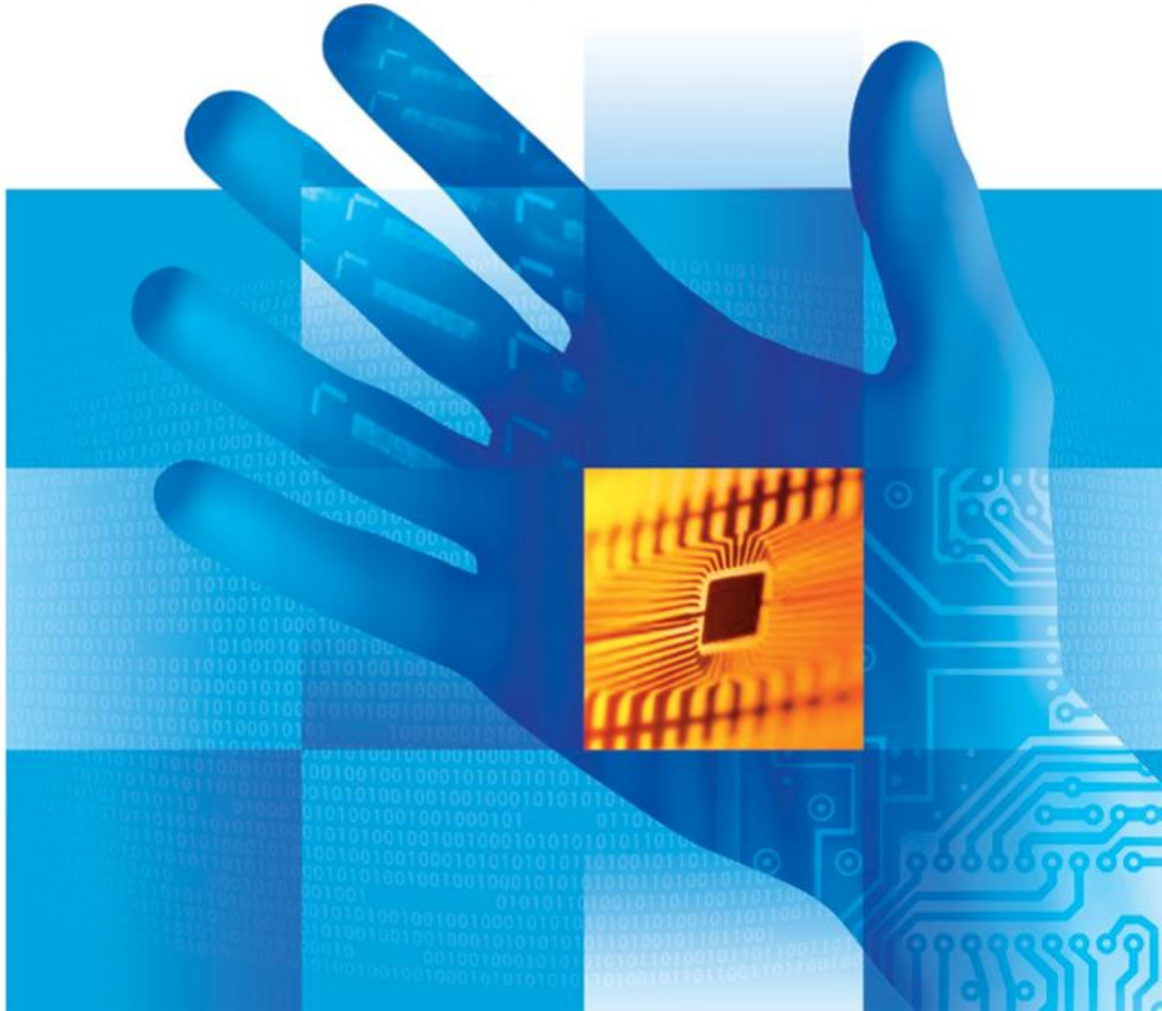
EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

# 4. BASICS OF MAGNETISM AND MAGNETIC CIRCUITS



Doc. Ing. Stanislav Kocman, Ph.D.

8. 12. 2017, Ostrava

# LECTURE PLAN

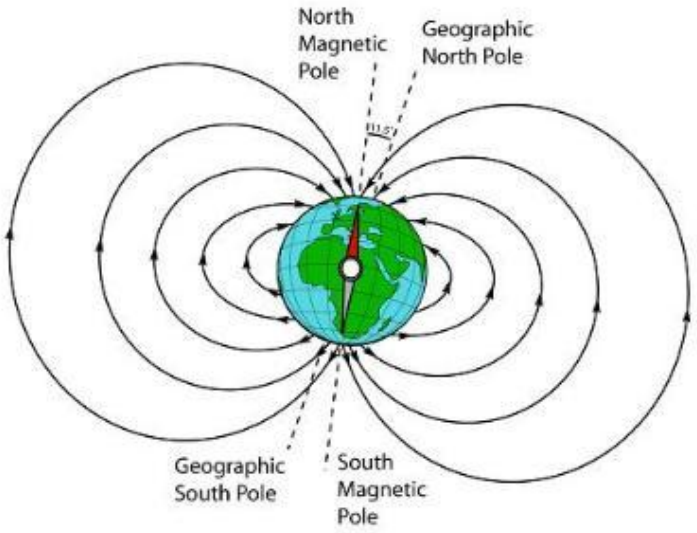
- origin of magnetic field and its quantities
- magnetic material characteristics and classification
- basic rules and laws of magnetic field
- application of magnetic field characteristics in electrical devices

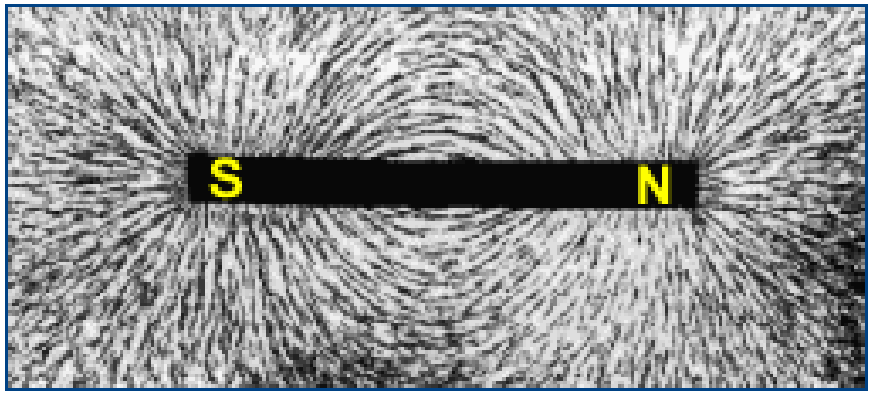
# Origin of magnetic field and its quantities

## Origin and sources of magnetism

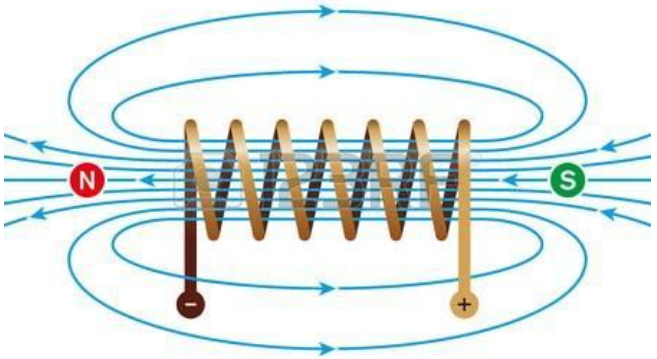
- lodestone: a natural magnet
- Earth is magnetic
- iron, nickel, cobalt and their alloys (magnets)
- electrical current
- electromagnet

# Origin and sources of magnetism



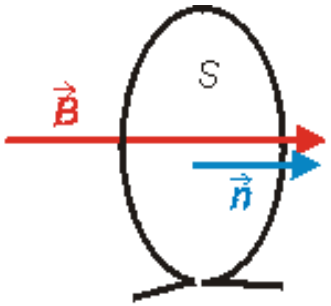





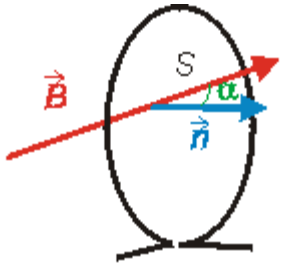
# Quantities of magnetic field

**Magnetic flux density *B* (T)** → **quantifies the strength of a magnetic field**




$$\varphi = B \cdot S \ (\mathrm{Wb})$$

**Magnetic flux $\varphi$ (Wb)**



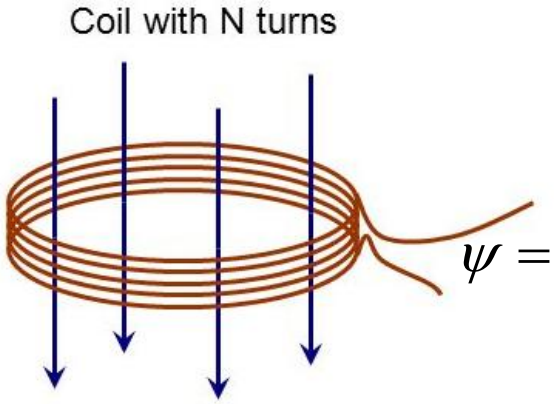

$$\varphi = B \cdot S \cdot \cos\alpha \ (\mathrm{Wb})$$

**Magnetic field intensity *H* (A/m)**

$$H = \frac{B}{\mu} = \frac{B}{\mu_0 \mu_r} \ (\mathrm{A/m})$$

- $\mu$ → **permeability**
- $\mu_0$ → **permeability of free space**
- $\mu_r$ → **relative permeability**

**Magnetic flux linkage $\psi$ (Wb-turns)**



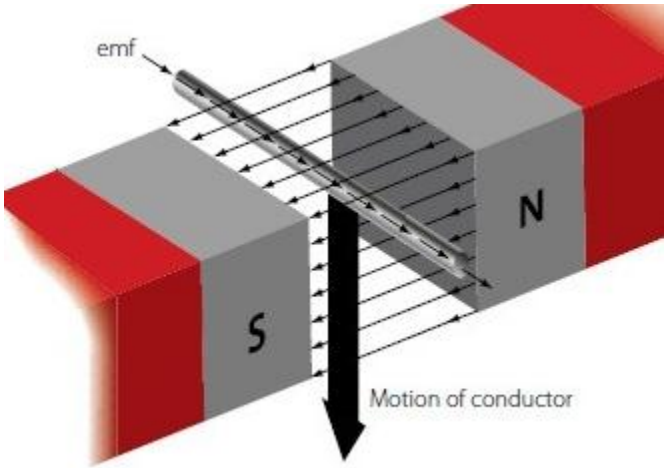

$$\psi = N \cdot \varphi \,(\text{Wb-turns})$$

**Magnetomotive force $F_m$ (A-turns)**

$$F_m = N \cdot i \,(\text{A-turns})$$

**Electromotive force (emf) $e$ (V)**

$$e = -\frac{\mathrm{d}\varphi}{\mathrm{d}t} \text{ or } e = -N\frac{\mathrm{d}\varphi}{\mathrm{d}t} \,(\text{V})$$



# Magnetic material characteristics and classification

- **Classification of materials according to their magnetic behavior:**
  - **diamagnetic: repelled by both poles of a magnet**
    - **e.g. gold, silver, copper, carbon, mercury….**

      $\mu_r \leq 1$
  - **paramagnetic: weakly attracted to either pole of a magnet e.g. aluminum, lithium, magnesium, sodium….**

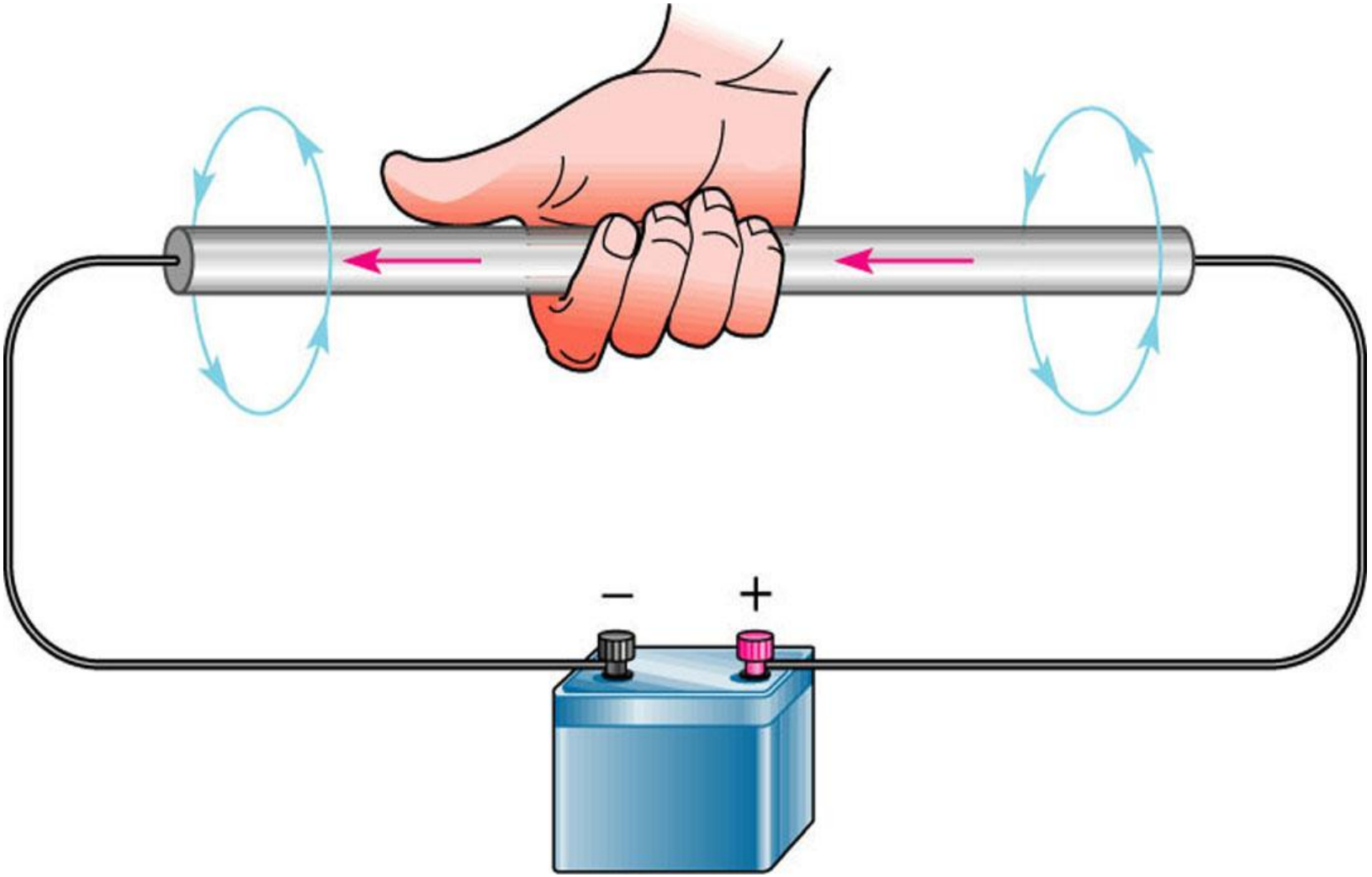
    $\mu_r > 1$ slightly
  - **ferromagnetic: attracted to a magnet strongly**
    - **iron, nickel, cobalt, and their alloys….**

      $\mu_r >> 1$
  - **ferrimagnetic: attracted to a magnet strongly**
    - **ferrite (iron oxides with aluminum, cobalt, nickel….)**

      $\mu_r >> 1$

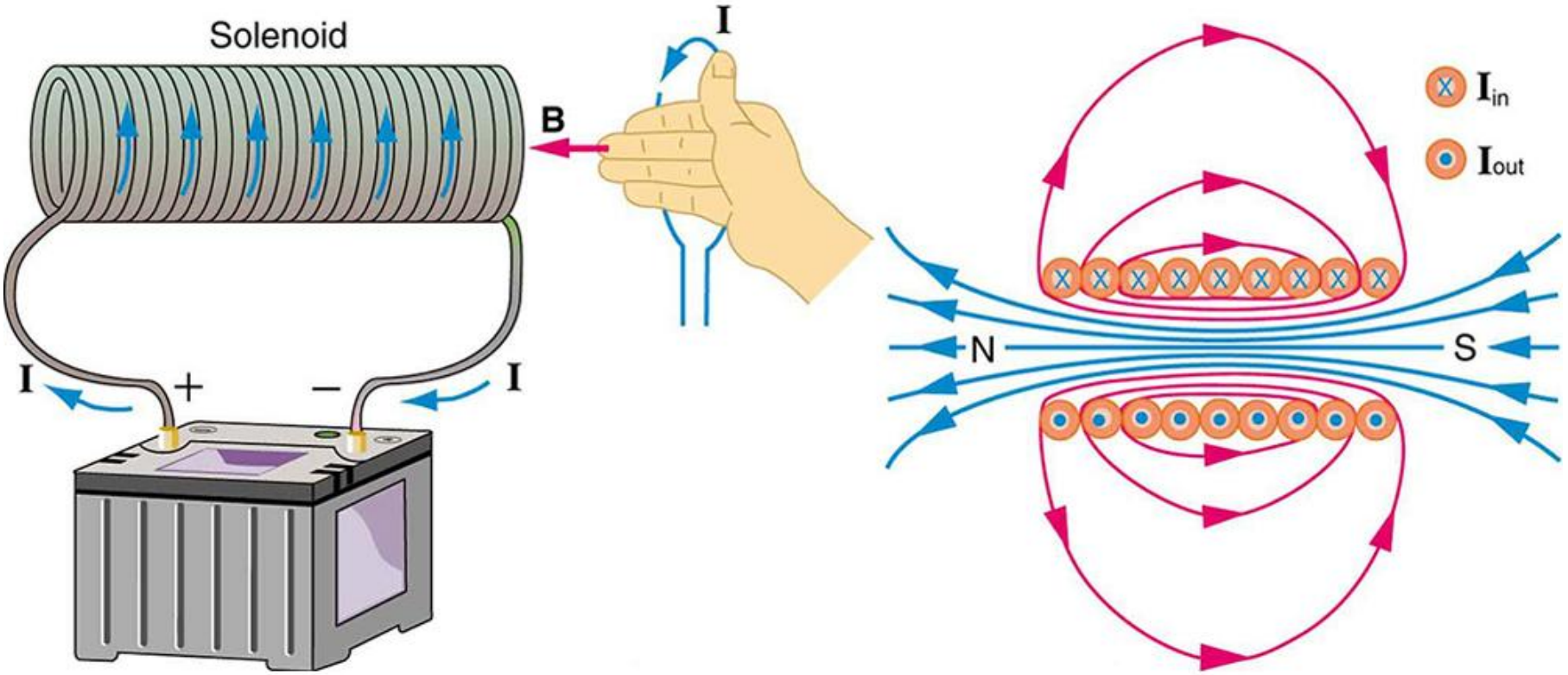
# Basic rules and laws of magnetic field

## Ampere´s Law



# Basic rules and laws of magnetic field

## Ampere´s Law for a solenoid



# Basic rules and laws of magnetic field

## Faraday´s Law

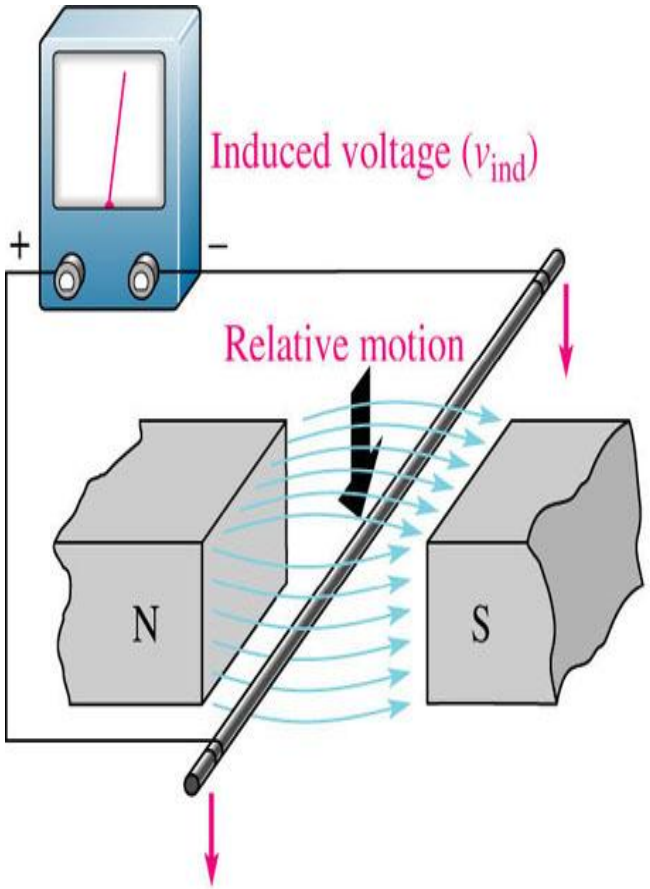
$$e = -\frac{\mathrm{d}\varphi}{\mathrm{d}t} \text{ or } v_{ind} = \frac{\mathrm{d}\varphi}{\mathrm{d}t} \text{ (V)}$$

**time varying flux**

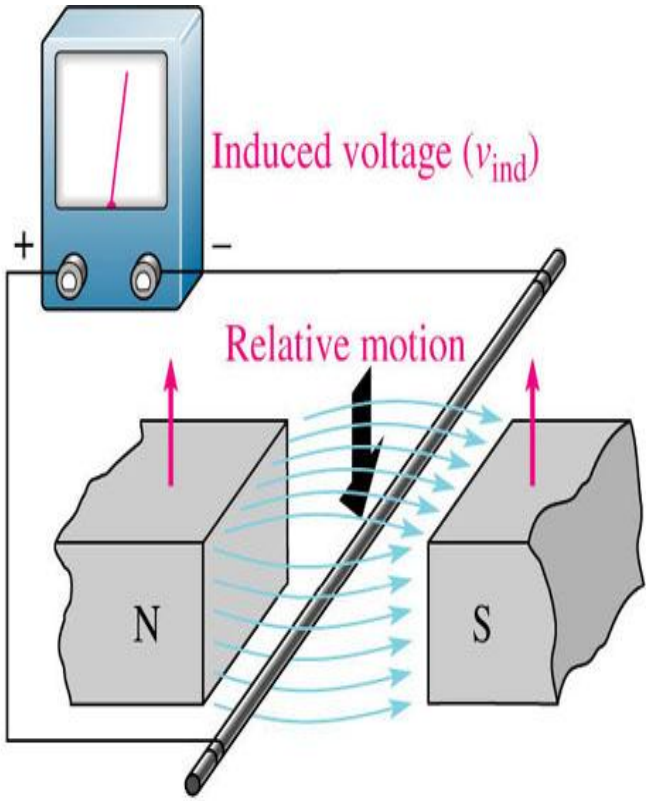
**a) by motion of a conductor in the magnetic field**
**b) by inserting of a conductor into alternating magnetic field**

# Basic rules and laws of magnetic field

## Faraday´s Law




(a) Wire moving downward



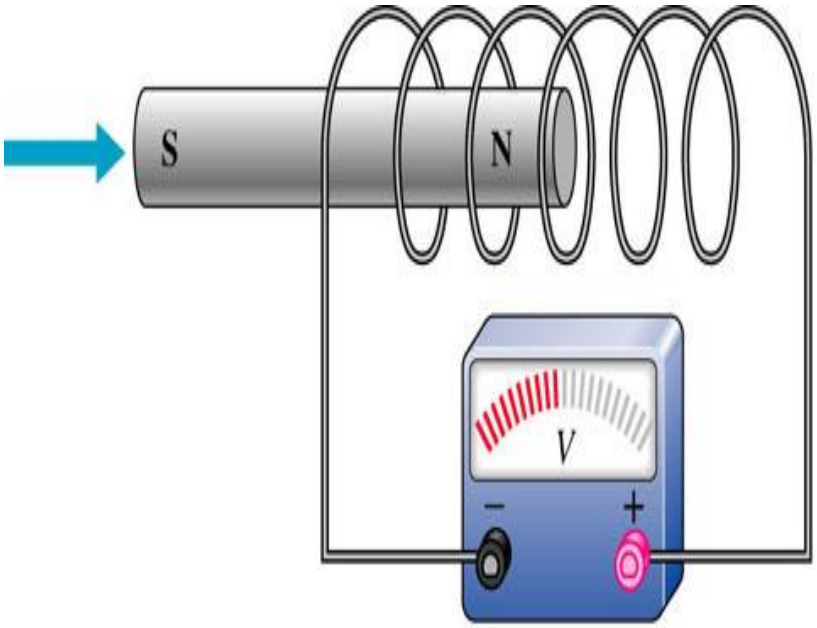

(b) Magnetic field moving upward

# Basic rules and laws of magnetic field

## Faraday´s Law

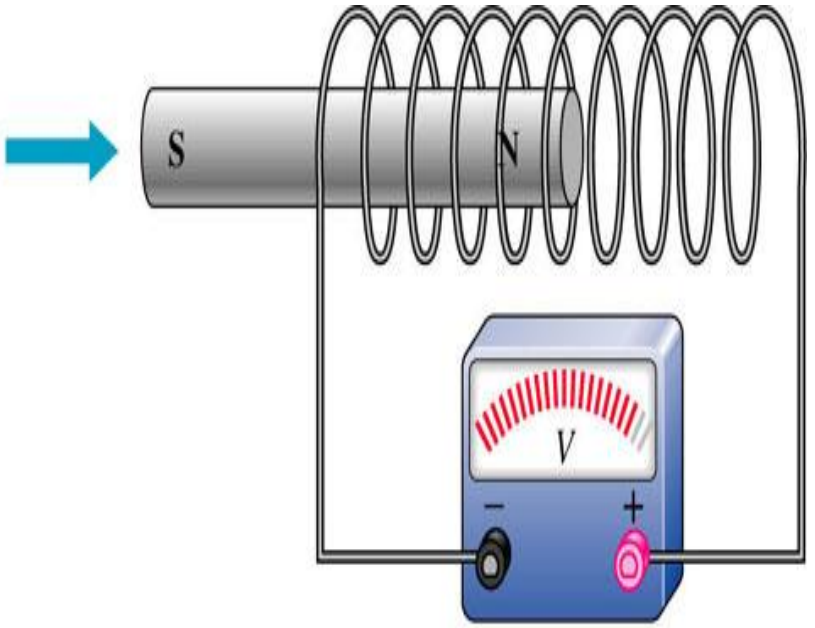
$$v_{ind} = N \frac{\mathrm{d}\varphi}{\mathrm{d}t} \,(\mathrm{V})$$

$N_1$




(a) Magnet moves through a coil and induces a voltage.

$N_2 > N_1$

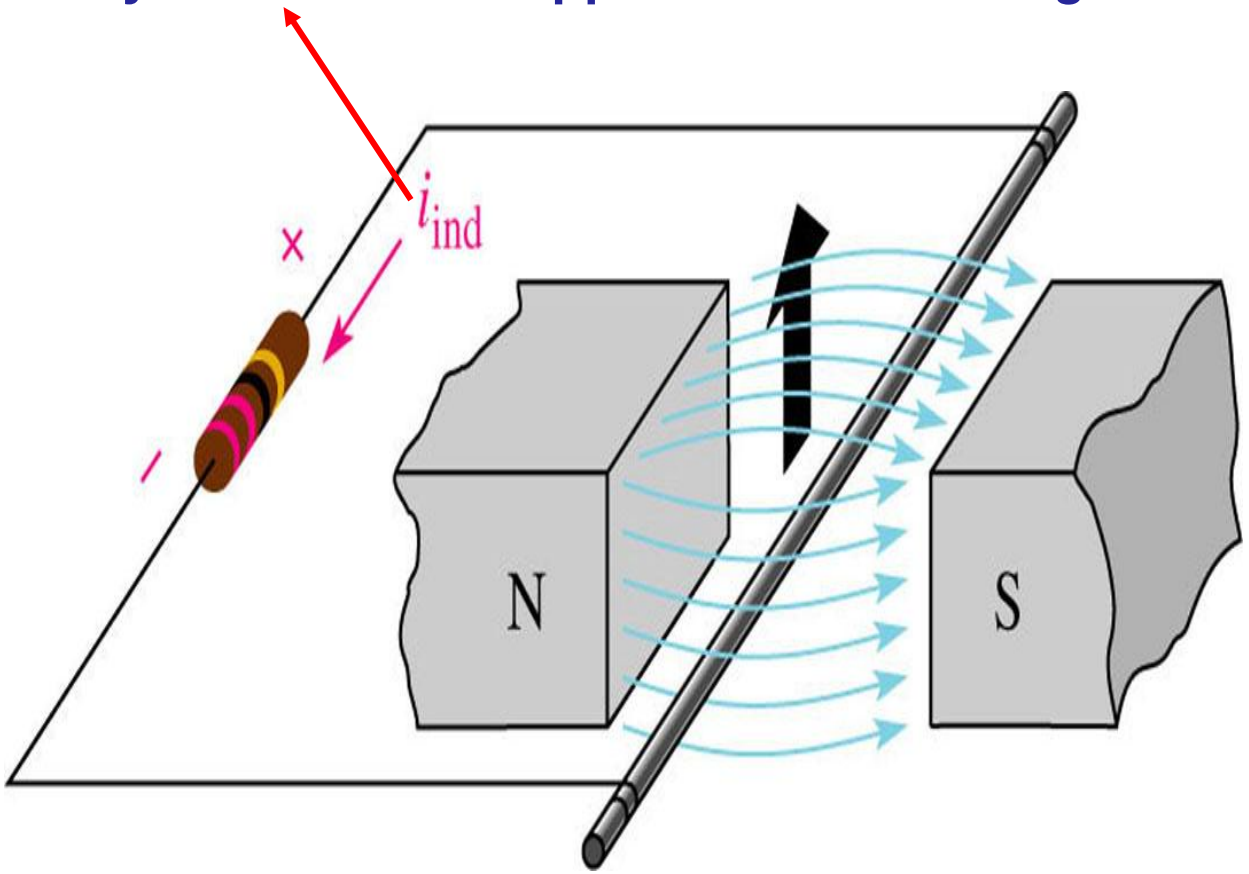



(b) Magnet moves at same rate through a coil with more turns (loops) and induces a greater voltage.

# Basic rules and laws of magnetic field

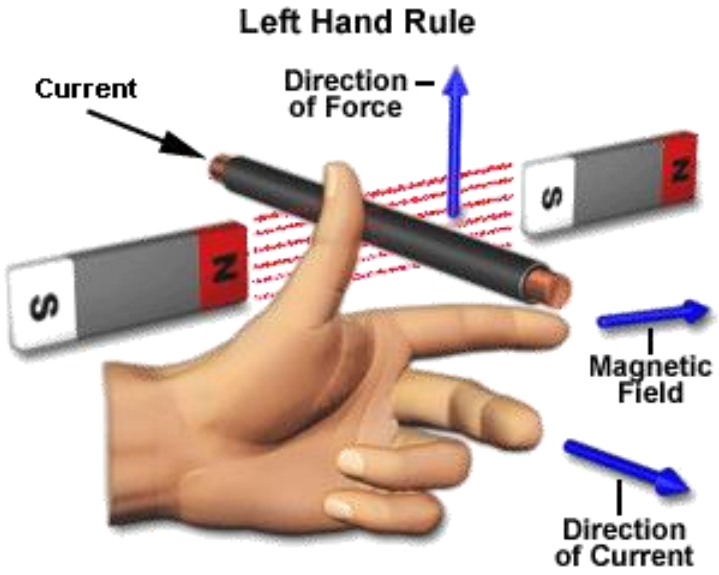
## Lenz´s Law

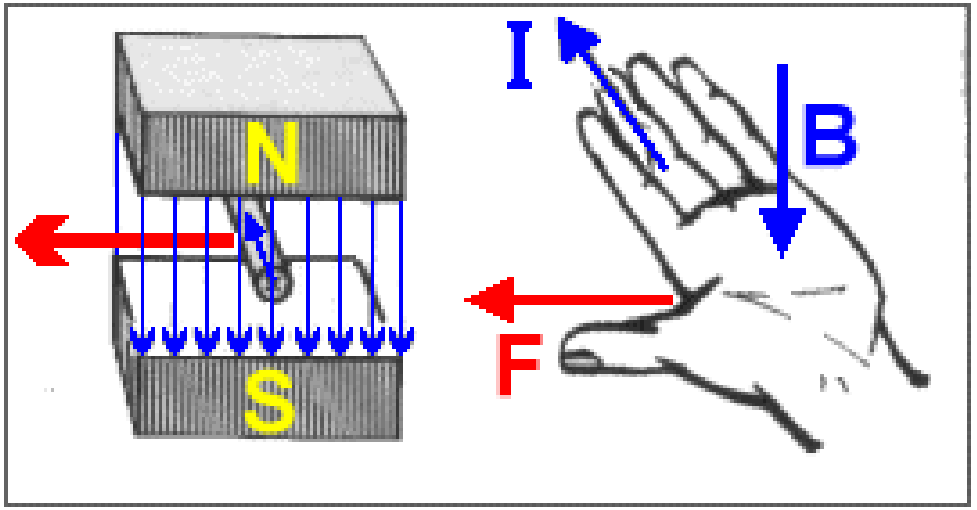
**Current flows in the conductor in such a way that the magnetic flux generated by the current is oppose the increasing flux.**



# Basic rules and laws of magnetic field

## Fleming´s Law (Left-hand rule)



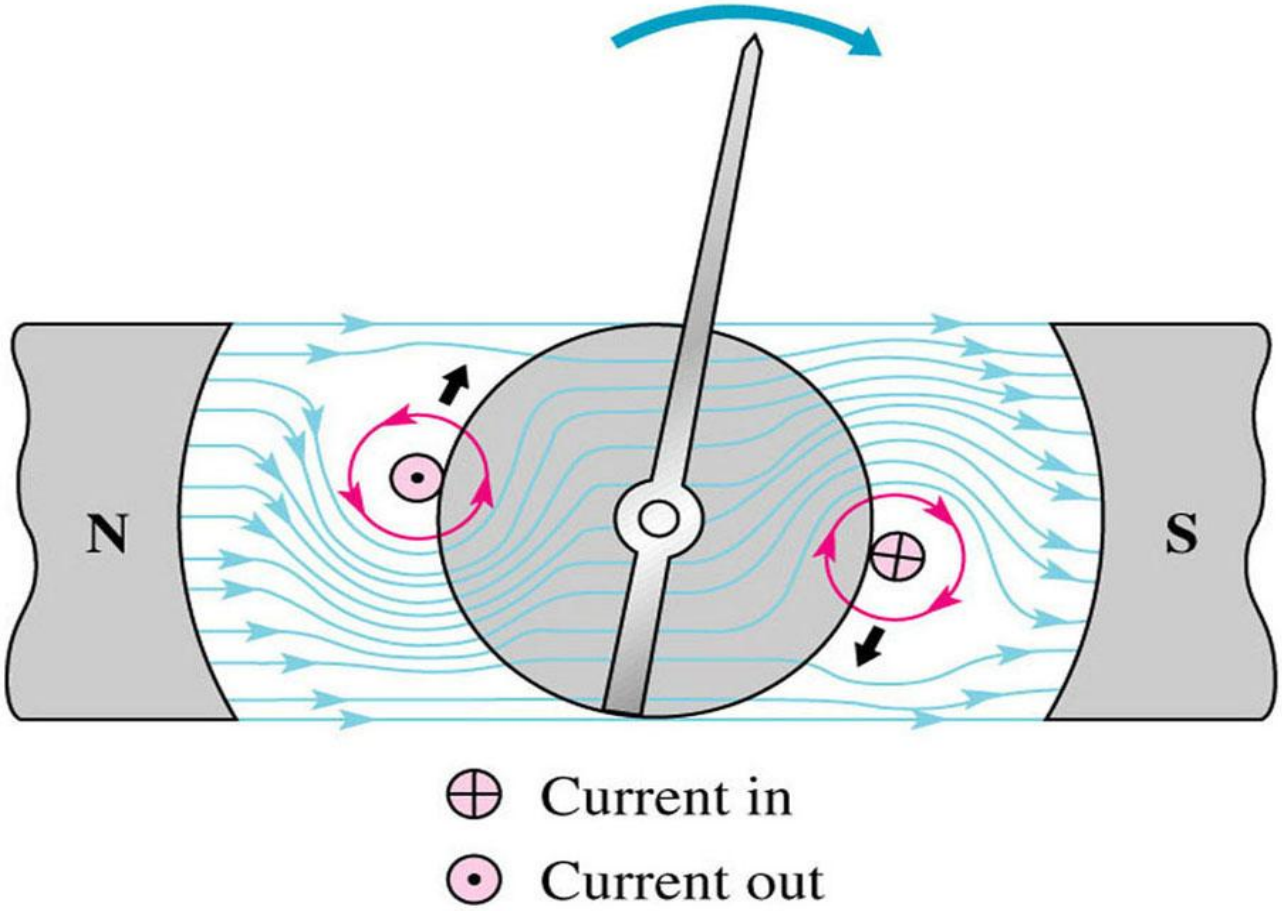




$$F = B \cdot I \cdot l$$

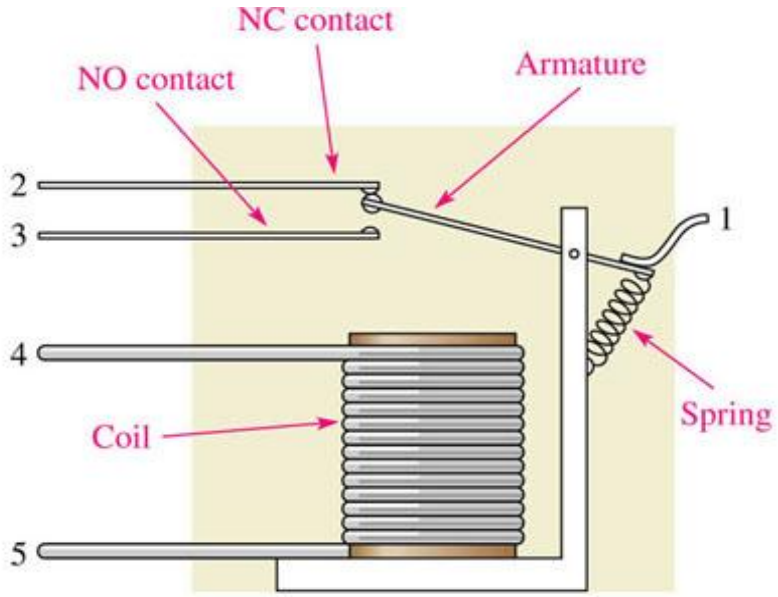
**length of the wire in the magnetic field, which is vertical to the magnetic field**

# Application of magnetic field characteristics in electrical devices

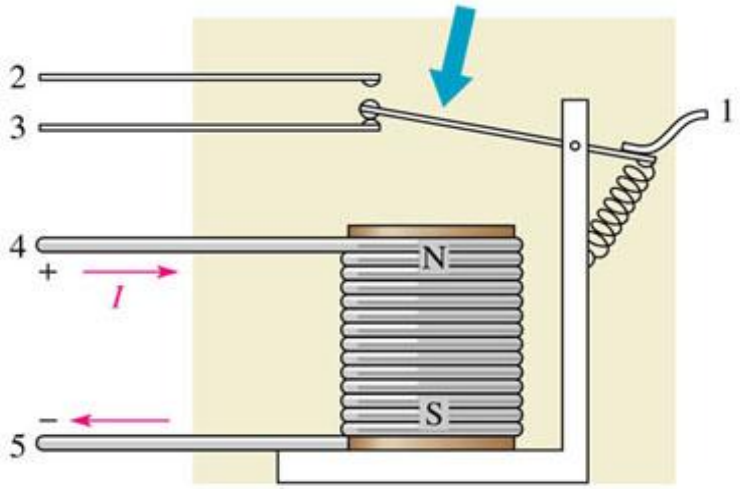
## Measuring instruments



# Relays, contactors

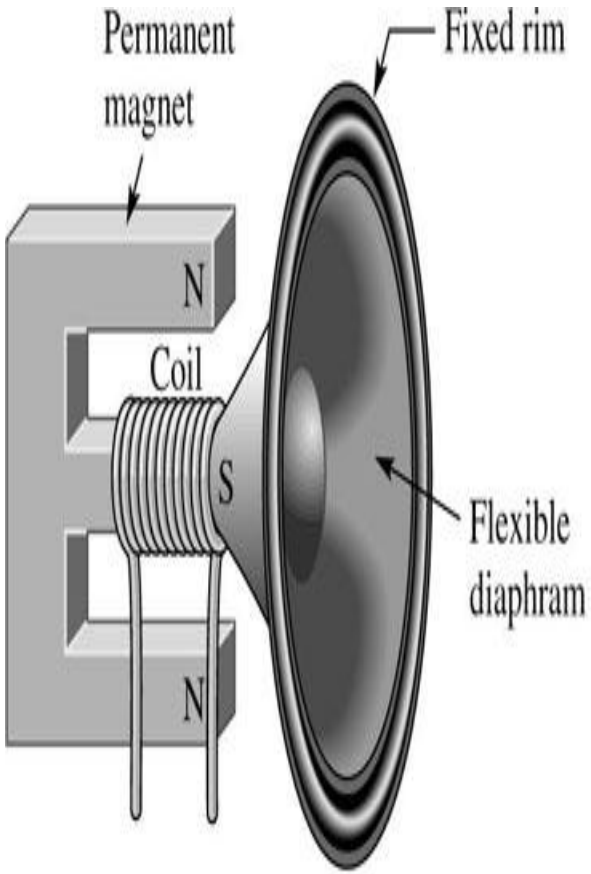



(a) Unenergized: continuity from terminal 1 to terminal 2

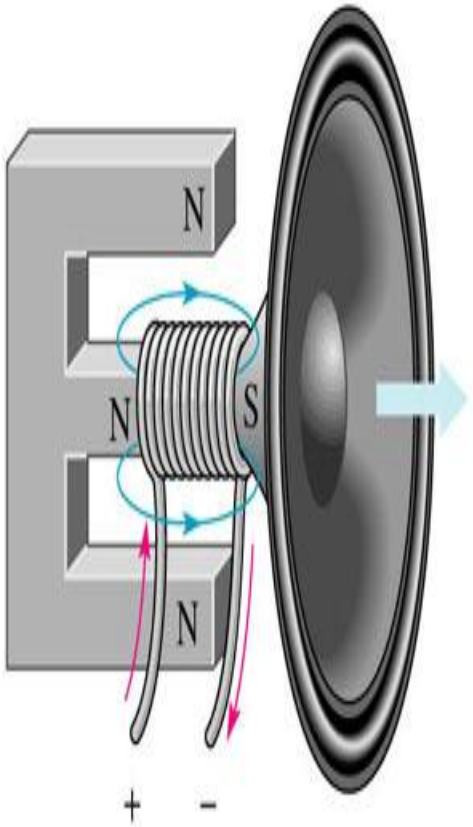



(b) Energized: continuity from terminal 1 to terminal 3

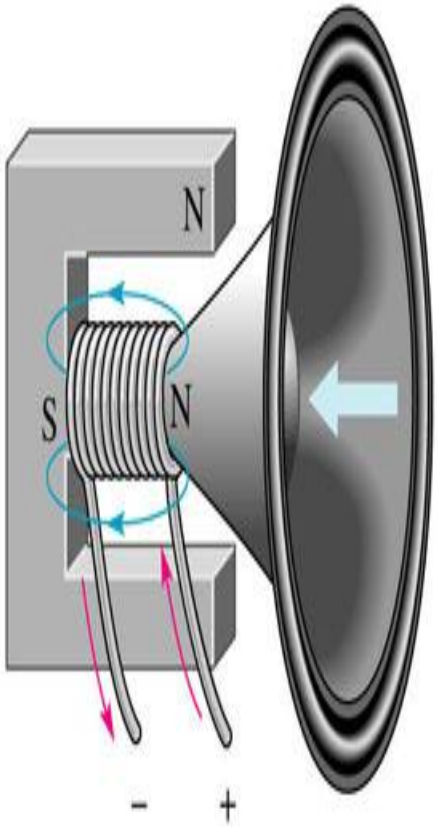
# Speakers




(a) Basic speaker construction

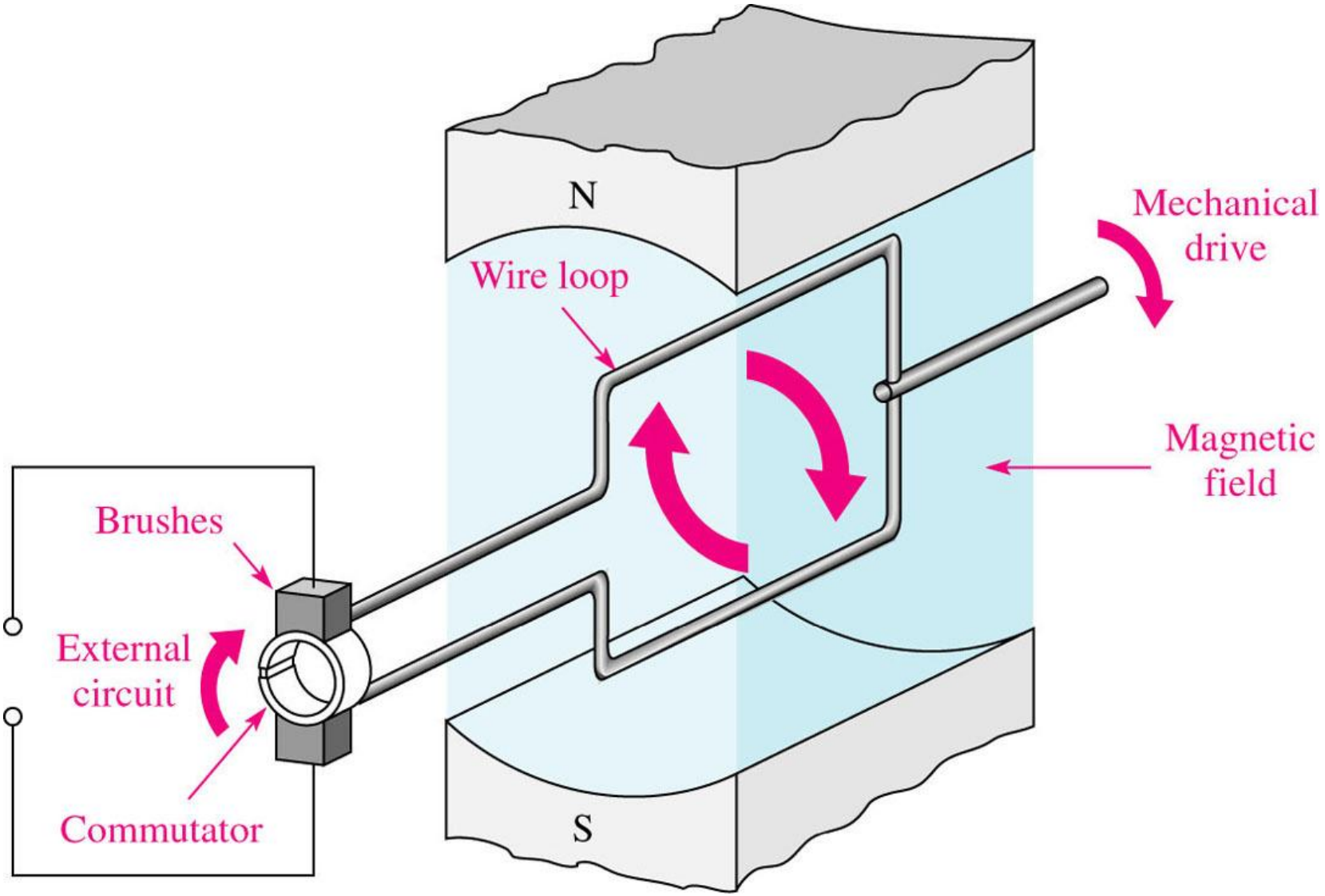



(b) Coil current producing movement of cone to the right




(c) Coil current producing movement of cone to the left

# Electrical machines



# Electromagnets

