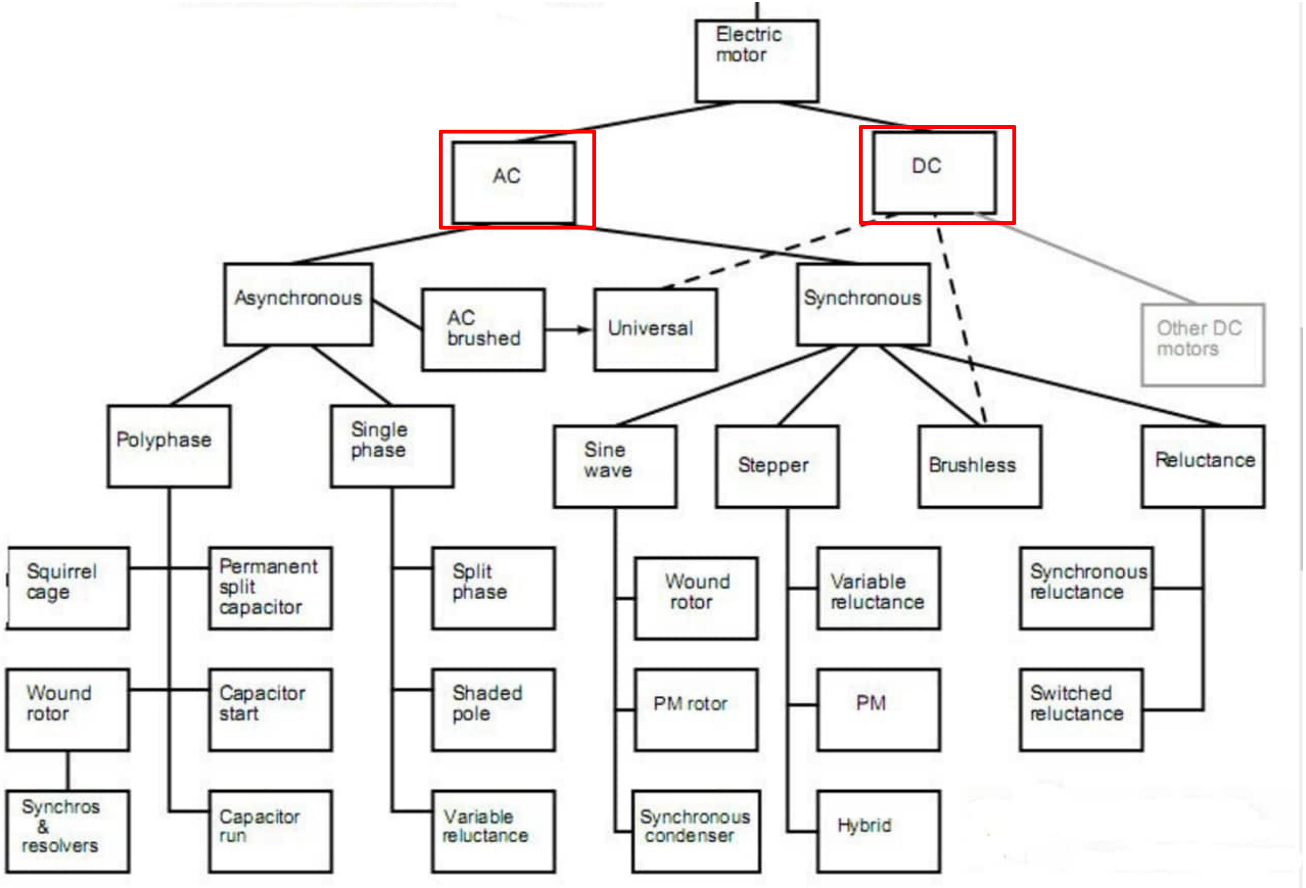
Jacobs University Bremen

Electric motors

Induction
motors

Automation
CO23-320203

Electric motor family



Electric motor's equations

- The essential physics of a motor

$$\|\boldsymbol{\tau}\| = K_\phi \, \phi \, I$$

Torque is proportional to the current and the applied flux!

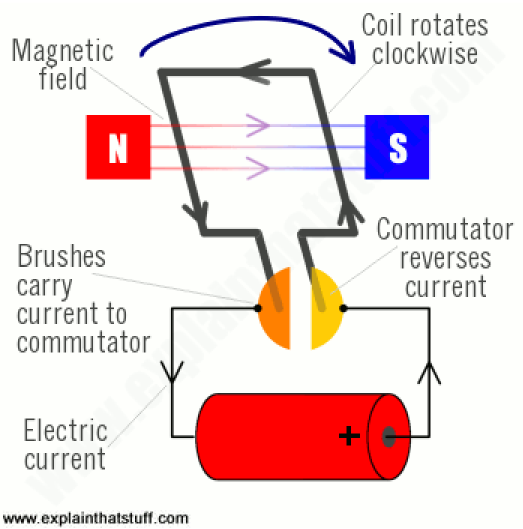
$$e = K_\phi \, \phi \, \omega$$

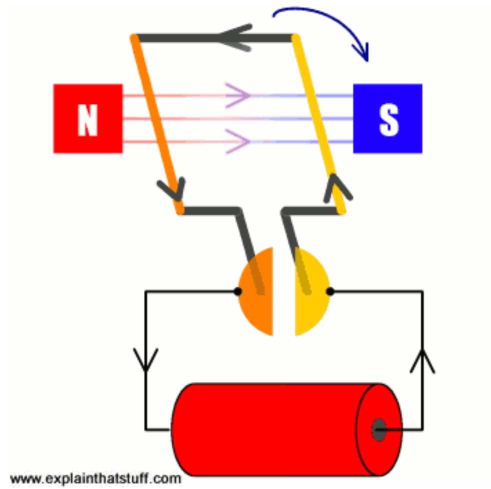
$$K_\phi \triangleq \frac{DL}{A}$$

Induced Back-EMF is proportional to the angular-speed and the applied flux!

Brushed DC Motor

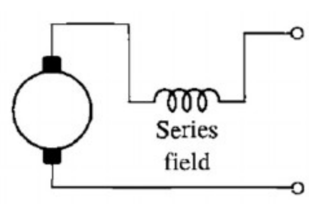
- The basic principle



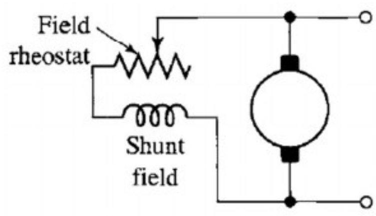


Universal Motor

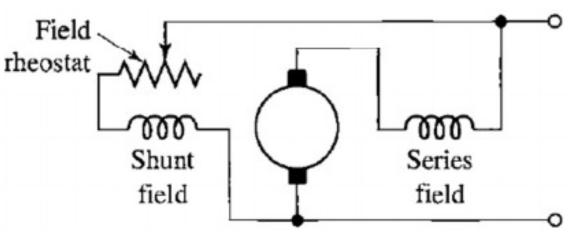
- Replace the fixed stator magnet by an electromagnet



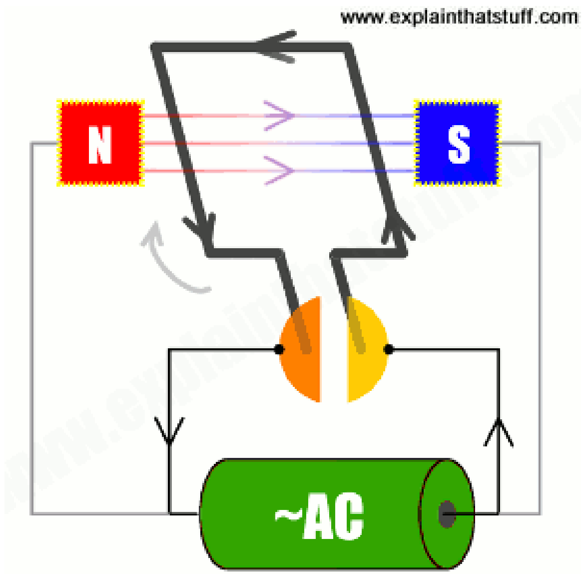
Series



Shunt

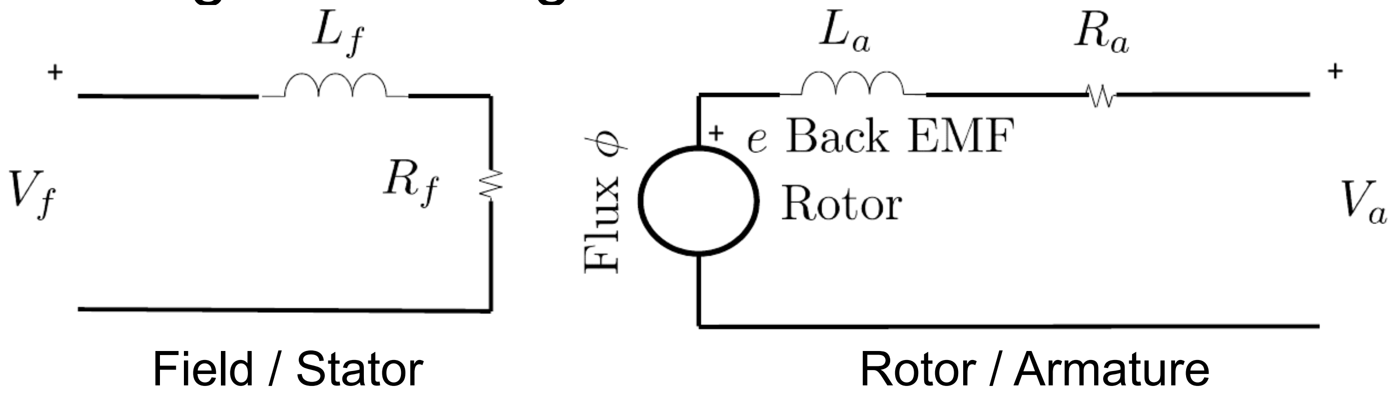


Compound



Universal Motor

- The general diagram:



$$V_f(t) = L_f \frac{dI_f}{dt} + R_f\, I_f$$

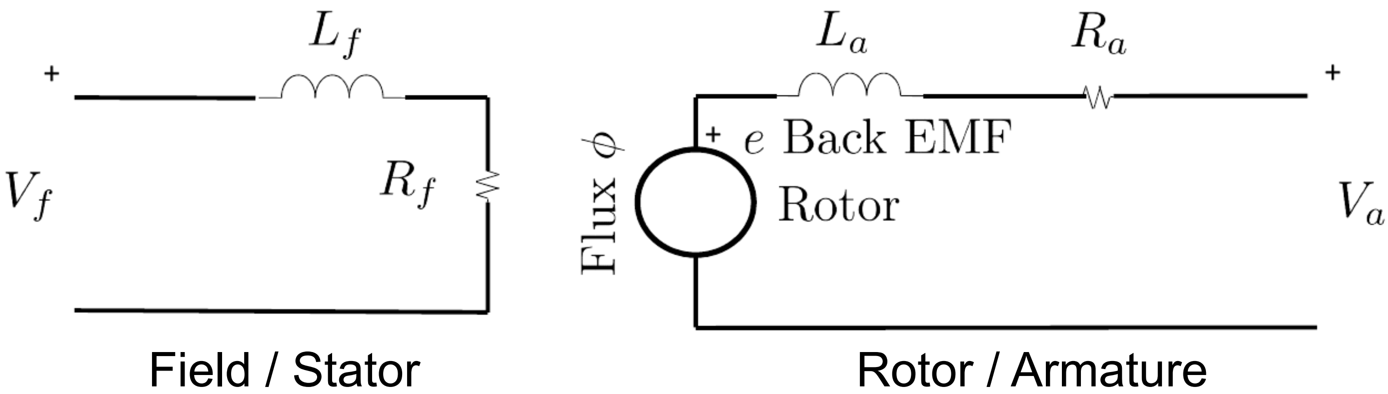
$$V_a(t) = L_a \frac{dI_a}{dt} + R_a\, I_a + e$$

$$e = K_\phi\, \phi\, \omega$$

$$\tau = K_\phi\, \phi\, I_a$$

Universal Motor

- The general diagram:



- The coupling between the two parts is through flux ϕ

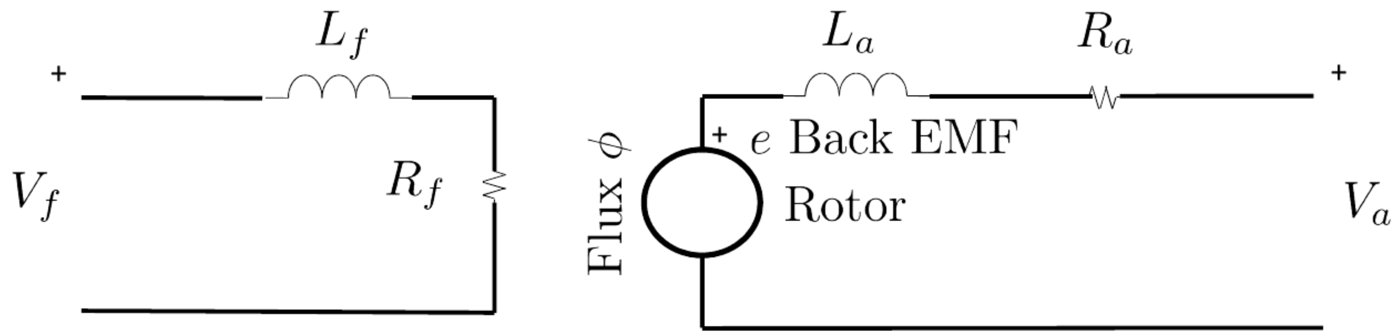
$$\phi \propto I_f$$

$$e = K_\phi \, \phi \, \omega = K \, I_f \, \omega$$

$$\tau = K_\phi \, \phi \, I_a = K \, I_f \, I_a$$

Universal Motor

- The general diagram:



Field / Stator

Rotor / Armature

- The coupling between the two parts is through flux ϕ

$$\phi \propto I_f$$

$$e = K_\phi \, \phi \, \omega = K \, I_f \, \omega$$

$$\tau = K_\phi \, \phi \, I_a = K \, I_f \, I_a$$

at steady state:

$$e = K_\phi \phi \, \omega = V_a - R_a \, I_a$$

$$I_a = \frac{\tau}{K_\phi \phi}$$

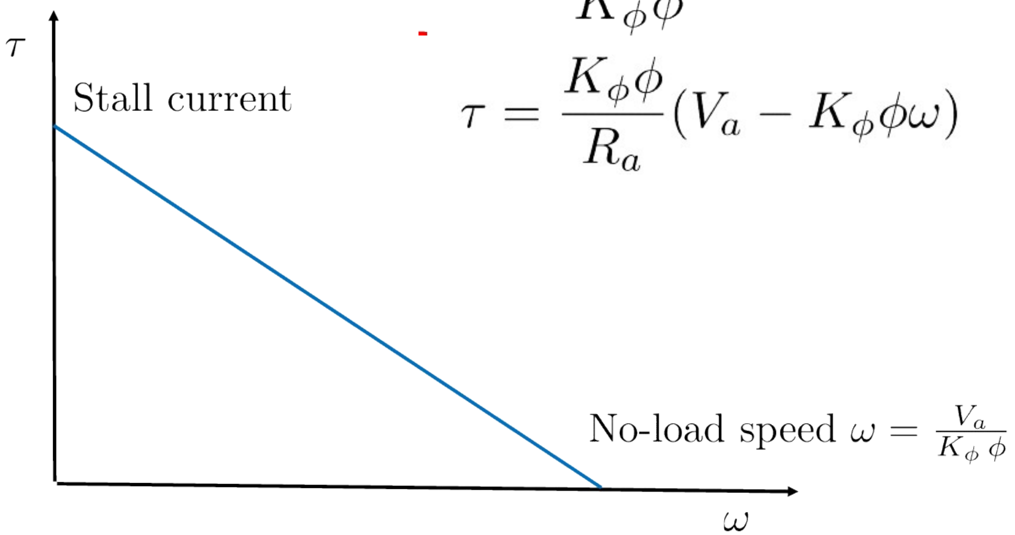
Universal Motor

- At steady state:

$$e = K_\phi \phi\, \omega = V_a - R_a\, I_a$$

$$I_a = \frac{\tau}{K_\phi \phi}$$

$$\tau = \frac{K_\phi \phi}{R_a}(V_a - K_\phi \phi \omega)$$



- Rough approximation of real motor's behavior

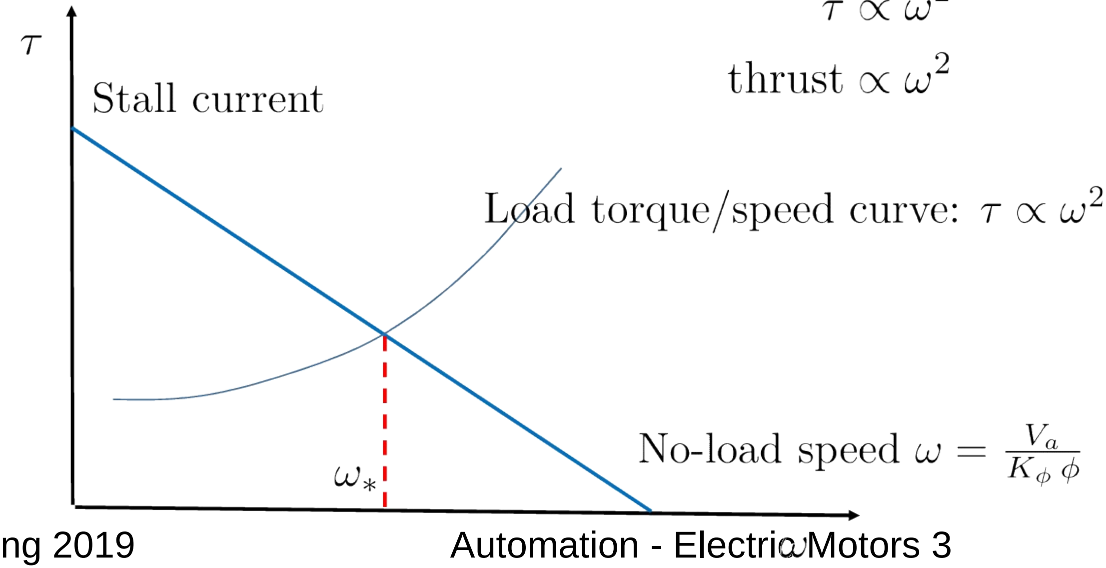
Universal Motor

- Real life load:

(Constant V_a)

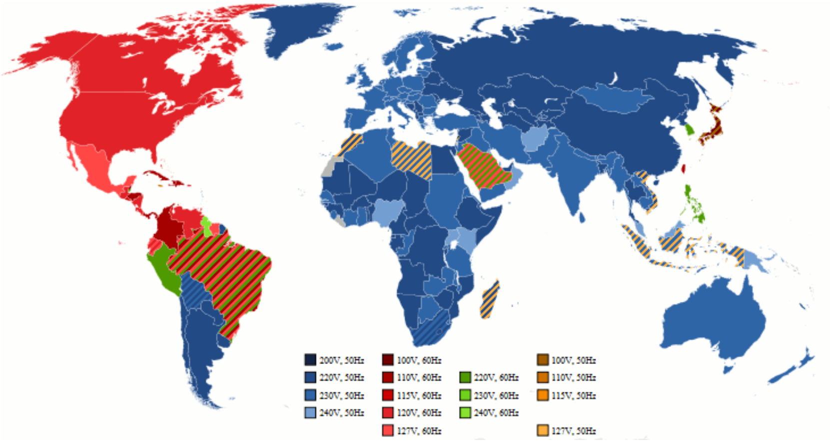
$\tau \propto \omega^2$

$\text{thrust} \propto \omega^2$



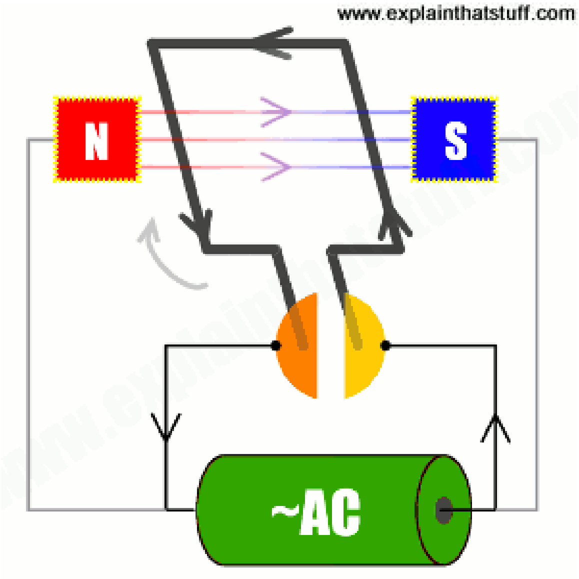
AC Motor

- It’s a clear advantage to have a motor working with AC current as most homes have a 230V 50 Hz / 120V 60 Hz AC installation at home!



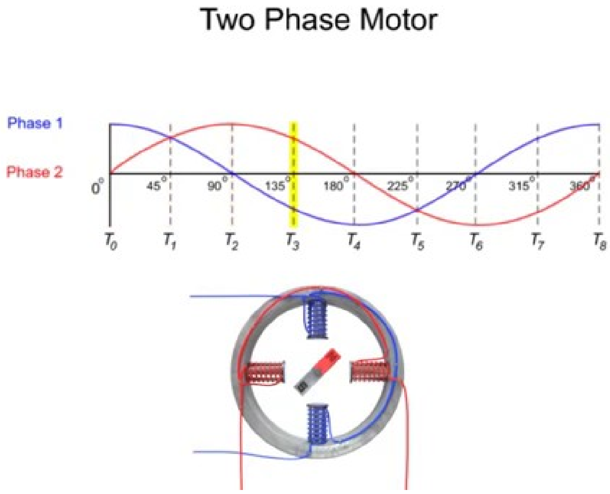
AC Motor

- What if we replace the rotor by a passive device?



AC Motor

- Let's start with a magnet



Working principle of AC motors
https://www.youtube.com/watch?v=qbNpONXRvj8

Induction Motor

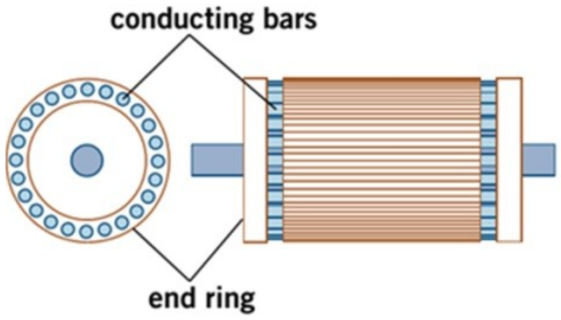
- Insight from Faraday’s law which led us to the quantification of back EMF: the coils of the rotor in operation produce EMF
  - If they are allowed to produce current, they can also generate magnetic field
- What happens if we put a loop of wire in the rotor?
  - In a changing field, a current will flow and it will create a magnetic field which will oppose the change of sensed magnetic field
  - The rotor will “break” with respect to the outside magnetic field

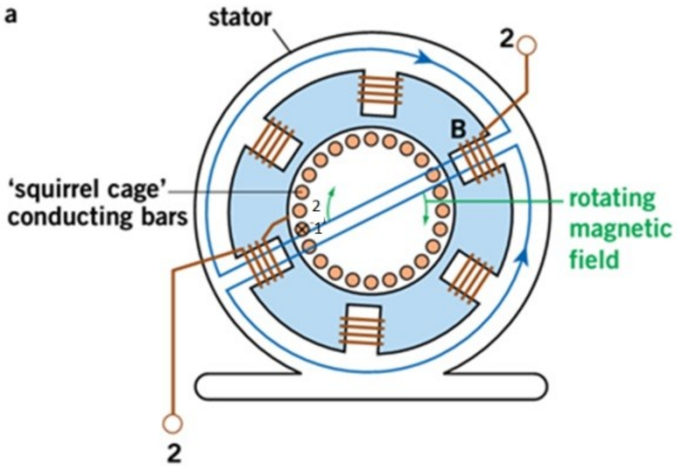
Induction Motor

- If the outside field moves, the rotor will be entrained by it and will move, too
- If it matches movement w.r.t. the external field, it will perceive stationary magnetic field. Thus, it will no longer induce current.

Practical induction motor

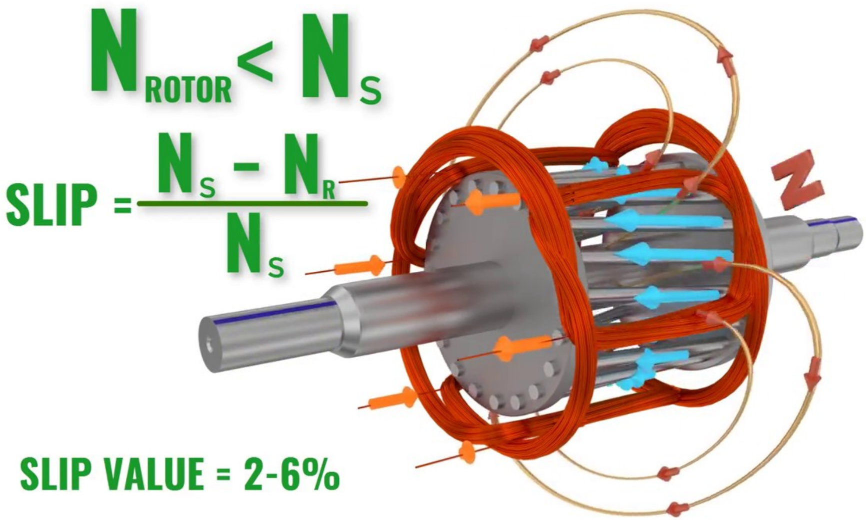
- The conducting bars of the rotors interconnected (electrically) by the end rings
- The rotor is additionally filled in by soft steel laminated core to amplify the magnetic field strength





Practical induction motor

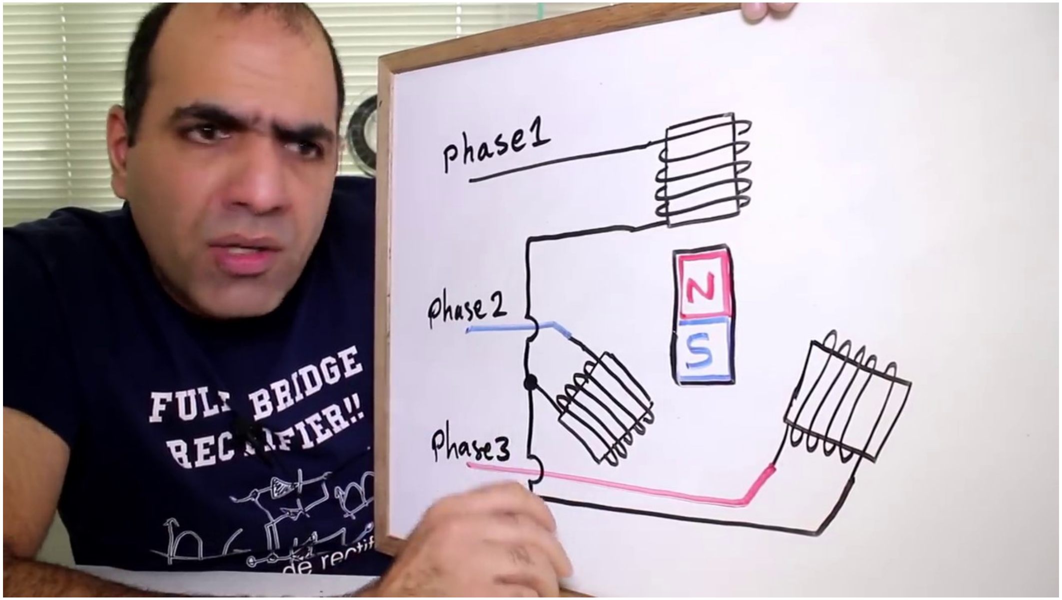
- An industrial three phase AC induction motor



How does an Induction Motor work ?
https://www.youtube.com/watch?v=AQqyGNOP_3o

Three phase systems

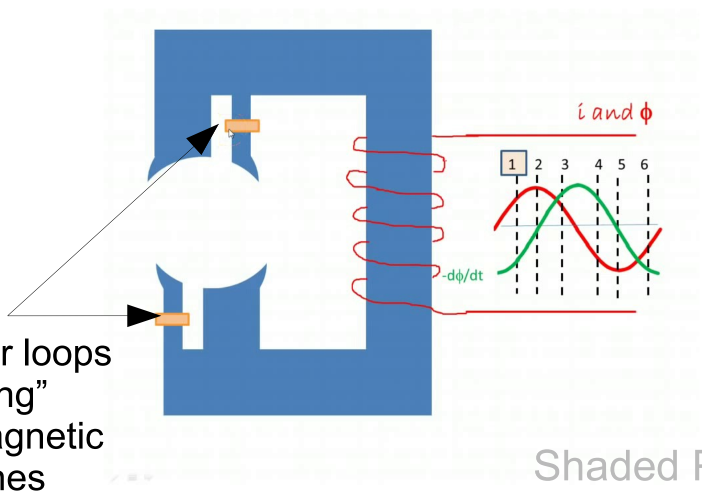
- Advantages of three phase solution:



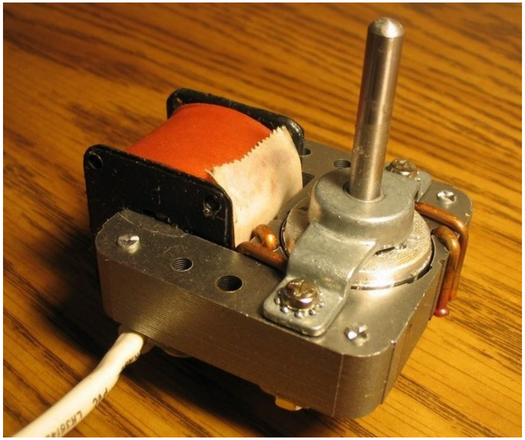
Why 3 Phase AC instead of Single Phase???
https://www.youtube.com/watch?v=quABfe4Ev3s

Shaded Pole Induction Motor

- Most of home AC installations are one phase only – how can induction motors operate in such conditions?
- Example: shaded pole motor
  - Extreme simplicity
  - Gives your fridge and AC electric fans their longevity



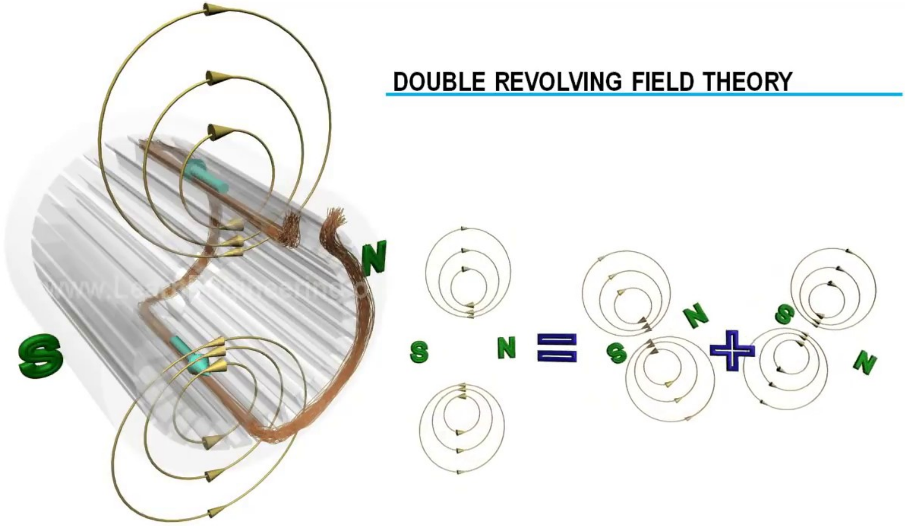
Copper loops "shorting" the magnetic field lines



Shaded Pole Motor
https://www.youtube.com/watch?v=MyEnwJ1Lazg

Single Phase Induction Motor

- Another mechanism common in household applications:



Single Phase Induction Motor, How it works ?
https://www.youtube.com/watch?v=awrUxv7B-a8