17-Generator and Motor Principles Part 2

ECEGR 3500

Text: 12.1-12.7

Electrical Energy Systems

Professor Henry Louie

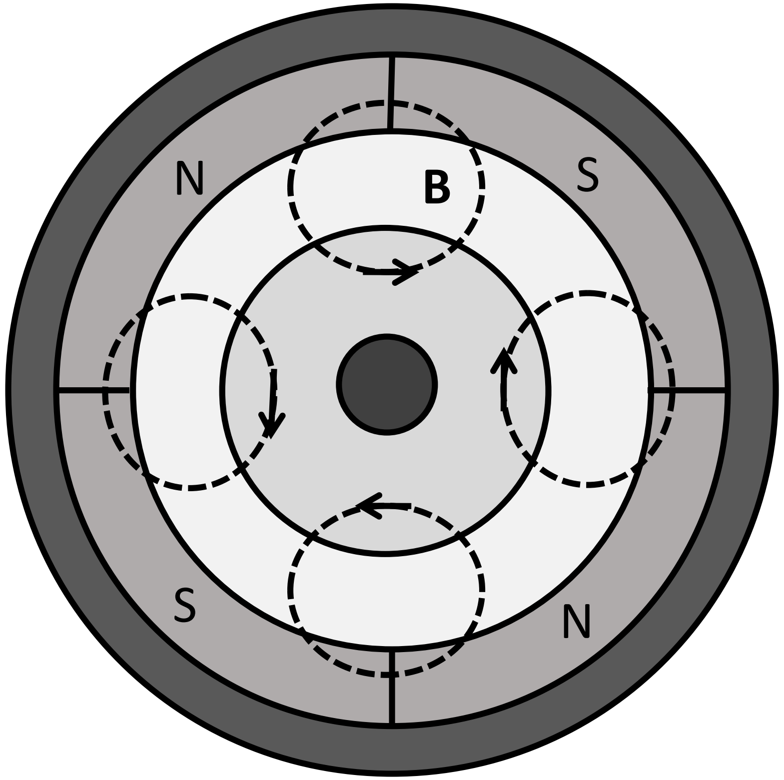
Overview

- Multi-Pole Machines
- Rotational Speed
- Motor Action

Multi-pole Machines

- Consider a 4 pole machine with one coil
- Where should the ends of the coil be placed?

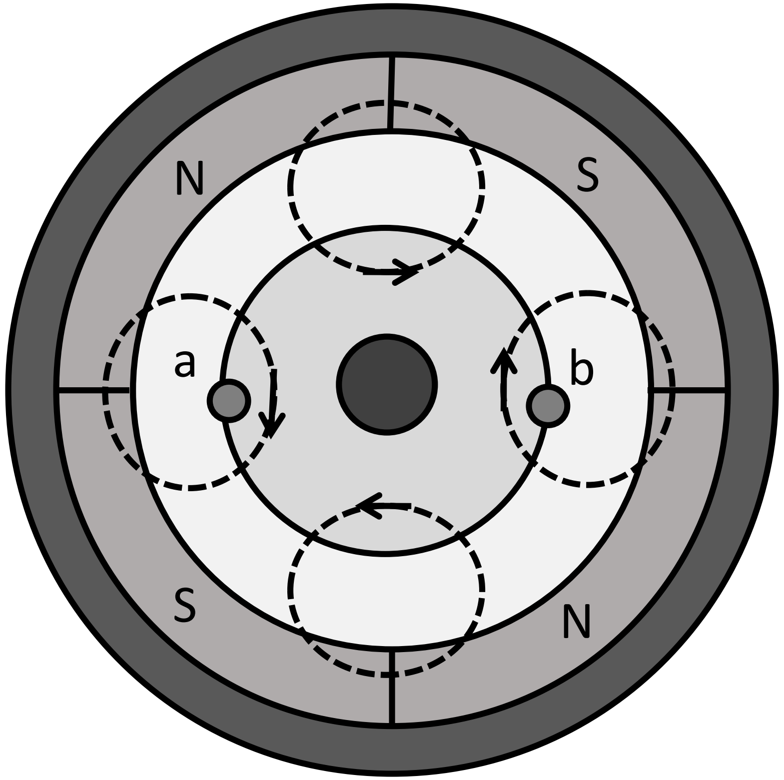
Also called a
“2 pole-pair” machine



Multi-pole Machines

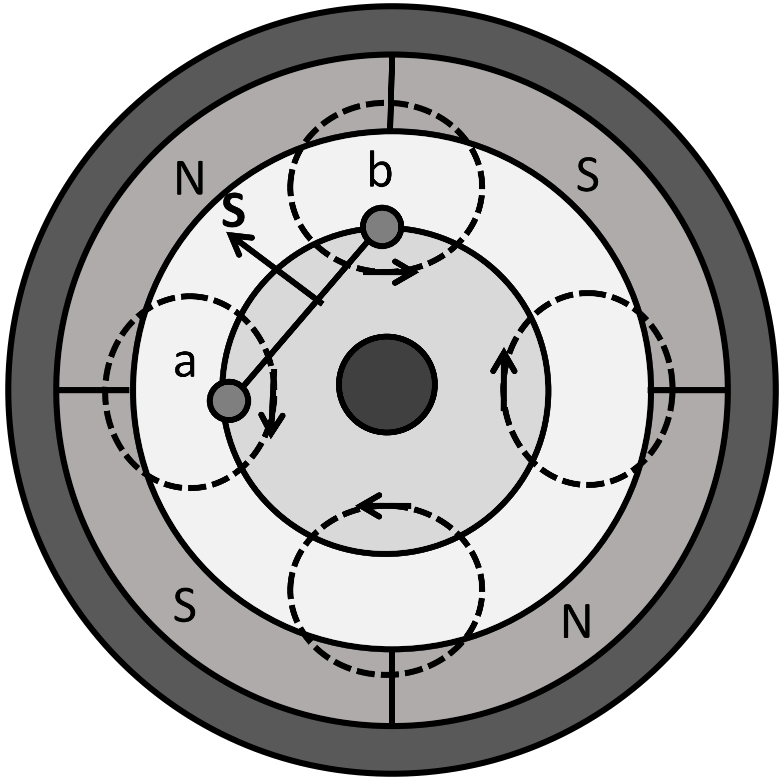
Should we place them here?

- No, net flux will always be zero



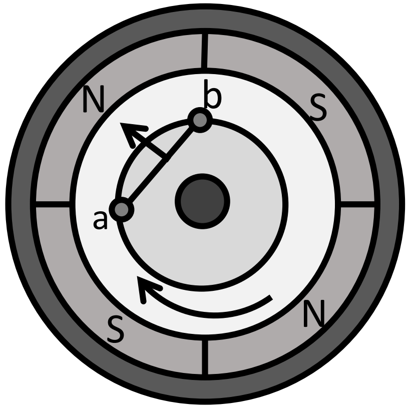
Multi-pole Machines

- This is configuration receives more flux
- The coil spans one full pole (full pitch)

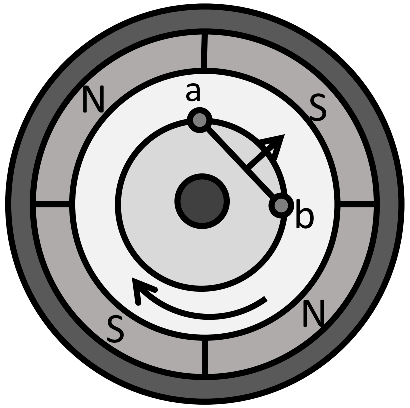


Note: other rotor coils not shown

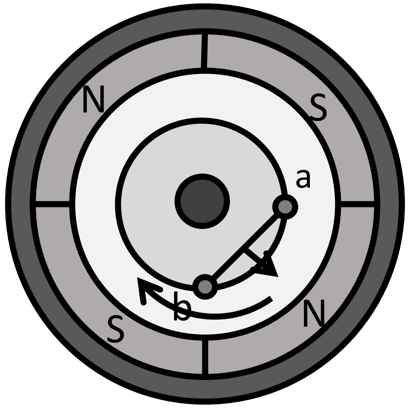
Multi-pole Machines



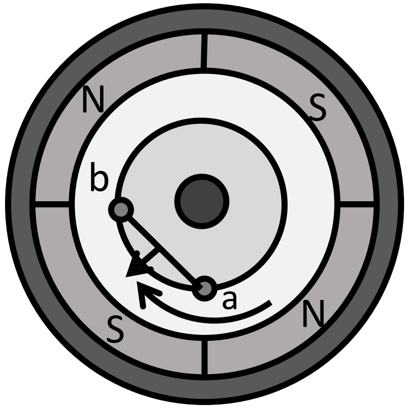
$\theta_m = 0^0$
$\Phi = \Phi_p$



$\theta_m = 90^0$
$\Phi = -\Phi_p$



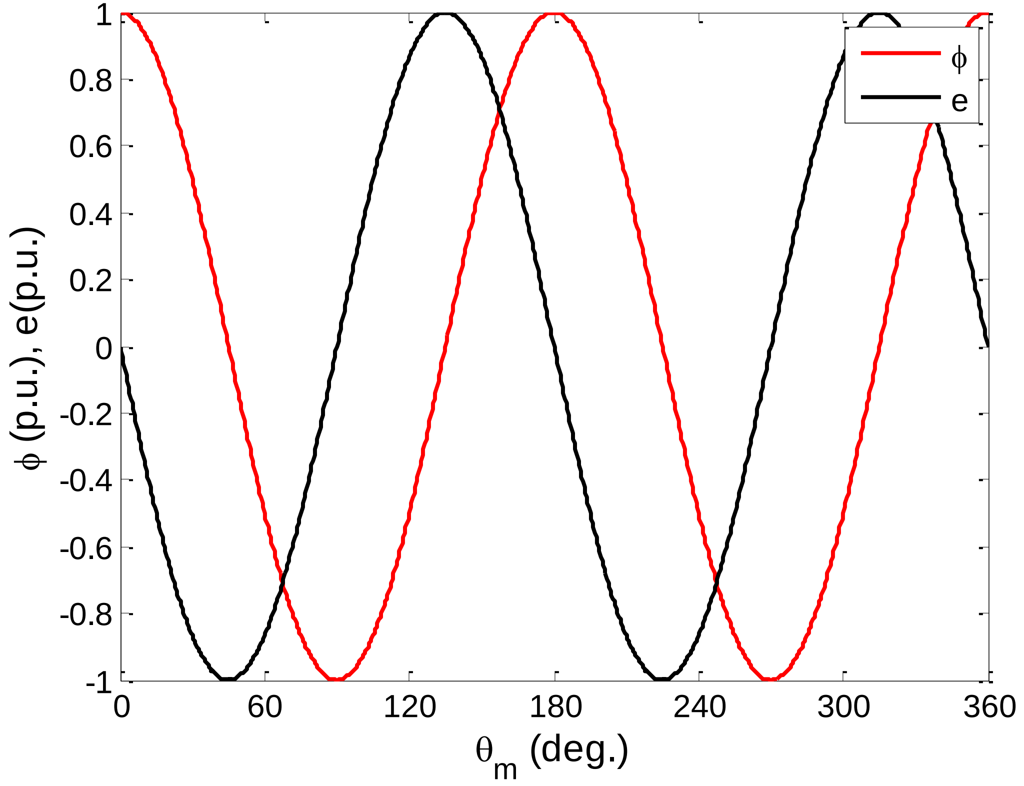
$\theta_m = 180^0$
$\Phi = \Phi_p$



$\theta_m = 270^0$
$\Phi = -\Phi_p$

Multi-pole Machines

Each full mechanical rotation results in <u>two complete sine waves</u> of induced emf



Multi-pole Machines

- The electrical angle is therefore twice the mechanical angle in a four pole machine
- It is easy to see that

$$\theta = \frac{P}{2}\theta_m$$

  - θ: electrical angle (degrees)
  - P: number of poles
- differentiating yields

Always an even number.
Do not confuse with power P.

$$\omega = \frac{P}{2}\omega_m$$

- the electrical frequency is therefore: $f = \frac{P}{2(2\pi)}\omega_m = f_m\frac{P}{2}$

Multi-pole Machines

- The maximum induced emf in a single turn coil is

$$E_m = \Phi_P \omega = \Phi_P \frac{P}{2} \omega_m$$

- For a dc machine, the average induced emf for a single turn is: $E_c = \frac{2}{\pi} E_m = \frac{P}{\pi} \Phi_P \omega_m$

verify this on your own

Exercise

An 8-pole machine with one full pitch winding rotates at 1600 rpm. What is the electrical frequency of its output?

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$$f_e = \frac{1600}{60} \times \frac{8}{2} = 106.7\text{Hz}$$

Exercise

What is the fastest speed (in rpm) a generator shaft may rotate at and still produce 60Hz AC voltage?

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What is the fastest speed (in rpm) a generator shaft may rotate at and still produce 60Hz AC voltage?

$$f = \frac{P}{4\pi}\omega_m$$

$$60 = \frac{P}{4\pi}\omega_m$$

$$\frac{60 \times 4\pi}{2} = \omega_m$$

$$\omega_m = 377\,\text{rad}/\text{s} = 60\text{Hz} = 3600\ \text{rpm}$$

Prime mover shaft may rotate at higher speeds if a gearbox couples it to generator shaft

Force on a Conductor

- Recall that a current-carrying conductor in a magnetic field experiences a force in accordance with the Lorentz Force Equation:

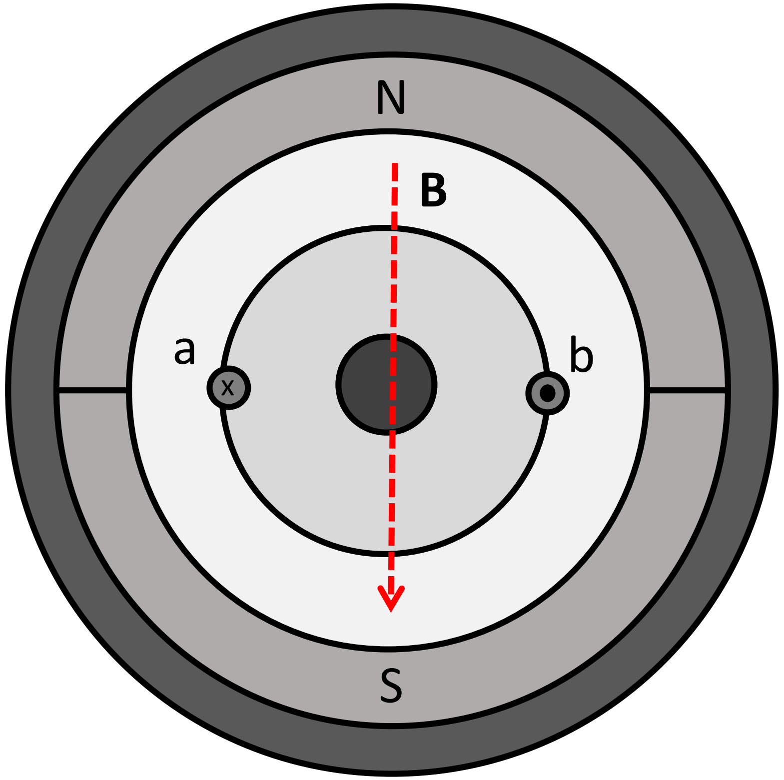
$$\mathbf{F} = \int_C I d\ell \times \mathbf{B}$$

$$\mathbf{F} = i\boldsymbol{L} \times \mathbf{B}$$

- We will use this to understand how motors work

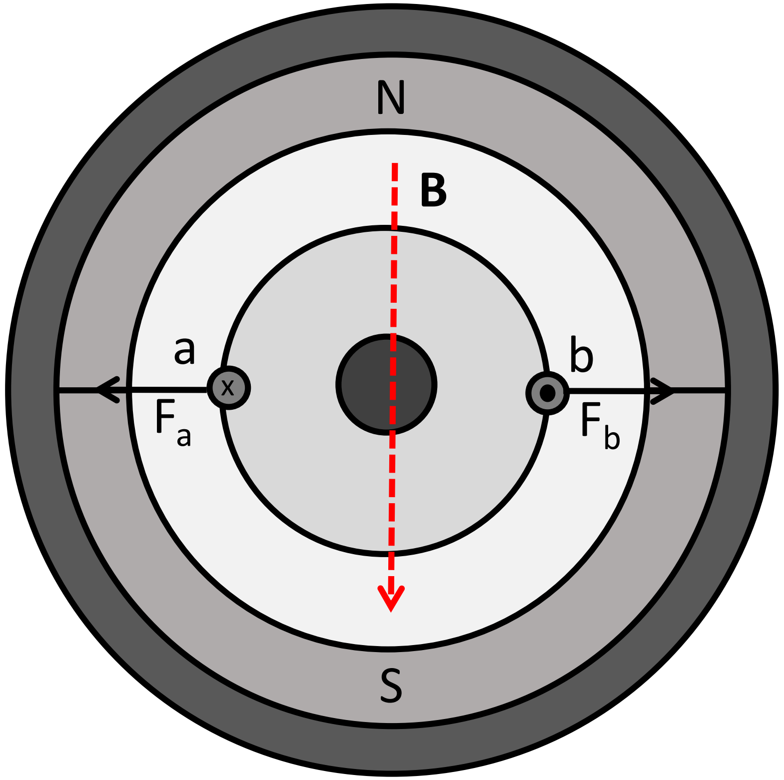
Motor Action

- Consider a 2-pole machine
- Assume that coil ends a and b are connected to a constant voltage source with current into coil end a and out b
- What are the directions of the force on the conductor a and b?



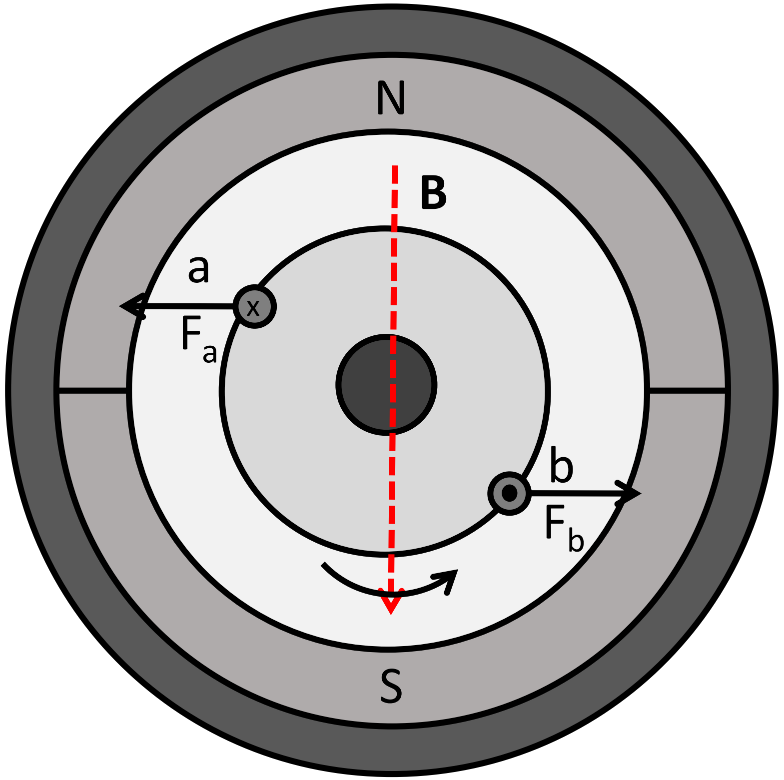
Motor Action

- No net force or torque in this position
- What about other positions?



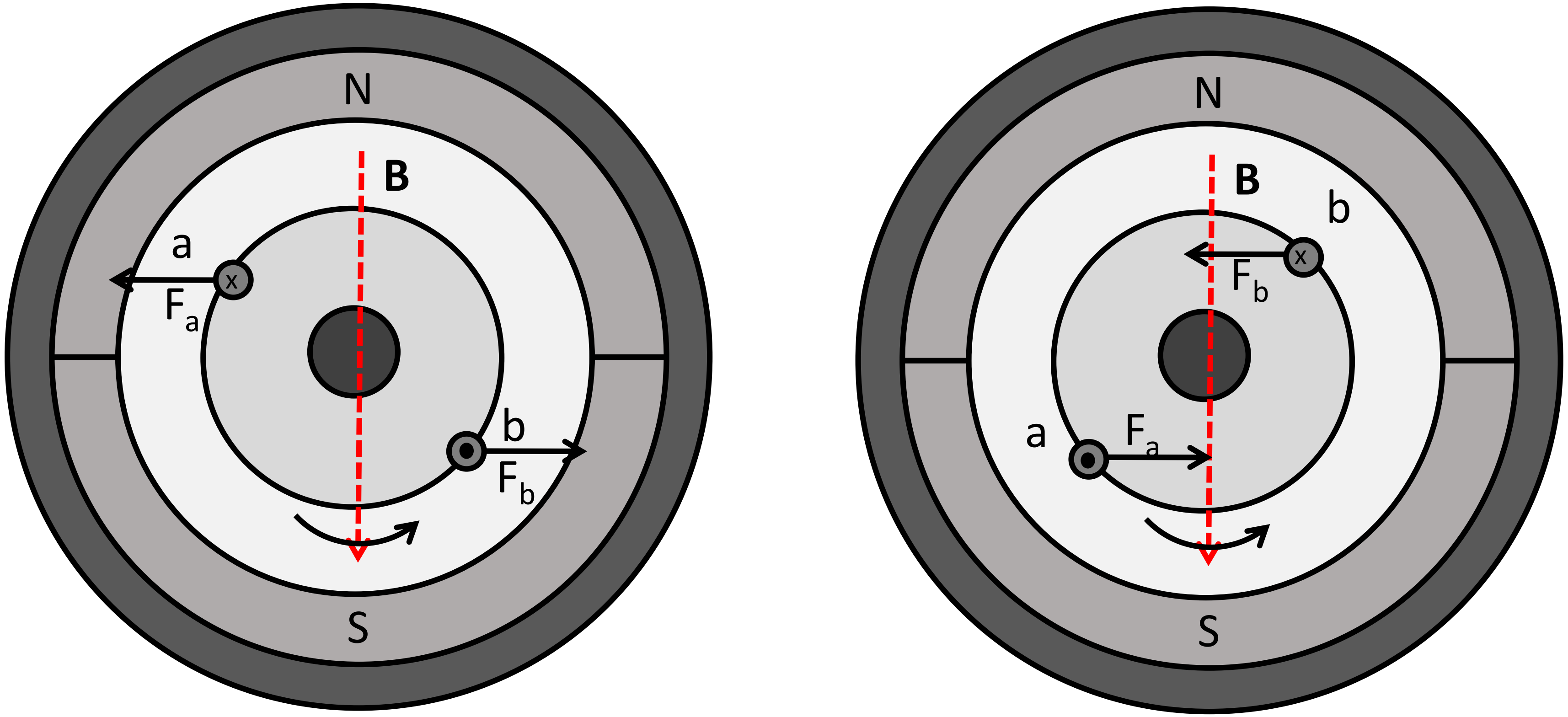
Motor Action

- Torque causes shaft to rotate in CCW direction
- If current polarity is reversed, rotation is in CW direction



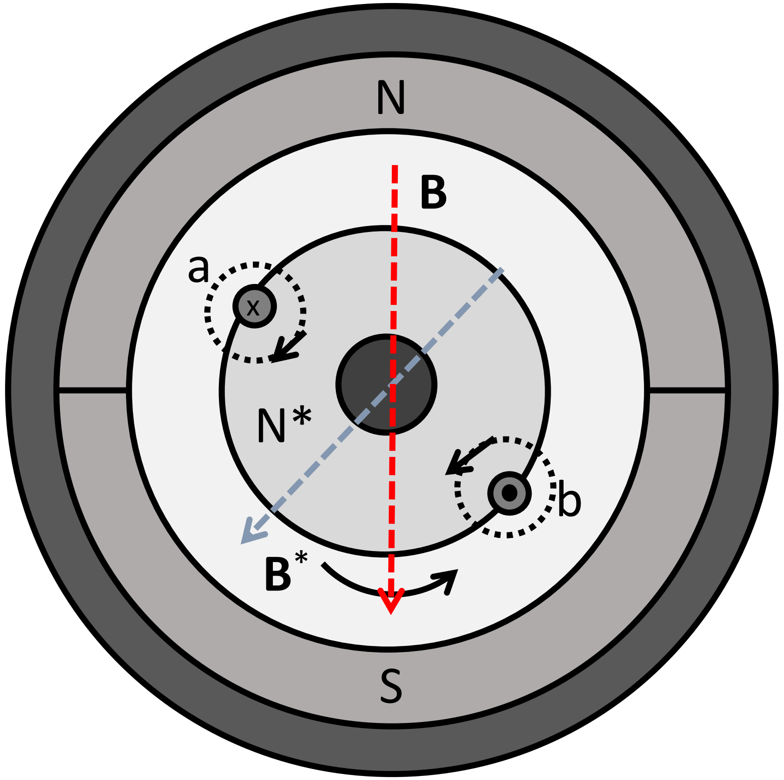
Motor Action

- Polarity must be reversed every half cycle to provide uni-directional rotation



Motor Action

- We can also find rotation direction by thinking of the coil as an electromagnet
- Since flux leaves the North of a magnet, the direction of the electromagnet's North is N*
- This will try to align with the South of the stator
- Hence, counterclockwise rotation



Summary

- Increasing number of poles increases the electrical frequency for a given mechanical frequency
- Induced emf increases with number of poles (for a given mechanical frequency)
- Motors operate by interaction of current flowing in rotor with magnetic field produced by the stator
- Current polarity must be reversed every half-cycle for uni-directional rotation