Physics

The magnetic field

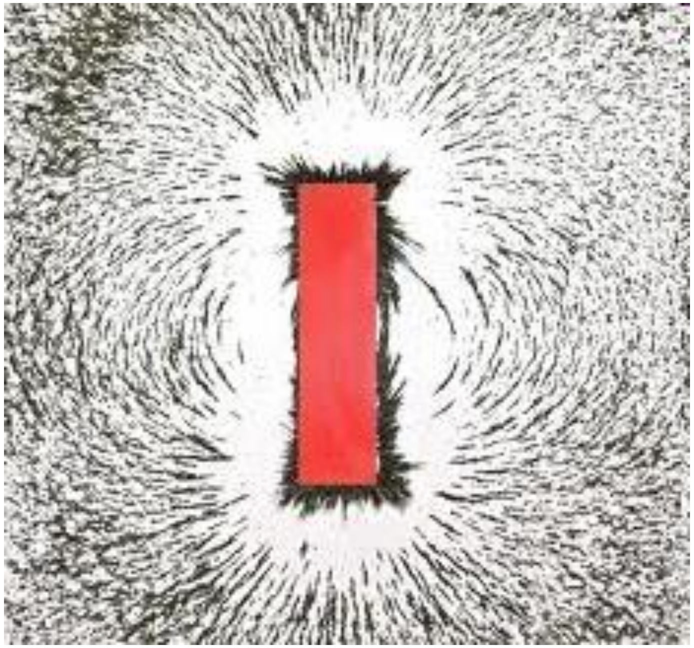
8. lecture

The magnetic field

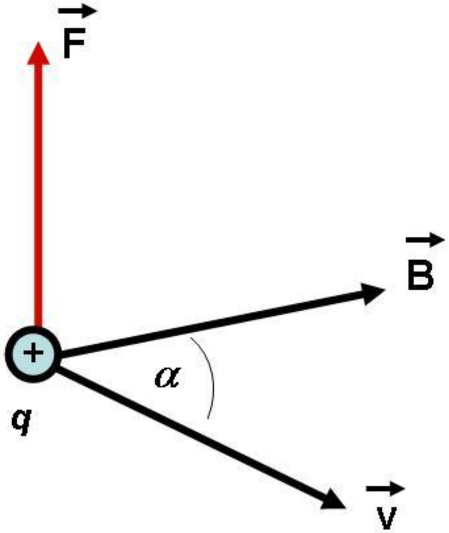
Symbol: *B*

Unit: Tesla = Ns/Cm

The magnetic field of the Earth
(at equator) appr. $3*10^{-5}$ T



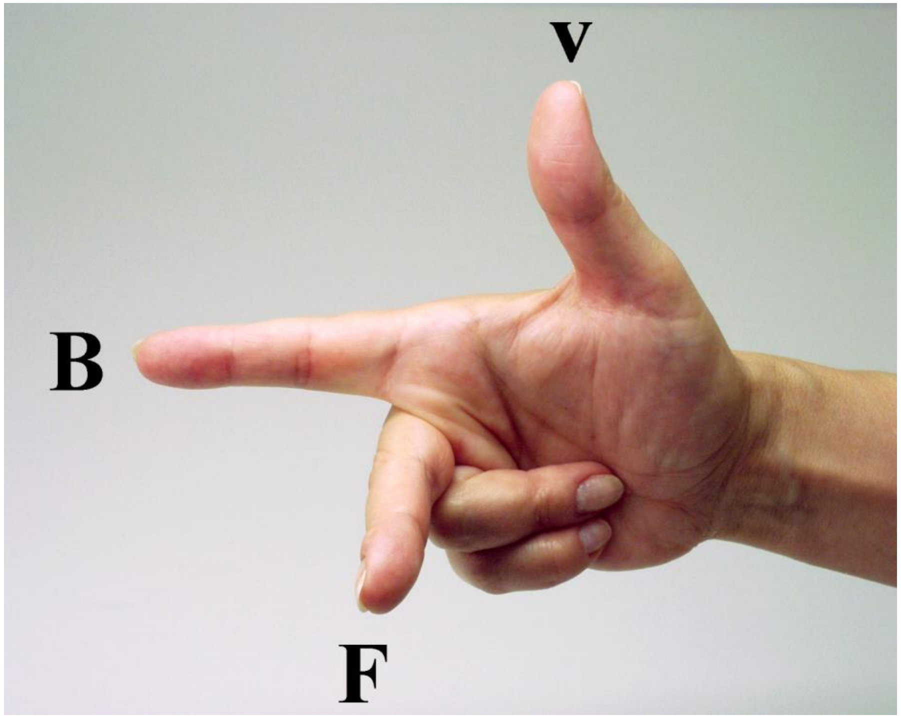
Lorentz-force: $\vec{F} = q\vec{v} \times \vec{B}$



Magnitude of Lorentz-force:

$$F = qvB\sin\alpha$$

The right-hand's rule



E ≠ 0: **Lorentz-force:** $\vec{F} = q\left[\vec{E} + \vec{v} \times \vec{B}\right]$

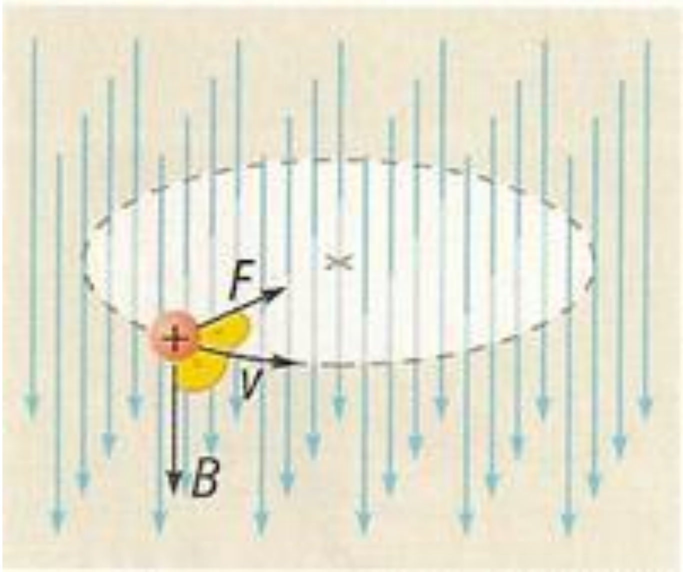
Charged particles in uniform electric and magnetic field I.

E = 0

B : uniform

$$qvB = m\frac{v^2}{R}$$

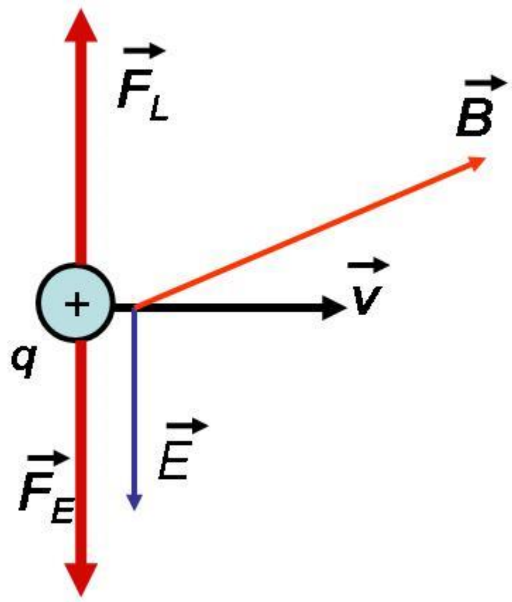
$$R = \frac{mv}{qB}$$

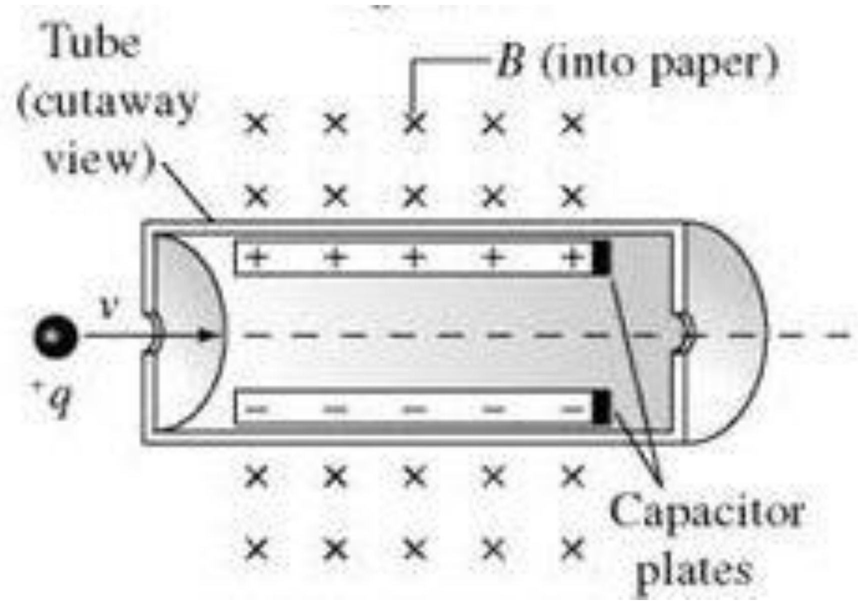


Period: $$T = \frac{2R\pi}{v} \longrightarrow T = \frac{2\pi m}{qB}$$

Charged particles in uniform electric and magnetic field II.

The velocity-selector:



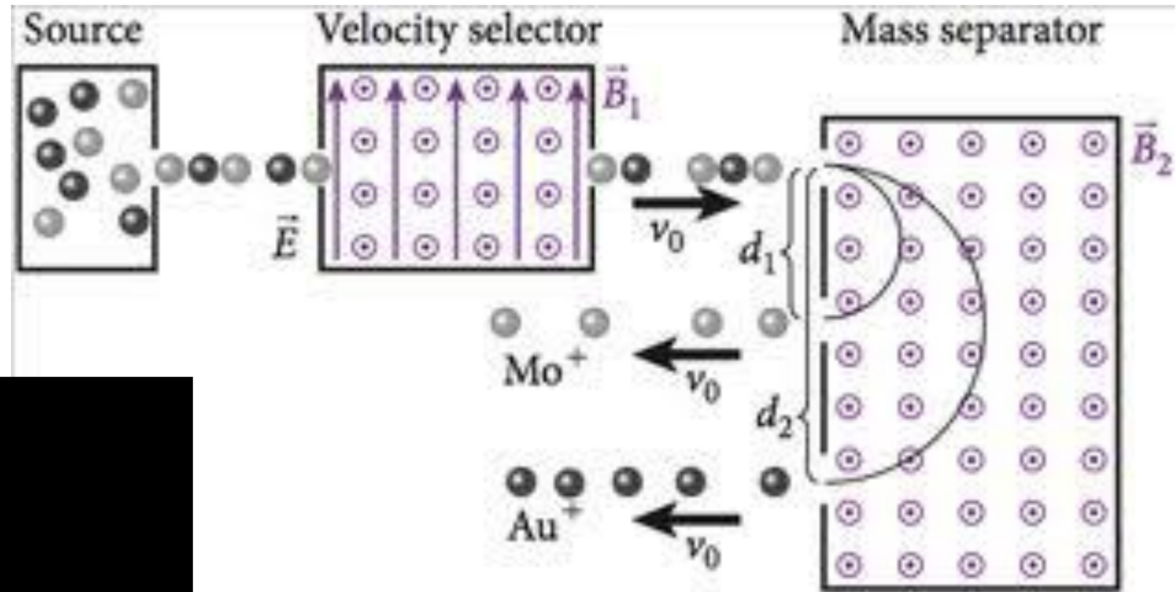


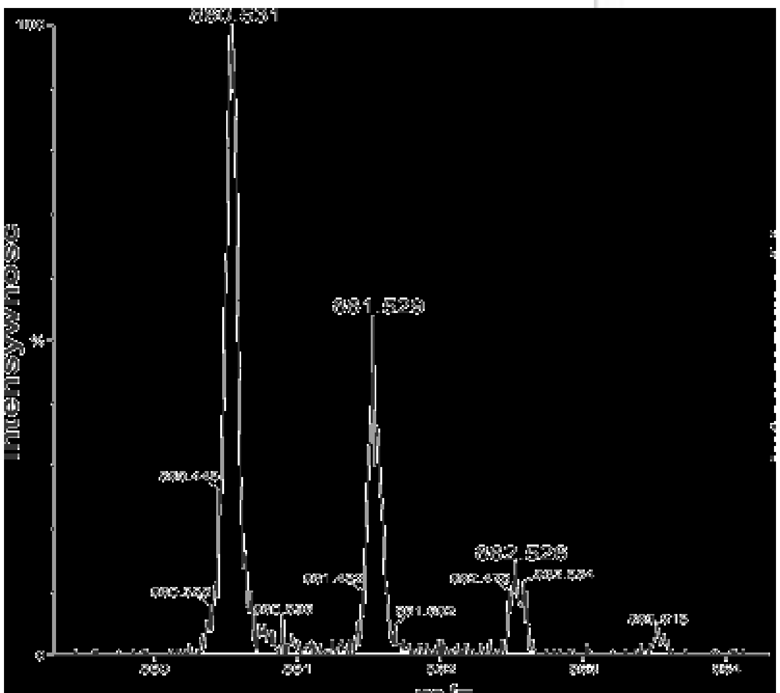
$$qE = qvB$$

$$v = \frac{E}{B}$$

Charged particles in uniform electric and magnetic field III.

The mass spectrometer:

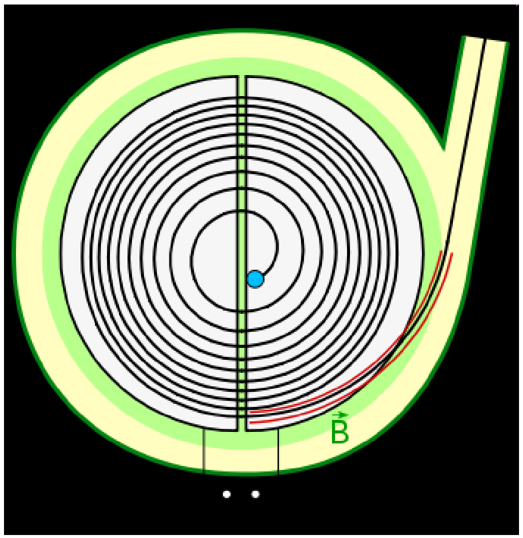


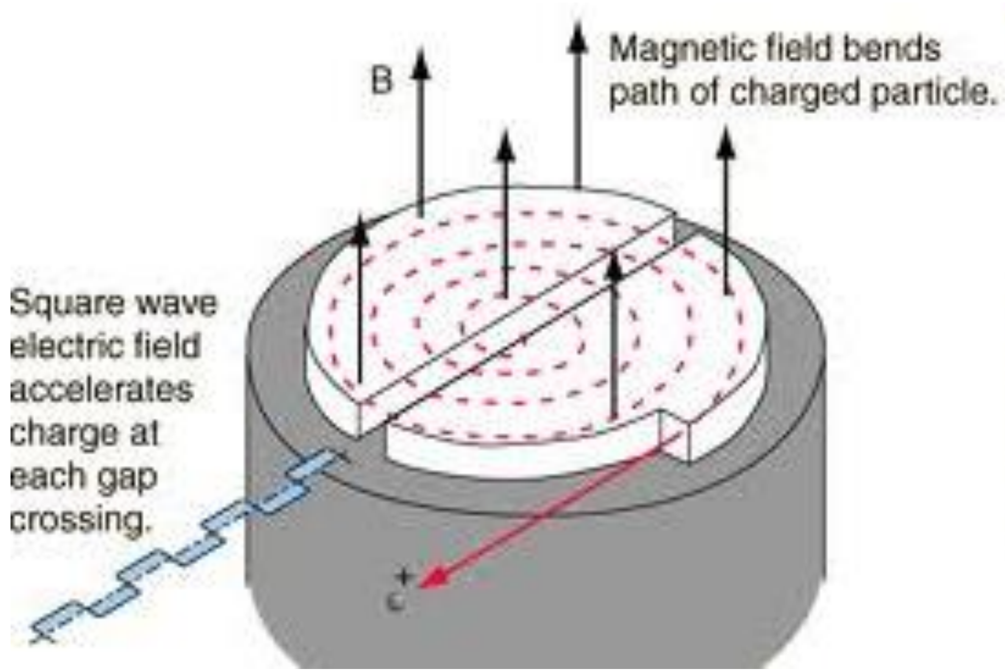


We have seen (cyclotron): R ~ mv

Charged particles in uniform electric and magnetic field IV.

The cyclotron



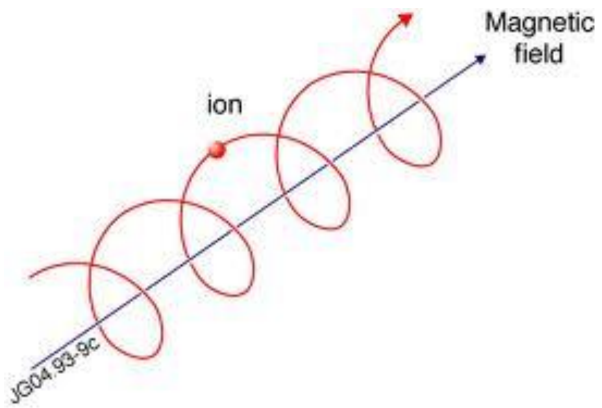


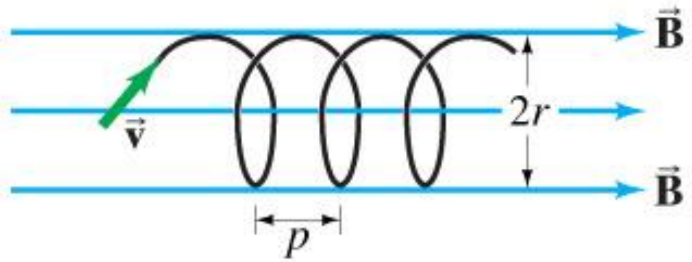
The cyclotron-frequency: f = 1/T

$$f = \frac{qB}{\pi m}$$

Charged particles in uniform electric and magnetic field V.

Electron-mycroscope:





$$p = v_B T = v\cos(\theta)\frac{2\pi m}{qB}$$

If θ is small (< 5°) → $cos(\theta) \approx 1$ → the beam focused

Charged particles in uniform electric and magnetic field VI.

Force acting on the current (wire):

$$\vec{F} = q\vec{v} \times \vec{B} \quad \Rightarrow \quad d\vec{F} = dq\vec{v} \times \vec{B} = dq\frac{d\vec{s}}{dt} \times \vec{B} = \frac{dq}{dt} d\vec{s} \times \vec{B}$$

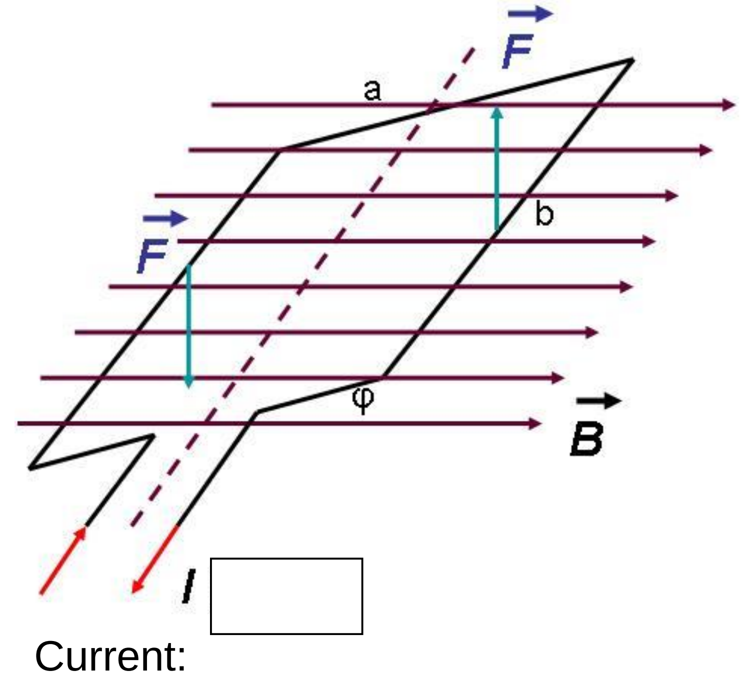
$$\vec{F} = I\int_{s} d\vec{s} \times \vec{B}$$

Special case:

B uniform, the lenght of the wire: ℓ

$$\vec{F} = I\vec{\ell} \times \vec{B}$$

Current loop in magnetic field, magnetic moment



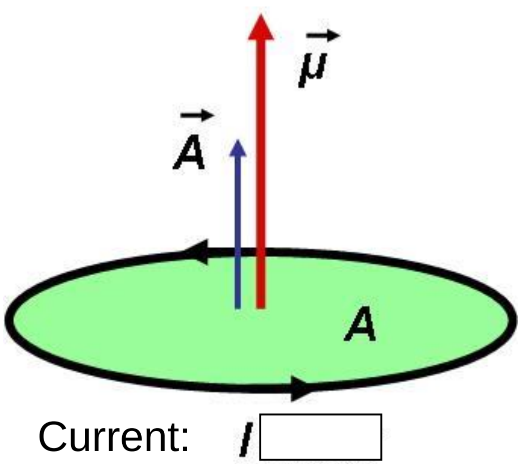
Force acting on wire(s): ***F = IbB***

$$M = 2\frac{a}{2}F\cos\varphi = IabB\cos\varphi \quad \Rightarrow \quad M = IAB\cos\varphi$$

$$\vec{M} = I\vec{A}\times\vec{B}$$

$$\vec{M} = \vec{\mu}\times\vec{B}$$

$$\vec{\mu} = I\vec{A}$$



The potential energy of magnetic moment in magnetic field:

$$U = -\vec{\mu}\vec{B}$$

Electrostatics (analogy):

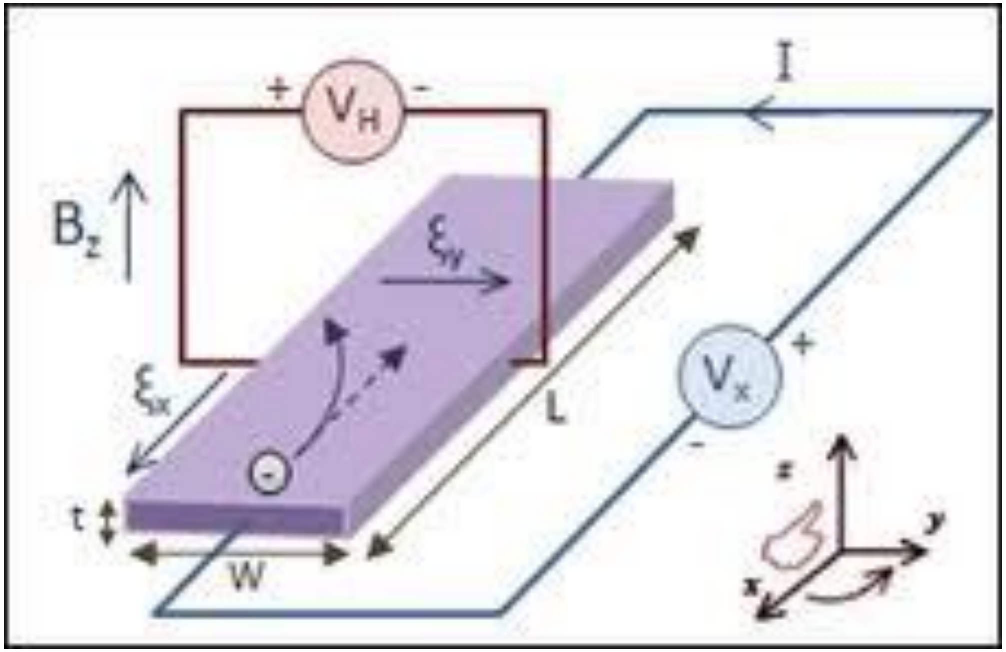
$$U = -\vec{p}\vec{E}$$

Charged particles in uniform electric and magnetic field VII.

Hall effect:

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$E = v_d B$$

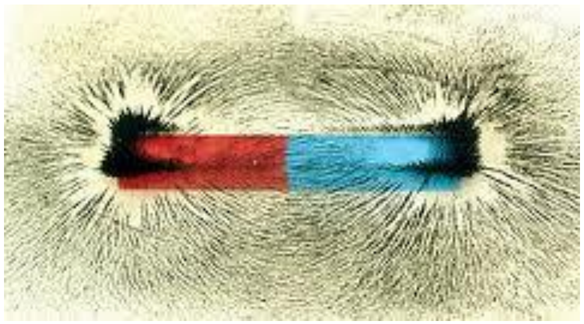


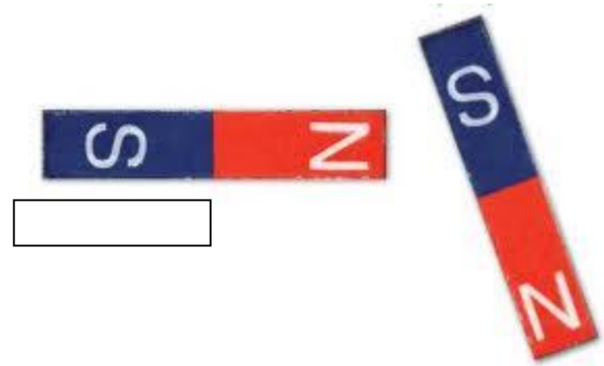
Hall-potential: $V_H = Ew = v_d Bw$

$$V_H = \frac{BI}{nq_e t}$$

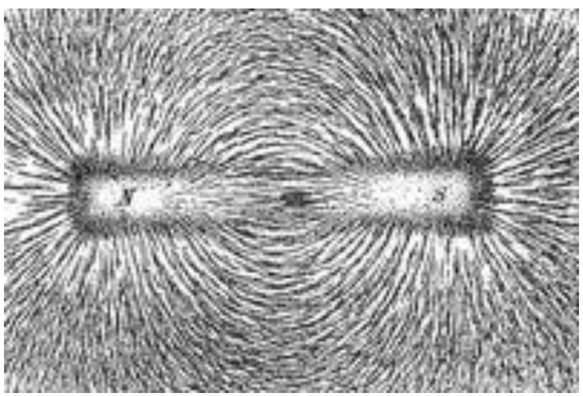
Measurement of B → Hall detector

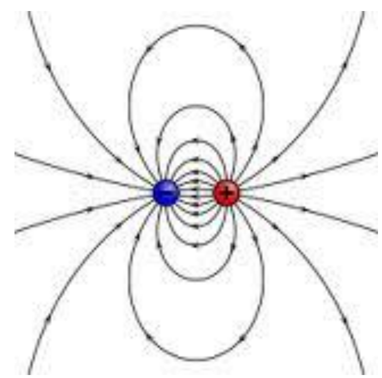
Magnetic field of a magnet





Analogy → electric dipole

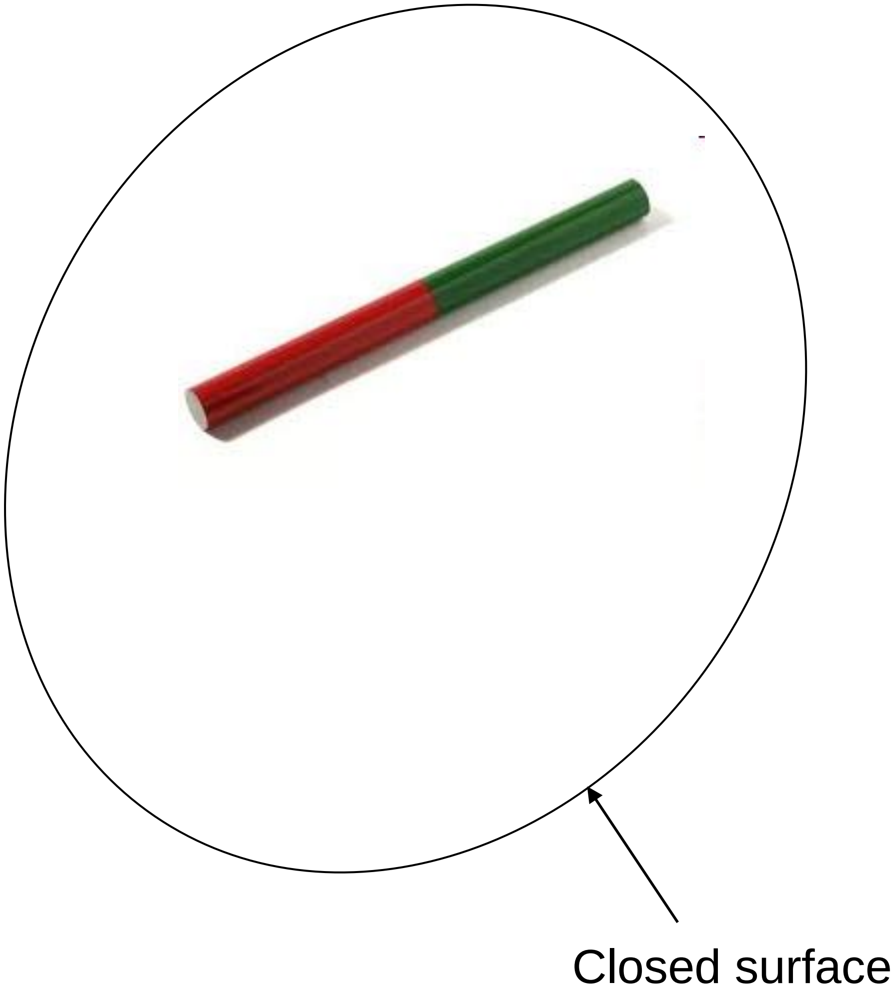




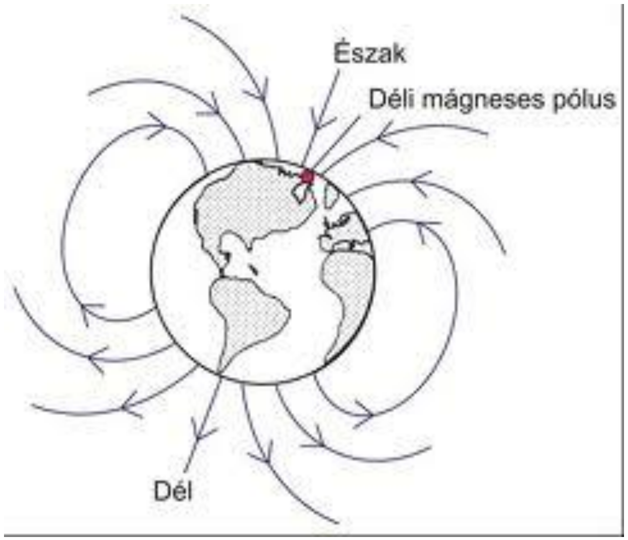
The magnetic Gauss's law

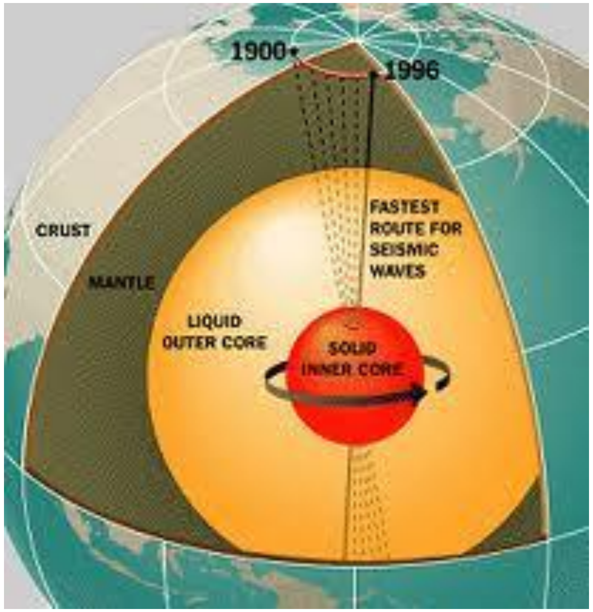
$$\oint_A \vec{B} d\vec{A} = 0$$

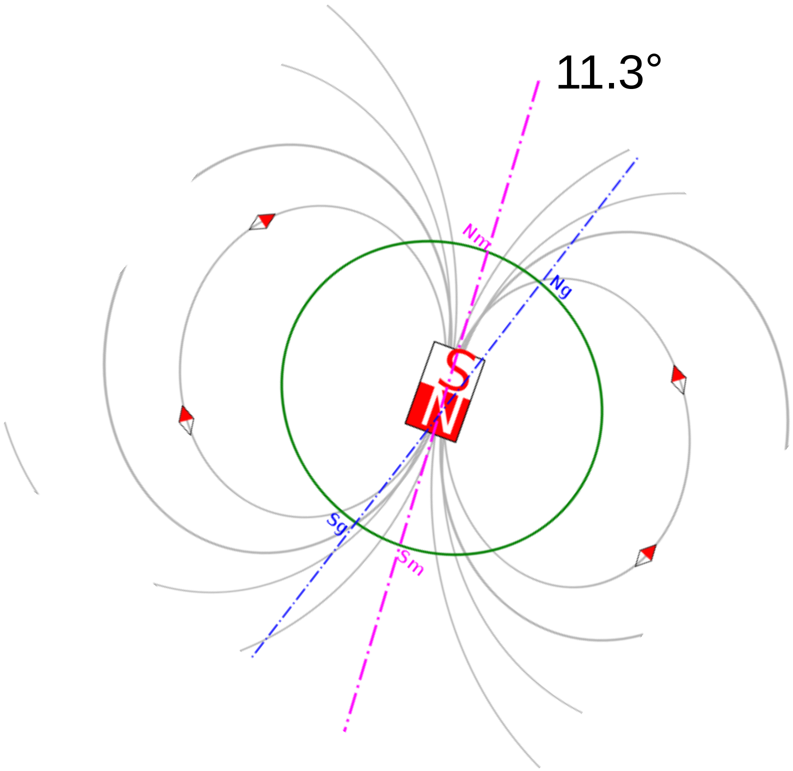
There is no magnetic monopole !!!



The magnetic field of Earth







The Van-Allen belt