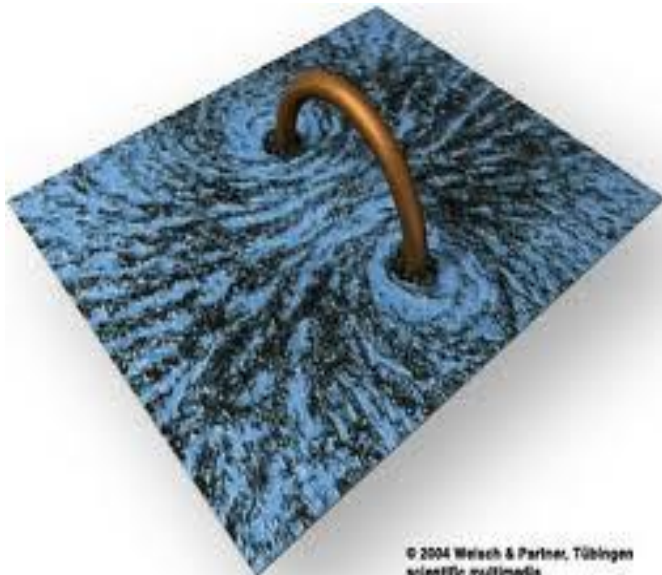
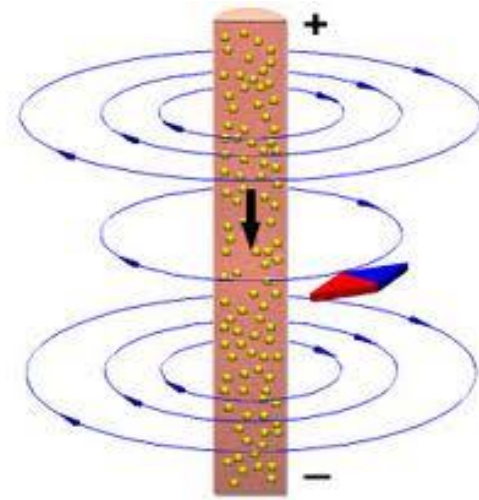


Physics

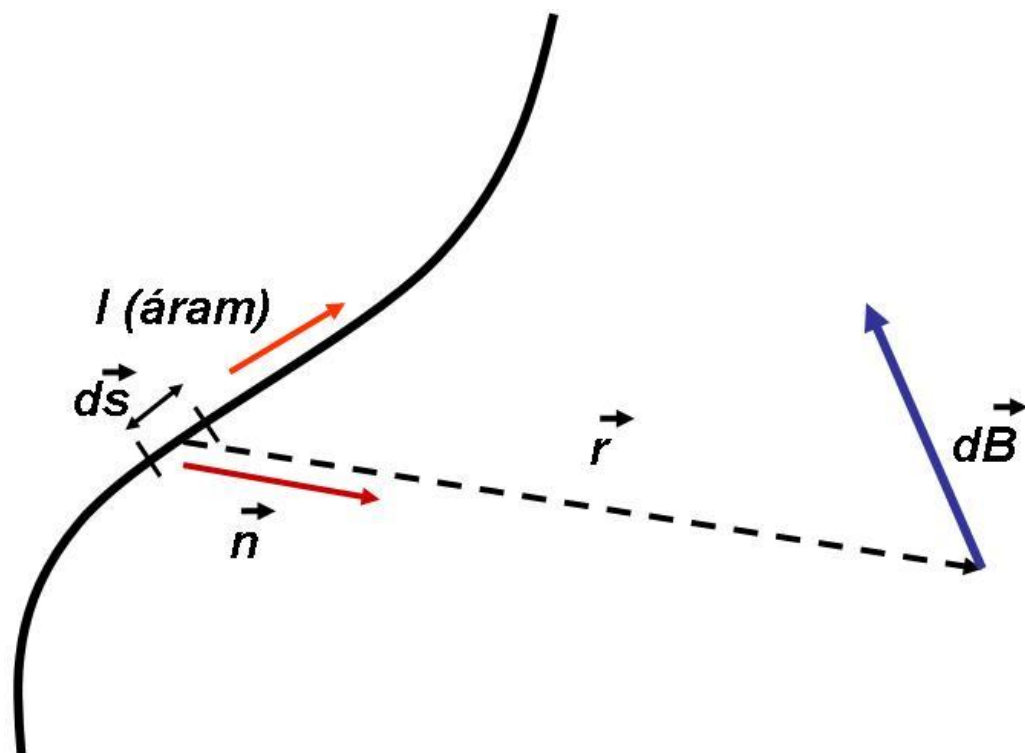
The magnetic field of moving
charged particles
and currents

Lecture 9.

The magnetic field of current

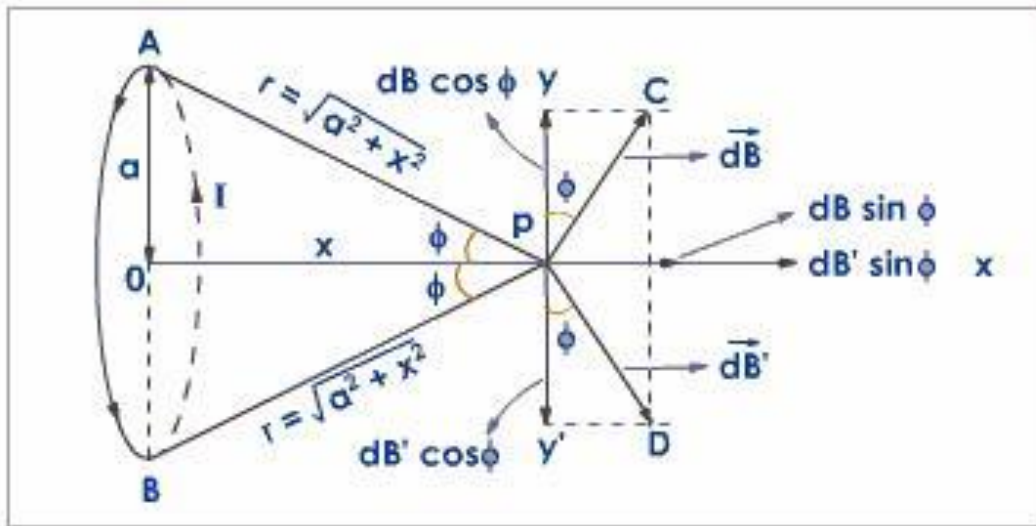


The Biot-Savart's law



$$d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{s} \times \vec{n}}{r^2}$$

Magnetic field of a current loop I.



$$dB = \frac{\mu_0}{4\pi} I \frac{ds}{r^2} = \frac{\mu_0}{4\pi} I \frac{ds}{a^2 + x^2}$$

$$dB_x = \frac{\mu_0}{4\pi} I \frac{ds}{a^2 + x^2} \sin \phi = \frac{\mu_0}{4\pi} I \frac{ds}{a^2 + x^2} \frac{a}{\sqrt{a^2 + x^2}} = \frac{\mu_0}{4\pi} I \frac{ds}{(a^2 + x^2)^{3/2}} \cdot a$$

$$B(x) = \frac{\mu_0}{2} \frac{Ia^2}{(a^2 + x^2)^{3/2}} \quad \text{or} \quad \vec{B} = \frac{\mu_0}{2\pi} \frac{\vec{\mu}}{(a^2 + x^2)^{3/2}}$$

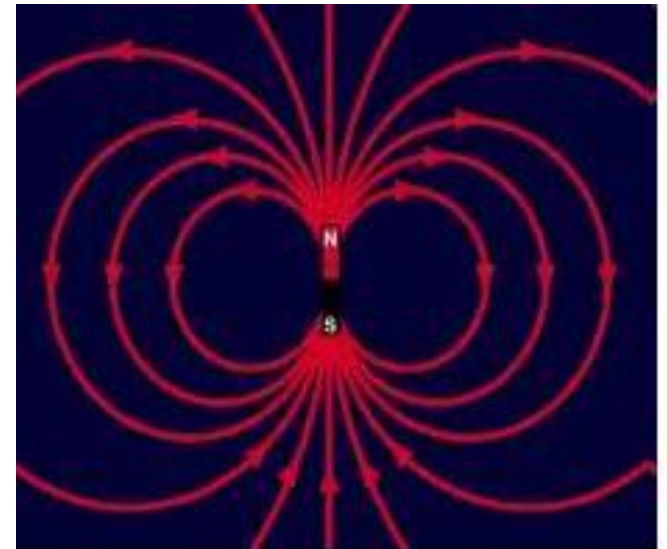
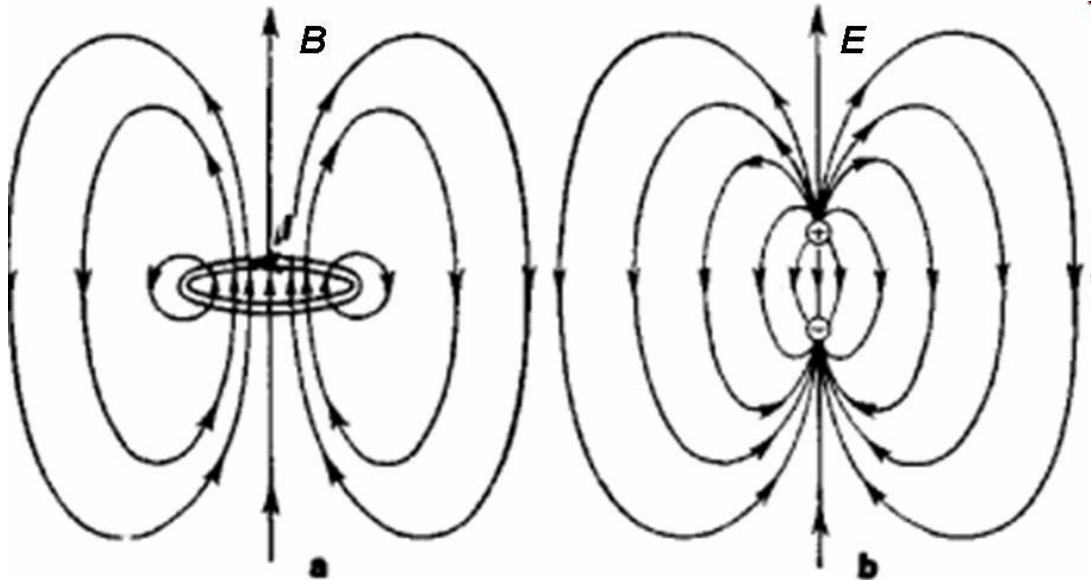
Special case:

$$B(x=0) = \frac{\mu_0}{2} \frac{I}{a}$$

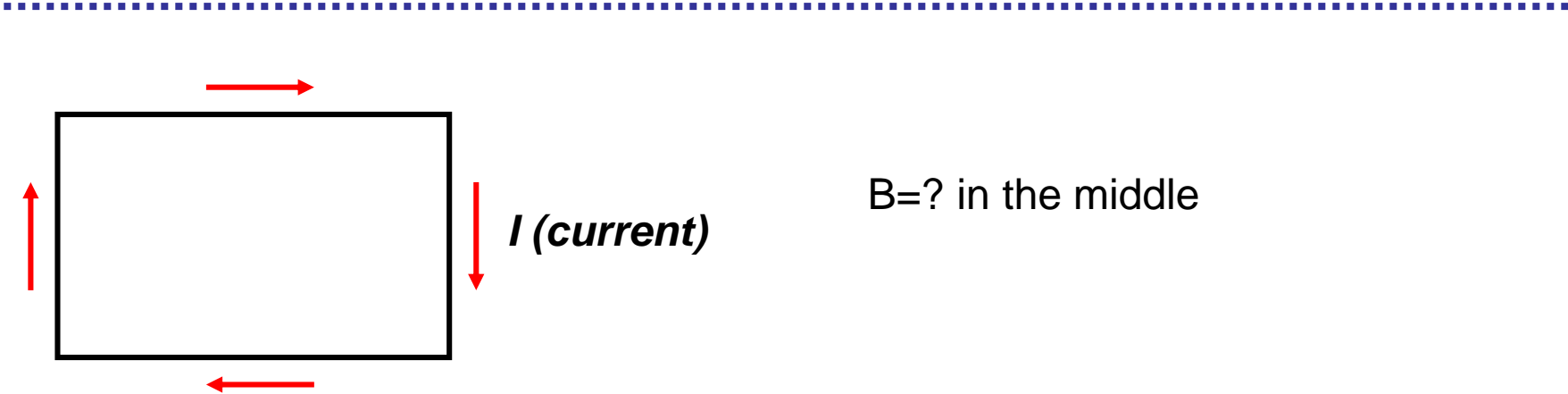
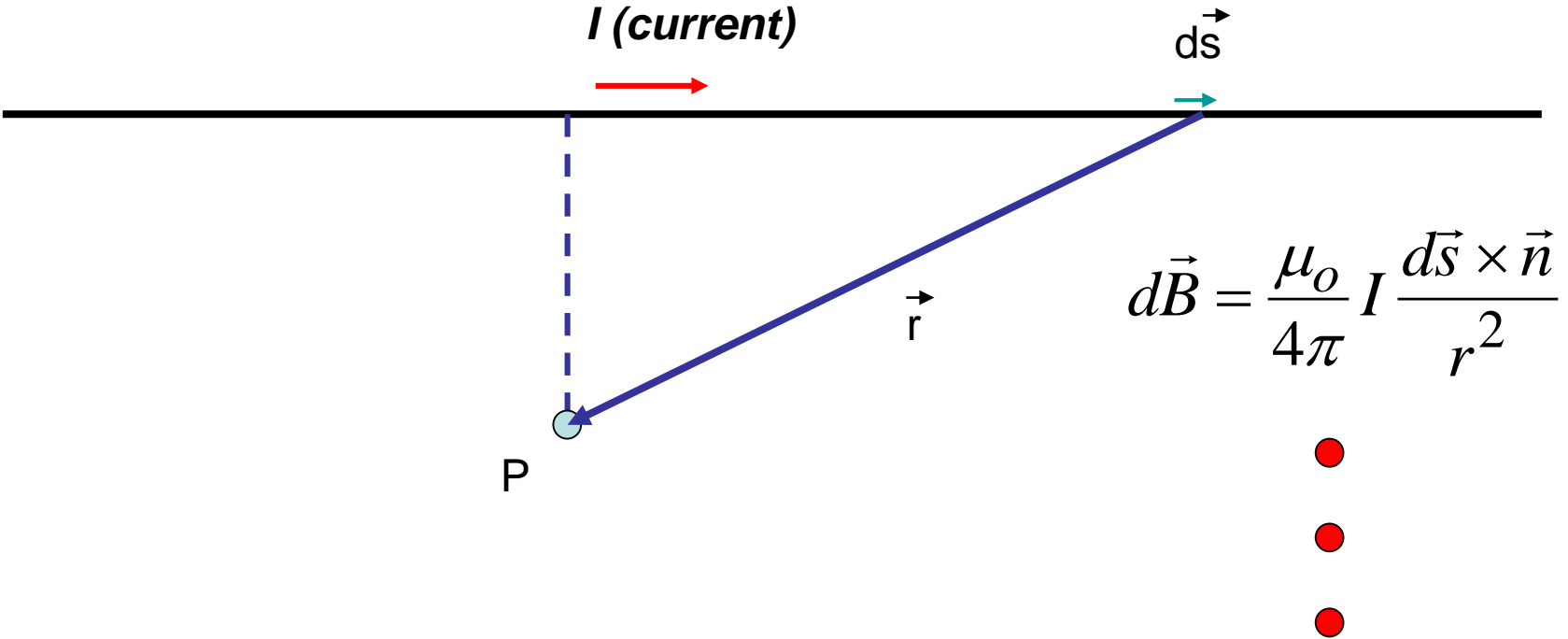
Magnetic field of a current loop II.

Special case: $B(x = 0) = \frac{\mu_0 I}{2 a}$

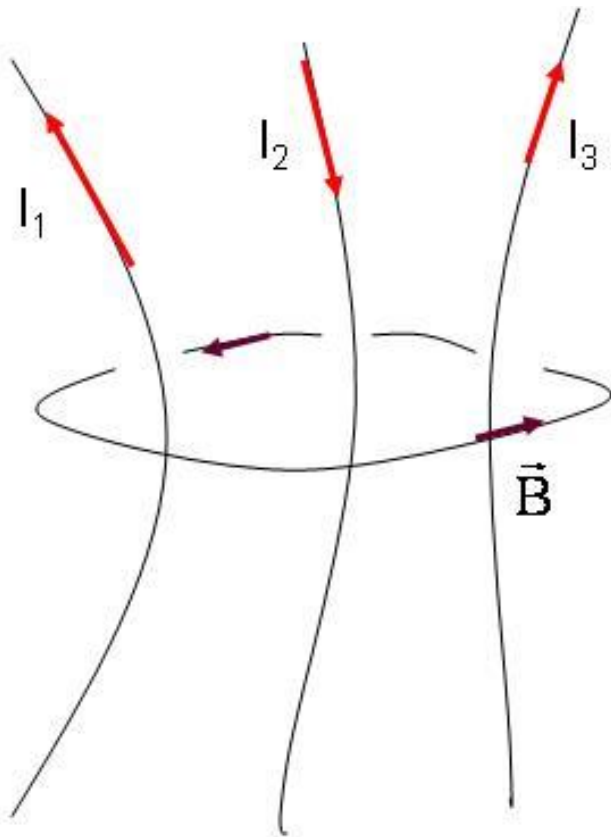
$$\vec{B} = \frac{\mu_0}{2\pi} \frac{\vec{\mu}}{(a^2 + x^2)^{3/2}} \quad \longrightarrow \quad x \gg a: \mathbf{B} \sim 1/x^3$$



An example: the ∞ current (Biot-Savart)



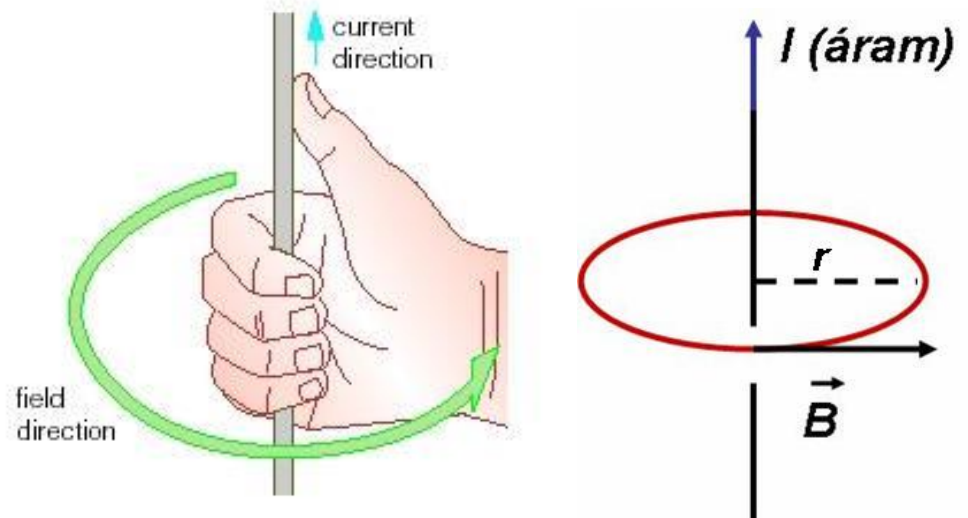
Ampère's law I.



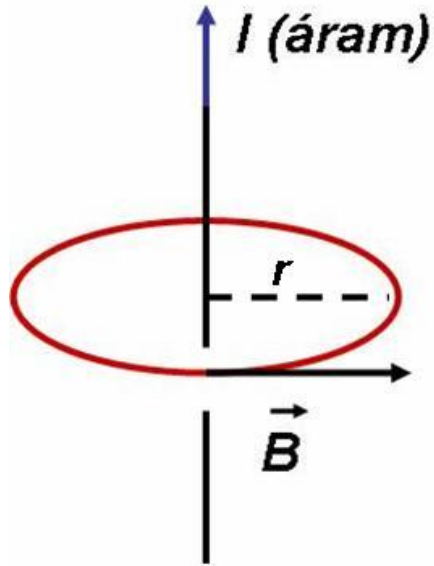
$$\Sigma I = I_1 - I_2 + I_3$$

$$\oint_s \vec{B} d\vec{s} = \mu_0 \sum_j I_j$$

Right-hand's rule:



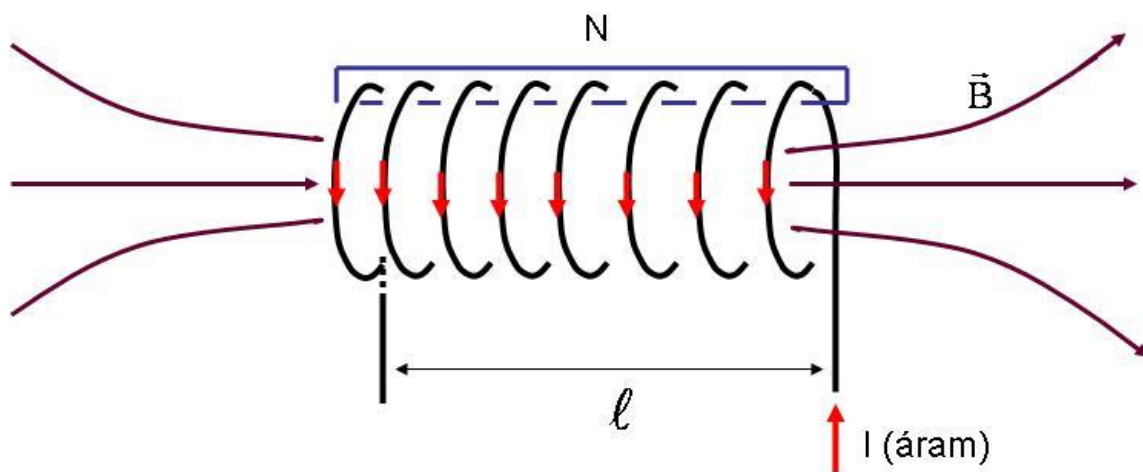
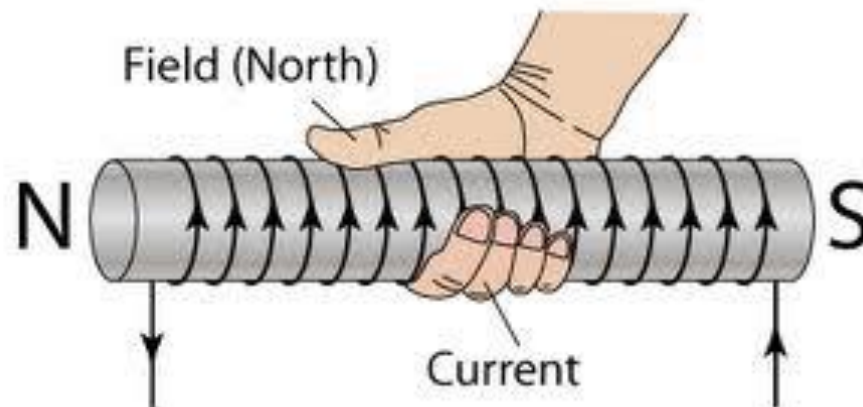
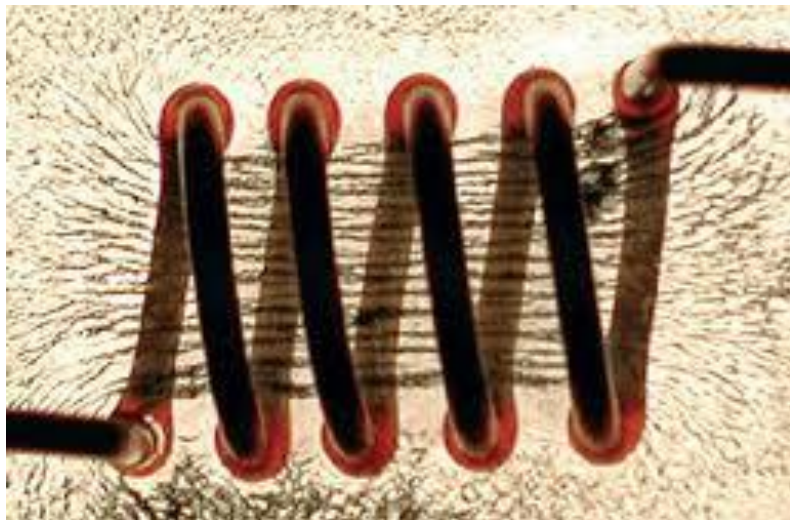
Ampère's law II.



$$\oint_s \vec{B} d\vec{s} = \mu_0 \sum_j I_j \quad \longrightarrow \quad \oint_s \vec{B} d\vec{s} = 2r\pi B \quad \text{ill.} \quad \mu_0 \sum_j I_j = \mu_0 I$$

$$2r\pi B = \mu_0 I \quad \Rightarrow \quad B = \frac{\mu_0 I}{2r\pi}$$

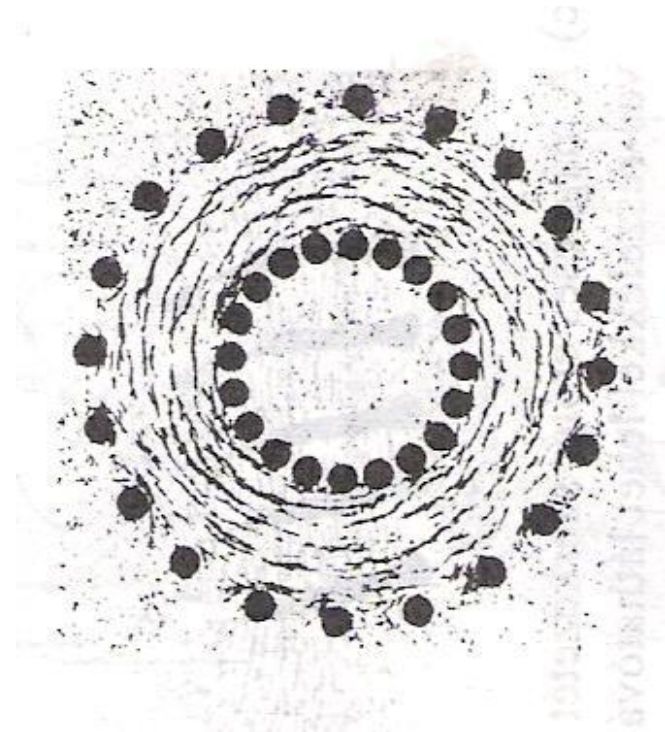
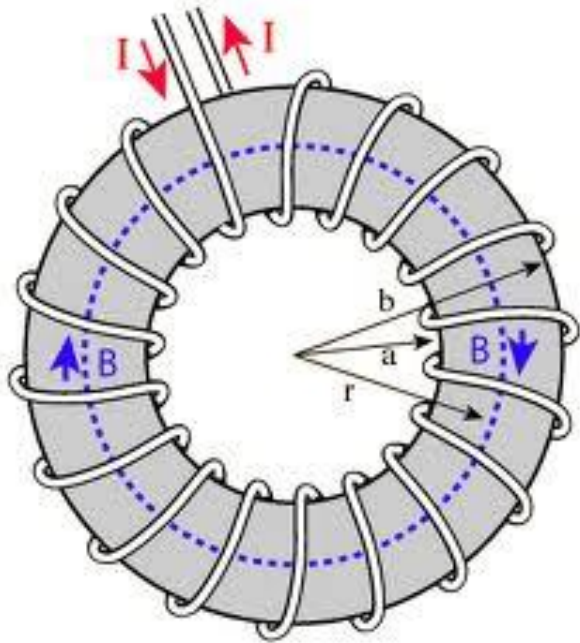
Ampère's law III.



$$\oint_s \vec{B} d\vec{s} = \mu_o \sum_j I_j$$

$$B = \frac{\mu_o NI}{\ell}$$

Ampère's law IV.

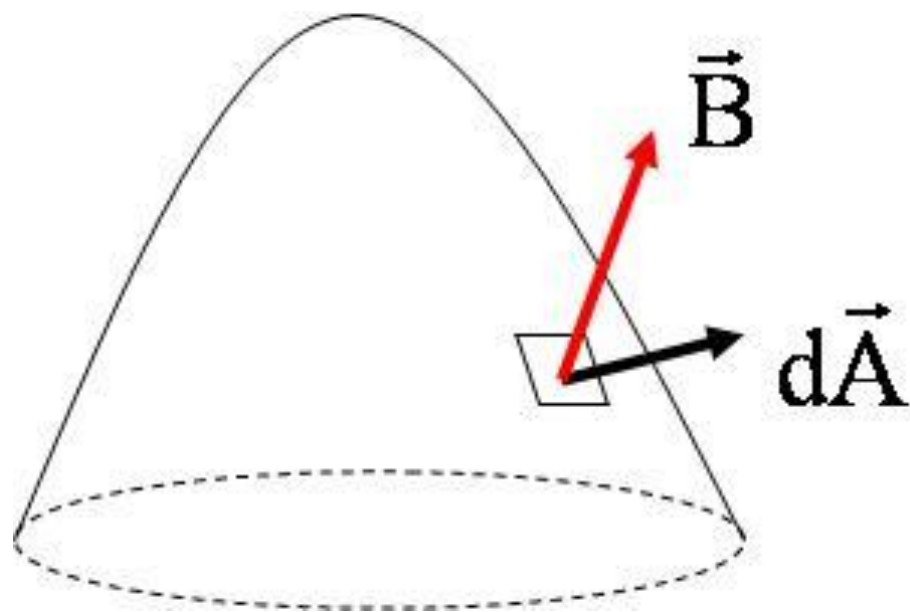


$$B = \frac{\mu_0 NI}{2r\pi}$$

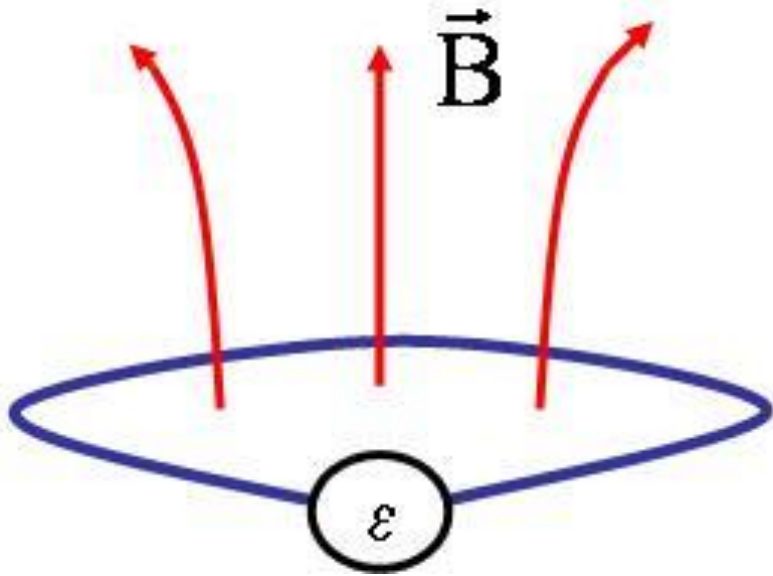
Induction I.

The magnetic flux:

$$\Phi_m = \int_A \vec{B} d\vec{A}$$



Induction II.

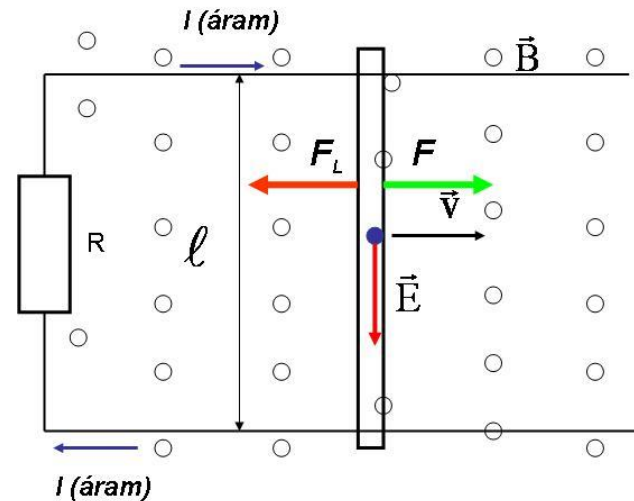
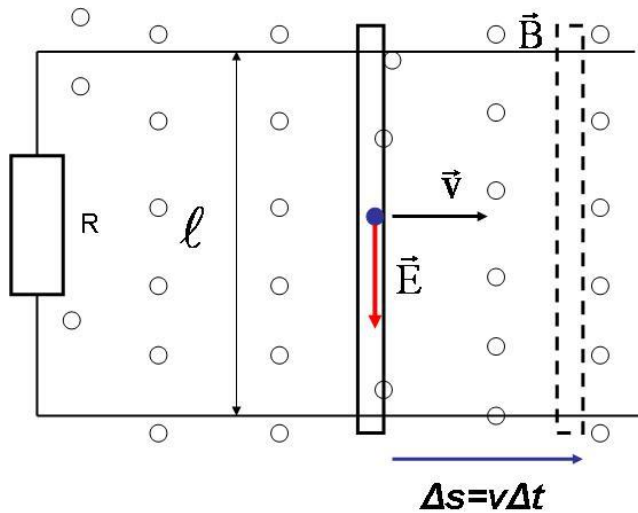


Electromotive force: $\varepsilon = \oint \vec{E} d\vec{s}$

$$\varepsilon = - \frac{d\Phi_m}{dt}$$

Lenz's law

Induction III.



$$\Delta\Phi_m = Blv\Delta t \longrightarrow |\varepsilon| = \frac{Blv\Delta t}{\Delta t} = Blv$$

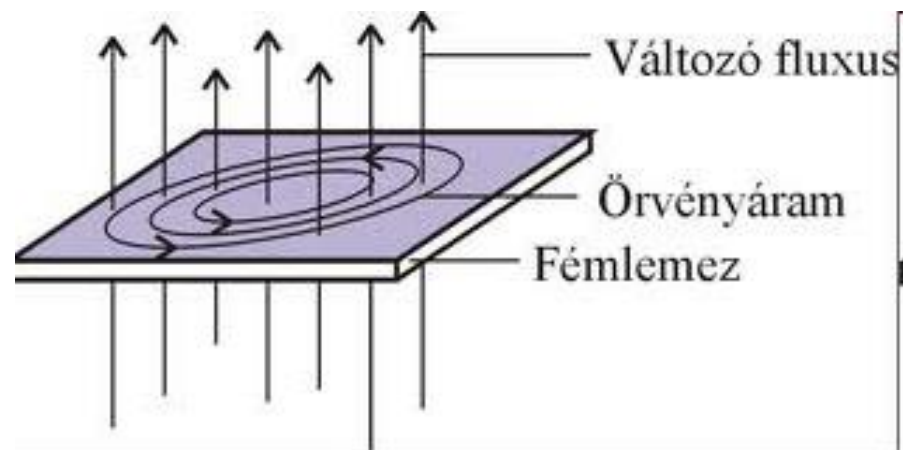
$$I = \frac{Blv}{R}$$

$$F_L = BI\ell = \frac{B^2\ell^2v}{R}$$

$$P = F_L v = \frac{B^2\ell^2v^2}{R}$$

$$P = I^2 R = \left(\frac{Blv}{R}\right)^2 R = \frac{B^2\ell^2v^2}{R}$$

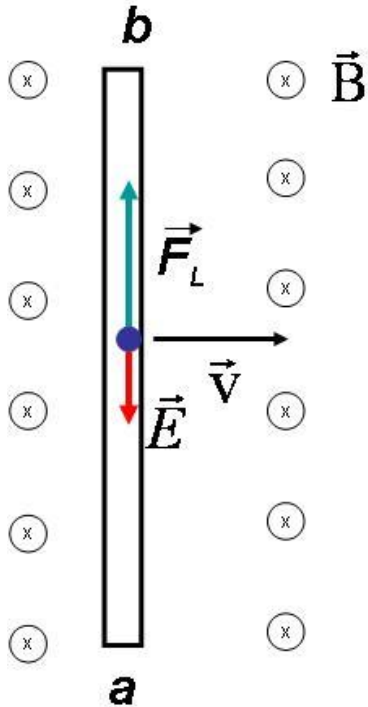
Eddy current



Induction oven (cooker)
Induction break

- .
- .
- .

Induction IV.

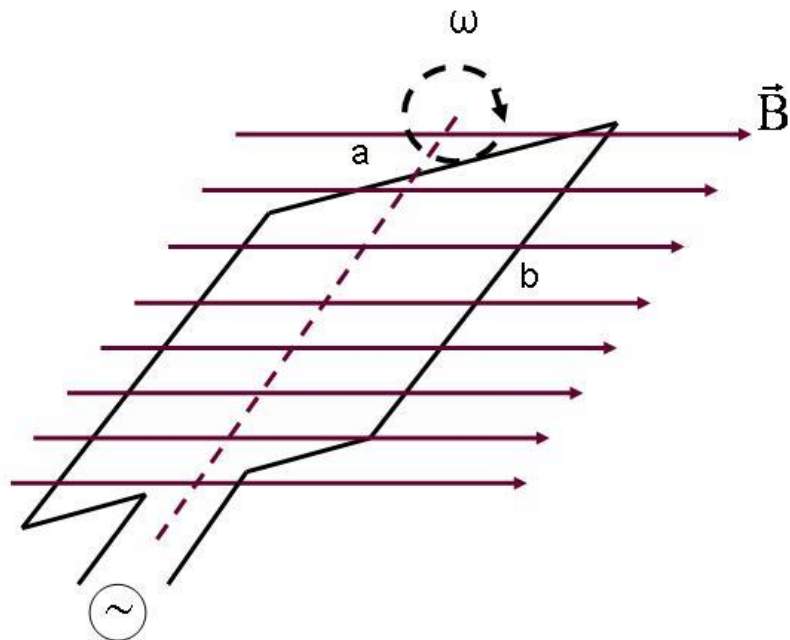


$$qE = qvB \Rightarrow E = vB$$

$$\varepsilon = V_{ab} = E\ell = vB\ell$$

Example: blades of helicopter

Alternating voltage generator



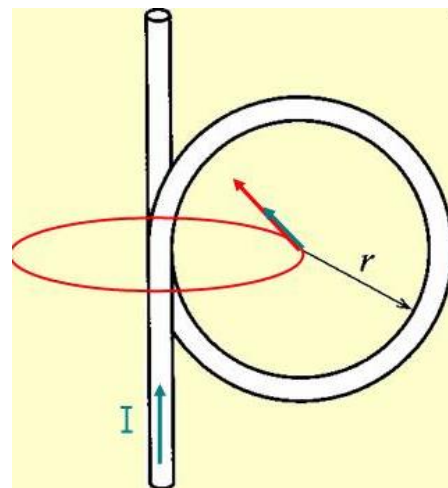
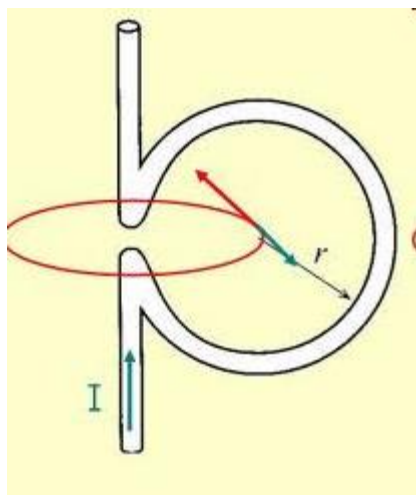
V (indukált feszültség)

$$A = ab$$

$$\Phi_m = BA \cos(\omega t)$$

$$\varepsilon = -\frac{d\Phi_m}{dt} = V(t) = BA \omega \sin(\omega t) = V_o \sin(\omega t)$$

Examples:



+

