Rotating Machines

- Motor
- Generator

Motor

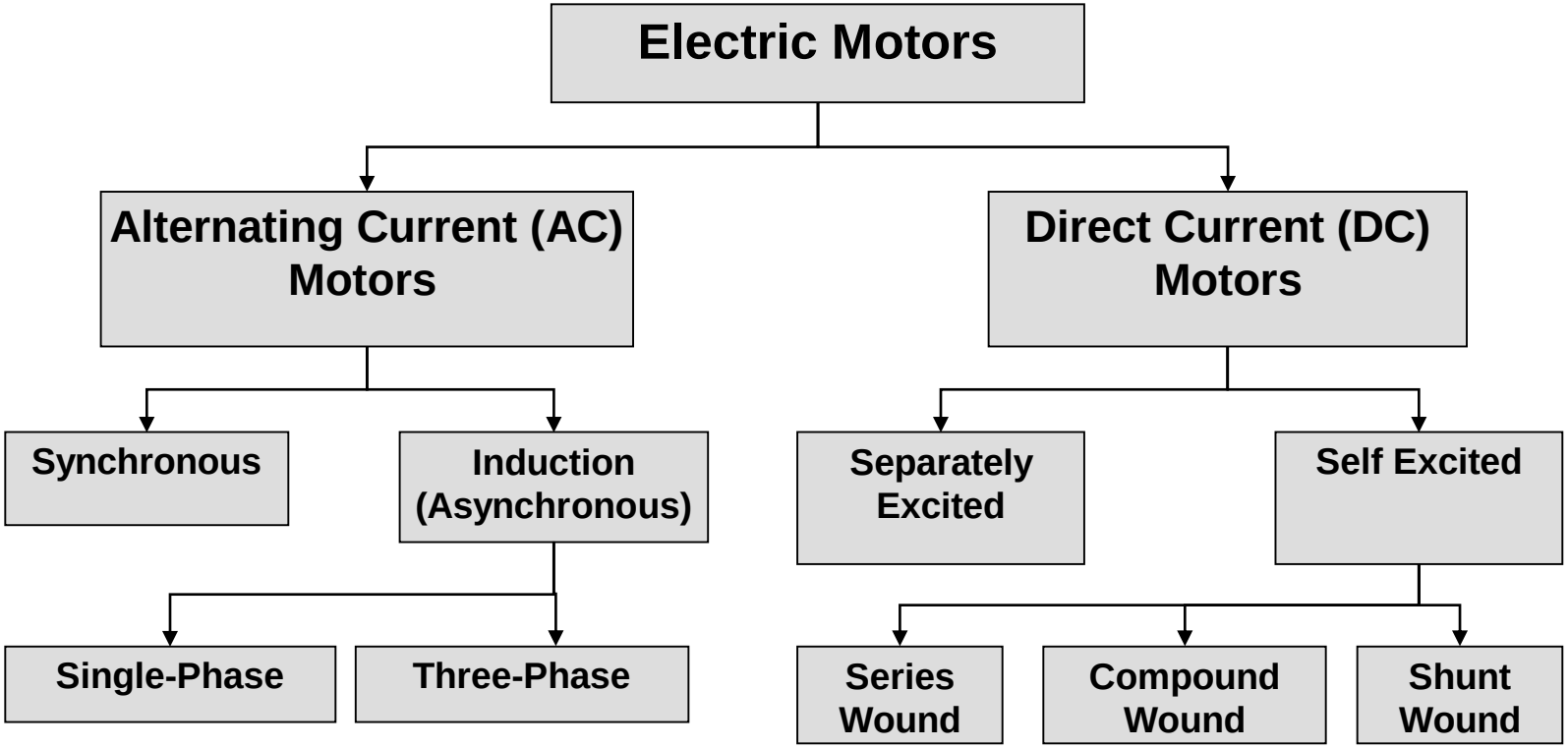
Electrical Power ⟹ Mechanical Power

Generator

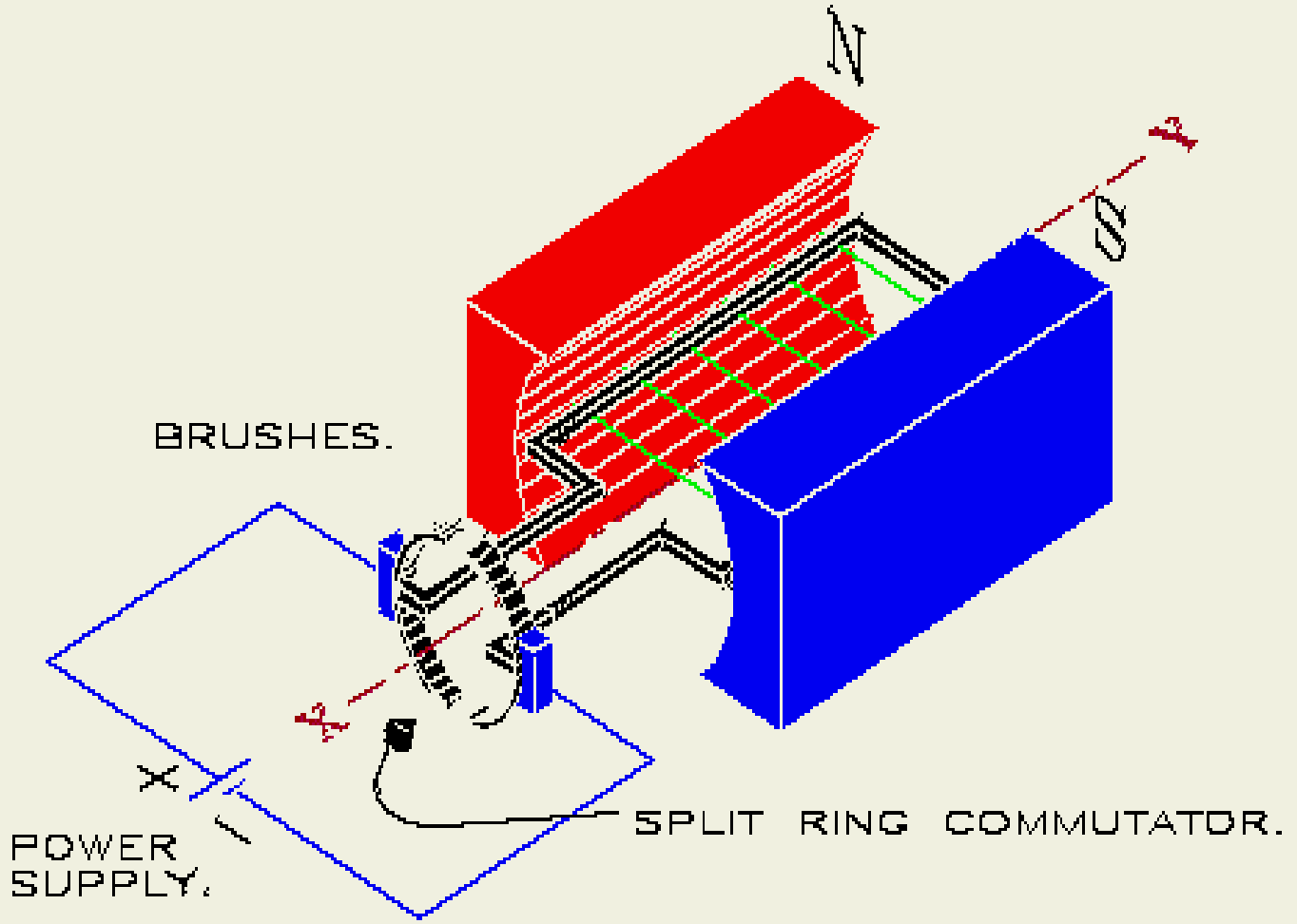
Mechanical Power ⟹ Electrical Power

Type of Electric Motors

Classification of Motors

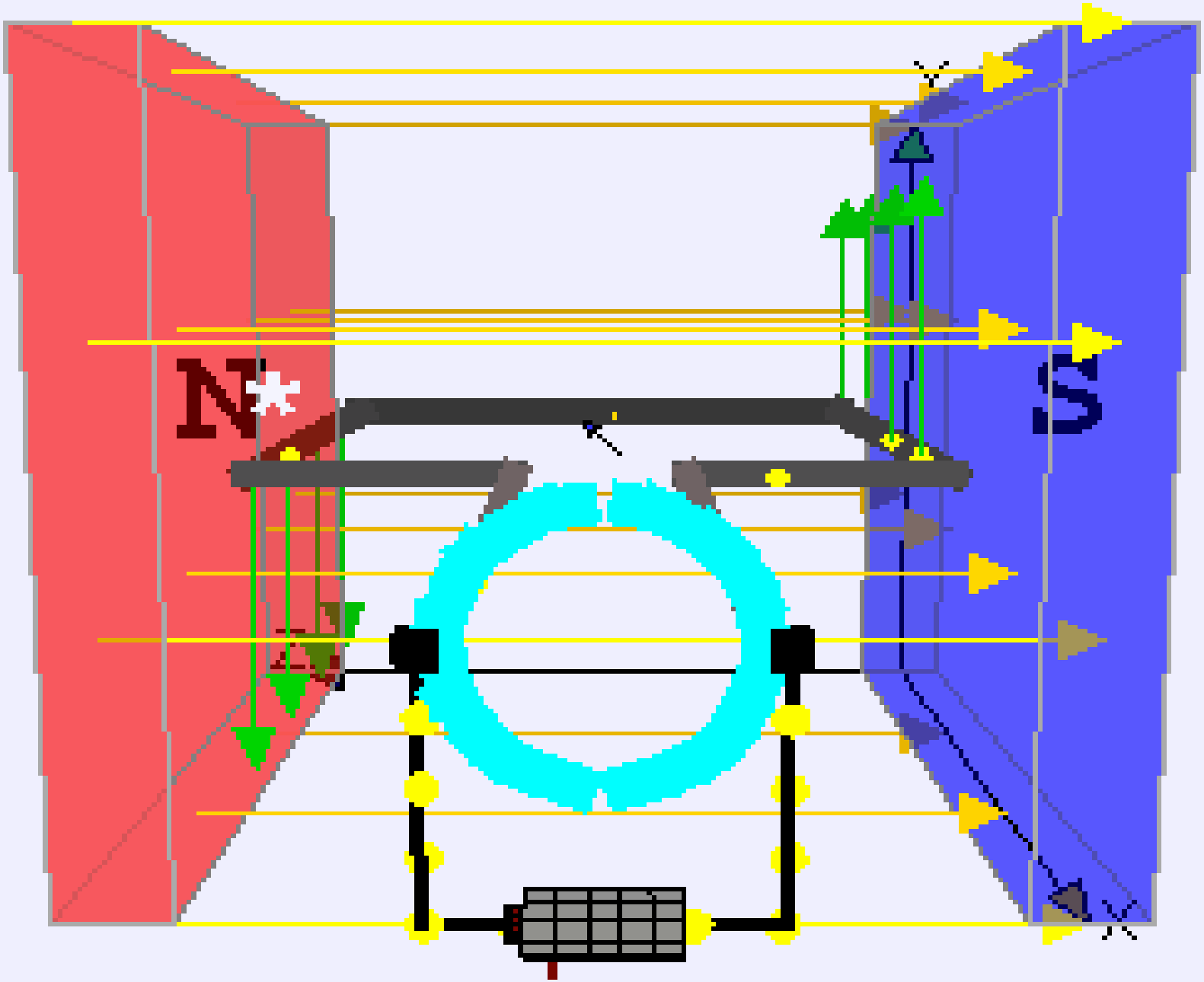


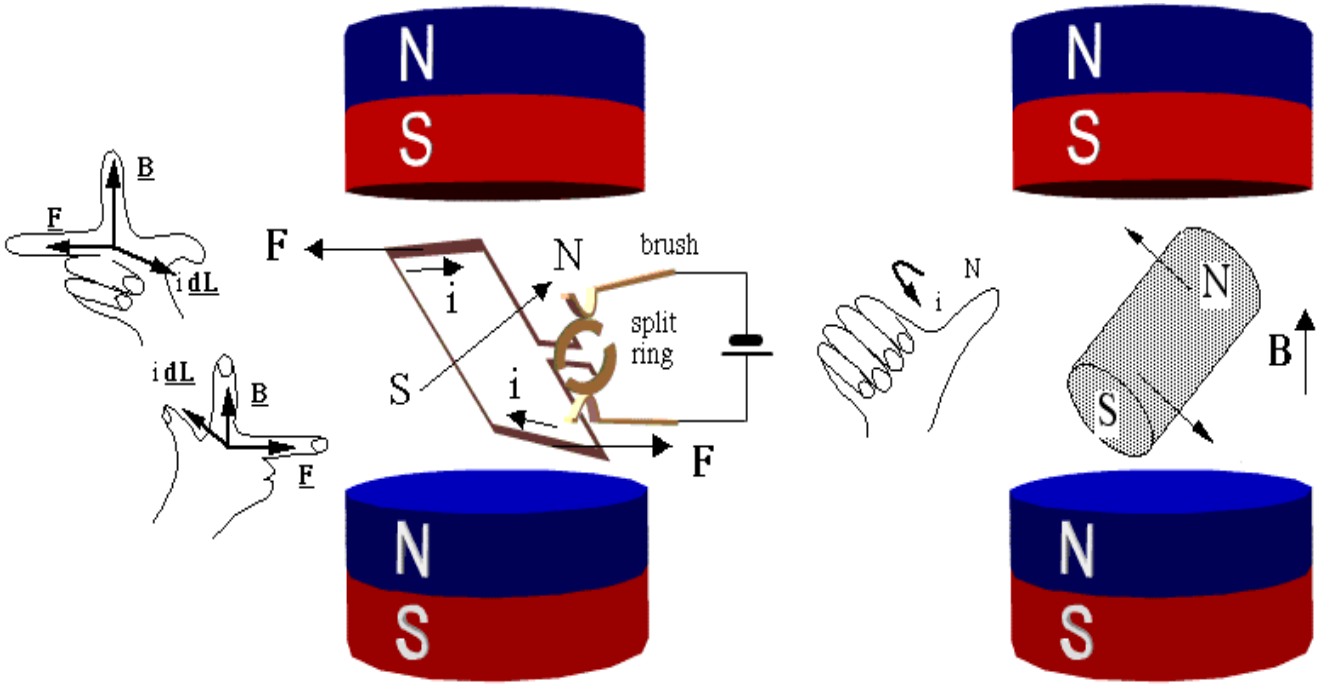
DC Machine



THE DIRECT CURRENT MOTOR.

DRAWN BY. Aidan Flynn.


N
S


N
S
B
F
i dL
i dL
B
F
F
N
brush
split
ring
S
i
i
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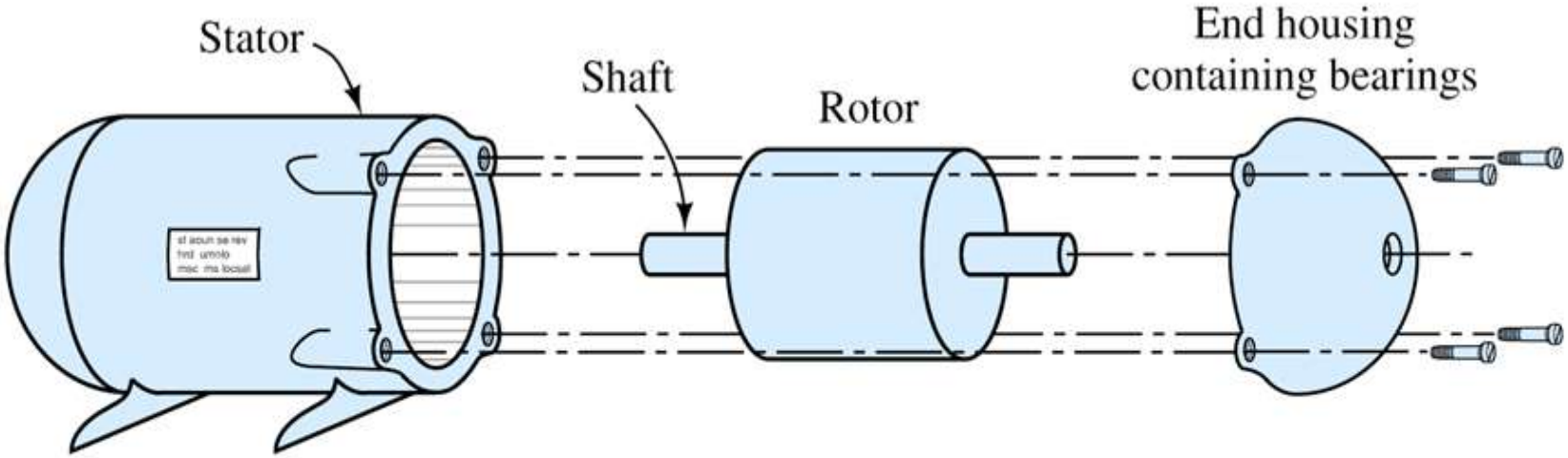
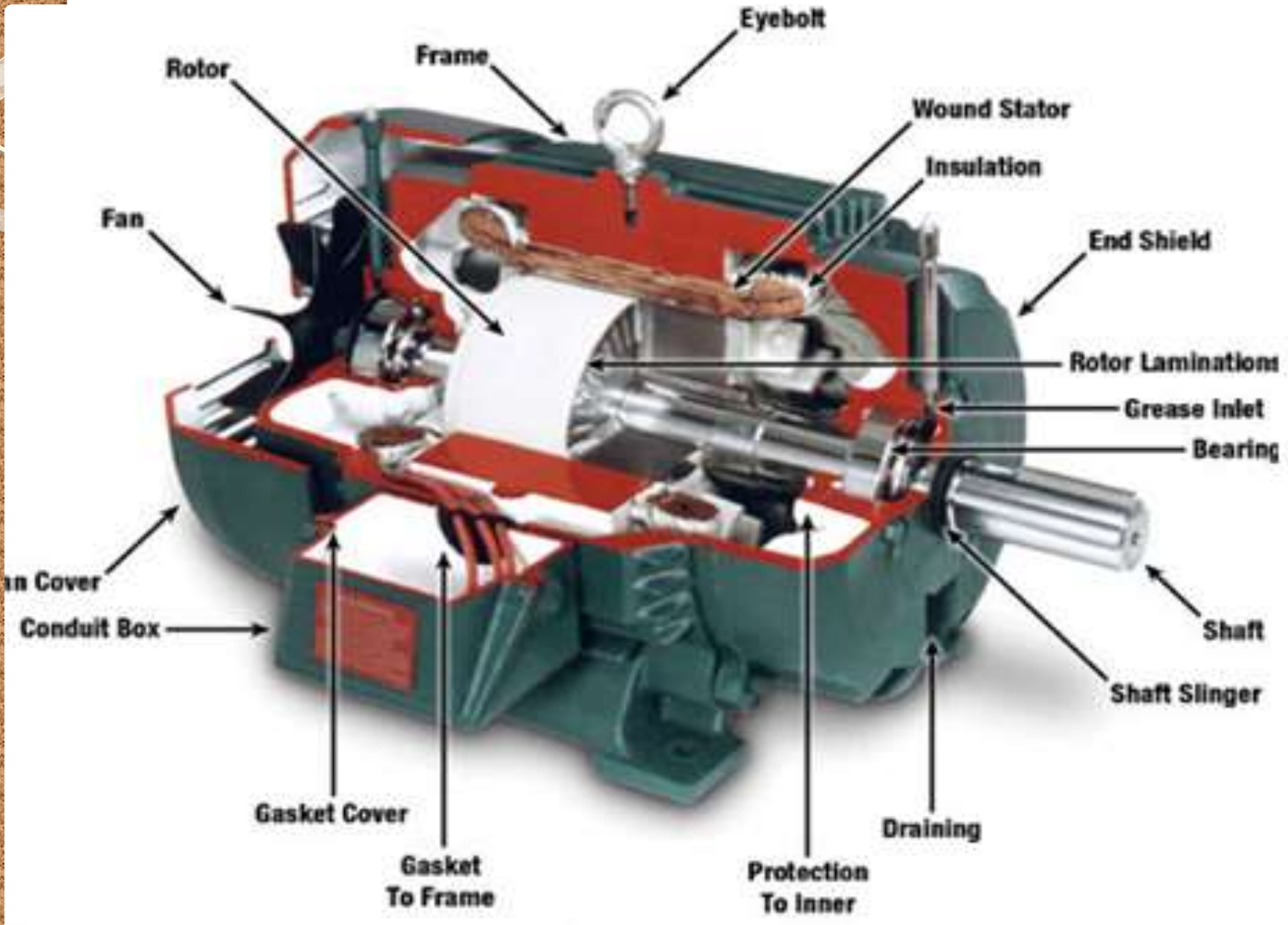
N
i
N
S
B
N
S
N
S

Rotating machine



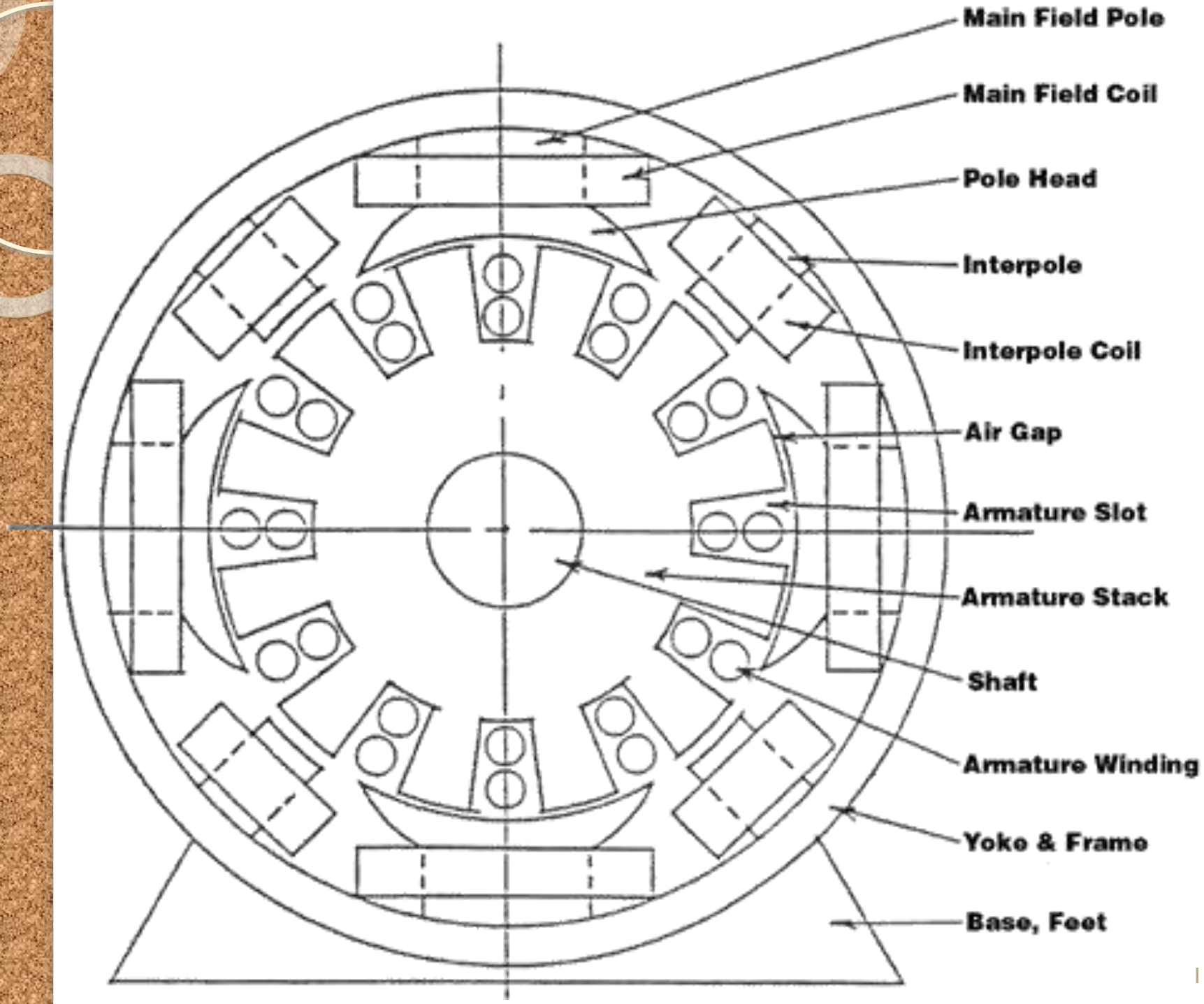
An electrical motor consists of a cylindrical rotor that spins inside a stator.

Cross sectional View of DC motor



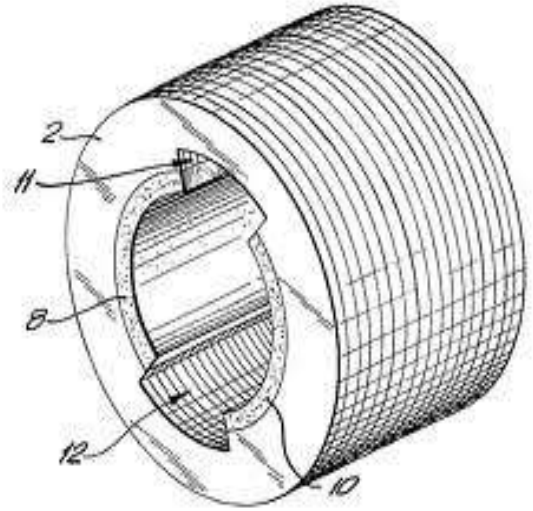
Major Parts of DC Motor

1. Magnetic frame or Yoke
2. Pole core & Pole shoes
3. Field or Exciting coils
4. Armature core
5. Armature winding
6. Commutator
7. Shaft
8. End Housing
9. Bearings
10. Brushes


Main Field Pole
Main Field Coil
Pole Head
Interpole
Interpole Coil
Air Gap
Armature Slot
Armature Stack
Shaft
Armature Winding
Yoke & Frame
Base, Feet

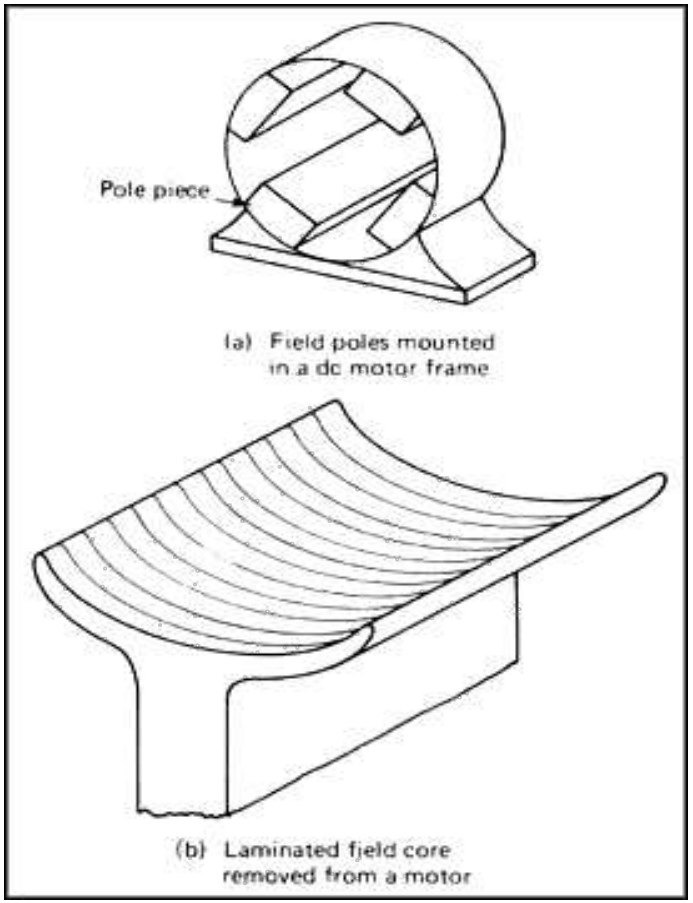
Magnetic frame or Yoke

- Mechanical protection
- Low reluctance for magnetic flux
- Made of cast iron –smaller M/c & cast steel or fabricated rolled steel – bigger M/c



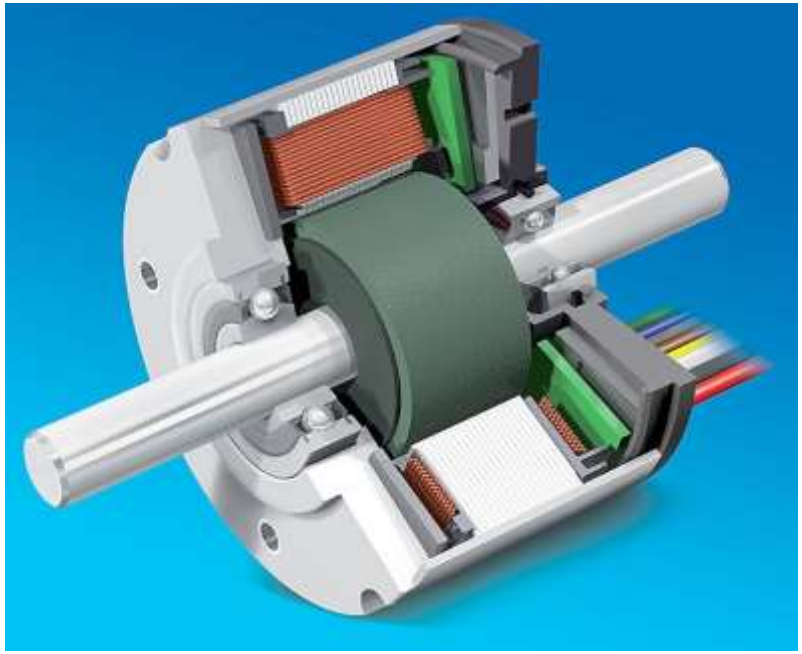
Pole core & Pole shoes

- Support field or exciting coils
- Spread magnetic flux over armature



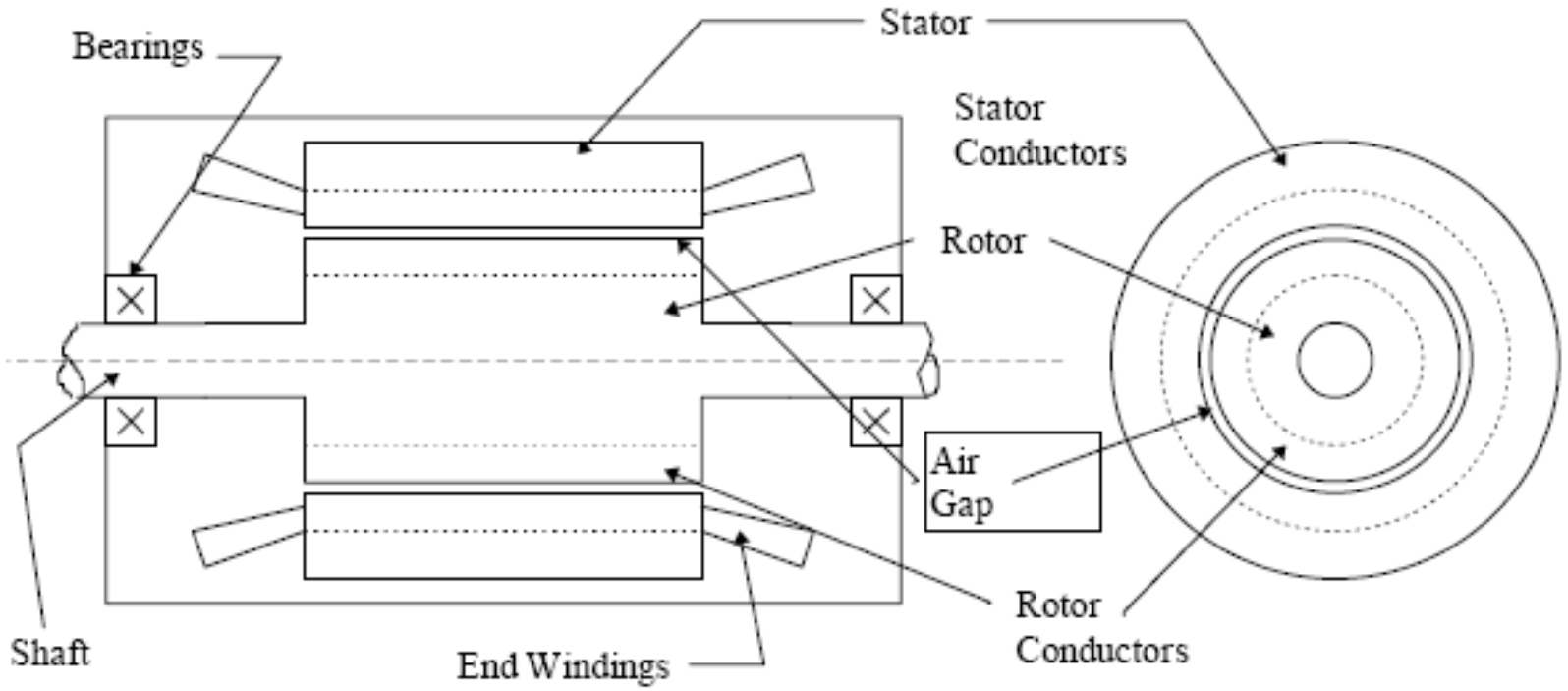
Field or Exciting coils

- Winding done on pole core



Armature

- Major parts of rotor (armature) and stator (field).

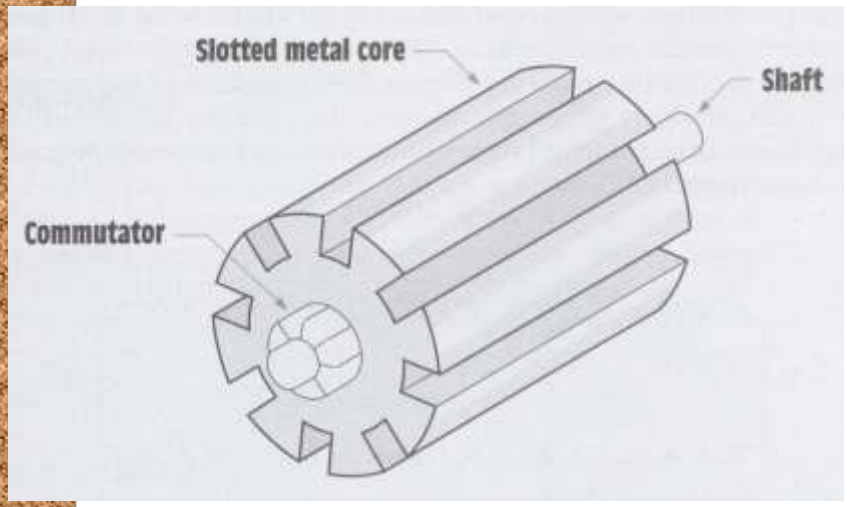


Armature core

- Rotating part of motor
- Made up by silicon steel stamping
- Stamping varies 0.3 to 0.5mm

ARMATURE

- More loops of wire = higher rectified voltage
- In practical, loops are generally placed in slots of an iron core
- The iron acts as a magnetic conductor by providing a low-reluctance path for magnetic lines of flux to increase the inductance of the loops and provide a higher induced voltage. The commutator is connected to the slotted iron core. The entire assembly of iron core, commutator, and windings is called the armature. The windings of armatures are connected in different ways depending on the requirements of the machine.



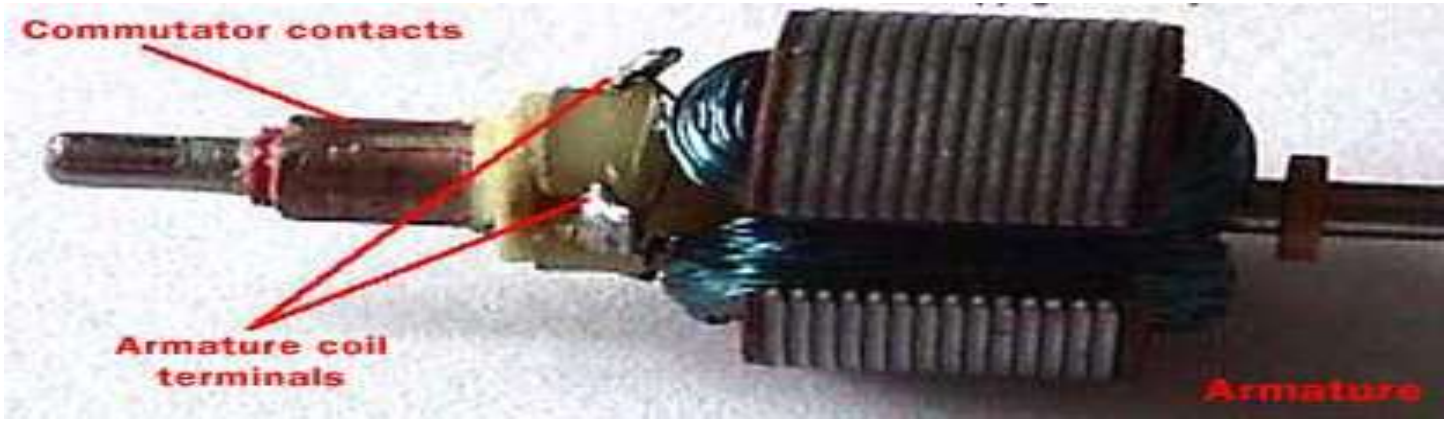
Loops of wire are wound around slot in a metal core

DC machine armature

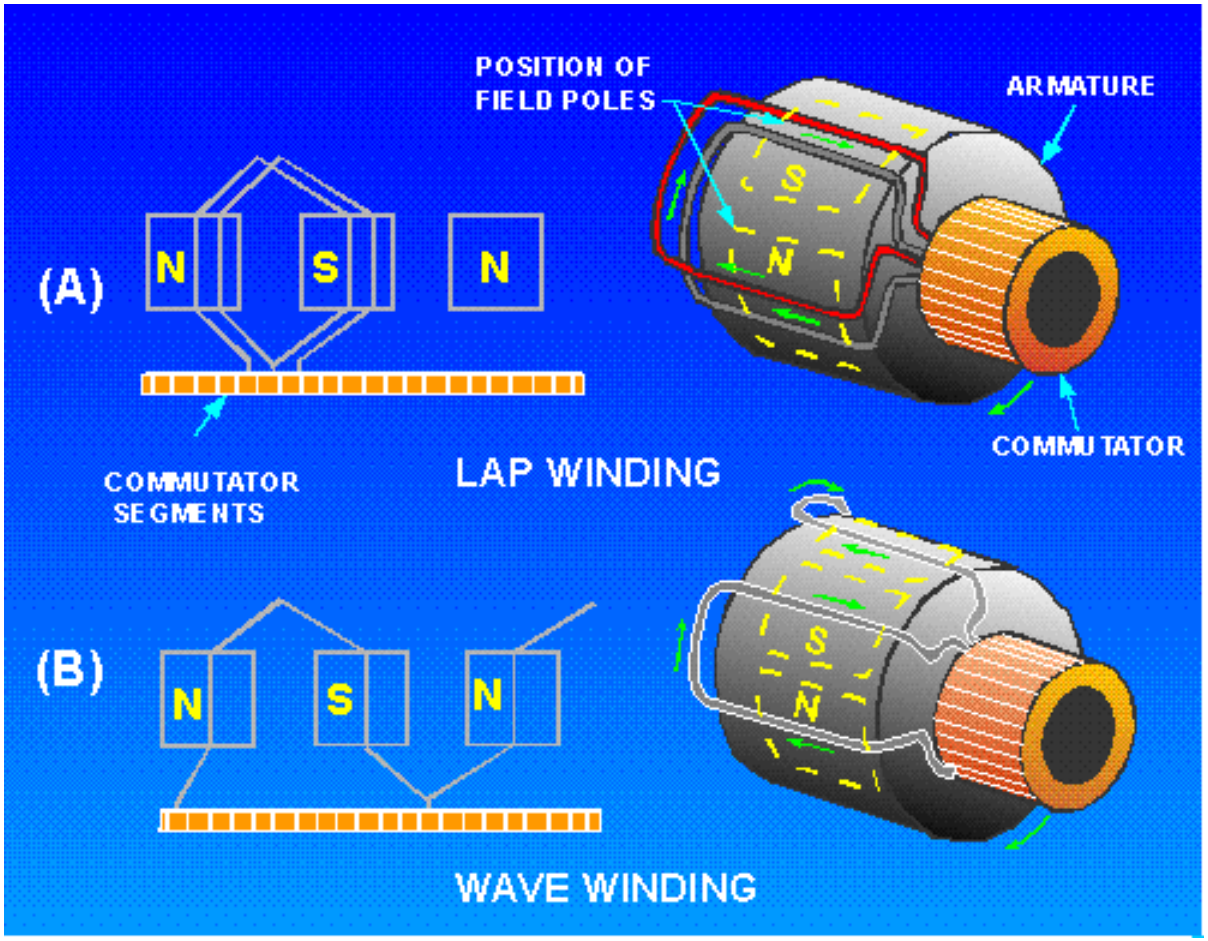
Armature winding

Lap winding and wave winding

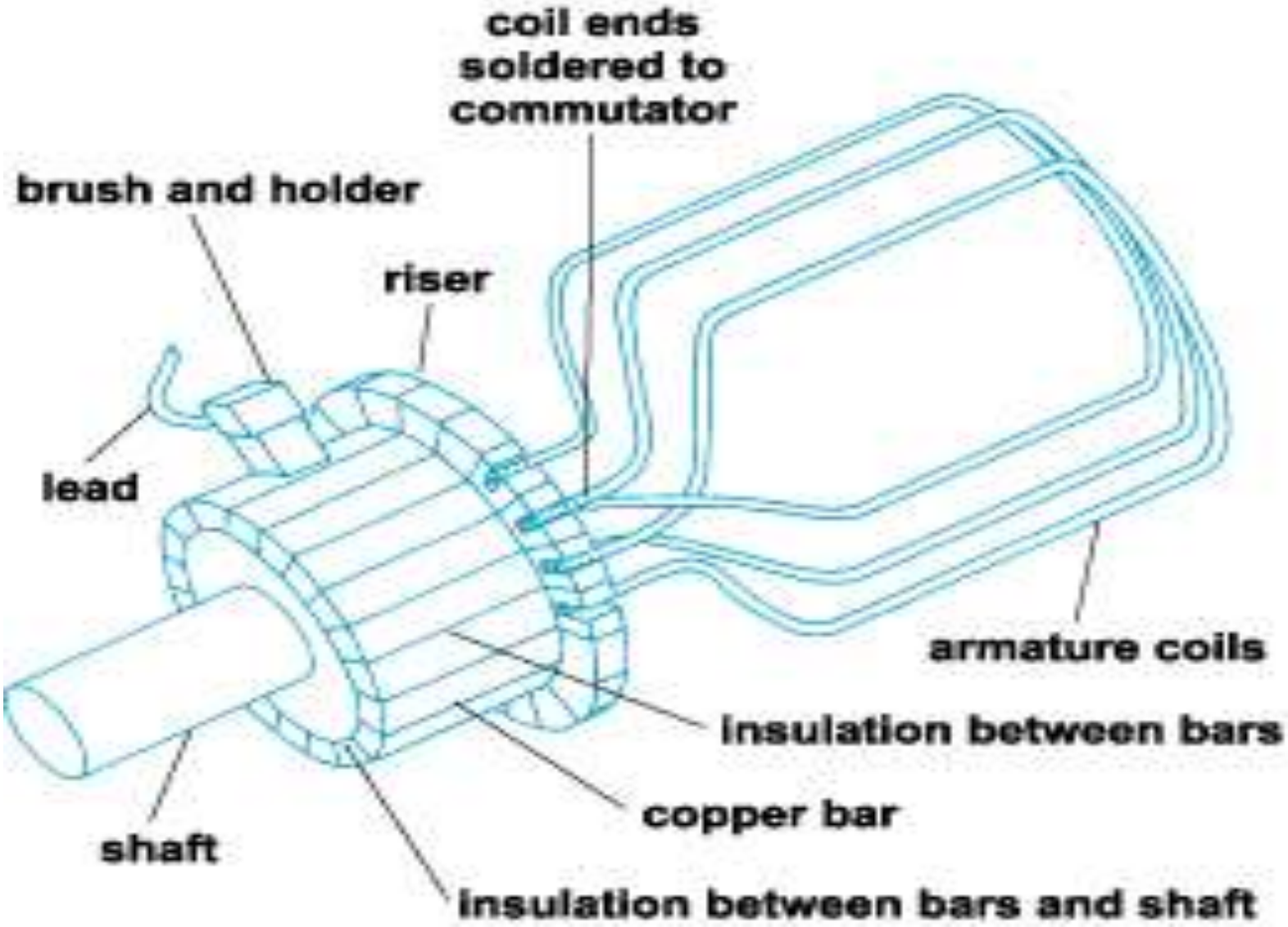
A=P for lap winding
A=2 for wave winding



ARMATURE WINDINGS (Cont)



Commutator & Brush connection

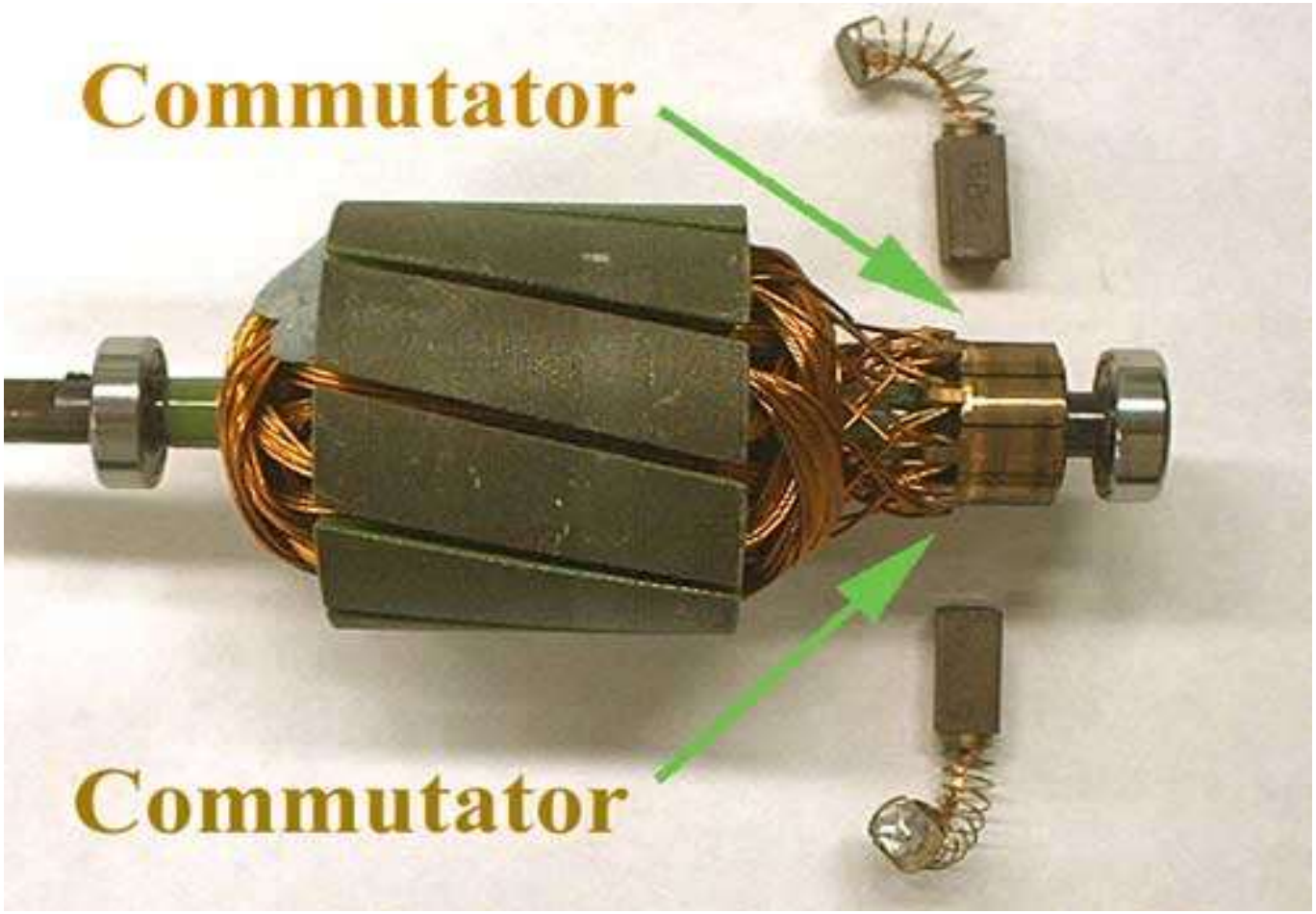


Commutator

- Connects the rotating armature conductors to stationary external circuit through brushes

- Converts alternating current AC induced in armature conductor into unidirectional current

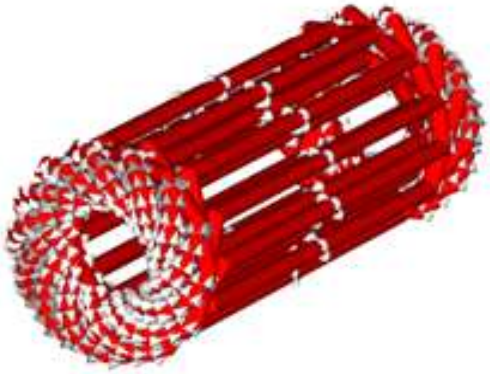
Armature with Commutator


Commutator
Commutator

Brushes

Made of high grade carbon

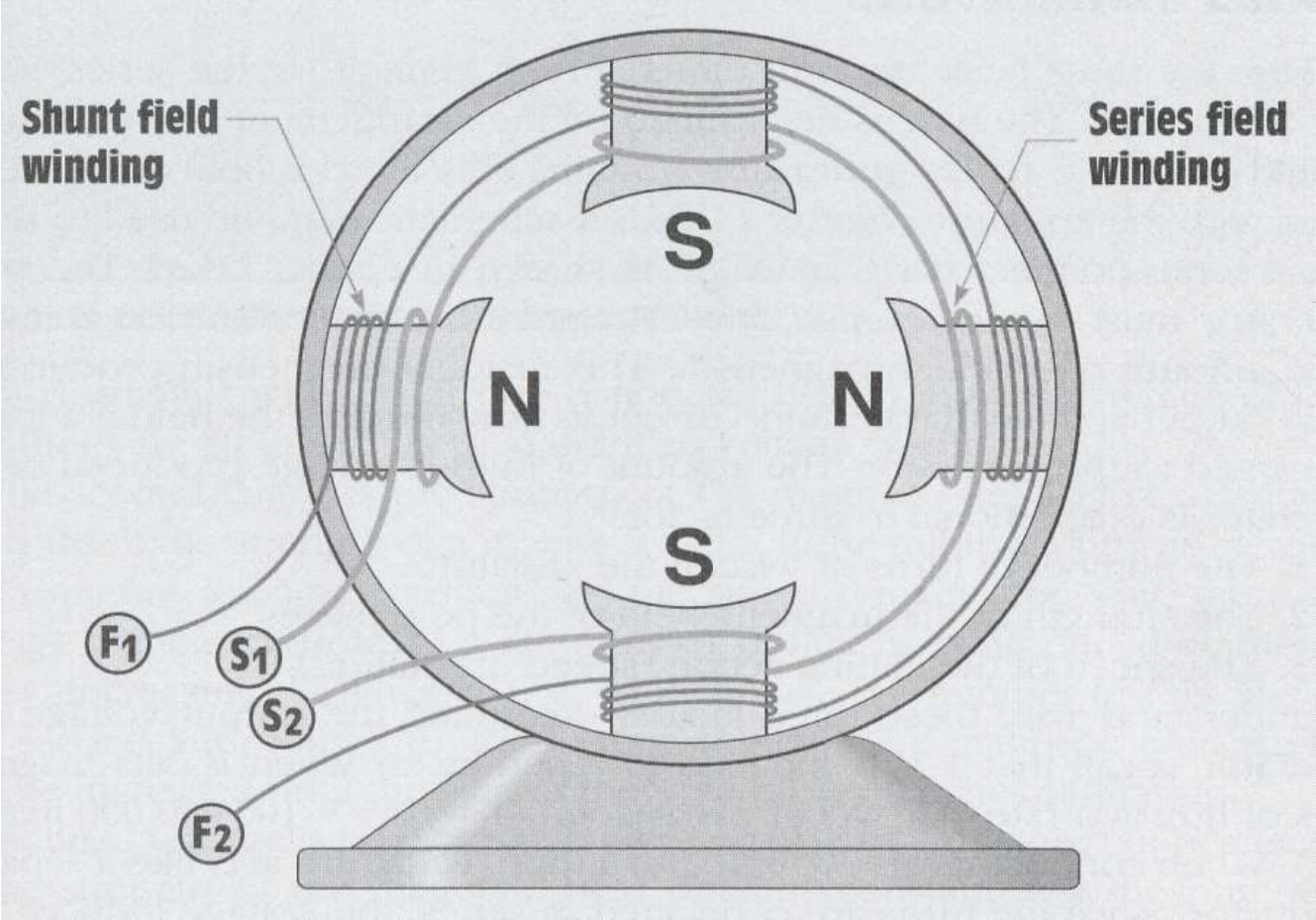
Rotor



Windings

Permanent Magnets

Stator


Shunt field winding
Series field winding
S
N
N
S
F1
S1
S2
F2

FIELD WINDINGS

- Most DC machines use wound electromagnets to provide the magnetic field.

- Two types of field windings are used :
  - series field
  - shunt field

EMF equation of a DC generator

Consider a DC generator with the following parameters,

P = Number of field poles
Ø= Flux produced per pole in Wb (weber)
Z = Total No. of armature conductors
A = No. of parallel paths in armature
N = Rotational speed of armature in revolutions per minute (rpm)

Now,
Average emf generated per conductor is given by
dΦ/dt (Volts) ……..... eqn. I

Flux cut by one conductor in one revolution = dΦ = PΦ….(Weber),

Number of revolutions per second (speed in RPS) =N/60

Therefore, time for one revolution = dt = 60/N(Seconds)

From eqn. 1, emf generated per conductor = dΦ/dt

= PΦN/60 (Volts) ……(eqn. 2)

Above equation-2 gives the emf generated in one conductor of the generator. The conductors are connected in series per parallel path, and the emf across the generator terminals is equal to the generated emf across any parallel path.

Therefore,

Generated EMF **Eg = PΦNZ / 60A (For Generator)**

Back EMF **Eb = PΦNZ / 60A (For Motor)**

For lap winding,

No. of parallel paths is equal to the number of poles (i.e. A = P)

For Wave winding,

Number of parallel paths is equal to 2 (i.e. A = 2)

Ex: A 4 pole generator with wave wound armature has 51 slots & each having 24 conductors. The flux per pole is 0.01 webers. At what speed must the armature rotate to give an induced emf of 220V. What will be the voltage developed if the winding is lap connected & armature rotates at the same speed

Induced Emf $E_g = \frac{\phi Z N P}{60 A}$

$\phi = 0.01$ wb

$Z = 51 \times 24 = 1224$

$E = 220V, \quad P = 4$

$A = 2$ (wave winding)

$$220 = \frac{0.01 \times 1224 \times N \times 4}{120}$$

$$N = 539.21 \text{ rpm.}$$

for lap winding $A = P = 4.$

$$E_g = \frac{0.01 \times 1224 \times 539.21 \times 4}{60 \times 4}$$

$$= 110 \text{ V.}$$

TYPE OF D.C. GENERATOR

1. Separately excited d.c. generators.
2. Self excited D.C. generators

   these are further classified 3 categories-

i. Shunt wound d.c. generators

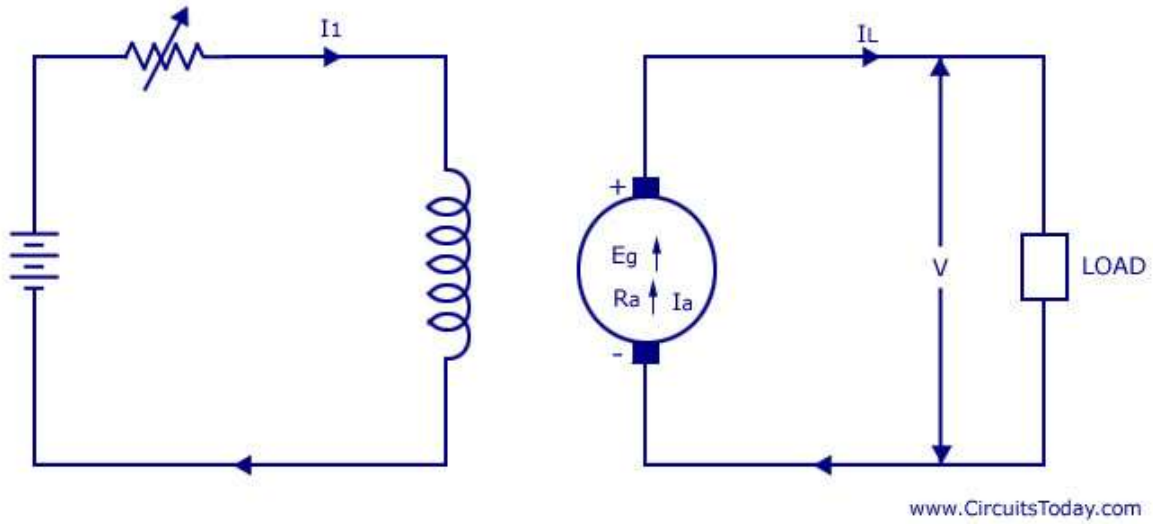
ii. Series wound d.c. generators

iii. Compund wound d.c. generators

a. Long shunt compund wound generators

b. Short shunt compund wound generators.

Separately excited DC generator



$V = Eg - IaRa$ $[Ia = I_L]$

$V = Eg - IaRa - 2Vb$ **(When Considering Brush drop)**

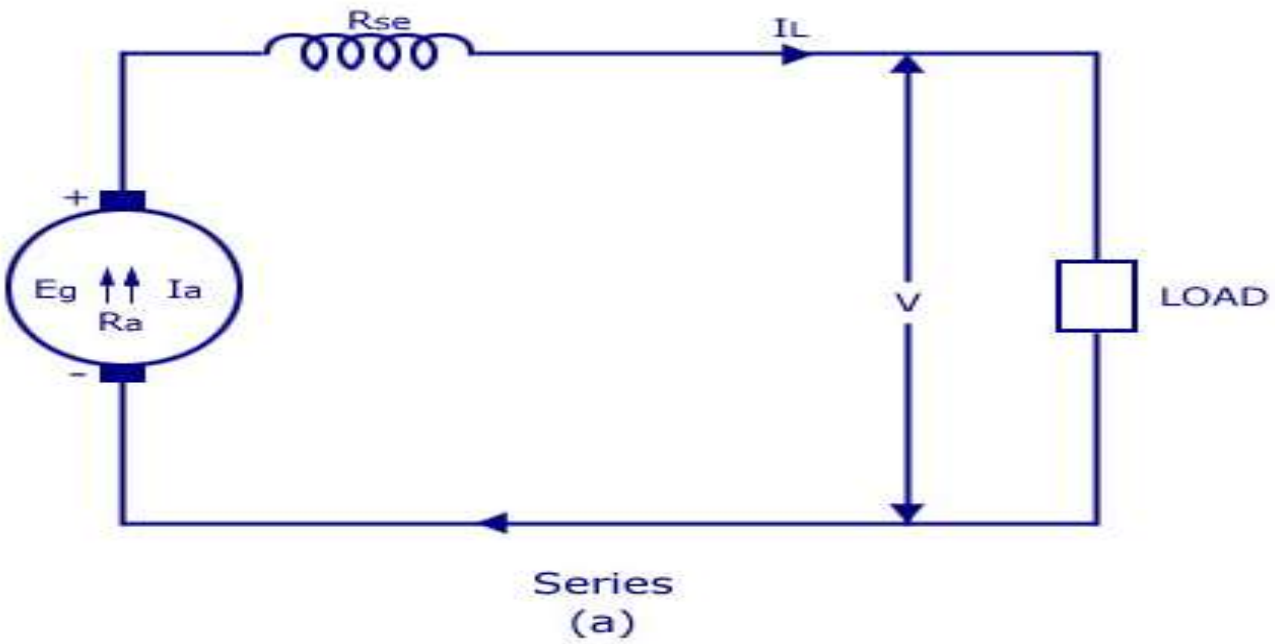
Power Developed = $IaEg$

Output Power = VI_L

Self Excited DC Generator

1) Series Wound DC Generator
2) Shunt Wound DC Generator
3) Compound Wound DC Generator

Series Wound DC Generator



$V = Eg - IaRa - I_L Rse$

$= Eg - Ia(Ra + Rse)$ $[Ia = I_L]$

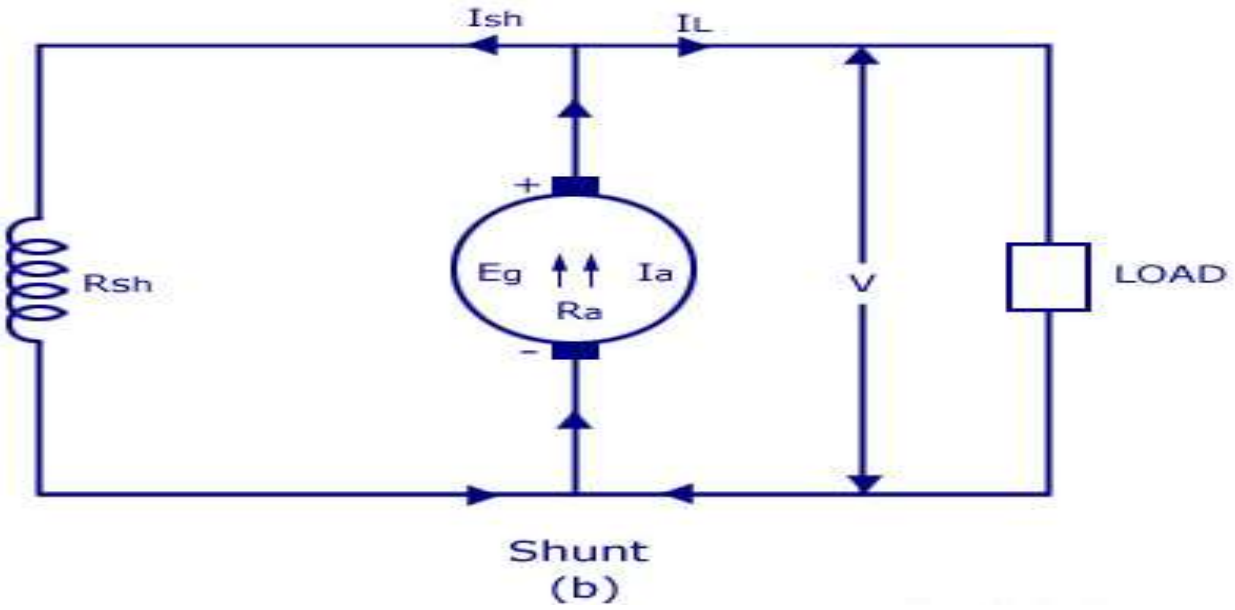
$V = Eg - Ia(Ra + Rse) - 2Vb$

(When Considering Brush drop)

Power Developed = $IaEg$

Output Power = VI_L

Shunt Wound DC Generator



$V = Eg - IaRa$ $[Ia = I_L + I_{Sh}]$

$V = Eg - IaRa - 2Vb$ **(When Considering Brush drop)**

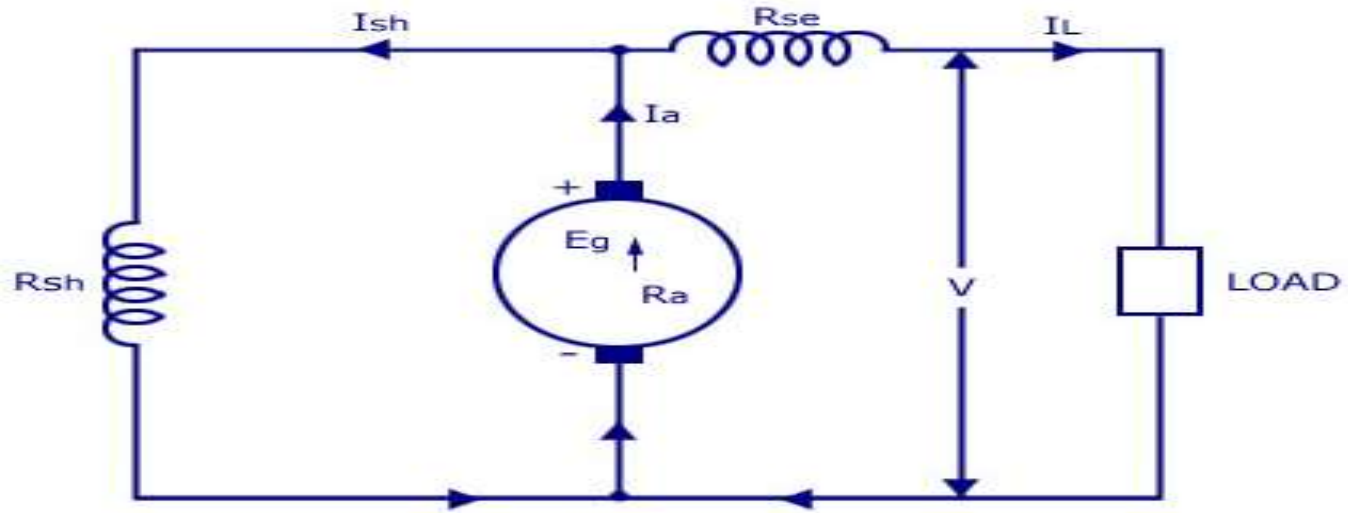
Power Developed = IaEg

Output Power $= VI_L$

Compound Wound DC Generator

1. Short Shunt Compound Wound DC Generator
2. Long Shunt Compound Wound DC Generator

Short Shunt Compound Wound DC Generator



Short Shunt Compound

$V = Eg - IaRa - I_L Rse$

$Ia = I_L + I_{Sh}$

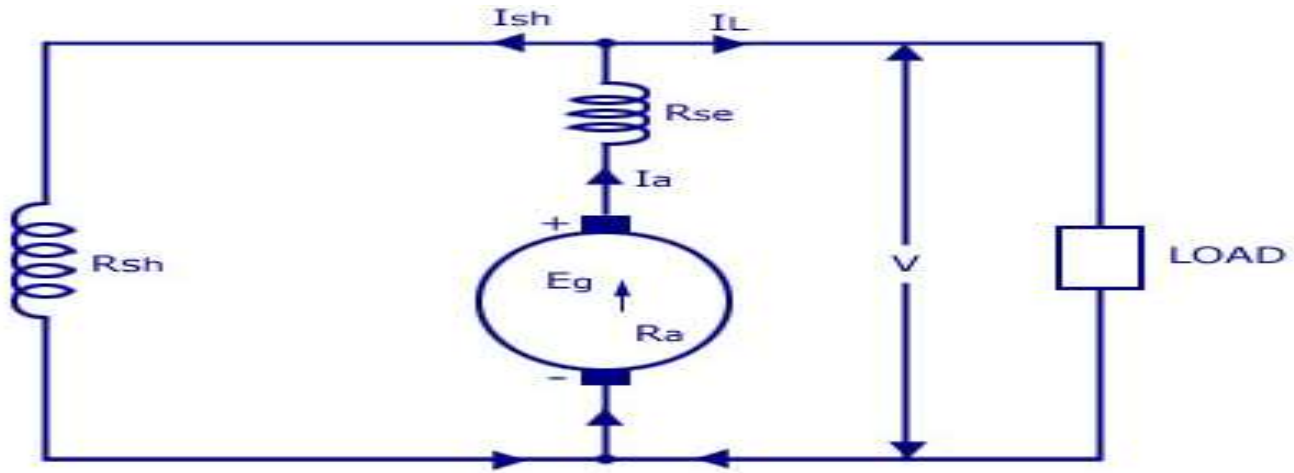
$V = Eg - - IaRa - I_L Rse - 2Vb$

(When Considering Brush drop)

Power Developed = $IaEg$

Output Power = VI_L

Long Shunt Compound Wound DC Generator



Long Shunt Compound

$V = Eg - IaRa - I_{Se}Rse$

$Ia = I_{Se} = I_L + I_{Sh}$

$V = Eg - - IaRa - I_{Se}Rse - 2Vb$

(When Considering Brush drop)

Power Developed = $IaEg$

Output Power = VI_L

TYPE OF D.C. MOTOR

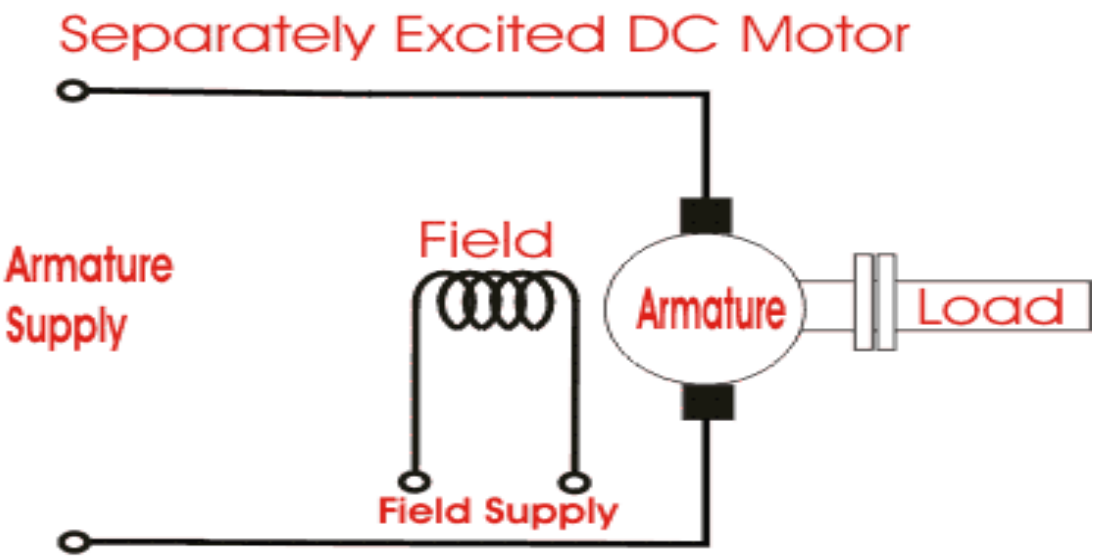
1. Separately excited d.c. motor.
2. Self excited D.C. motor

these are further classified 3 categories-

i. Shunt wound d.c. motor
ii. Series wound d.c. motor
iii. Compund wound d.c. motor

a. Long shunt compund wound motor
b. Short shunt compund wound motor.

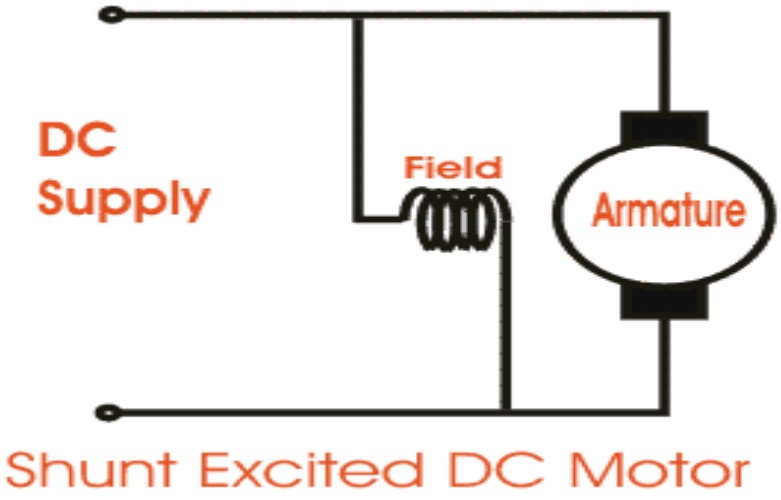
Separately Excited DC Motor



$E_b = V - I_aR_a = V - I_LR_a$ **$[I_L = I_a]$**

$E_b = V - I_aR_a - 2V_b$ **(When Considering Brush drop)**

Shunt Wound DC Motor

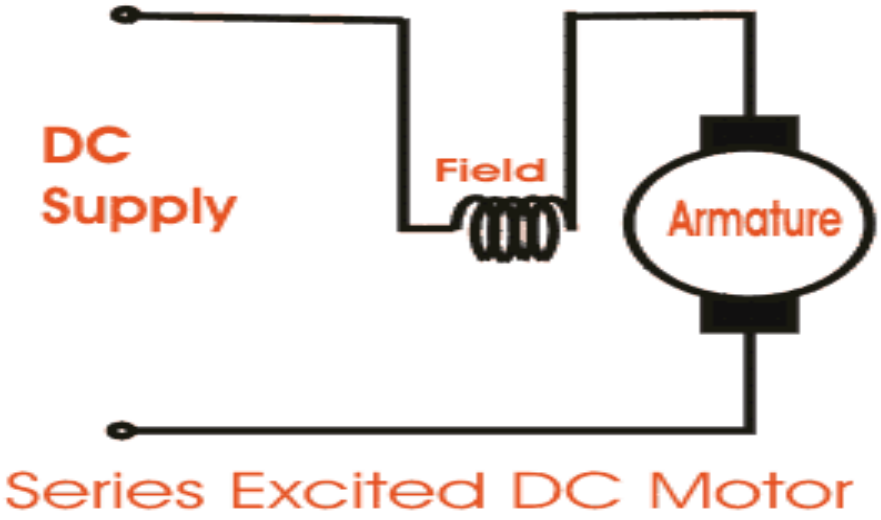


Shunt Excited DC Motor

Eb = V – IaRa **[I_L = Ia + Ish]**

Eb = V – IaRa – 2Vb **(When Considering Brush drop)**

Series Wound DC Motor



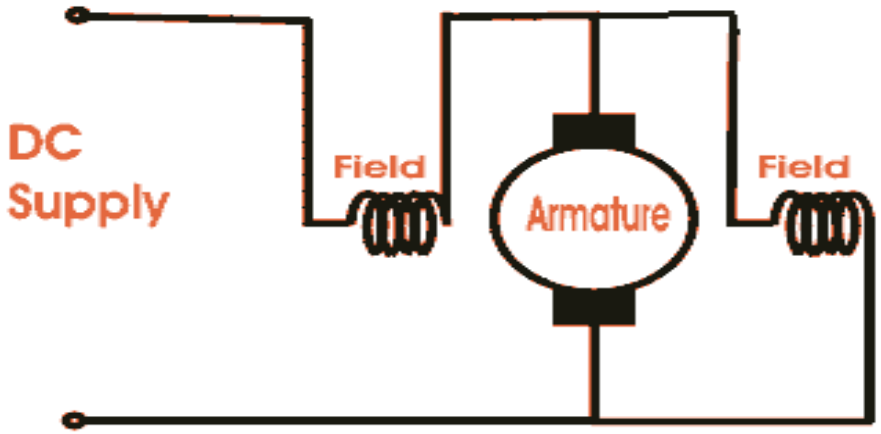
Series Excited DC Motor

$E_b = V - I_{se}R_{se} - I_aR_a$

$E_b = V - I_a(R_{se} + R_a)$ **$[I_a = I_{se} = I_L]$**

$E_b = V - I_{se}(R_{se} + R_a) - 2V_b$ (When Considering Brush drop)

Short Shunt DC Motor



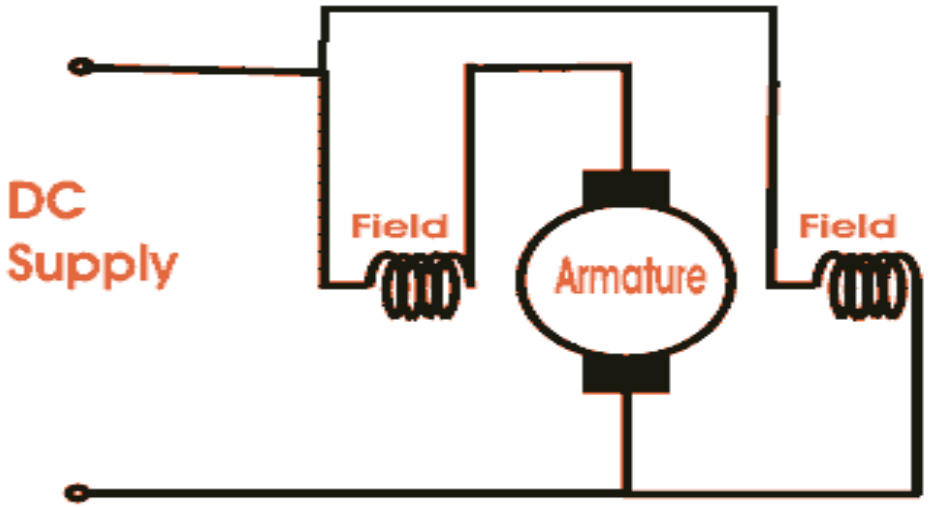
Short Shuna DC Motor

$Eb = V - I_{se}R_{se} - I_aR_a$

$[I_L = I_a + I_{sh}]$
$[I_L = I_{se}]$

$Eb = V - I_{se}R_{se} - I_aR_a) - 2V_b$ (When Considering Brush drop)

Long Shunt DC Motor



Long Shunt DC Motor

$Eb = V - I_{se}R_{se} - I_aR_a$

$Eb = V - I_a(R_{se} + R_a)$

$[I_L = I_{sh} + I_a]$
$[I_{se} = I_a]$

$Eb = V - I_{se}(R_{se} + R_a) - 2V_b$ (When Considering Brush drop)