DEE 3143 BASIC ELECTRICAL MACHINE & POWER SYSTEMS

CHAPTER 3
DIRECT CURRENT MOTOR

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Chapter Outline

1 Direct current (DC) machines - Overview

2 Construction of DC machnices

3 Principles of operation

4 DC motor types

5 Power flow diagram

6 Speed control

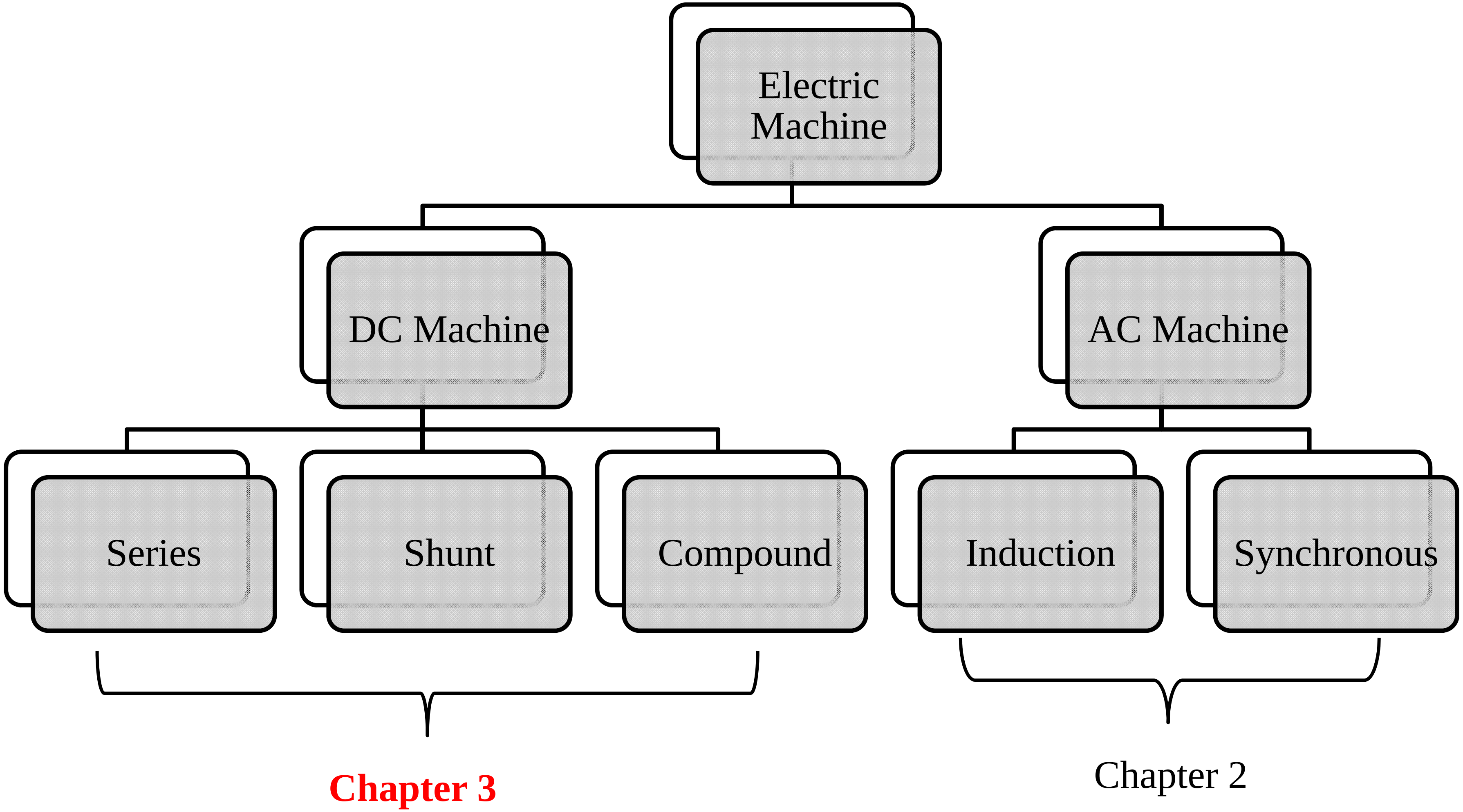
Learning Outcomes

After complete this chapter, students should be able to:

1. Describe and understanding of DC machines.
2. Understand the construction of and DC motor equations.
3. Analyze the operation of DC motor.
4. Differentiate between three types of DC motors.
5. Analyze the power flow of DC motor.
6. Understand different types of speed control.

2.1 DIRECT CURRENT (DC) MACHINES - OVERVIEW

Overview of Electric Machines



What is DC machines?

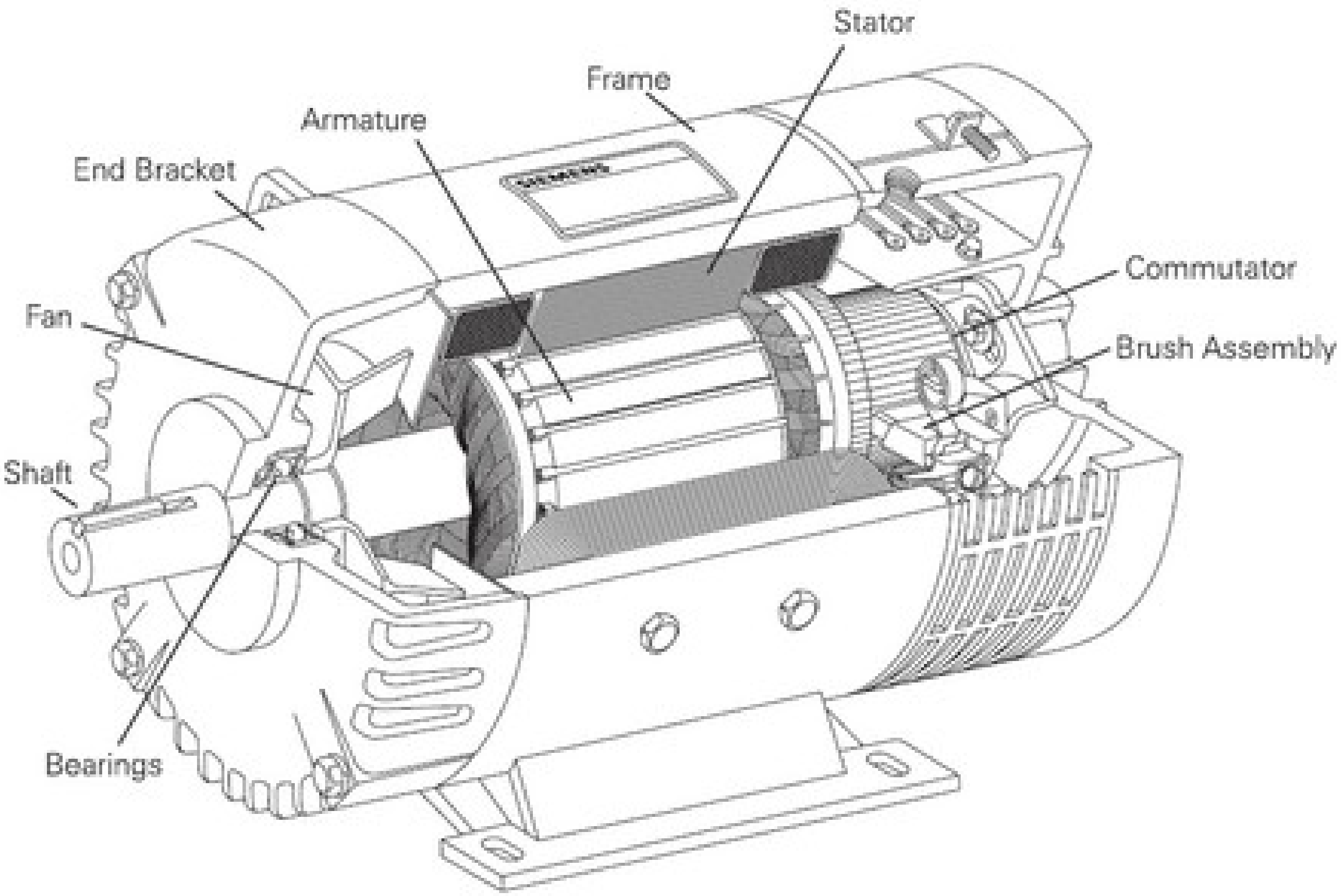
- The direct current (dc) machine can be used as a motor or as a generator.

Electrical Energy → Motor → Mechanical Energy

Mechanical Energy → Generator → Electrical Energy

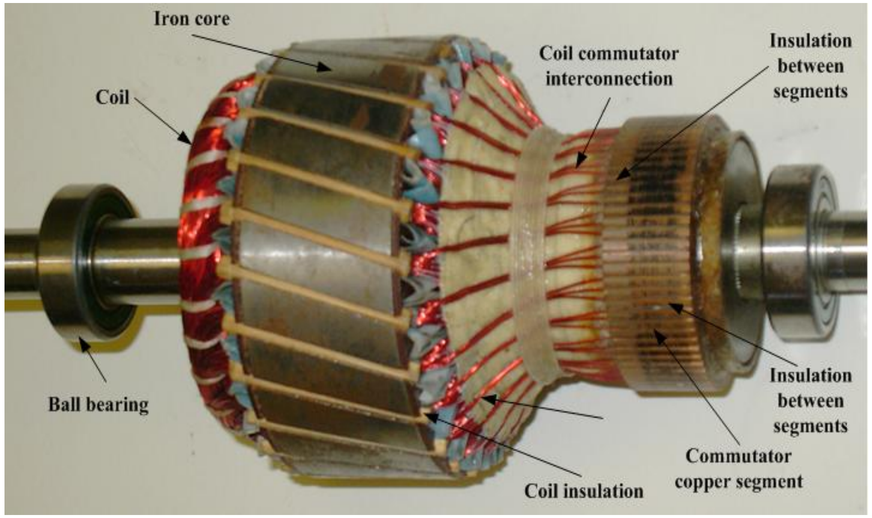
2.2 CONSTRUCTION

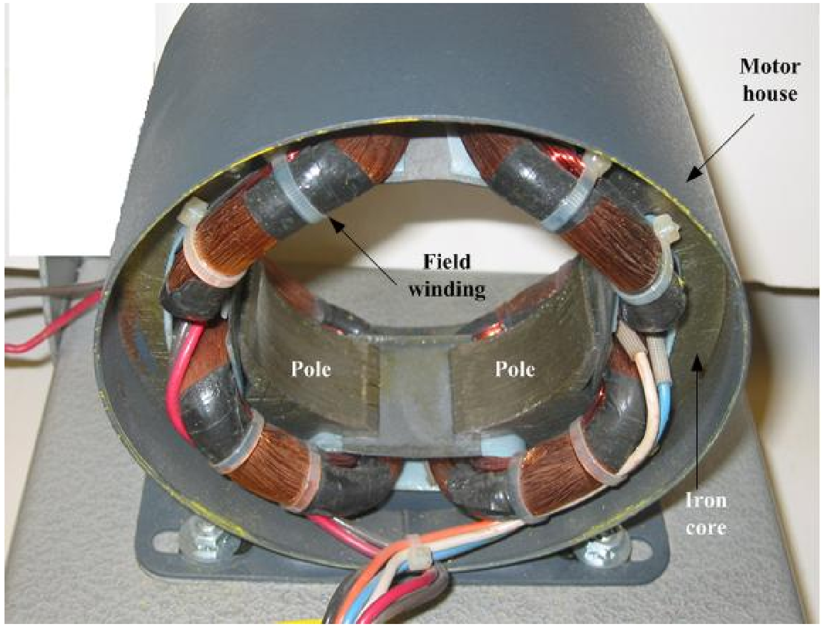
Dc machines construction overview



Source: https://sibotic.wordpress.com/2013/12/20/pwm-speed-control-of-a-d-c-motor/

Basic components





Source: http://slideplayer.com/slide/8010054/

Basic components

STATOR

- The stationary outside part of a DC motor.

ROTOR

- The inner part which rotates.
- Magnetic field from the stator induces an opposing magnetic field onto the rotor causing the rotor to “push” away from the stator field.

ARMATURE

- DC motor rotating part
- Current flow in armature coils induced magnetic field
- Interaction between armature magnetic field and direct current (produced by field windings) cause rotation of armature

Basic components

SHAFT

- Rotating part of dc motor
- Final output – mechanical energy

BRUSHES

- Placed against the commutator surface.
- Made of carbon or graphite material
- Main function is to collect current from moving commutator.

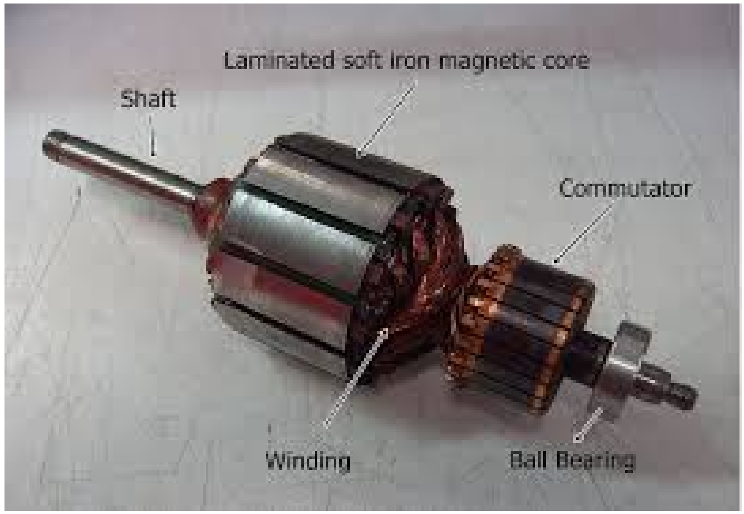
COMMUTATOR

- A ring made of segments (insulated from one another).
- The commutator is part of the armature that connects each armature coil to the brushes using copper bars (segments) that are insulated from each other with pieces of mica.
- Main function is to collecting the current from the armature conductor and converting current from AC to DC.

Armature windings

- The armature windings of a DC machine is modeled as double layer winding, consisting of line conductor in top layer and return conductor in the bottom layer.

- Two different wiring methods are used for separate windings:
  - Lap winding
  - Wave winding



Source: Wikipedia

Lap winding

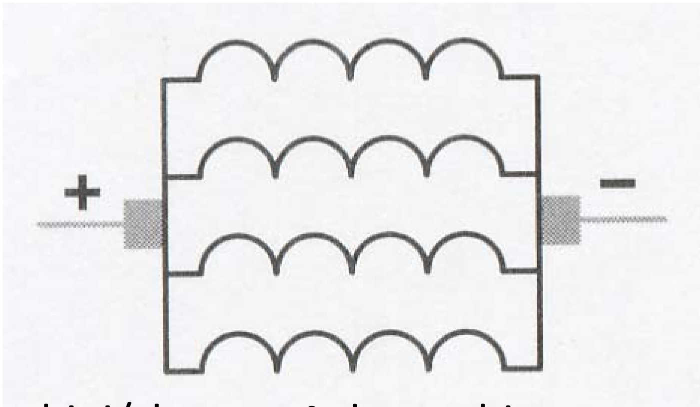
- For machine modelled with low voltage & high current

✖ Armatures designed with large wire diameter due to high current flow.

✖ Lap wound armature windings are modelled in parallel for high current flow

✖ Number of current path, **C = 2p**

p = number of poles



Source: https://www.slideshare.net/abhinaypotlabathini/chapter-4-dc-machine-autosaved

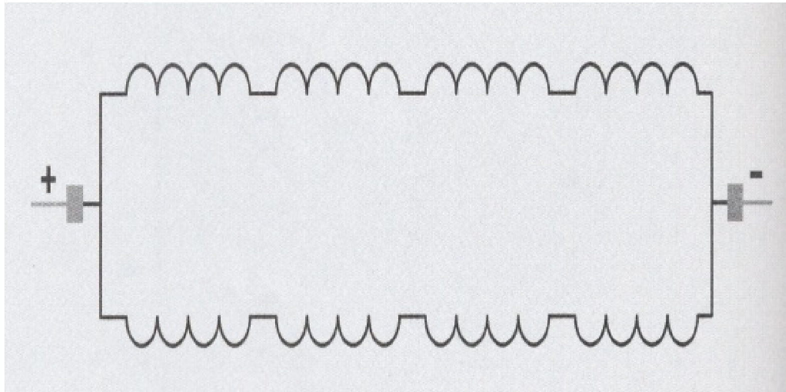
Wave winding

- For machines modelled with high voltage and low current

✖ Armature windings configure in series.

✖ Voltage of each winding add up due to series connection, but current flow remains the same.

✖ Number of current path, C=2.



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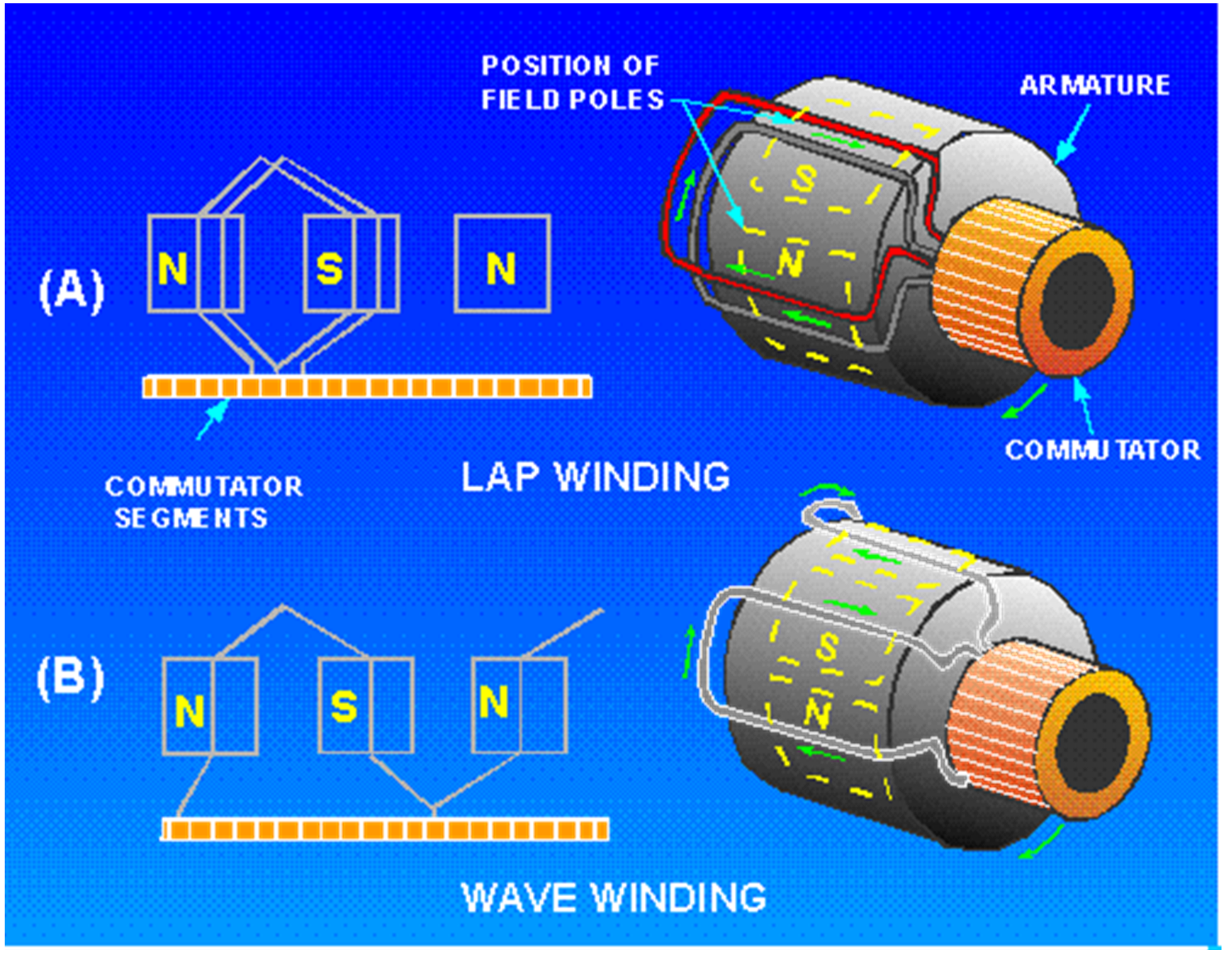
Summary of Armature Windings



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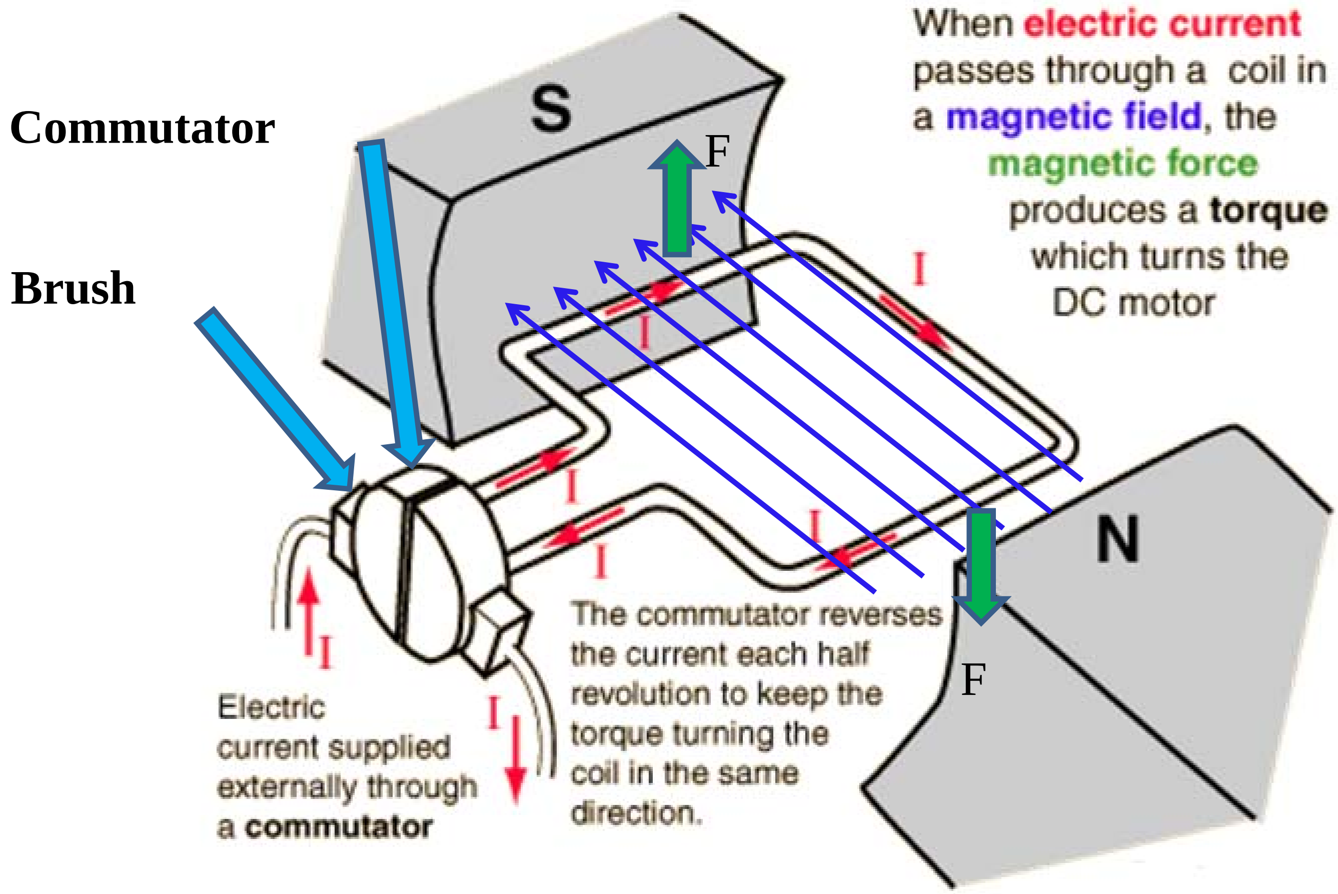
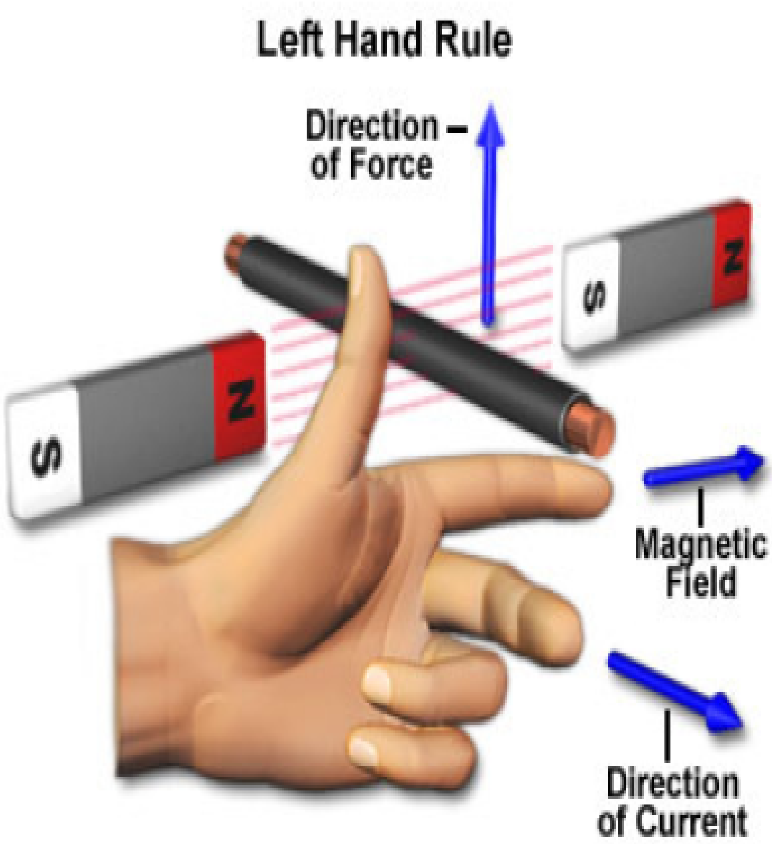
2.3 PRINCIPLES OF OPERATION

DC Motor Operation



Source: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/motdc.html

Fleming left hand rule



Magnitude of force in motor:

$$F = BlI \text{ (N)}$$

B = flux density due to the flux produced by the field winding

l = length of the conductor

I = magnitude of the current passing through conductor

Source: https://www.electrical4u.com/fleming-left-hand-rule-and-fleming-right-hand-rule/

Back EMF

- An EMF induced due rotational of coil within magnetic field, which the flux field changes at different positions
- The EMF induced in several coils:

$$E_a = \frac{\phi ZNP}{60a} = V - I_a R_a$$

Ø	Flux per pole
Z	no of conductors in the armature
P	no of poles
a	no of parallel paths
N	speed of the motor
V	supply voltage
Ia	Armature current
Ra	Armature resistance

Developed torque

- The force acting on the rotor: $F = il \times B$
- The rotor rotates at a speed of N rpm, so the angular speed of the rotor: $$\omega_m = \frac{2\pi N}{60} rad/\sec$$
- Current in a single conductor is: $$I_{cond} = \frac{I_a}{a}$$
- The total induced torque is:

$$\tau_{ind} = \frac{ZP\phi I_a}{2\pi a} = K\phi I_a \quad where\ K = \frac{ZP}{2\pi a}$$

- The mechanical power generated is: $$P_{dev} = E_a I_a = \tau\omega_m$$

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Research interest: Reliability, Distribution network, smart grid, risk asessment