$= E_g - I_a (R_a + R_{sc})$$

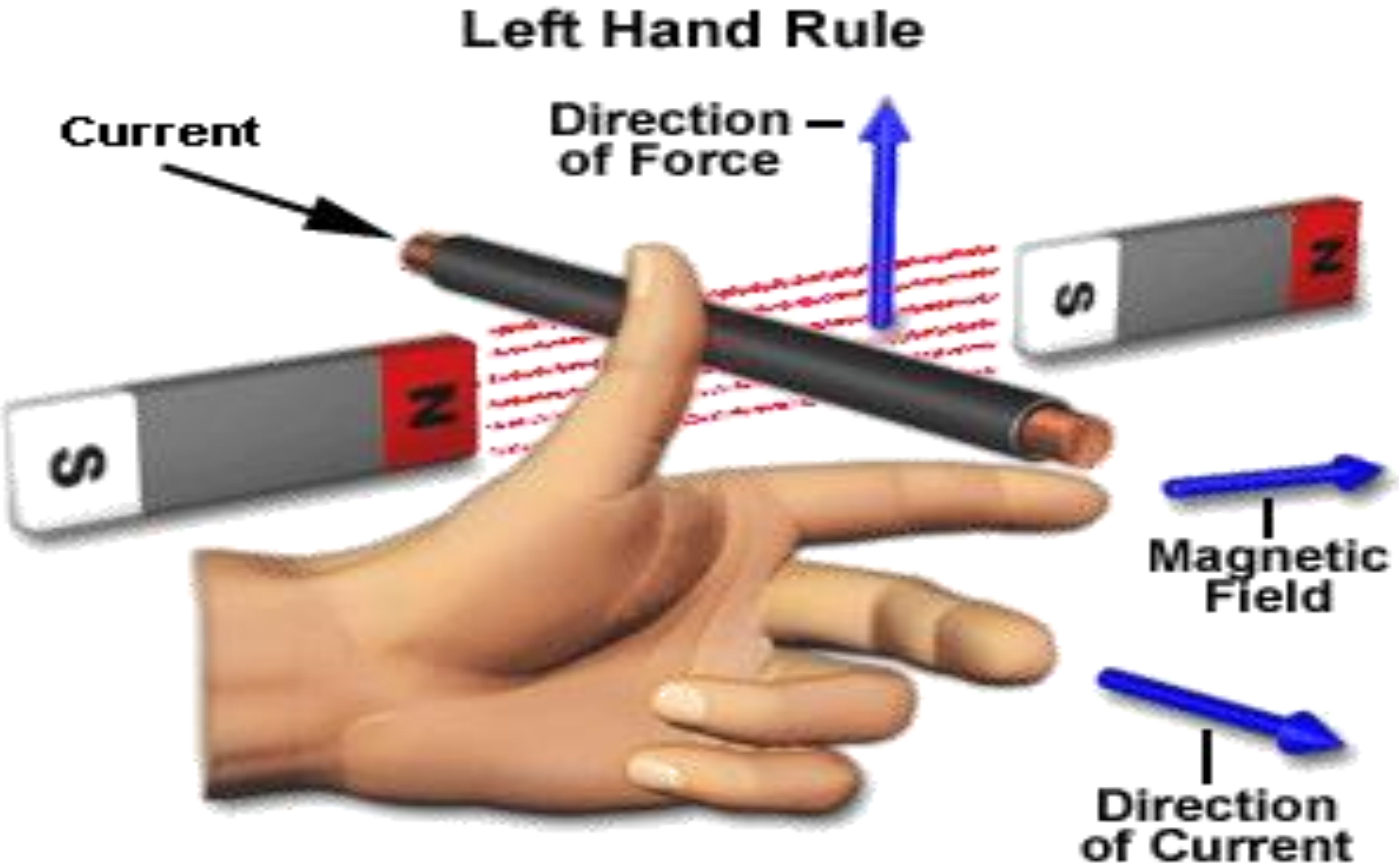
Generated EMF,

$$E_g = V + I_a R_a + I_{sc} R_{sc}$$
$$= V + I_a (R_a + R_{sc})$$




Long Shunt Compound Wound Generator

# Fleming's left hand rule



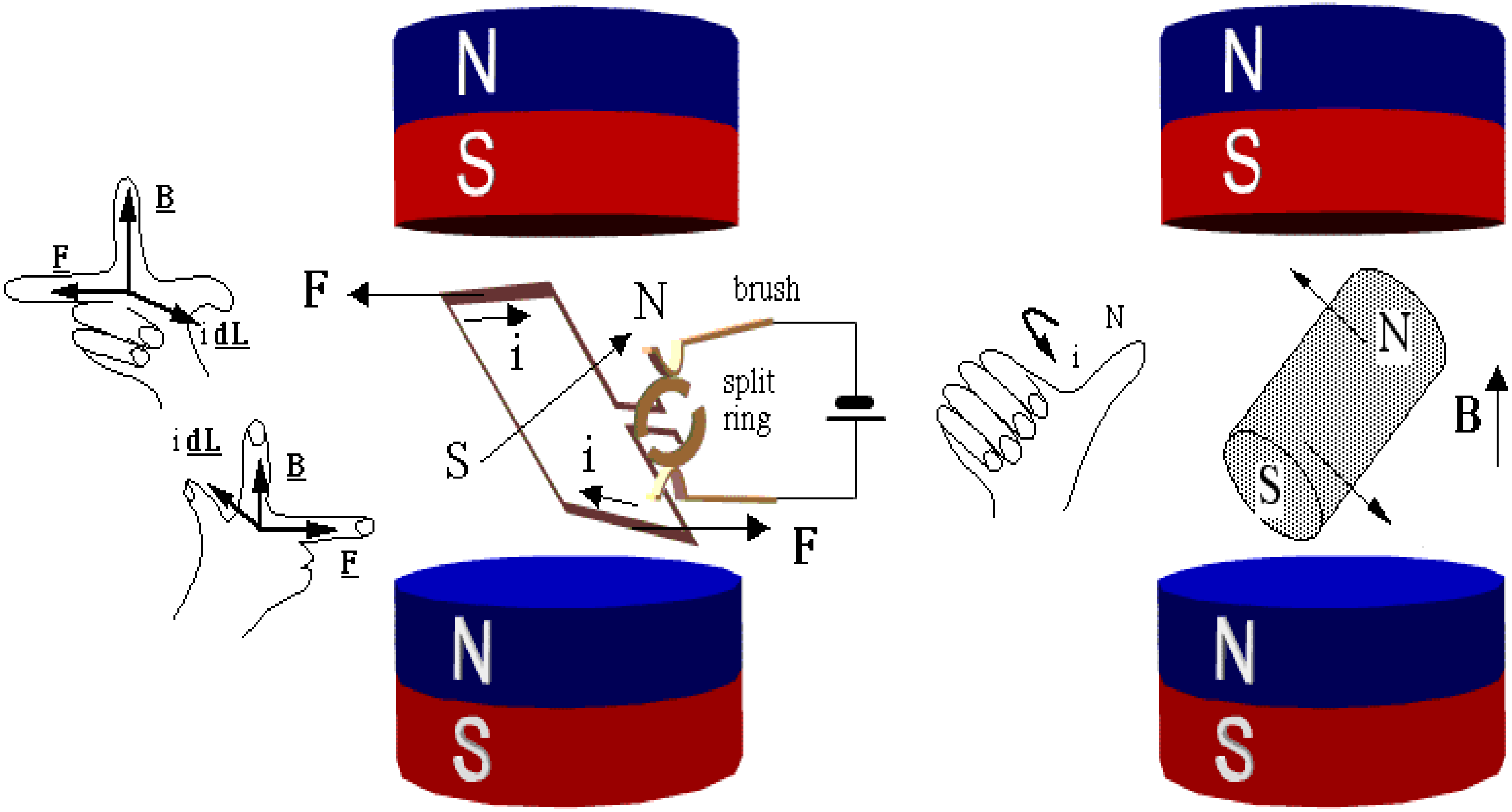
# Fleming's left  hand rule

- Used to determine the <u>direction of force acting on a current carrying conductor </u>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.**

# Force in DC motor



# Types of D.C. Motors

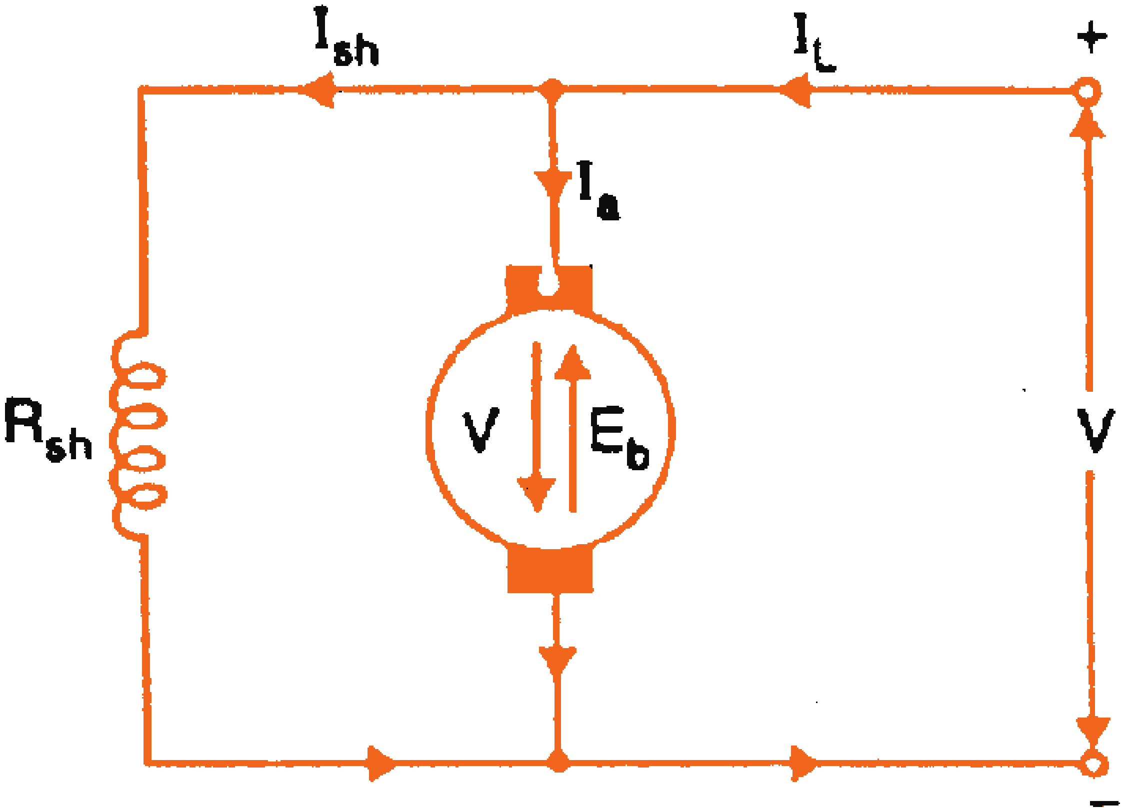
- Like generators, there are three types of D.C. motors characterized by the connections of field winding in relation to the armature. They are:
    1. Shunt Wound DC Motor
    2. Series Wound DC Motor
    3. Compound Wound DC Motor
        a. Short Shunt Connection
        b. Long Shunt Connection

# Types of D.C. Motors

## 1. Shunt Wound DC Motor

- Shunt-wound motor in which the field winding is connected in parallel with the armature.

Here, $I_L = I_a + I_{sh}$

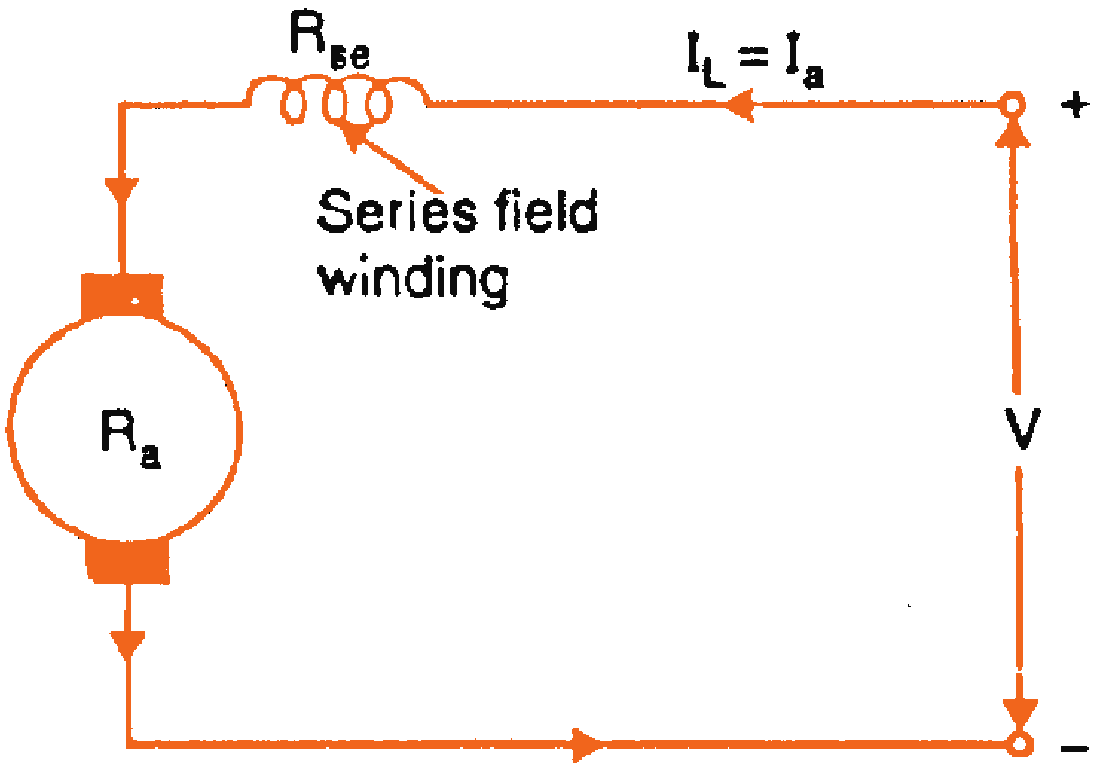


# Types of D.C. Motors

## 2. Series Wound DC Motor

- Series-wound motor in which the field winding is connected in series with the armature.

$$\text{Here, } I_L = I_a = I_{sc}$$



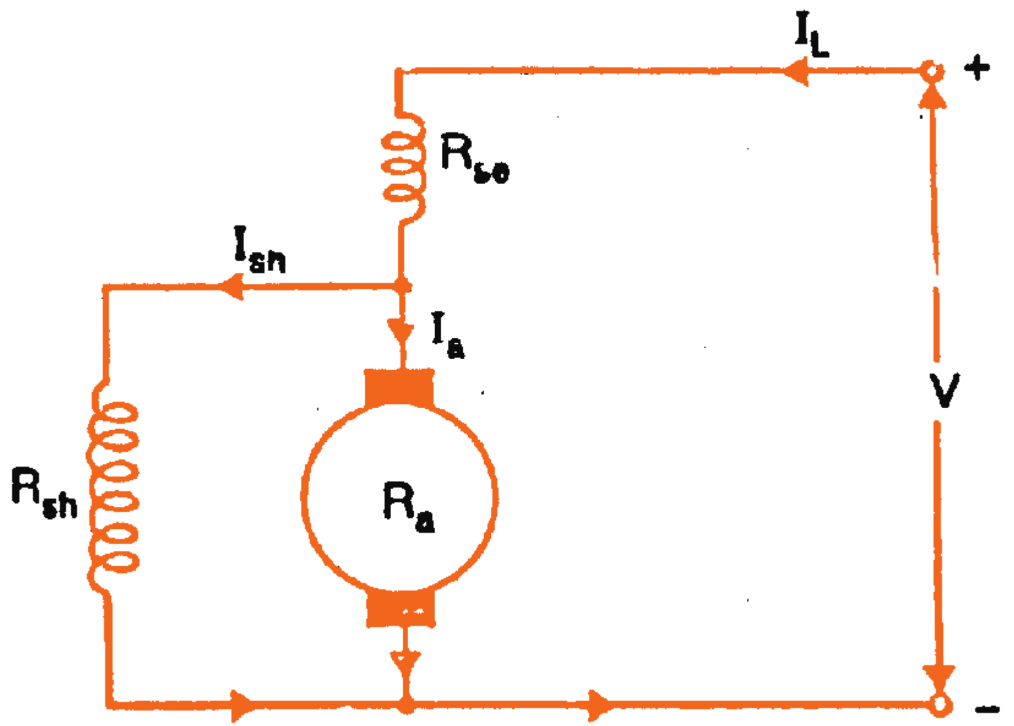
# Types of D.C. Motors

## 3. Compound Wound DC Motor

- Compound-wound motor which has two field windings; one connected in parallel with the armature and the other in series with it.

### a. Short shunt compound wound motor

Here, $I_L = I_{sc} = I_a + I_{sh}$

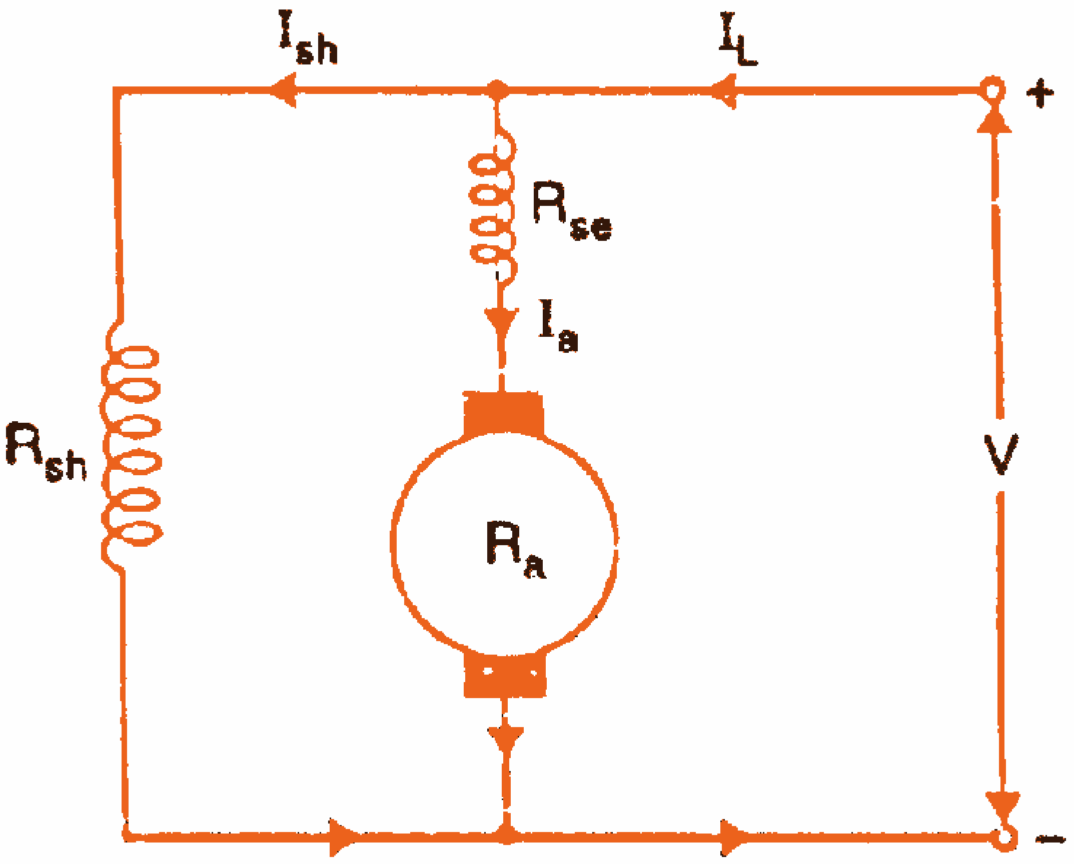



Short-shunt connection

# Types of D.C. Motors

3. Compound Wound DC Motor
   b. Long-Shunt compound wound motor

Here, $I_L = I_{sc} + I_{sh}$




Long-shunt connection

# Applications of D.C. Motors

1. D.C. shunt motor
   - Lathes, fans, pumps and band saw drive requiring moderate torques.
2. D.C. Series motor
   - Electric traction, high speed tools, Universal Motor
3. Compound motor
   - Rolling mills and other loads requiring large momentary toques.

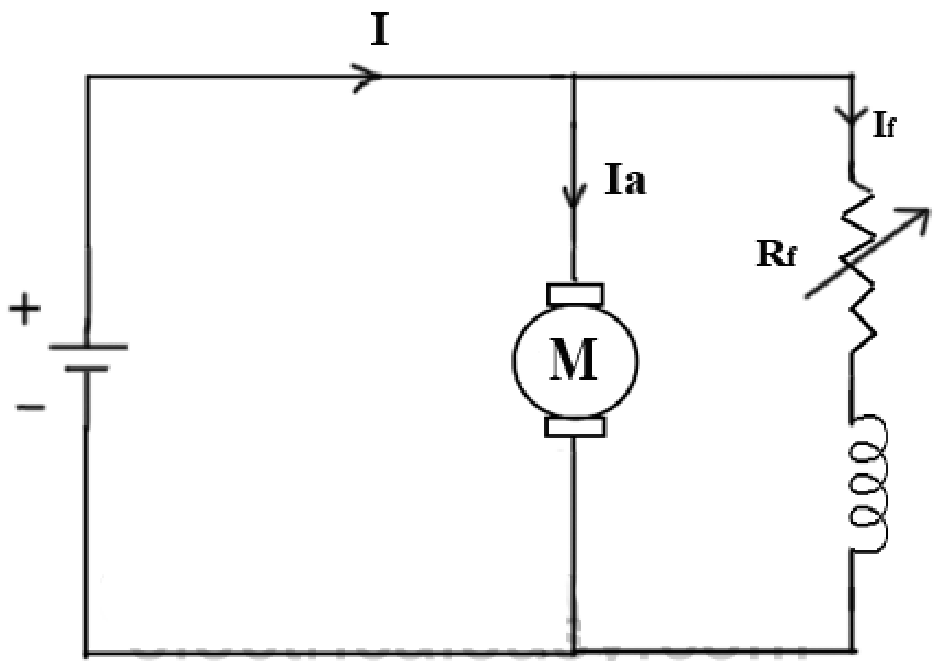
# Speed Control of DC Shunt Motors

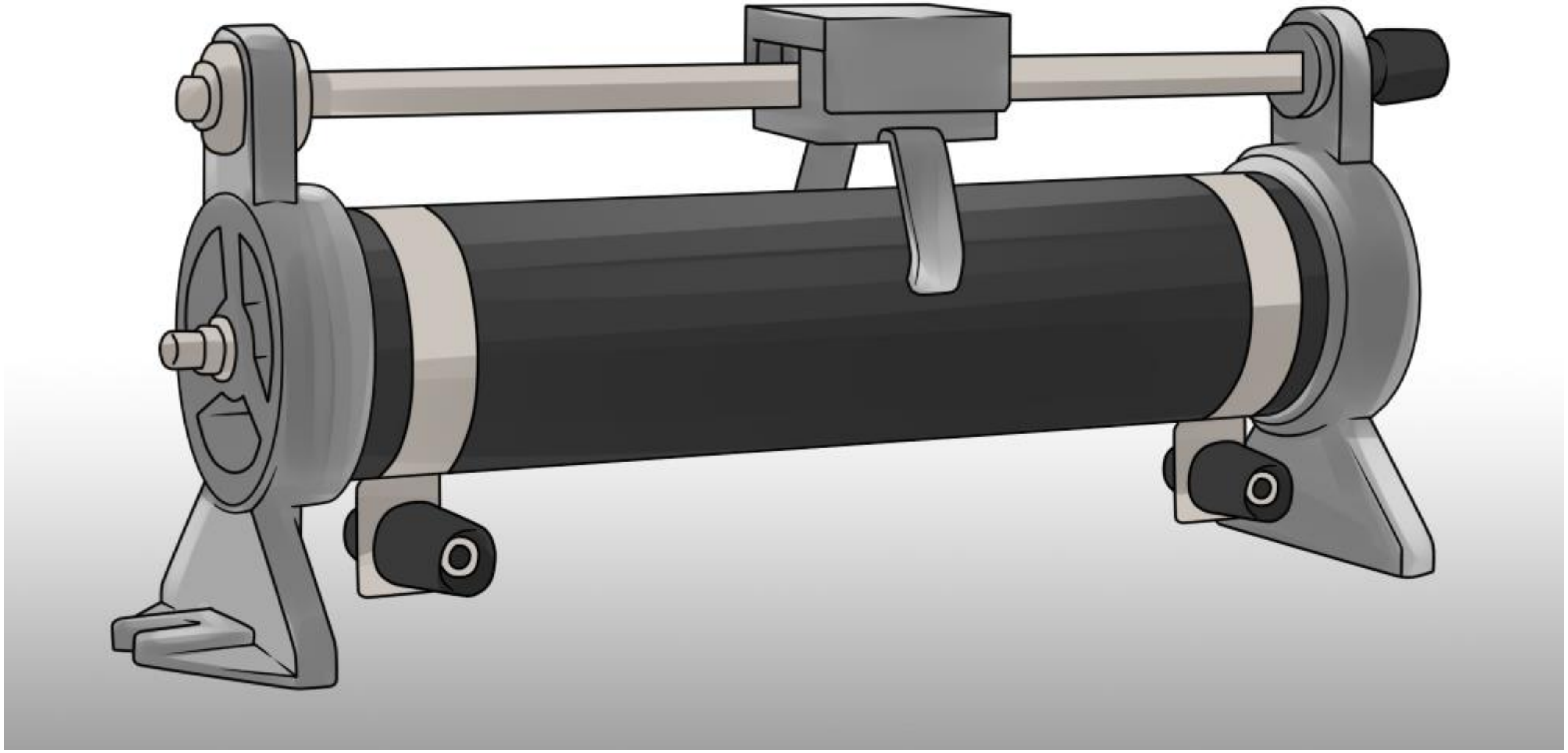
## 1. Flux Control Method

- Speed is inversely proportional to flux. So by varying flux we can change the speed of the motor.

$$N = \frac{E_b 60A}{\phi ZP} \Rightarrow N = K\frac{E_b}{\phi} \Rightarrow N \alpha \frac{E_b}{\phi}$$

- The field rheostat reduces the shunt field current $I_f$. So the flux also get reduced. Therefore the speed can be increased.





# Torque

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

- $P = T * 2\pi N/60$
- $E_b * I_a = T_a * 2\pi N/60$
- $T_a \propto \varphi$
- $T_a \propto I_a$
- $T_a \propto \frac{1}{N}$

# Characteristic of DC motors

- T/ Ia  characteristic
- N/ Ia   characteristic
- N/T characteristic

# Speed control of DC motors

According to the speed equation of a dc motor

$$N \propto E_b/\varphi$$
$$\propto (V - I_a R_a)/\varphi$$

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.

# 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 efficiency , 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