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DC Motors

By
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Motors

One such equipment which created a giant leap to the mankind in both domestic & industrial sectors.

If life can be imagined without motors!!!

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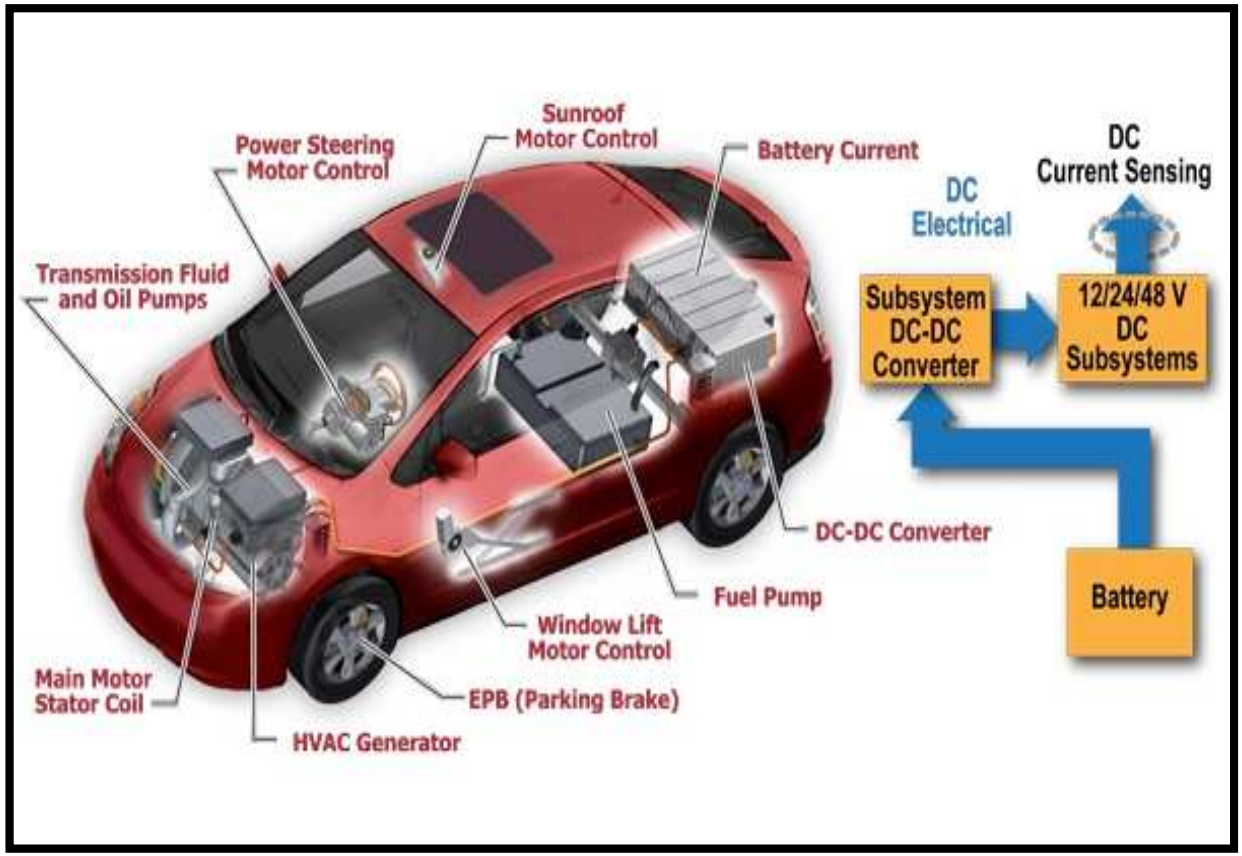
Motor Applications in Car

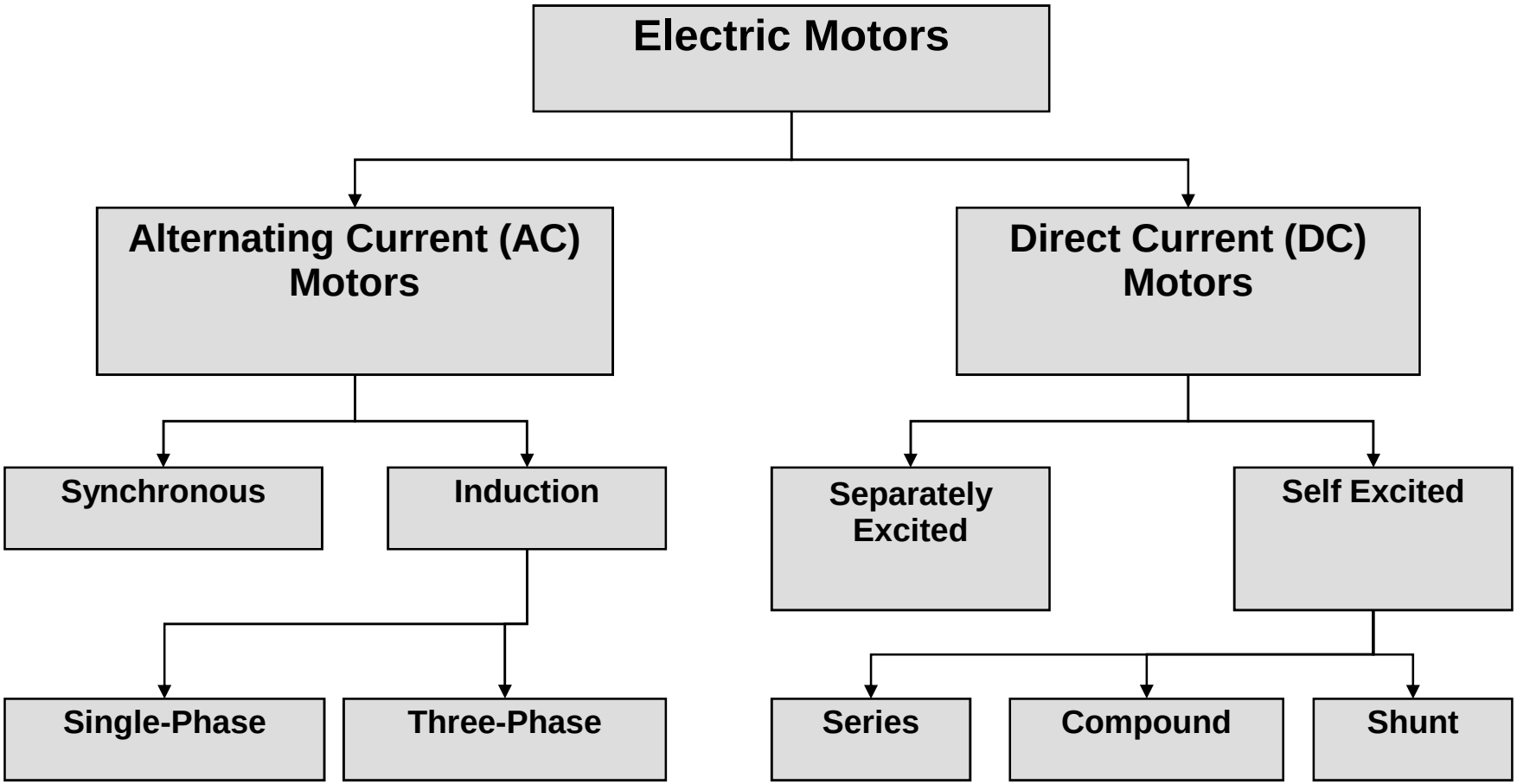


Refrigeration Systems

Motors

- Motors convert electrical energy to mechanical energy
- Motors make things move

Classification of Motors



* Permanent Magnet DC Motor

Classification of Motors

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Other types of motors are:

- Stepper motor
- Brushless DC motor
- Hysteresis motor
- Reluctance motor
- Universal motor
- Servomotors

Motors

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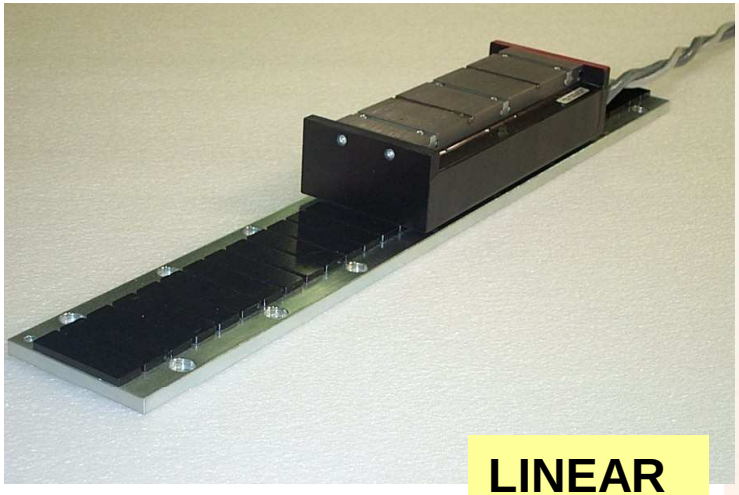
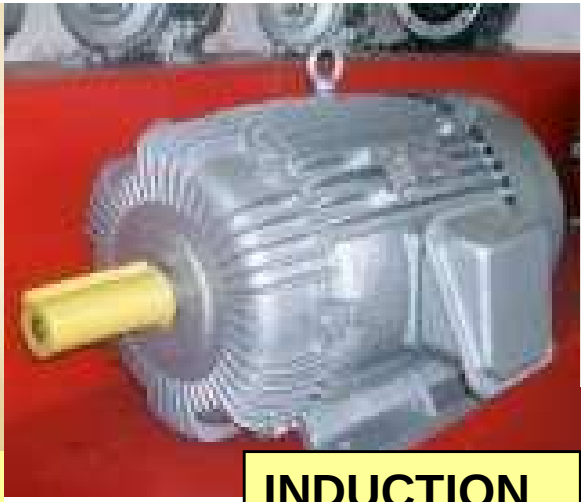


LINEAR

DC BRUSH



INDUCTION

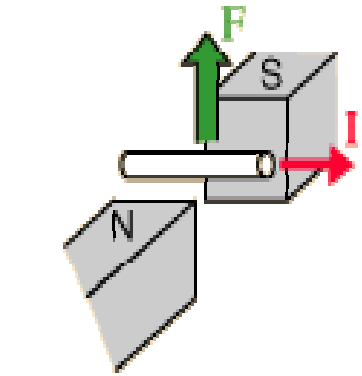
STEPPER

UNIVERSAL

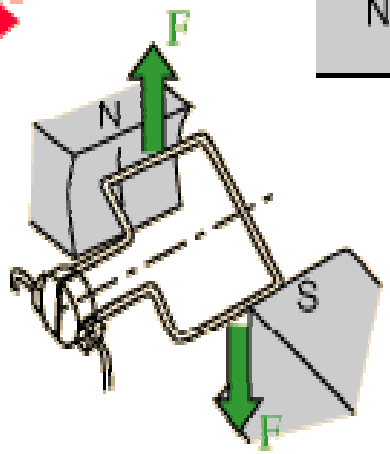
- A.C. Motors play a very vital role in everyday life, right from pumping water to overhead tank to modern robot‘s.

- The largest of electric motors are used for ship propulsion, pipeline compression and pumped-storage applications with ratings reaching 100 megawatts.

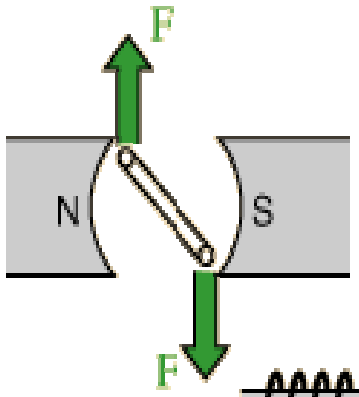
How Does an Electric Motor Work?



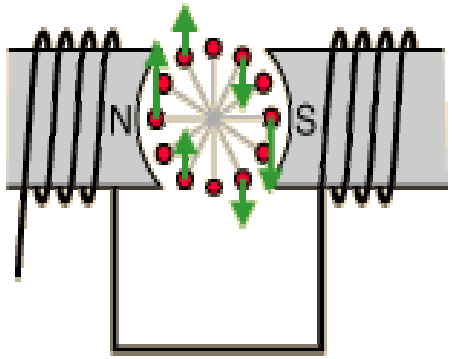
An electric current in a magnetic field will experience a force.



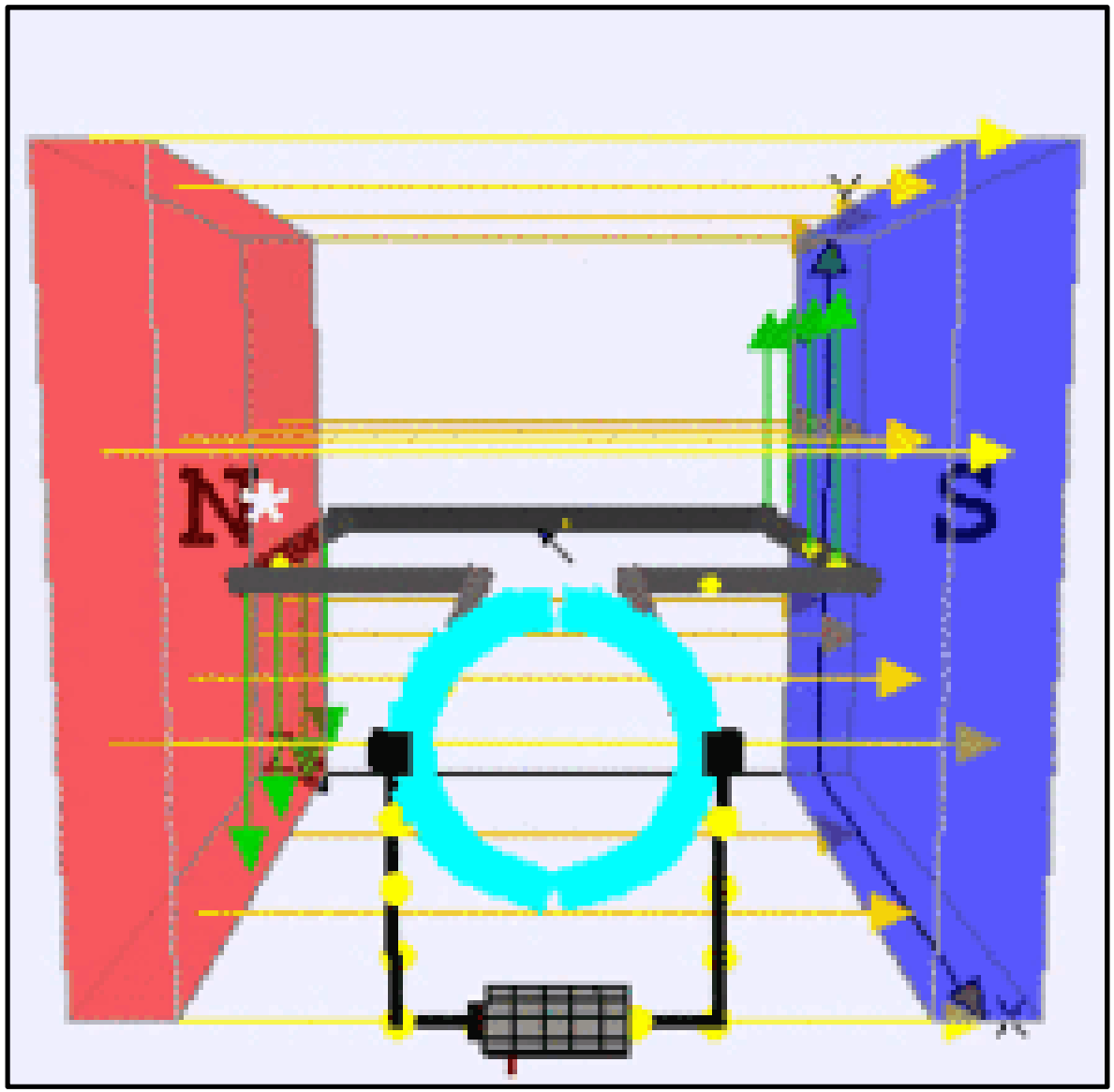
If the current-carrying wire is bent into a loop, then the two sides of the loop which are at right angles to the magnetic field will experience forces in opposite directions.



The pair of forces creates a turning influence or torque to rotate the coil.



Practical motors have several loops on an armature to provide a more uniform torque and the magnetic field is produced by an electromagnet arrangement called the field coils.


N
S

Working of Motor

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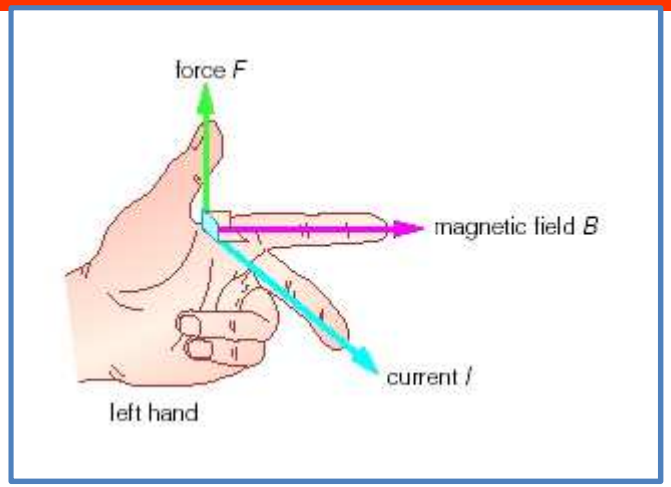
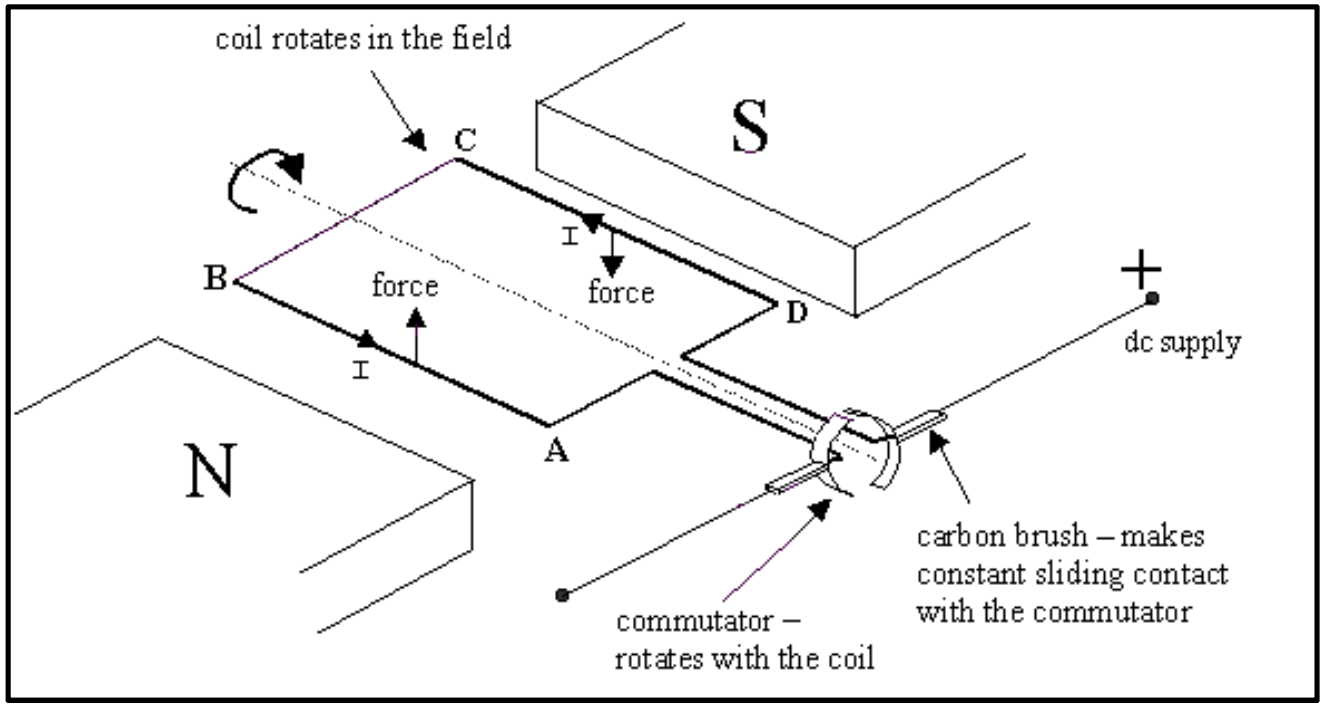
- When current flows in a conductor it produces a magnetic field about it.
- When the current-carrying conductor is within an externally generated magnetic field, the fields interact and a force is exerted on the conductor.
- F= B I L Newton
- Direction of force can be determined by applying Fleming's Left Hand Rule.

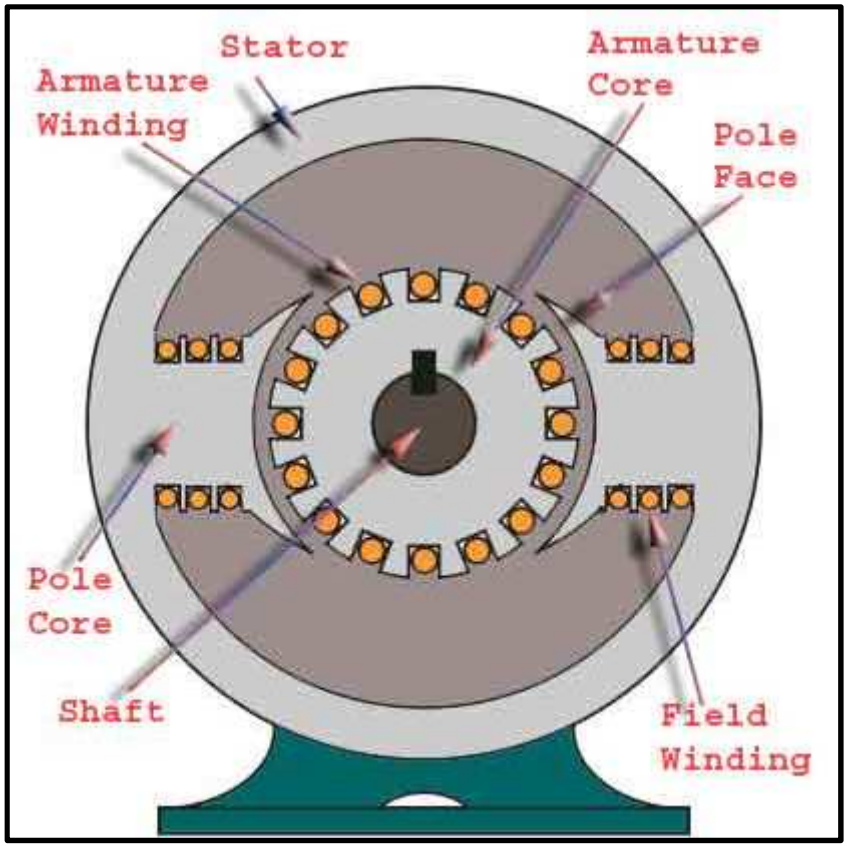

force F
magnetic field B
current I
left hand

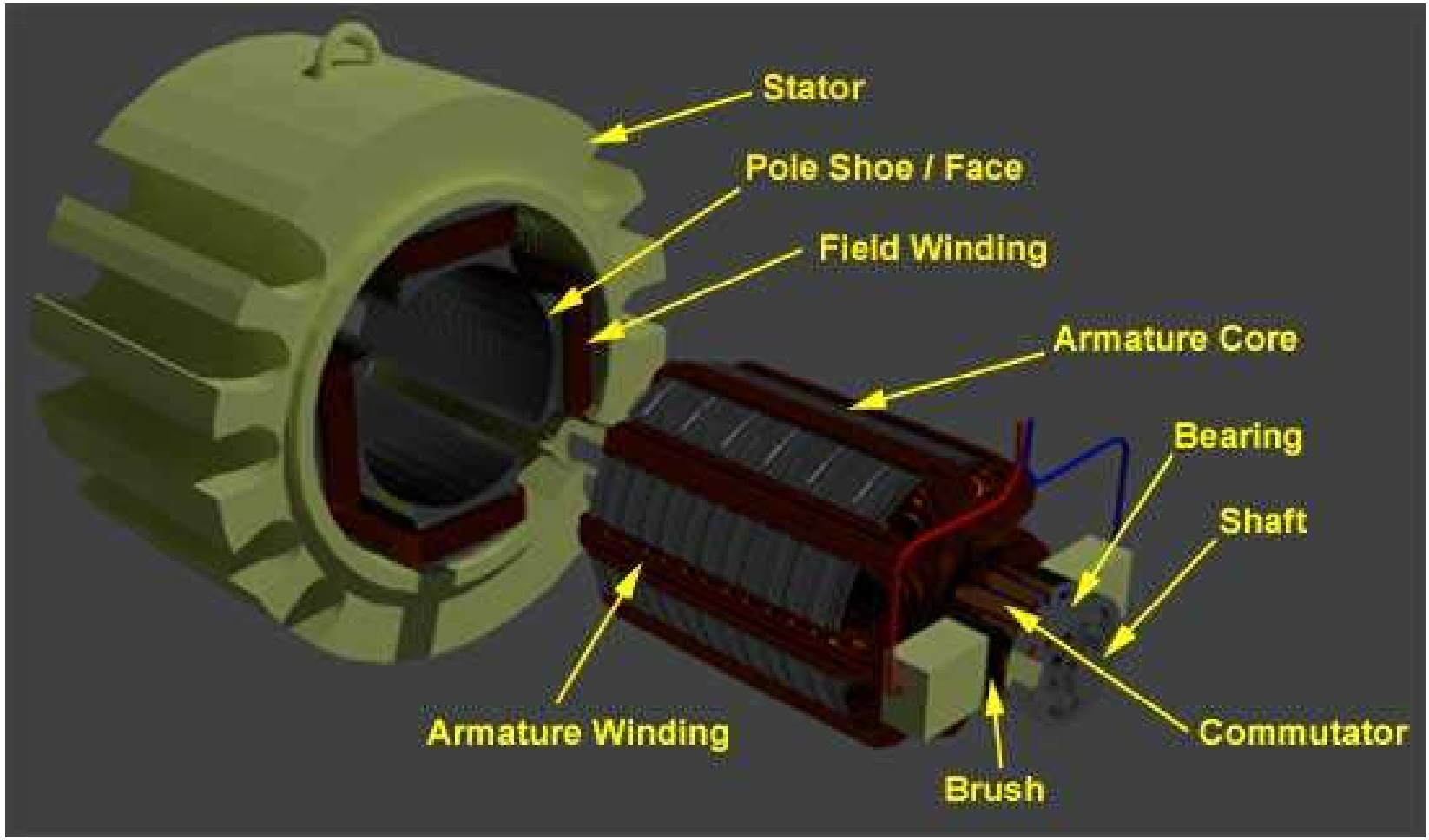

coil rotates in the field
C
S
B
force
force
D
I
I
dc supply
N
A
carbon brush – makes constant sliding contact with the commutator
commutator – rotates with the coil

Construction of DC Motor

Stator:The static part that houses the field windings and receives the supply.

Rotor:The rotating part that brings about the mechanical rotations.




Stator
Pole Shoe / Face
Field Winding
Armature Core
Bearing
Shaft
Armature Winding
Brush
Commutator

Stator

Stator consists of

- ✓ Field Poles
- ✓ Yoke
- ✓ Interpoles

Yoke of DC Motor

- The magnetic frame or the yoke of dc motor made up of cast iron or steel and forms an integral part of the stator or the static part of the motor.
- Its main function is to form a protective covering over the inner sophisticated parts of the motor and provide support to the armature.
- It also supports the field system by housing the magnetic poles and field winding of the dc motor.

Poles of DC Motor

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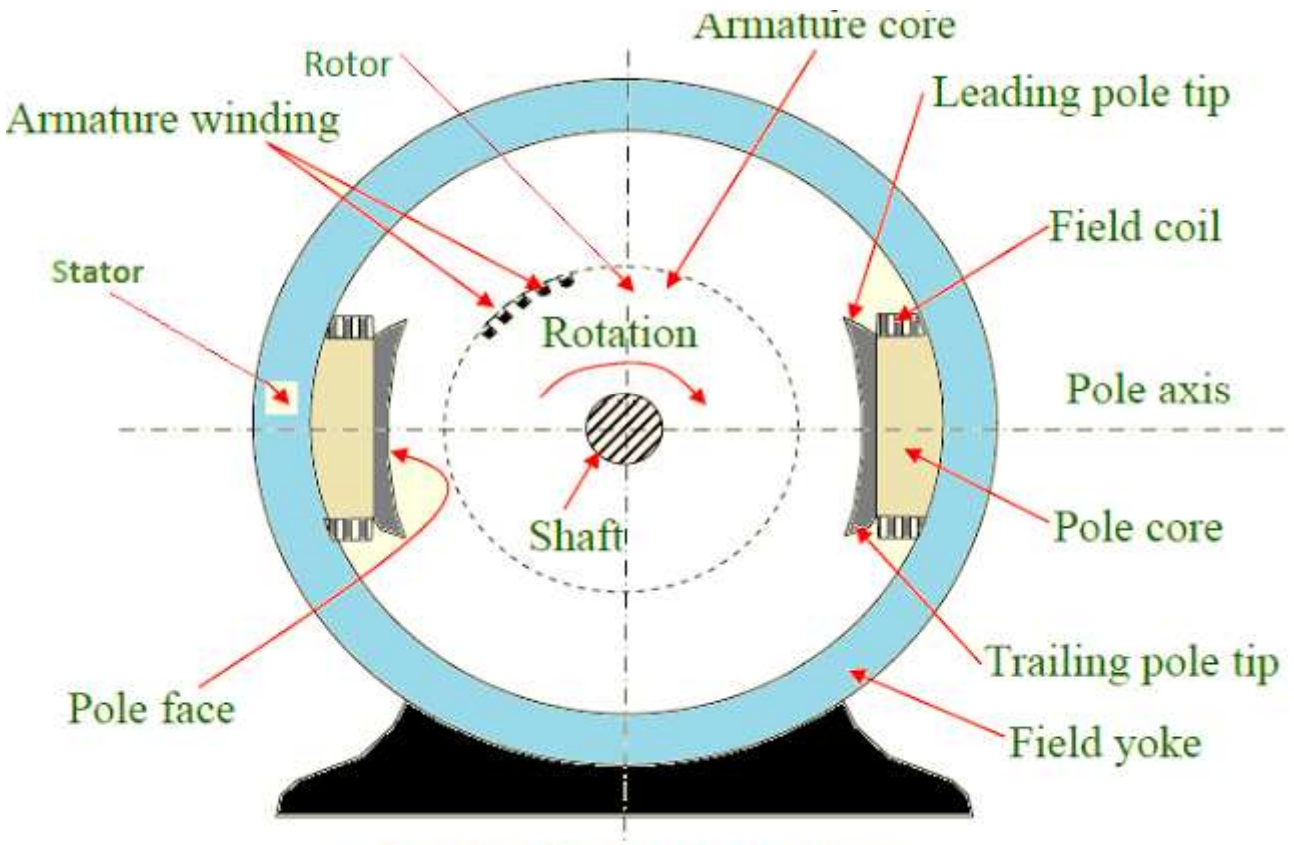
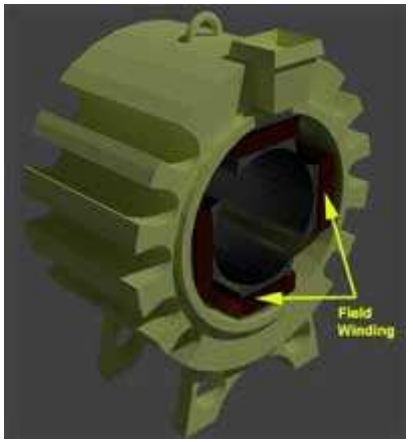
- The magnetic poles of DC motor are structures fitted onto the inner wall of the yoke with screws.
- Magnetic poles comprises of two parts: pole core and the pole shoe stacked together under hydraulic pressure and then attached to the yoke.
- Pole core is of small cross sectional area. It is used to carry the coils of insulated wires carrying field current.
- Pole shoe having a relatively larger cross-sectional area spreads the flux produced over the air gap between the stator and rotor to reduce the loss due to reluctance.



Construction of DC Motor

Field Winding of DC Motor

- The field winding of dc motor is made with field coils (copper wire) wound over the slots provided on the pole core in such a manner that when field current flows through it, then adjacent poles have opposite polarity are produced.
- The field winding basically form an electromagnet, that produces field flux within which the rotor -armature of the dc motor rotates, and results in the effective flux cutting.



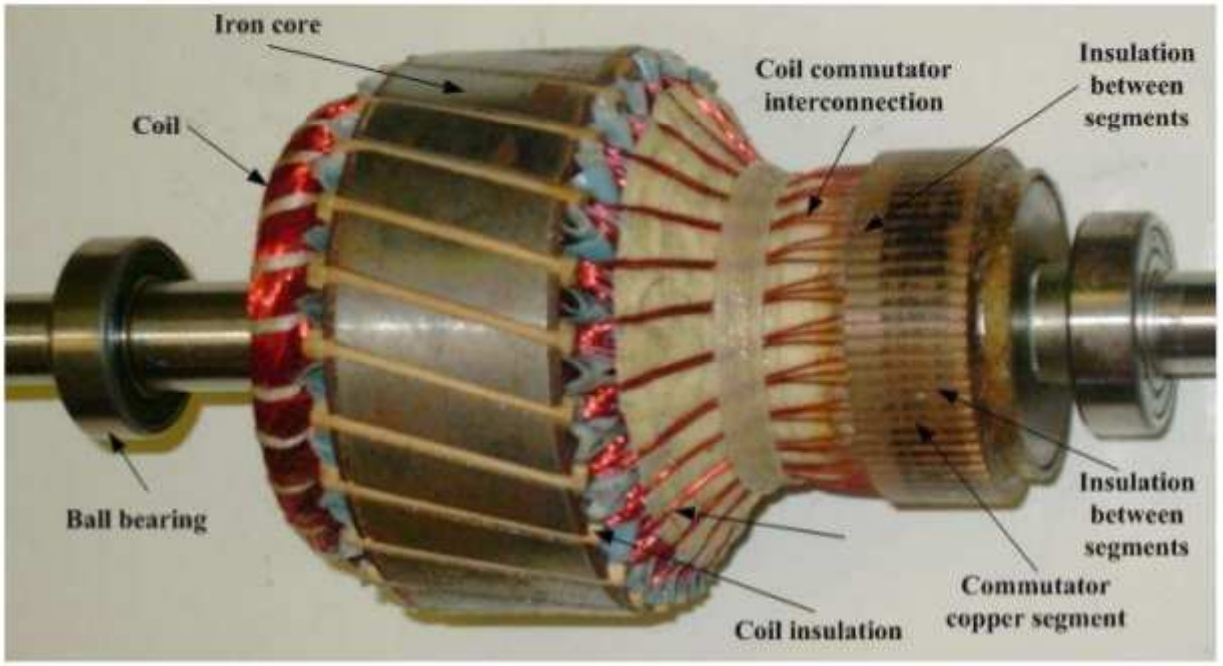
Interpoles

- The interpoles are located in the interpolar region between the main poles.
- The winding on the interpole is connected in series with the armature circuit to ensure that the mmf is proportional to the armature current.

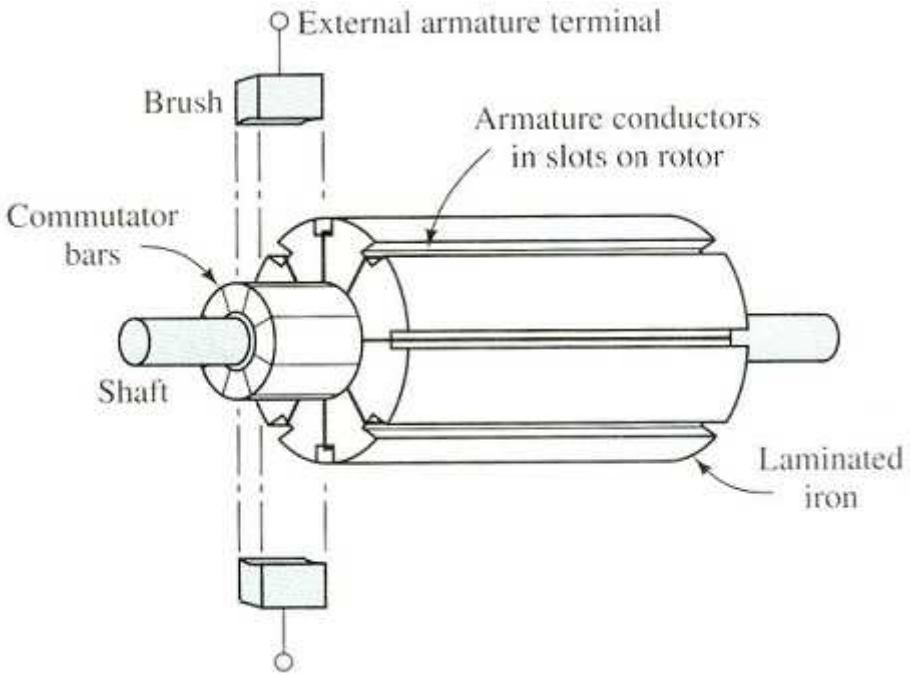
Rotor

Rotor Consists of

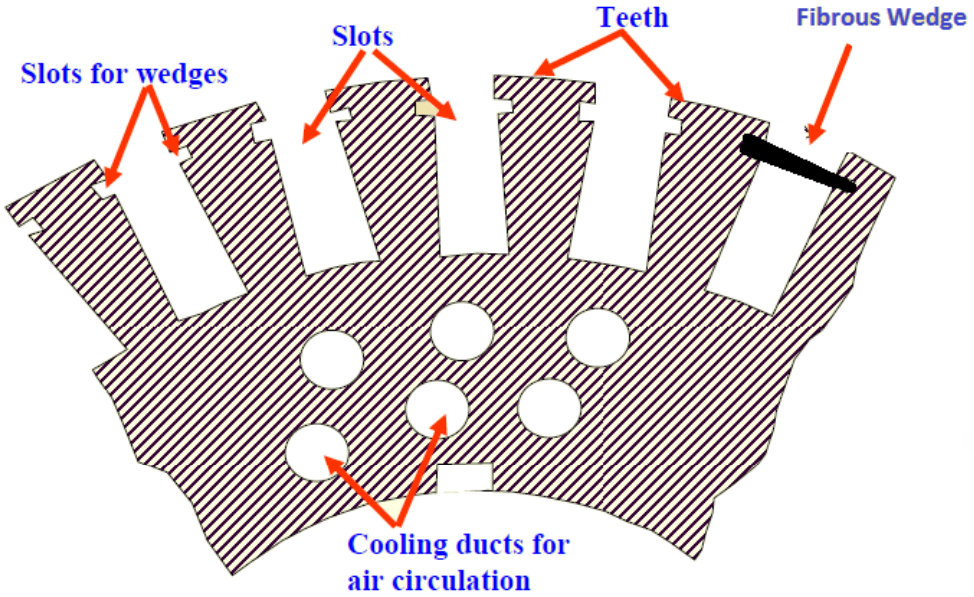
- ✓ Armature Core
- ✓ Armature Winding

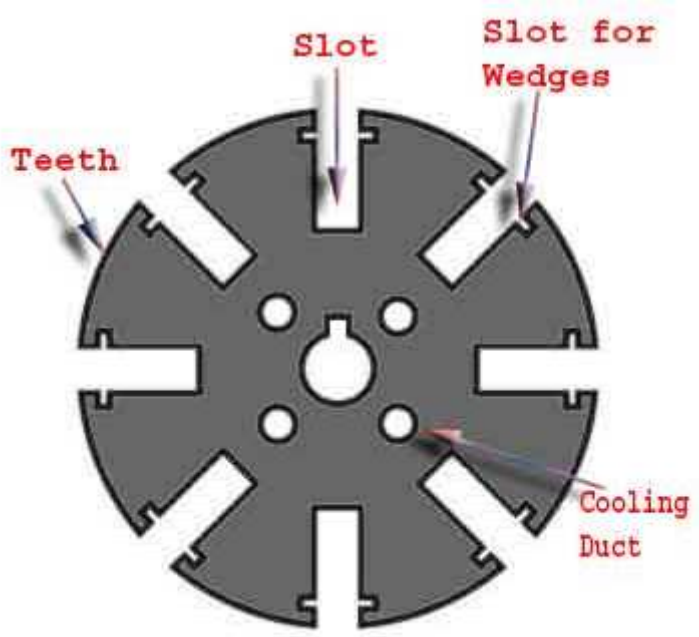


Armature of DC Motor


External armature terminal
Brush
Armature conductors
in slots on rotor
Commutator
bars
Shaft
Laminated
iron

Slots and Teeth





Armature Core & Winding

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- Armature core is made with several low-hysteresis silicon steel lamination, to reduce the magnetic losses like hysteresis and eddy current loss respectively.
- These laminated steel sheets are stacked together to form the cylindrical structure of the armature core.
- The armature core is provided with slots to house armature winding.
- Armature winding is made with several turns of copper wire distributed uniformly over the entire periphery of the core.
- The slot openings are shut with fibrous wedges to prevent the conductor from plying out due to the high centrifugal force produced during the rotation of the armature, in presence of supply current and field.

Armature Winding

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Lap Winding

In this case the number of parallel paths between conductors A is equal to the number of poles P.

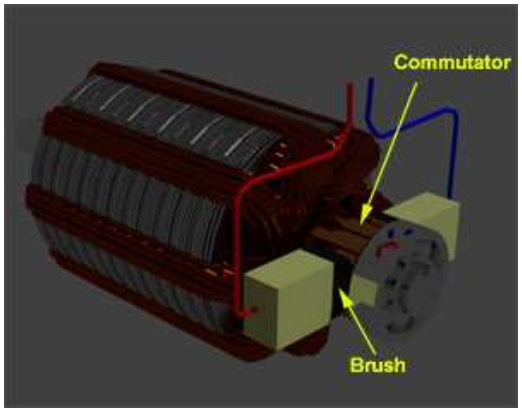
i.e. A = P

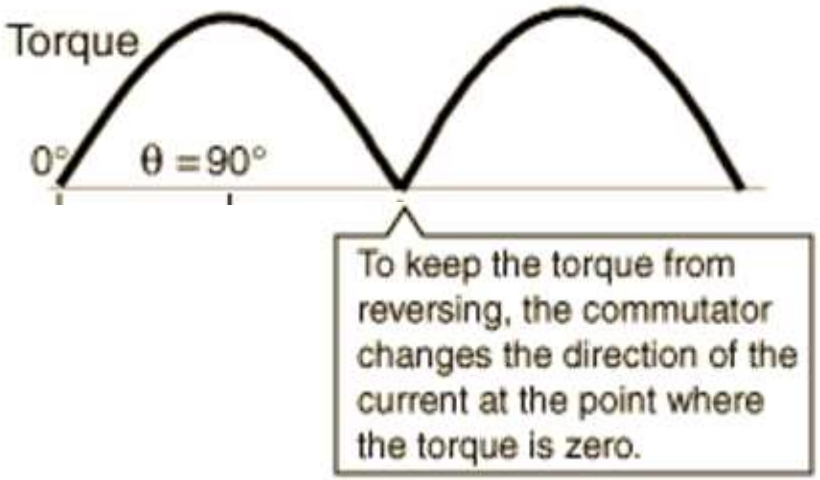
Wave Winding

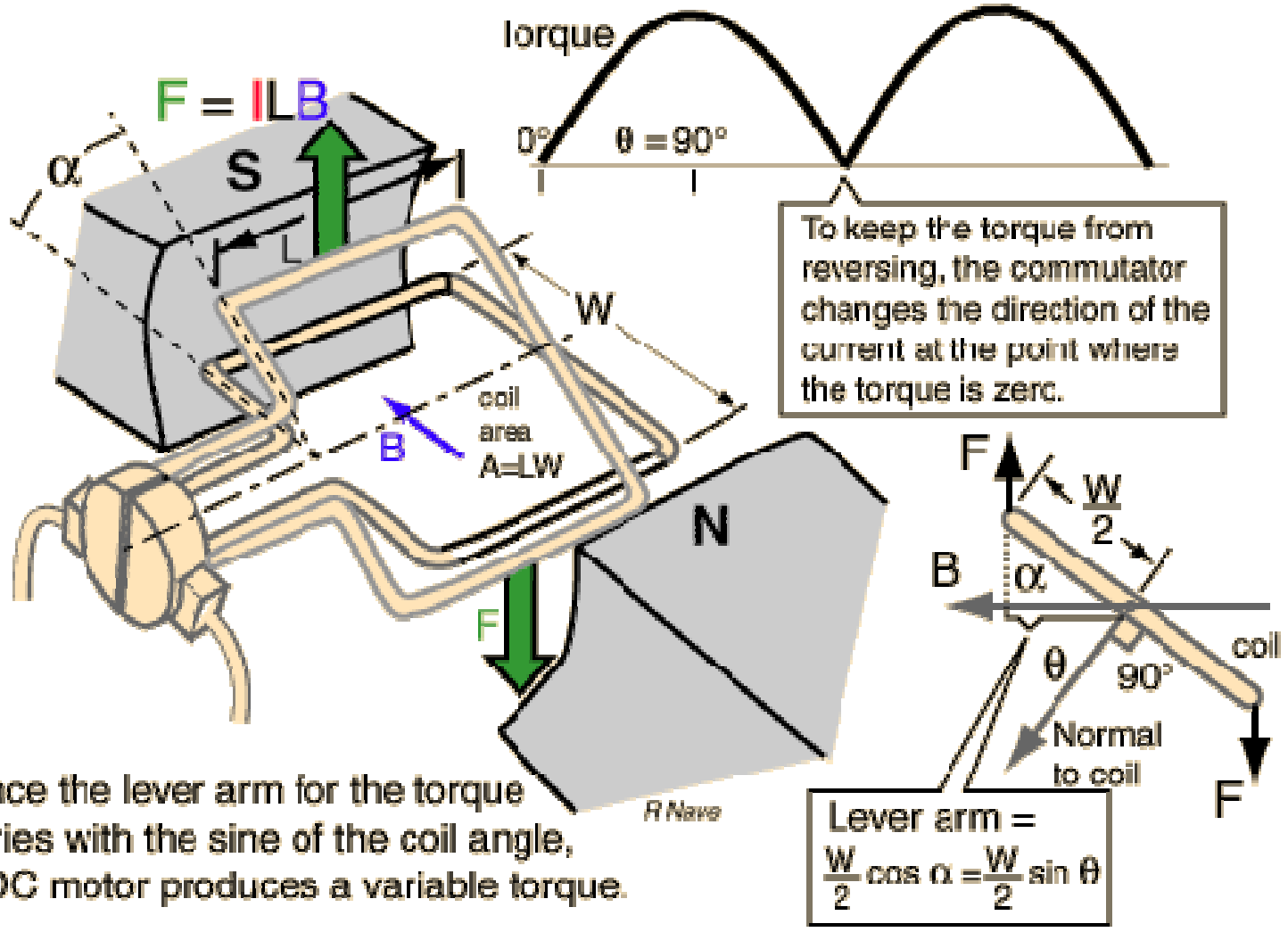
The number of parallel paths between conductors A is always equal to 2 irrespective of the number of poles.

Commutator

- To keep the torque on a DC motor from reversing every time the coil moves through the plane perpendicular to the magnetic field, a split-ring device called a commutator is used to reverse the current at that point.
- The commutator is a cylindrical structure made up of copper segments stacked together, but insulated from each other by mica.



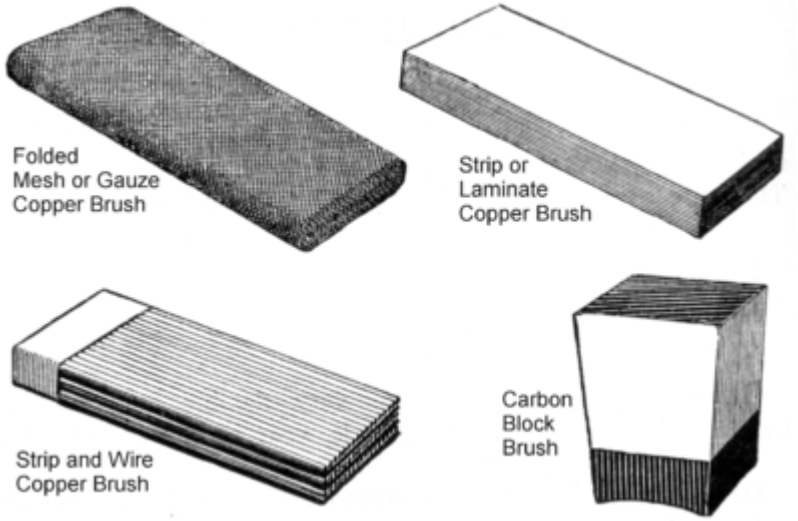




Since the lever arm for the torque varies with the sine of the coil angle, a DC motor produces a variable torque.

Brushes

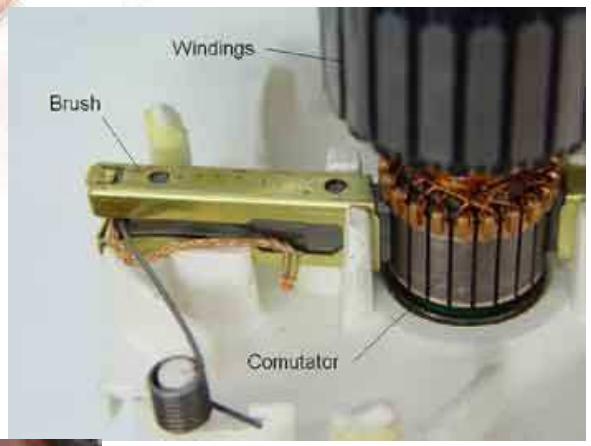
- The brushes of dc motor are made with carbon or graphite structures, making sliding contact over the rotating commutator. Modern motors use spring-loaded carbon contacts.
- The brushes are used to relay the electric current from external circuit to the rotating commutator from where it flows into the armature windings.



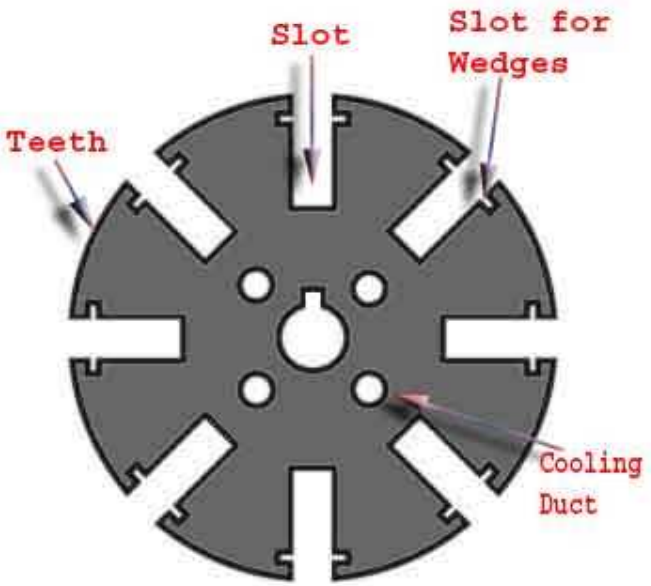
Various types of copper and carbon brushes

Yoke or Casting of DC Motor

Commutator



Brush



Armature

Armature Winding

Relationship between speed, field flux and armature voltage

Back electromagnetic force: $E = K\Phi N$

Torque: $T = K\Phi I_a$

E = electromagnetic force developed at armature terminal (volt)

Φ = field flux which is directly proportional to field current

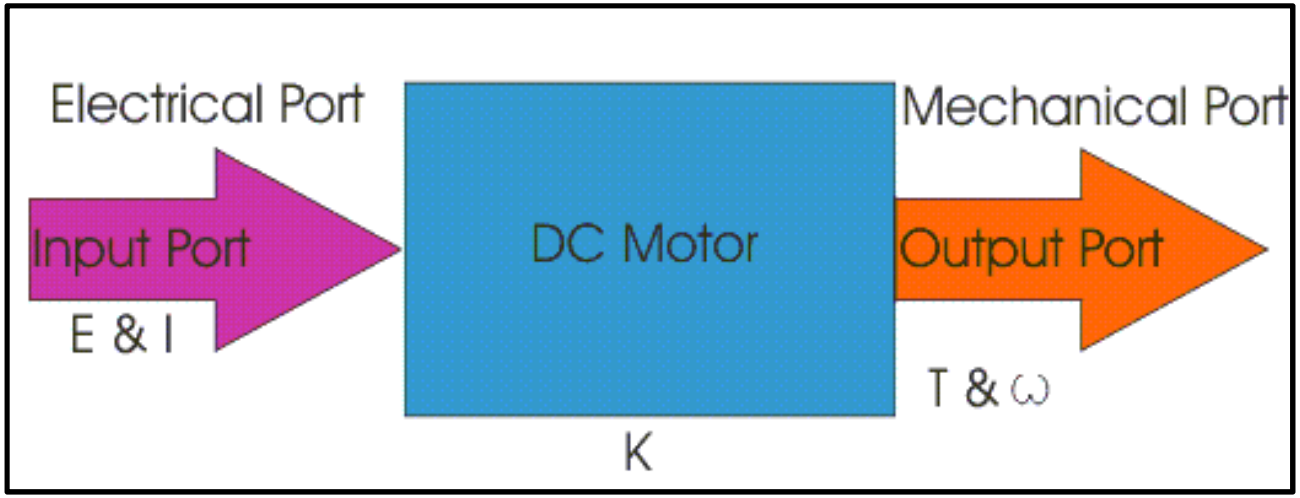
N = speed in RPM (revolutions per minute)

T = electromagnetic torque

I_a = armature current

K = an equation constant

DC Motors



$$T = KI \text{ and } E = K\omega$$

Types of DC Motors

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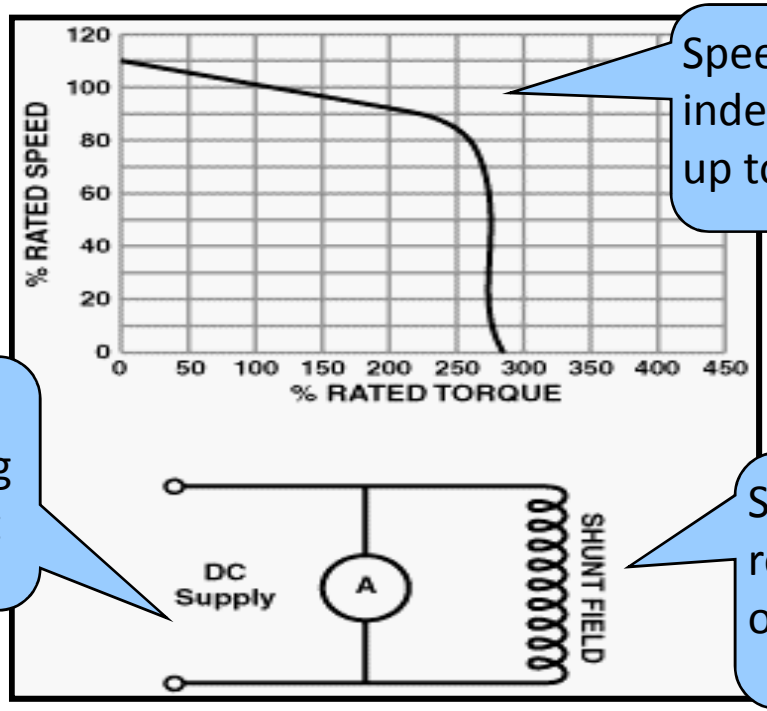
- ❑ Separately excited DC motor: field current supplied from a separate force
- ❑ Self-excited DC motor:
- ✓ Shunt motor
- ✓ Series Motor
- ✓ Compound Motor
- Cumulative Compound Motor
- Differential Compound Motor

*A compound DC motor connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor. This motor is used when both a high starting torque and good speed regulation is needed.

- Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation.
- Differential compound DC motors have good speed regulation and are typically operated at constant speed.

Self-excited DC motor: Shunt motor



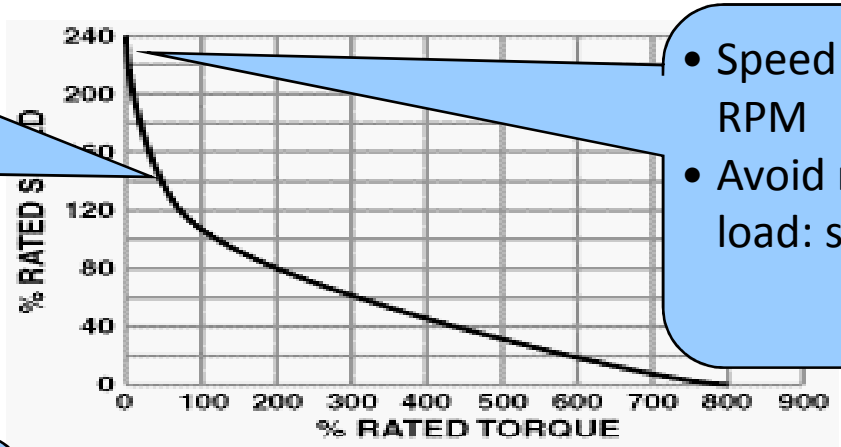
Speed constant independent of load up to certain torque

- Field winding parallel with armature winding
- Current = field current + armature current

Speed control: insert resistance in armature or field current

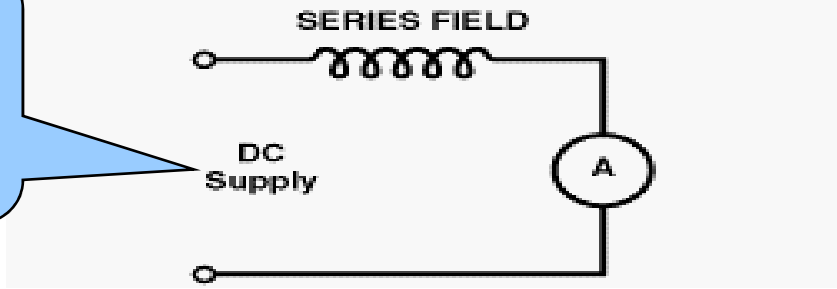
Self-excited DC motor: Series Motor

Suited for high starting torque: cranes, hoists



- Speed restricted to 5000 RPM
- Avoid running with no load: speed uncontrolled

- Field winding in series with armature winding
- Field current = armature current



Self-excited DC motor: Compound motor

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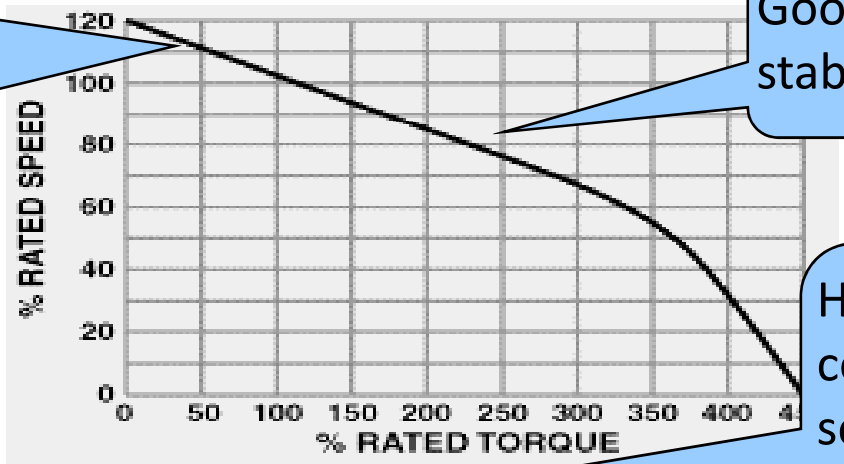
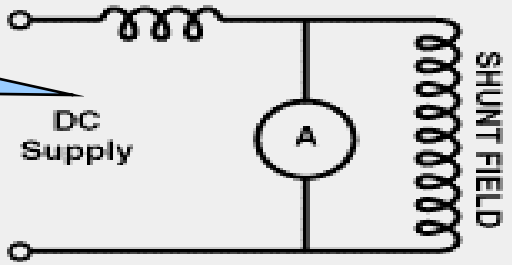
Suited for high starting torque if high % compounding: cranes, hoists

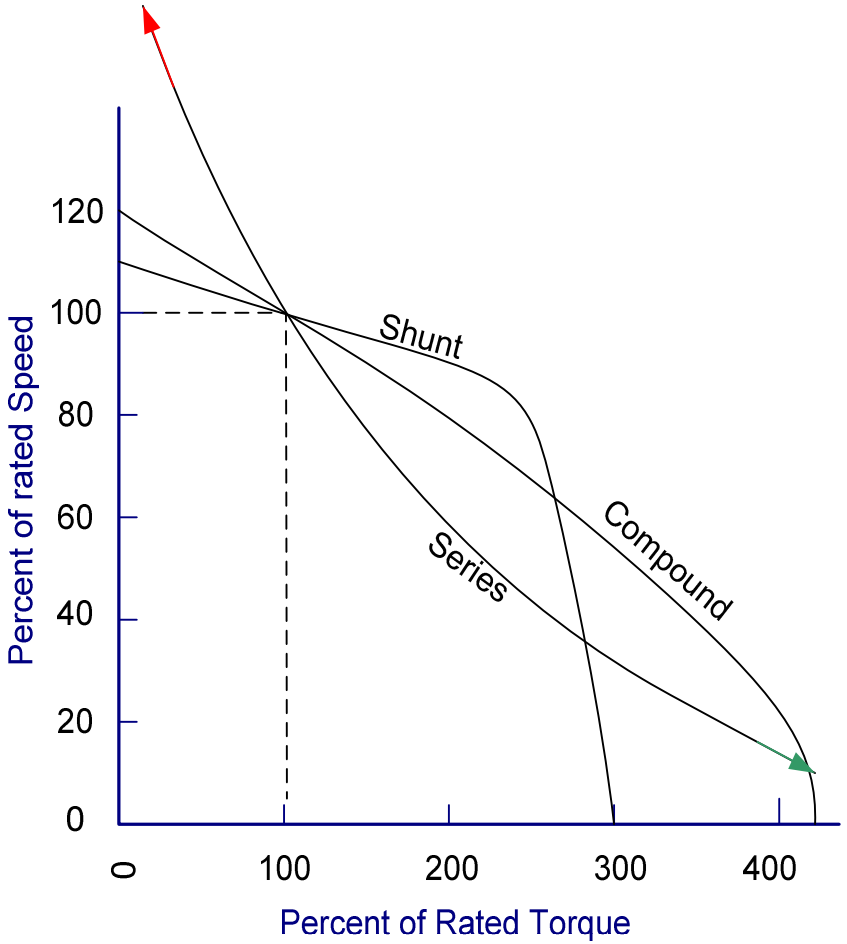


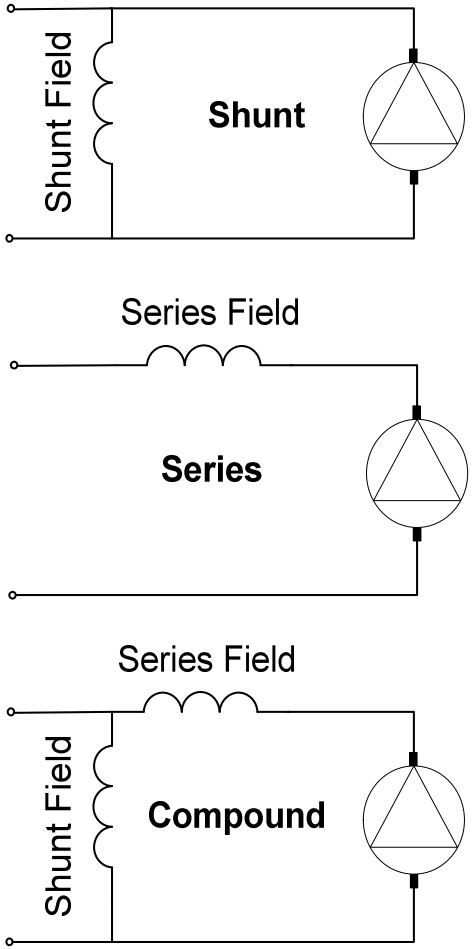
Good torque and stable speed

Higher % compound in series = high starting torque

Field winding in series and parallel with armature winding




Percent of rated Speed
120
100
80
60
40
20
0
0
100
200
300
400
Percent of Rated Torque
Shunt
Compound
Series


Shunt Field
Shunt
Series Field
Series
Series Field
Shunt Field
Compound

Applications of Series Motors

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Series Motor: Armature and field connected in a series circuit.

- Starting torque is 300% to as high as 800% of full load torque.

- Apply for high torque loads that do not require precise speed regulation. Useful for high breakaway torque loads.

– E.g. are locomotives, hoists, cranes, automobile starters

Applications of Shunt Motors

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Shunt Motor: Field coil in parallel (shunt) with the armature.

Current through field coil is independent of the armature.

» Motors have excellent speed control.

- Starting torque is 125% to 200% full load torque (300 for short periods).
- Apply where starting loads are low.

– E.g. Are fans, blowers, centrifugal pumps, machine tools

Compound Wound Motor

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- Performance is roughly between series-wound and shunt-wound
- Moderately high starting torque
- Moderate speed control
- Inherently controlled no-load speed

– safer than a series motor where load may be disconnected

» e.g. cranes

Applications of DC Motors

Used where high starting torque or where smooth acceleration over a broad range speed is required, used for low speed, low to medium power applications like machine tools, rolling mills and traction systems. Used in printing, textile industry etc.

Traction System

DC motor being used for pumping oil in hydraulic system of electric vehicle.

DC Motor

Pump

Oil Tank


DC Motors in
Hydraulic Pump Applications


DC Motors in Forklift Applications


Motors for HVAC applications


DC Motors in Mobile
HVAC Applications

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Thank you!