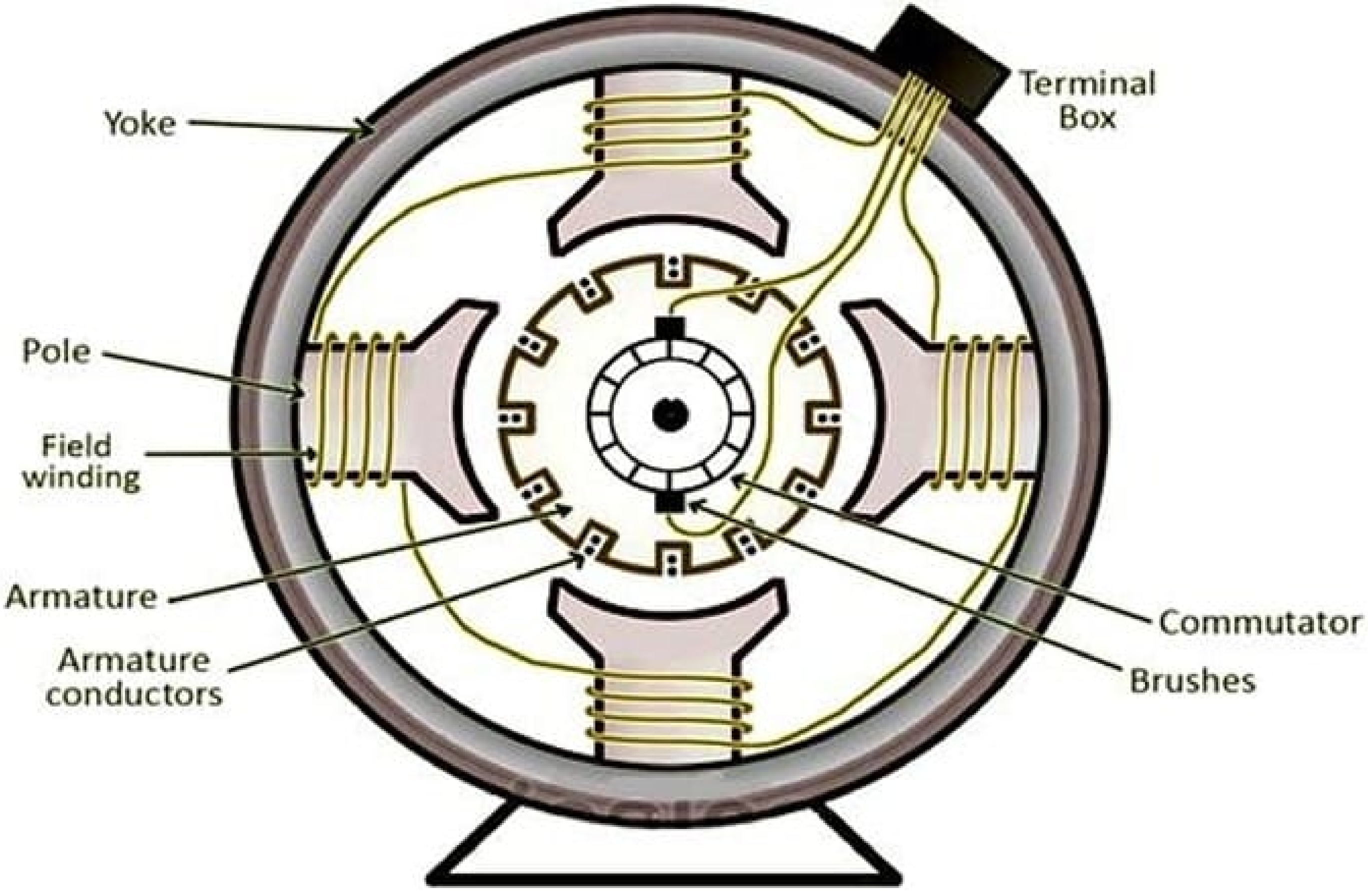
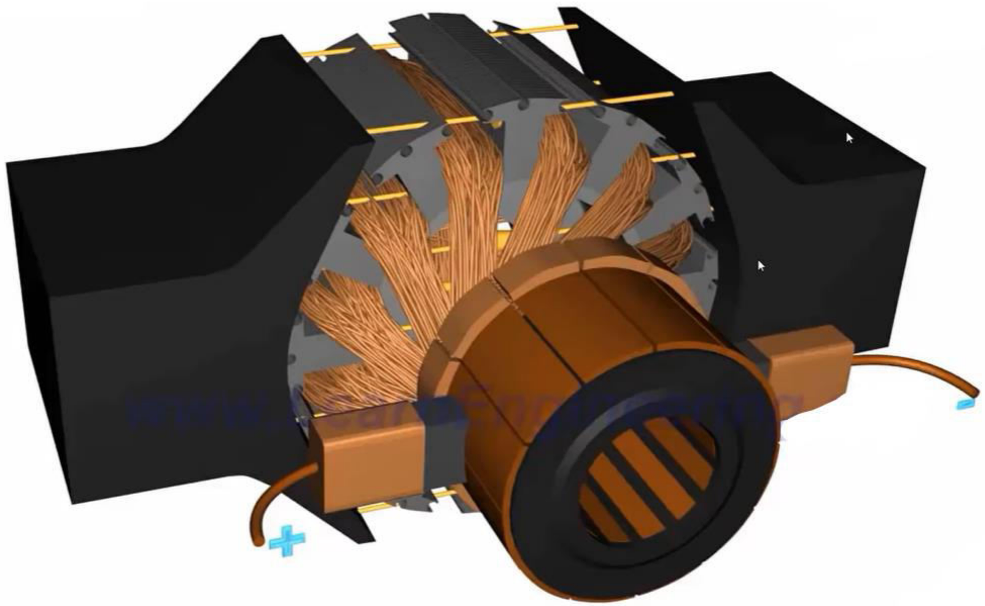
DC Motor Equations and Principles of Control
Lecture - 18


Terminal Box
Yoke
Pole
Field winding
Armature
Armature conductors
Commutator
Brushes

Overview of DC Motor Operation

- DC motors convert electrical energy into mechanical motion.
- Comprised of a stator (stationary part) and a rotor (rotating part).
- Uses the principle of electromagnetic induction to generate rotational motion.



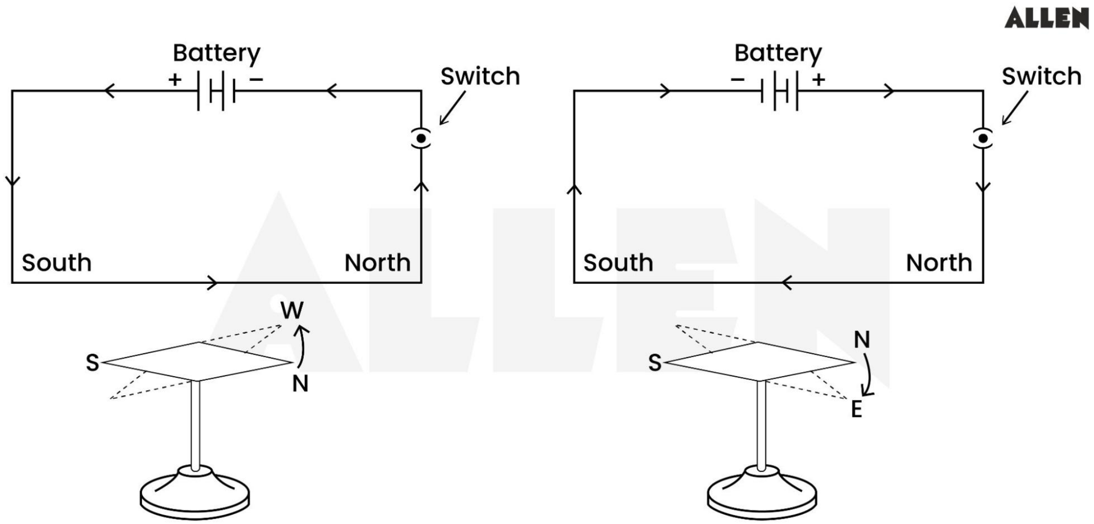
Faraday's Law

- Faraday's Law states that a changing magnetic field through a conductor induces an electromotive force (EMF) or voltage across the conductor.
- In robotics, this law is relevant in scenarios where electromagnetic actuators, such as solenoids or motors, are used. The changing magnetic field produced by the actuator interacts with conductive elements (e.g., coils or wires) to induce an EMF.

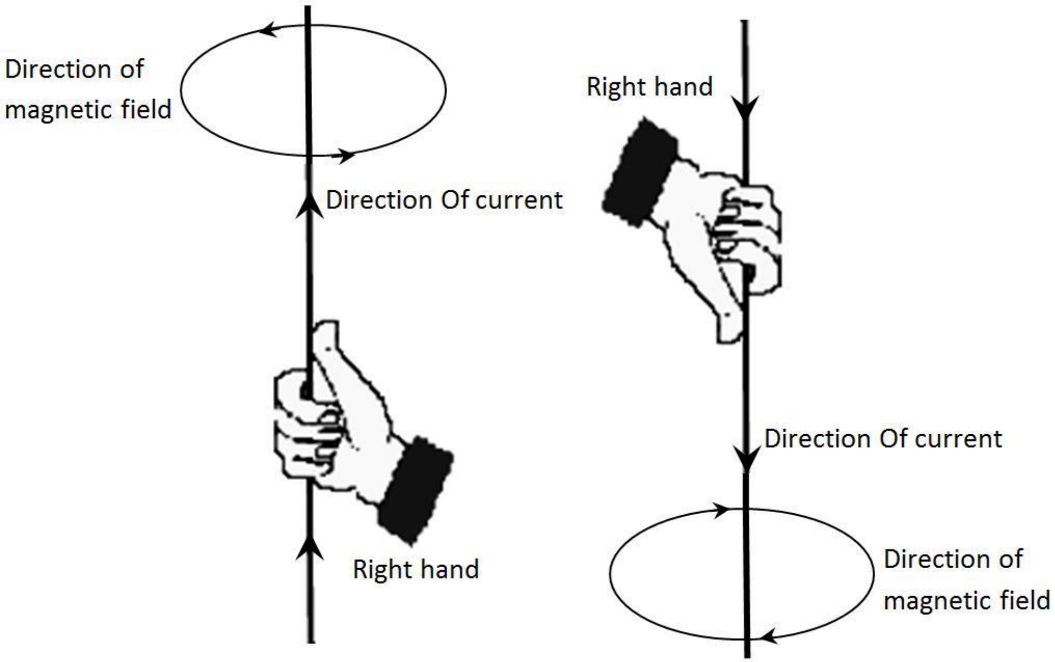
Lenz's Law

- Lenz's Law, derived from Faraday's Law, describes the direction of the induced current resulting from electromagnetic induction.
- Lenz's Law states that the induced current will always flow in a direction that opposes the change in the magnetic field that caused it.
- In the context of robotics, Lenz's Law is crucial for understanding and controlling the behavior of electromagnetic actuators.

H.C Oersted experiment



Maxwell Right hand thumb rule



For clear understanding the principle of DC motor we have to determine the magnitude of the force, by considering the diagram below.

We know that when an infinitely small charge dq is made to flow at a velocity 'v' under the influence of an electric field E, and a magnetic field B, then the Lorentz Force dF experienced by the charge is given by:

$$dF = dq(E + vB)$$

For the operation of dc motor, considering E=0

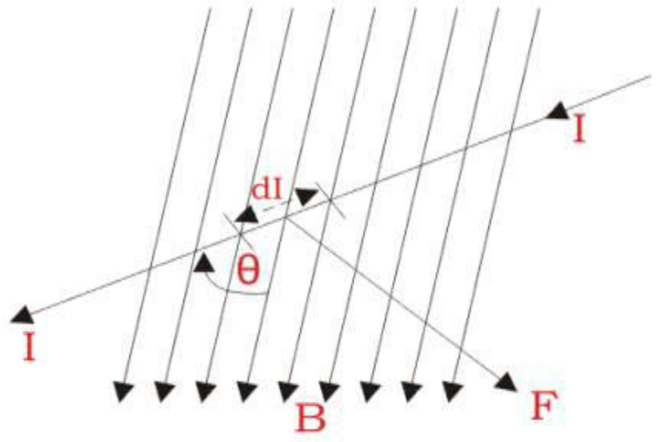
$$dF = dq \times v \times B$$

$$dF = dq\frac{dL}{dt} \times B$$

$$dF = I\ dL\ \times B\ [Since, current\ I = \frac{dq}{dt}]$$

$$F = IL \times B$$

$$F = BIL \sin\theta$$



DC Motor Equations

- Back EMF equation: $E = K.\omega$ **(proportional to the speed)**
  - E: Back electromotive force (EMF)
  - K: Motor constant
  - ω: Angular velocity of the rotor

- Torque equation: $\tau = k \cdot \Phi \cdot I$
  - τ : Torque generated by the motor
  - K: Torque constant
  - I: Current flowing through the motor

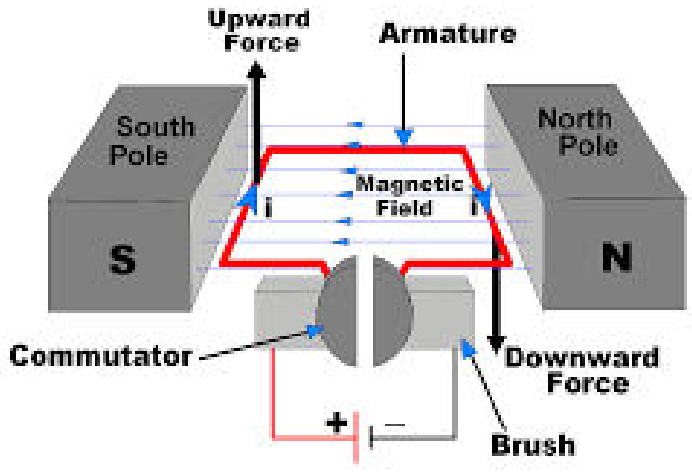
  Φ = Magnetic flux per pole

  Torque is proportional to flux and armatuer current

Stator – Field Assembly

Rotor – Armature Assembly

- Large number of conductor placed around the rotor and connected a suitable manner.
- External voltage is applied.



DC Motor Conceptual Diagram

Armature Voltage Equation

$$V = E_b + I.R + V_{Brush}$$

Steady State Equation

$$V = I.R + k\omega \dots\dots\dots(1)$$

$$V = I.R + L\frac{dI}{dt} + k\omega$$

$$\tau_e = k.I$$

$$J\frac{d\omega}{dt} = k.I - \tau_L$$

From Equation No. 1

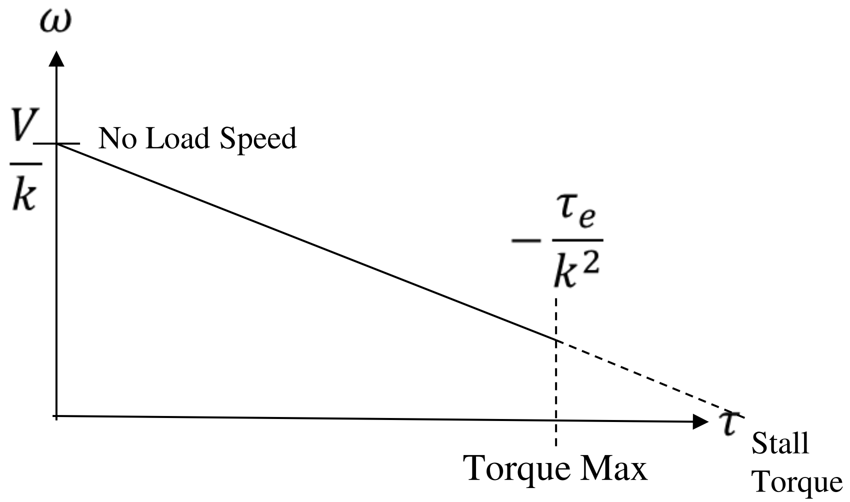
$$V = I.R + k\omega$$

$$\rightarrow V = R.(\frac{\tau_e}{k}) + k\omega$$

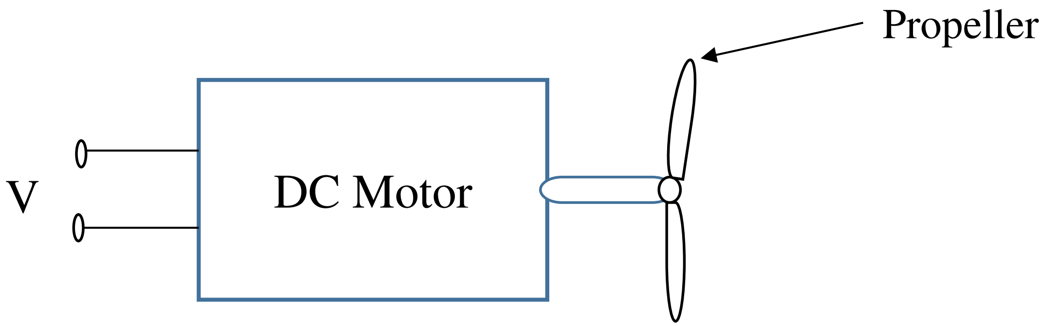
$$\rightarrow V - R.\left(\frac{\tau_e}{k}\right) = \mathrm{k}\omega$$

$$\text{So, } \omega = \frac{V}{k} - R.\frac{\tau_e}{k^2}$$

$Y: \dfrac{V}{k}$ and Slope: $-\dfrac{\tau_e}{k^2}$



Underwater Mobile Robot Application



Increase Power Supply:

1. Decrease Resistance
2. Increase Voltage

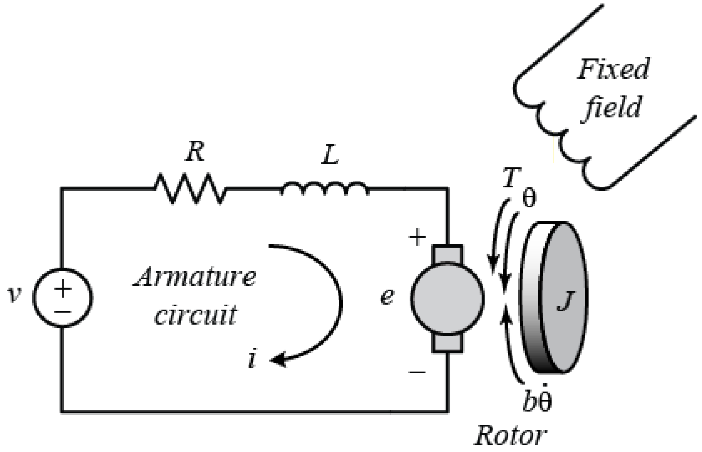
Ratings of Motor:

- ✔ Max Voltage
- ✔ Max Current
- ✔ Max Speed

Armature Voltage Control Desirable?

Armature voltage control is often desirable in certain applications and for specific reasons. Here are a few reasons why armature voltage control may be desirable:

- ❑ Speed Control
- ❑ Torque Control
- ❑ Energy Efficiency
- ❑ Regenerative Braking
- ❑ Overload Protection



Thank You!