Monday March 27, 2017

Last time:

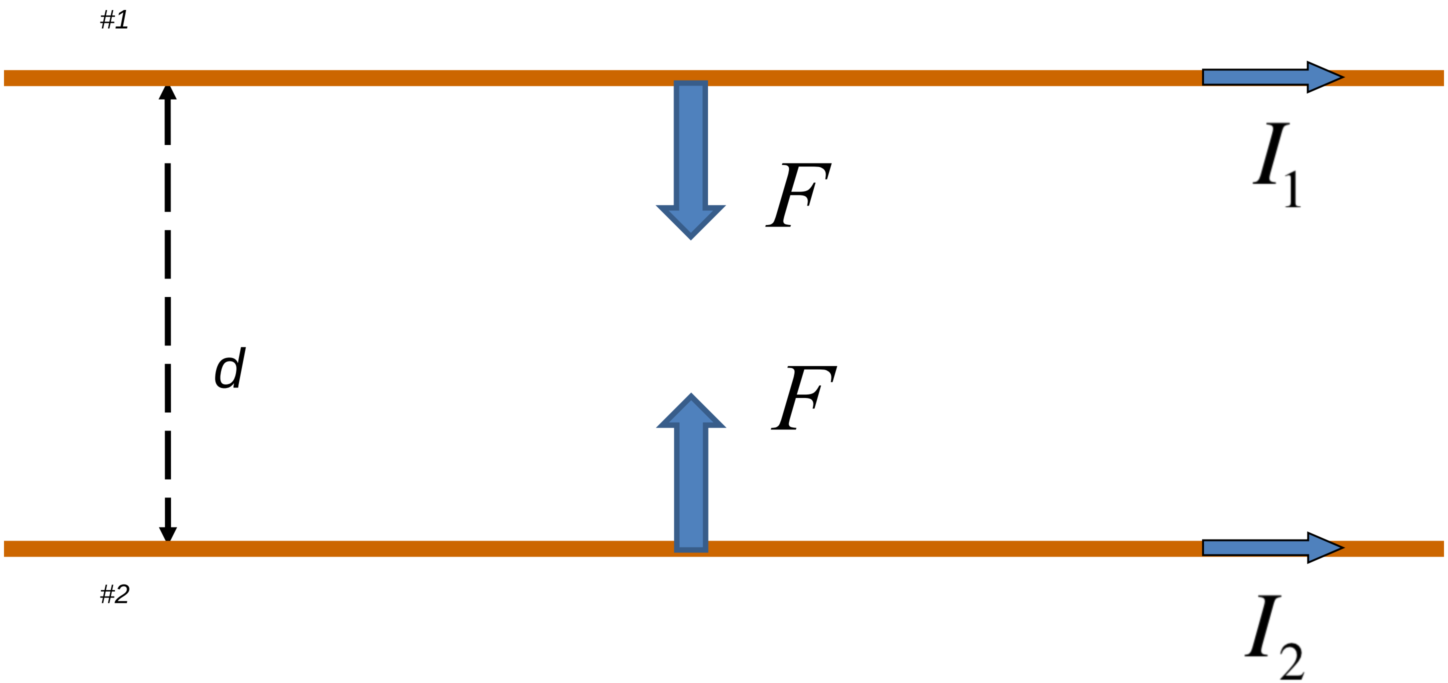
- Charge to mass apparatus demonstration
- Group activity

Today:

- Magnetic force between parallel current-carrying wires
- Torque on a current loop
- Biot-Savart Law (like Coulomb's Law for magnetism)
- B-field of a line of current

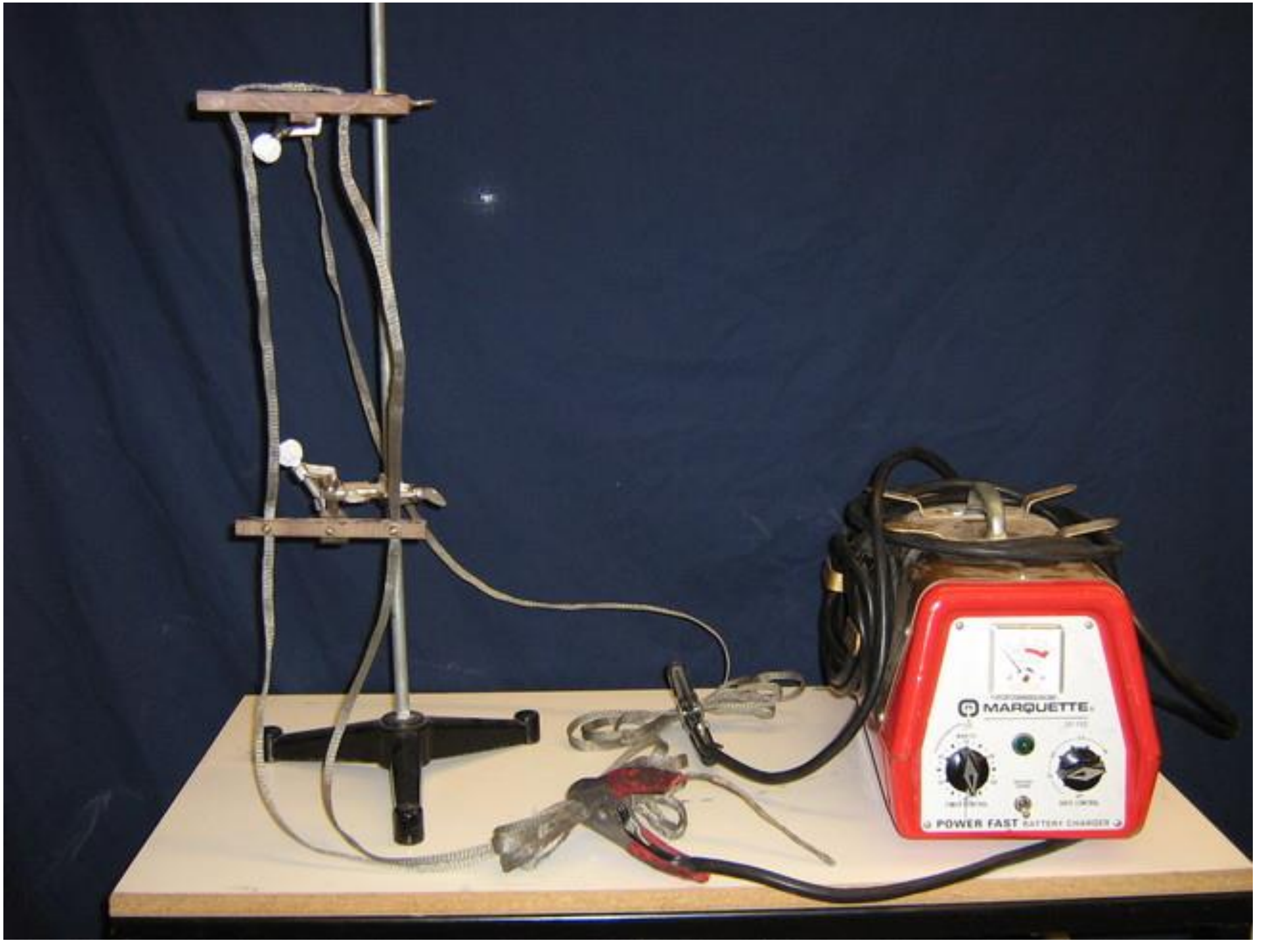
Force Between Two Parallel Wires

$$\vec{F}_B = i\vec{L} \times \vec{B}$$



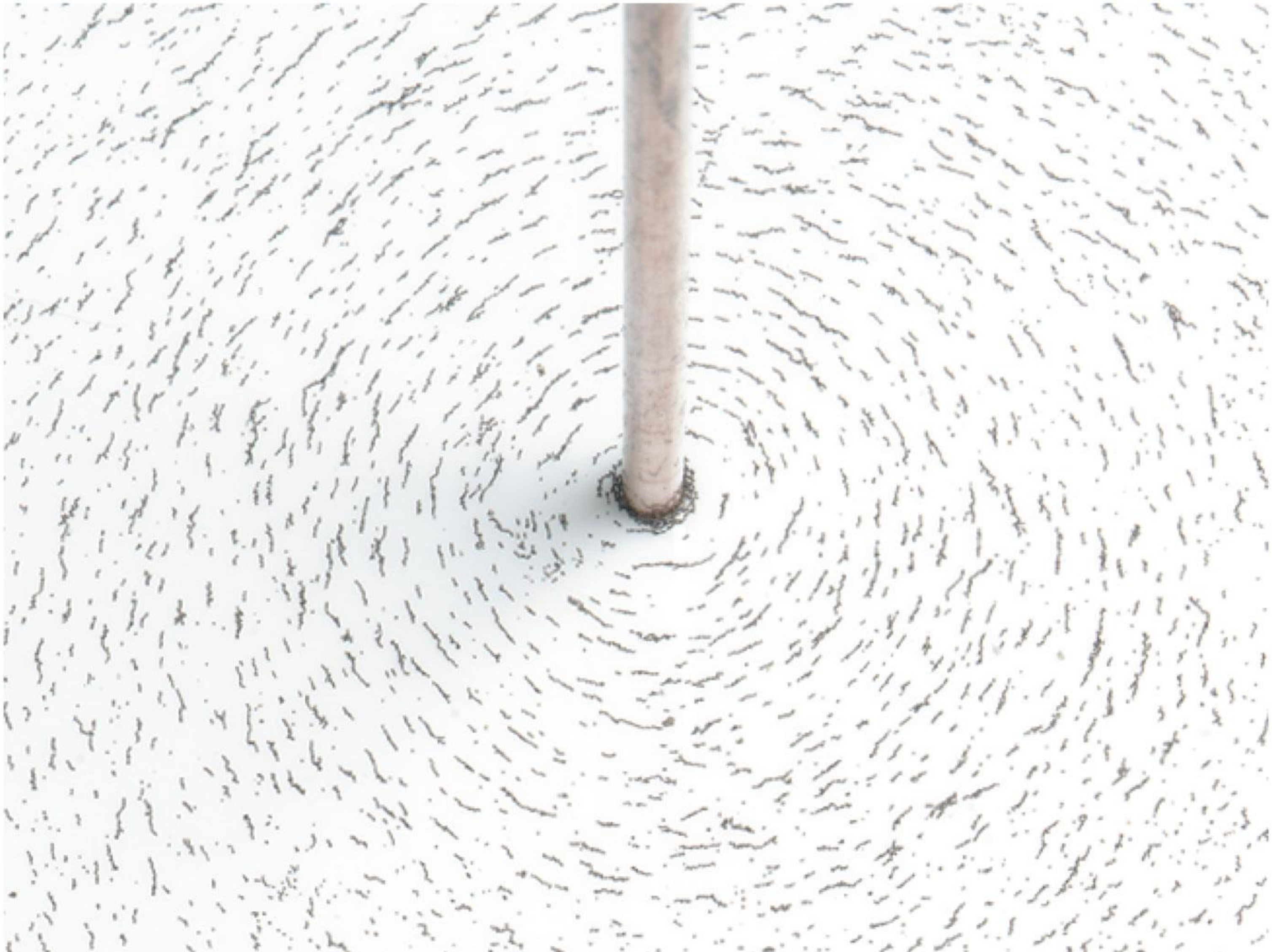
Derive an expression for the magnetic force on wire #2 due to the magnetic field created by the current flowing in wire #1.

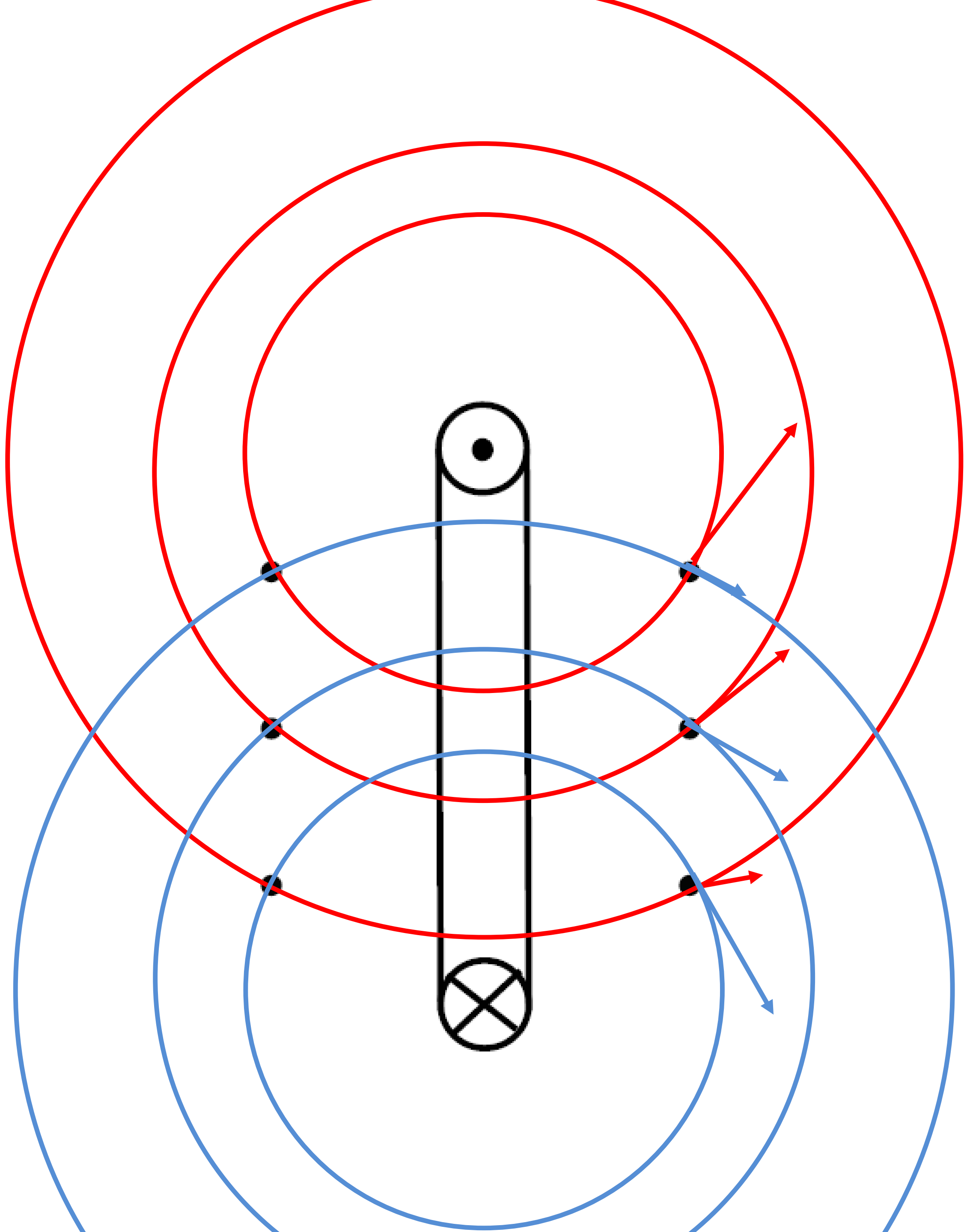
Demonstration wires



http://www.phas.ucalgary.ca/teaching_learning/demonstrations/electricity_and_magnetism

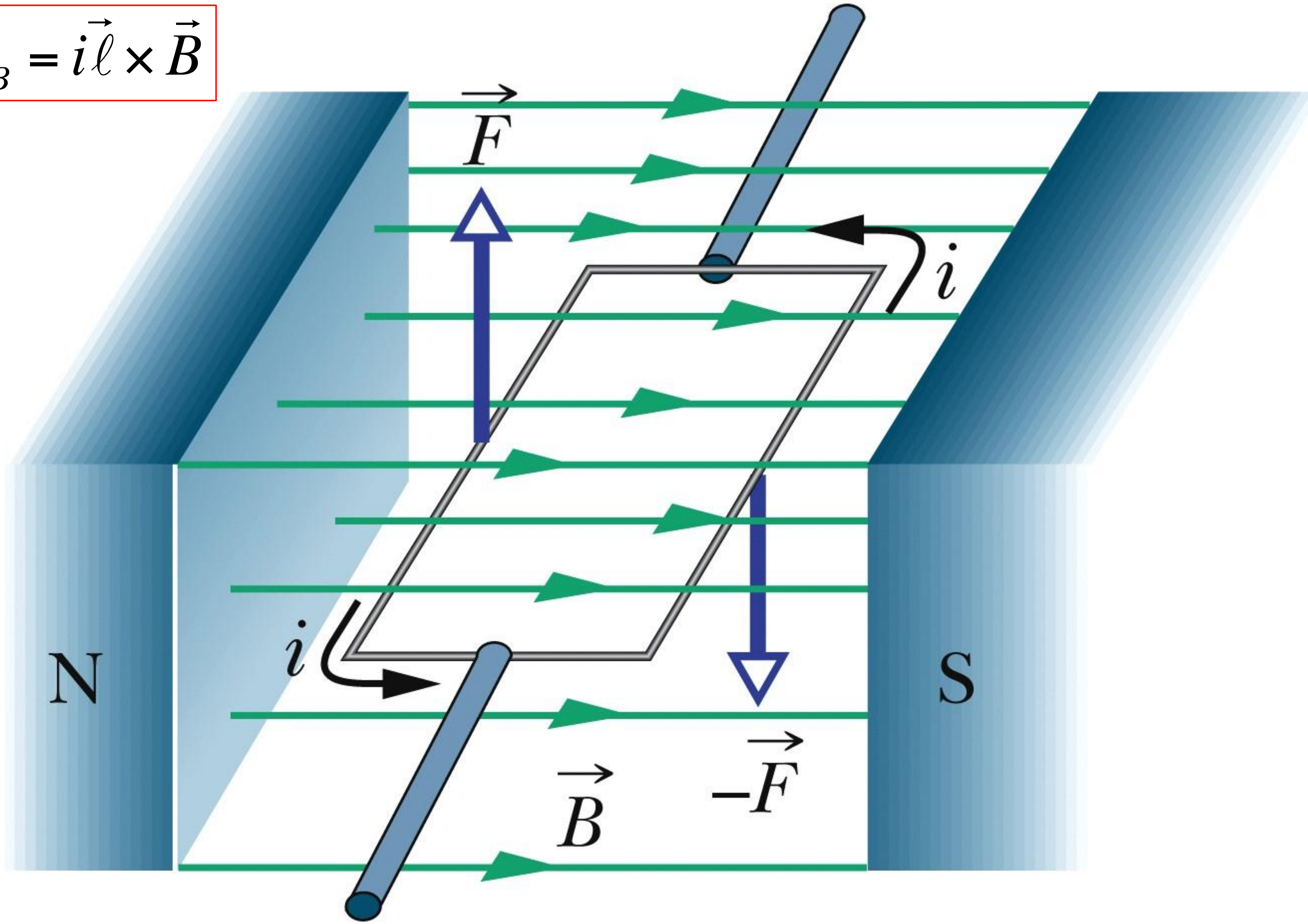
Magnetic Field of a Long, Straight Wire





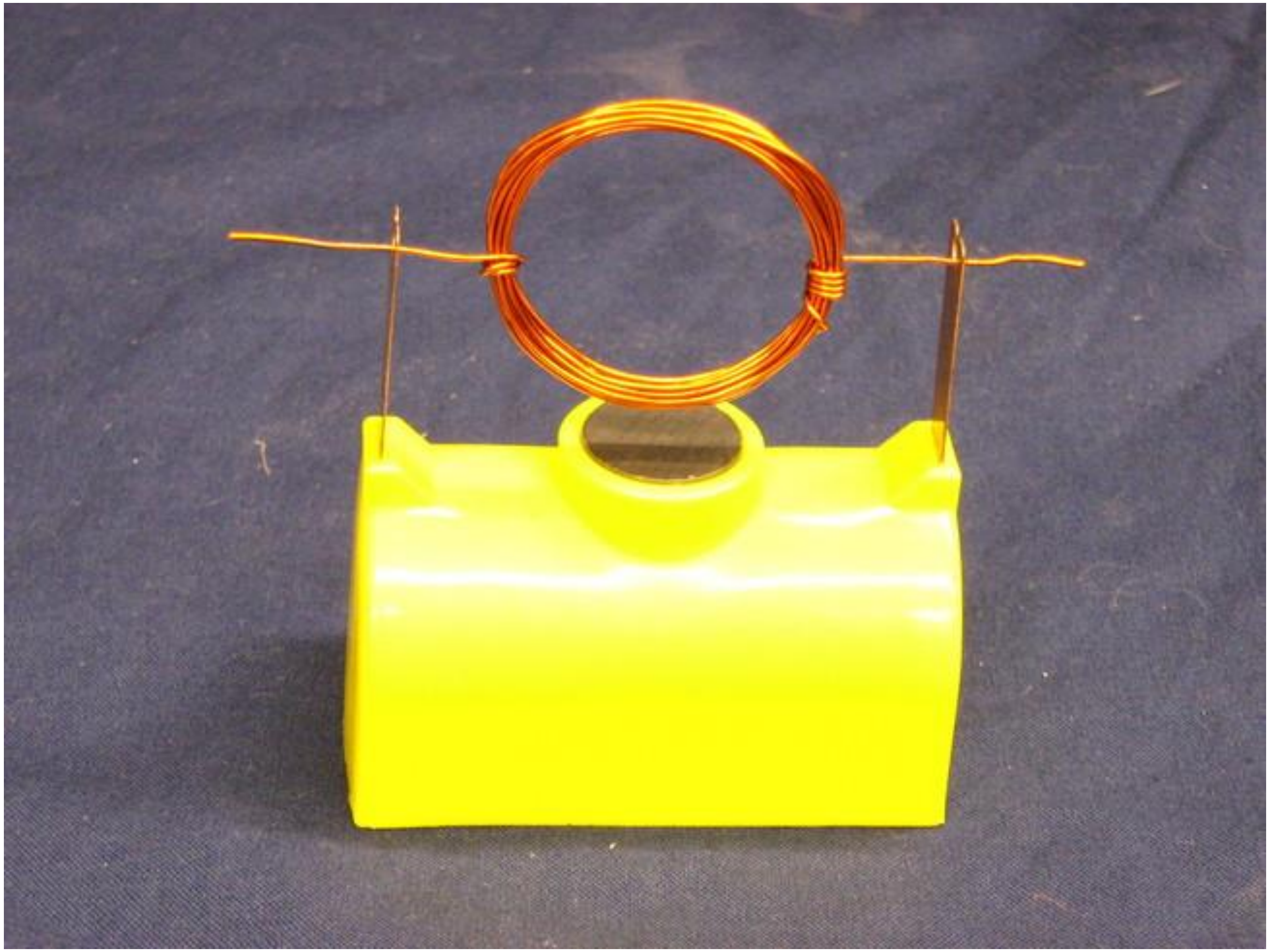
Torque on a current loop

$$\boxed{\vec{F}_B = i\vec{\ell} \times \vec{B}}$$



halliday_10e_fig_28_18

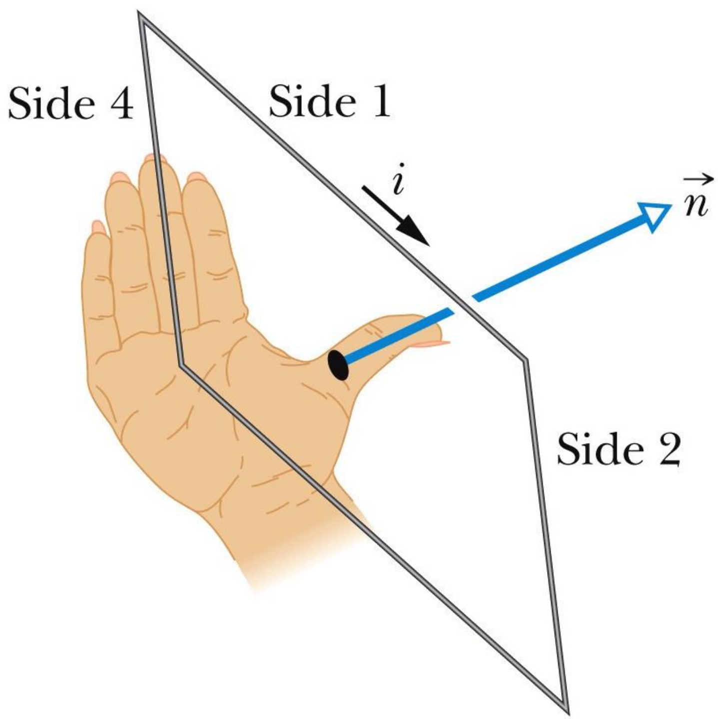
Demonstration

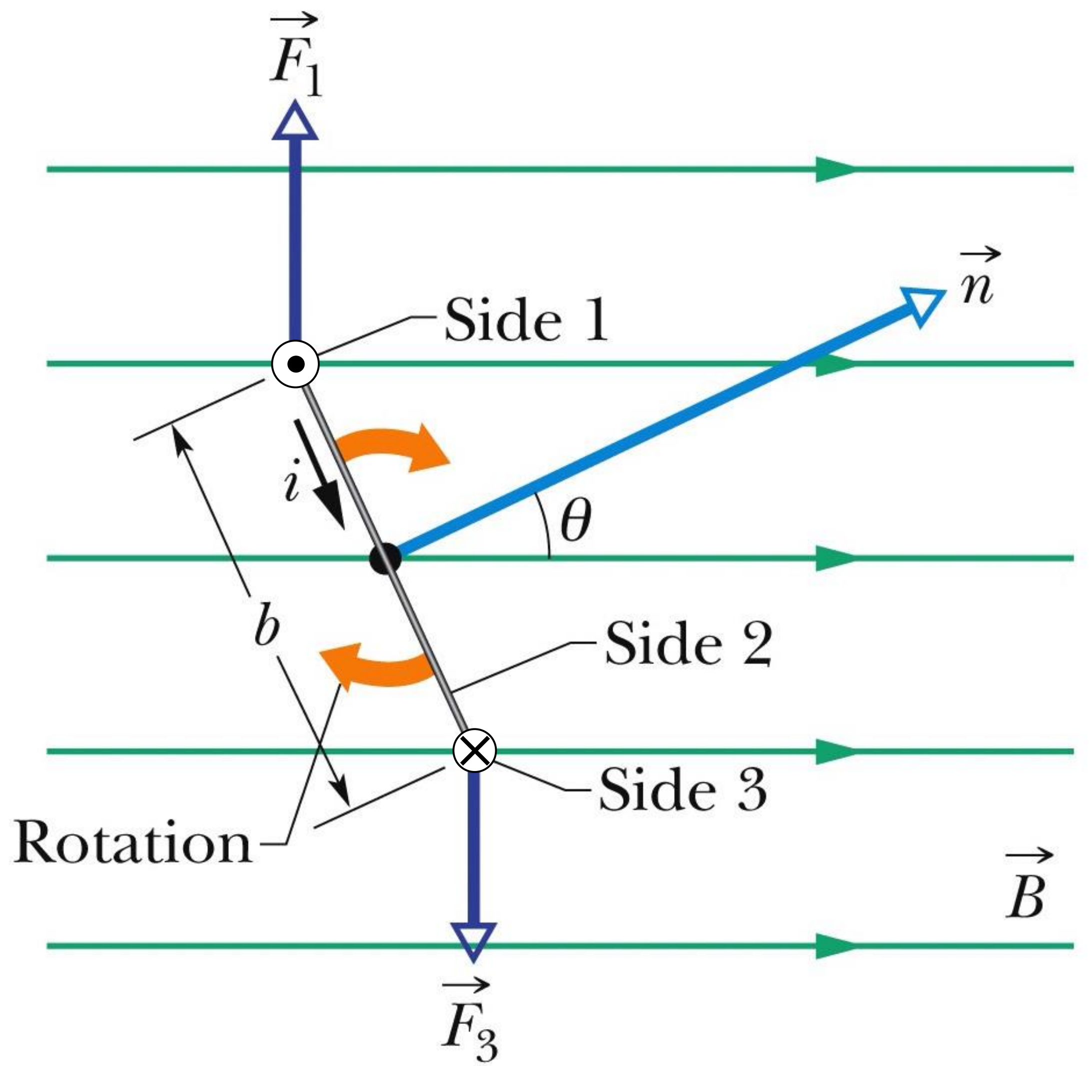


http://www.phas.ucalgary.ca/files/phas/5k40_05_worlds_simplest_motor_pic1.jpg

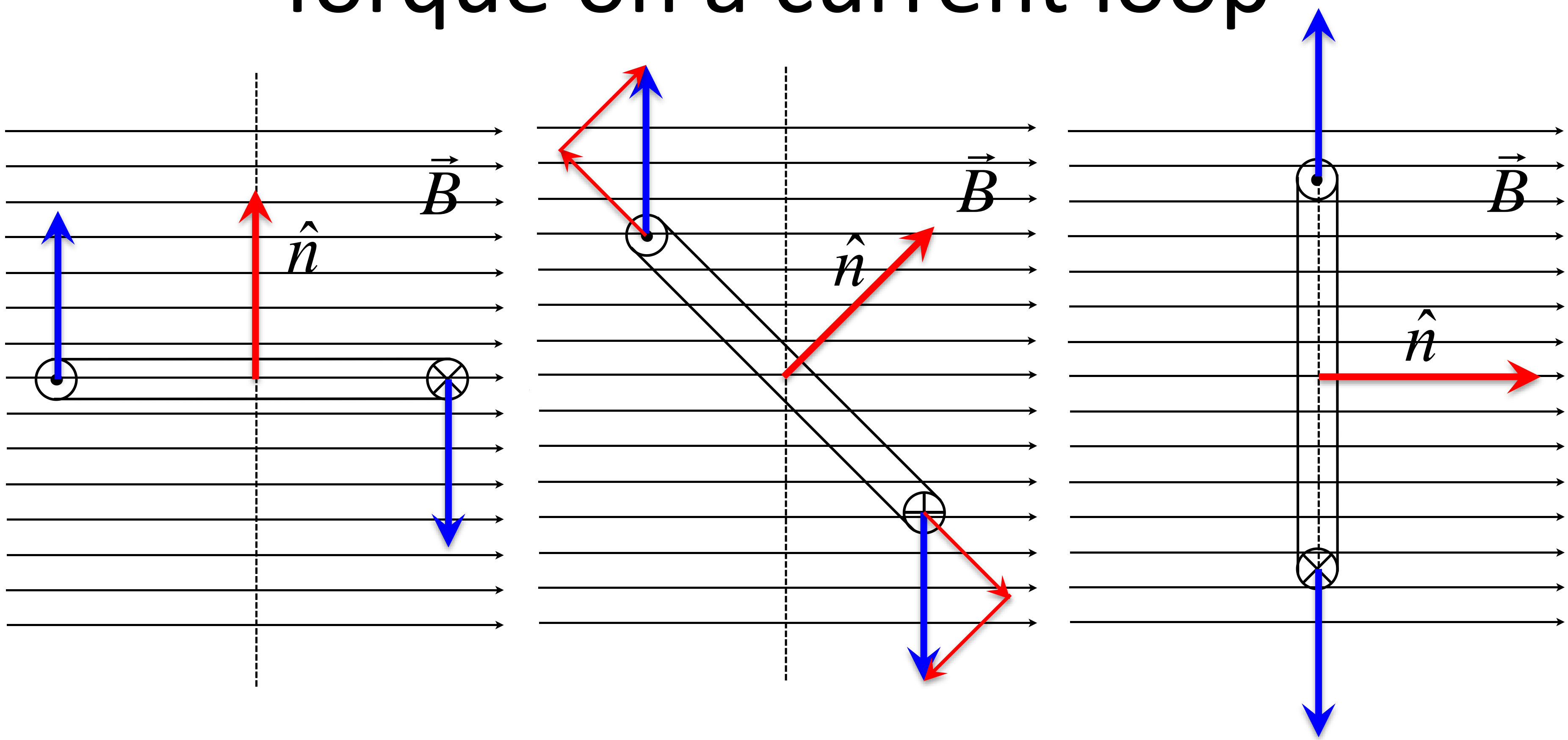
Torque on a current loop

Pick the normal vector to the loop area by RHR: curl your fingers in the direction of i, thumb points in direction of n





Torque on a current loop



The normal vector is at right angles to the B-field: all magnetic force causes rotation of the loop

The normal vector is at some angle to the B-field: some of the magnetic force causes rotation of the loop

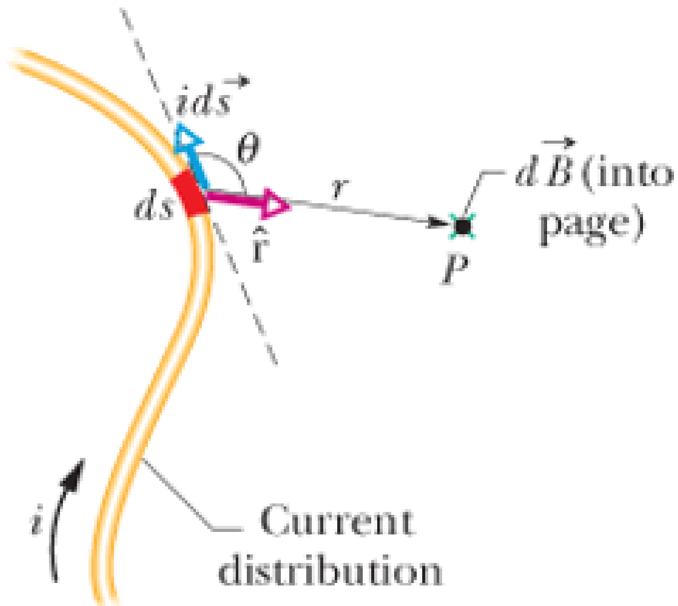
The normal vector is parallel to the B-field: none of the magnetic force causes rotation of the loop

Conclusion: components of magnetic force (anti)parallel to normal vector that cause torque

The Biot-Savart Law

(Bee-oh Sah-var)

This element of current creates a magnetic field at P, into the page.



$$\boxed{\vec{B}_{\text{current segment}} = \frac{\mu_0}{4\pi}\frac{I\,\Delta\vec{s}\times\hat{r}}{r^2}}$$

$$\mu_0 = 4\pi\times10^{-7}\,\frac{N\cdot s^2}{C^2}$$

"Permeability of free space"

Constants of nature

"Permittivity of free space"

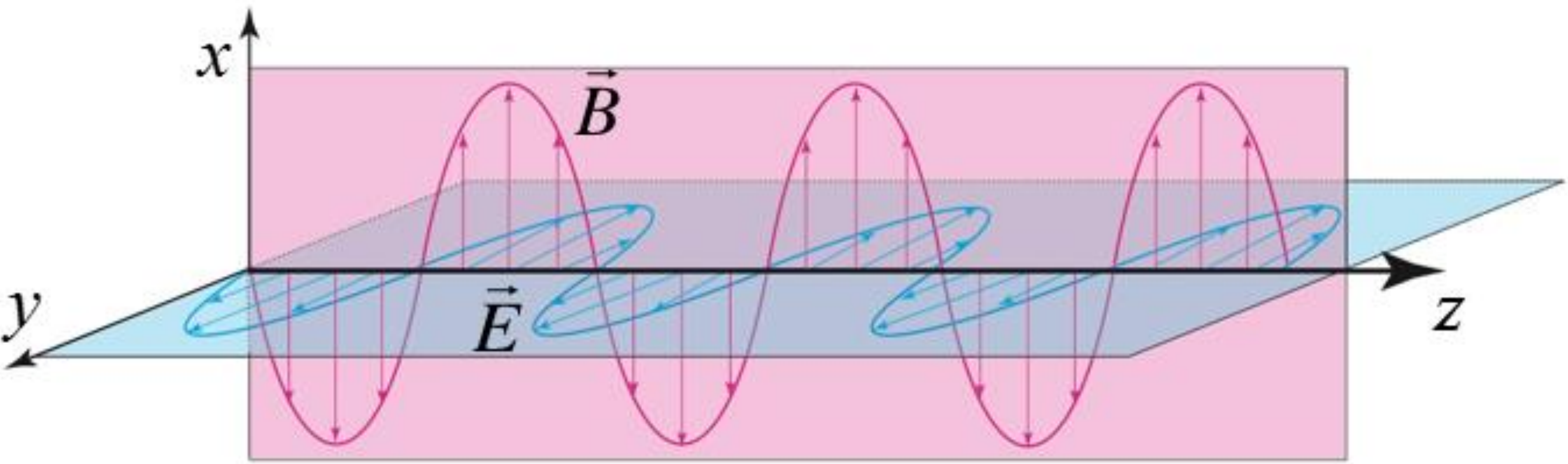
$$\varepsilon_0 = 8.854187817 19\times 10^{-12}\,\frac{C^2}{N\cdot m^2}$$

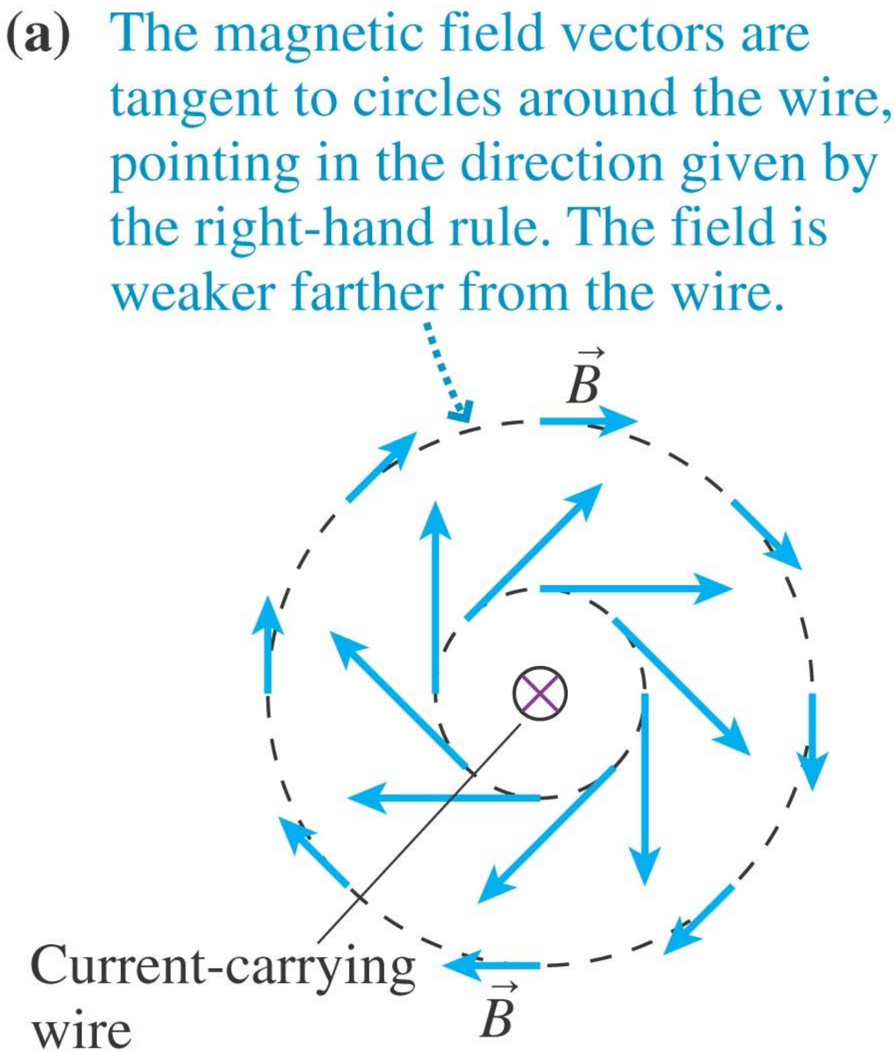
"Permeability of free space"

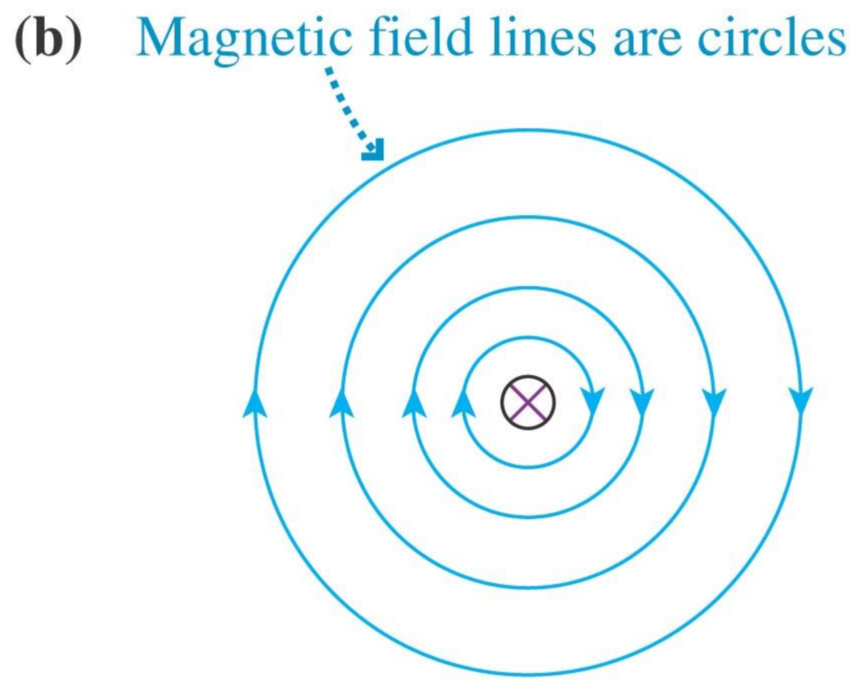
$$\mu_0 = 4\pi\times 10^{-7}\,\frac{N\cdot s^2}{C^2}$$

$$\frac{1}{\sqrt{\mu_0\varepsilon_0}} = 299,792,458\ \mathrm{m/s}$$

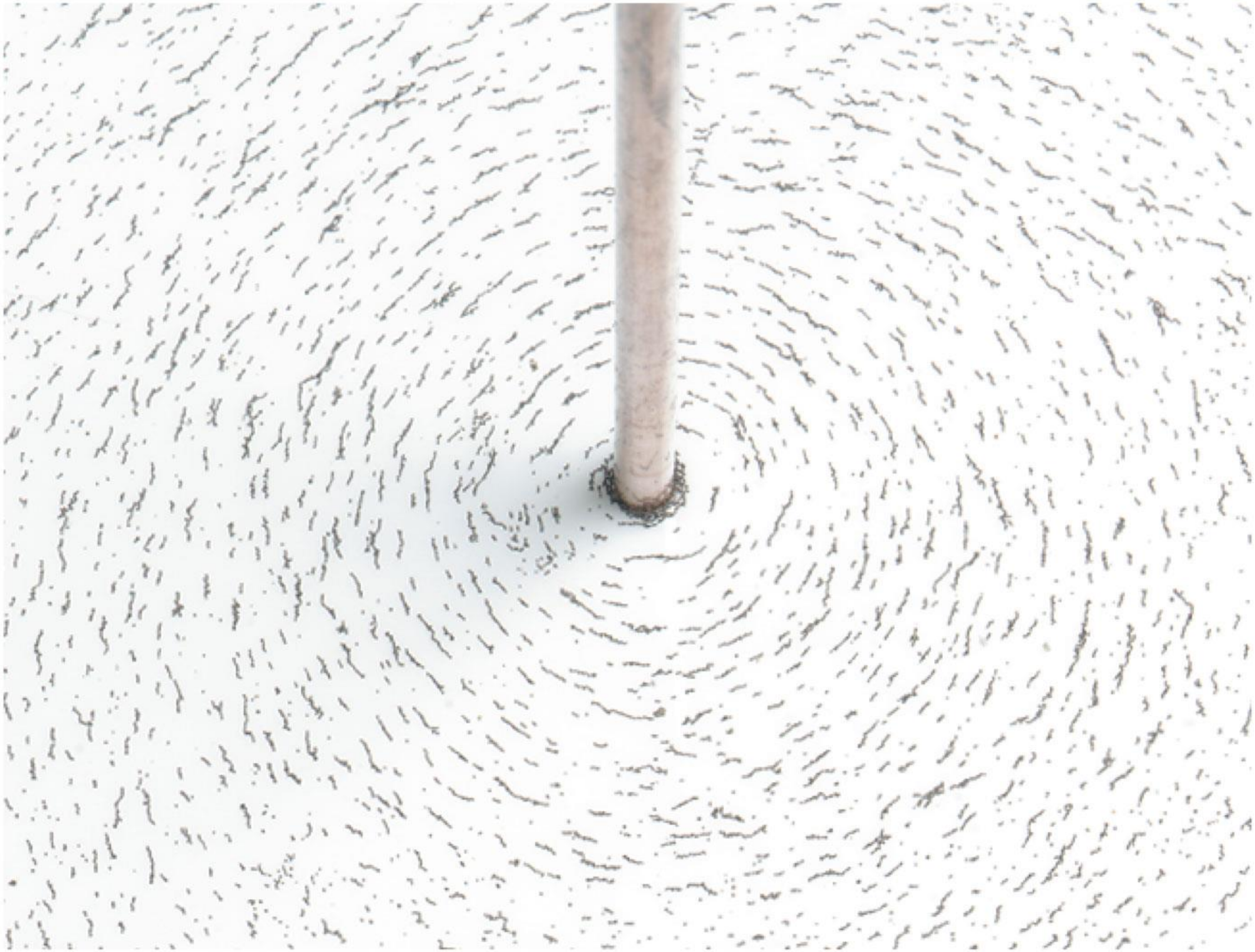
Speed of light!

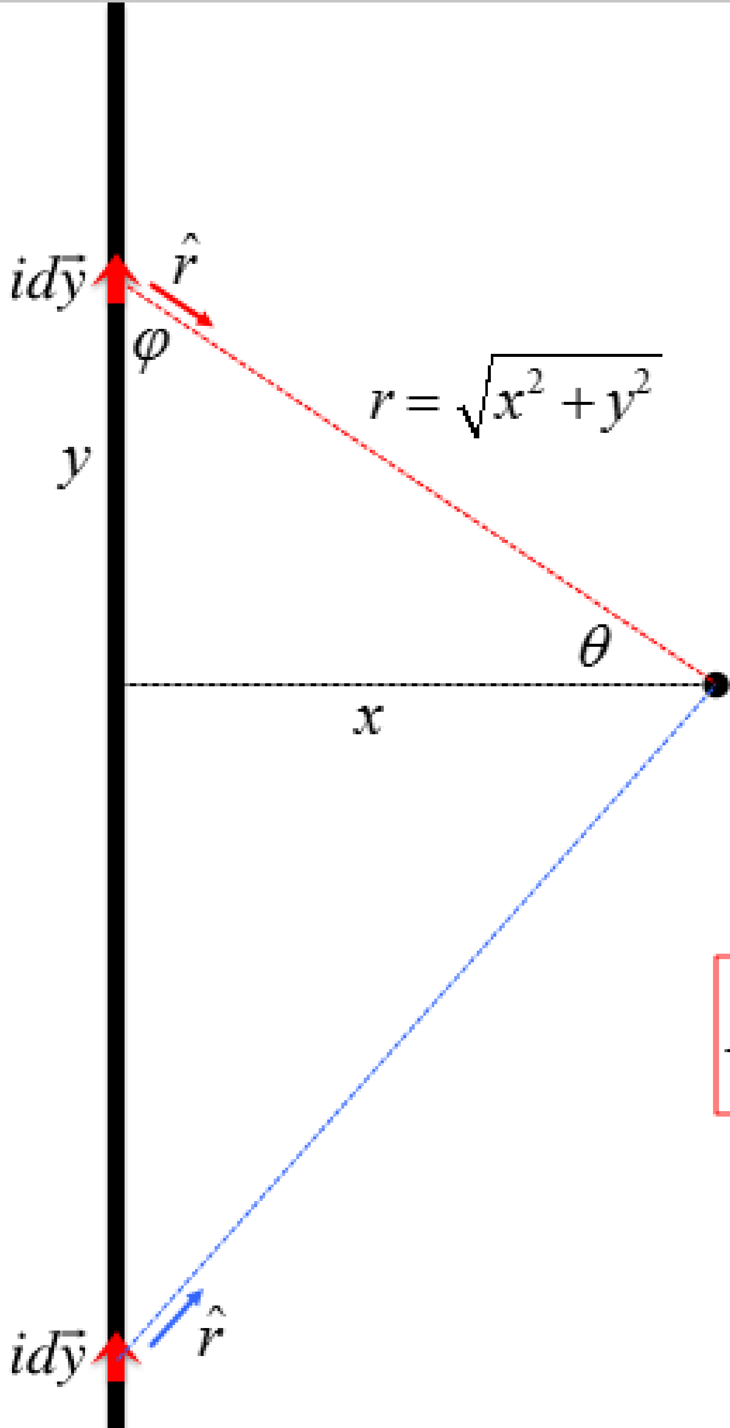



(a) The magnetic field vectors are tangent to circles around the wire, pointing in the direction given by the right-hand rule. The field is weaker farther from the wire.
$\vec{B}$
Current-carrying wire
$\vec{B}$


(b) Magnetic field lines are circles.

Magnetic Field of a Long, Straight Wire





$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i d\vec{y} \times \hat{r}}{r^2}$$

$$i d\vec{y} \times \hat{r} = i dy \sin\varphi \left(-\hat{k}\right) = -i dy \frac{x}{\sqrt{x^2 + y^2}} \hat{k}$$

$$d\vec{B} = -\frac{\mu_0}{4\pi} \frac{i x dy}{\left(x^2 + y^2\right)^{3/2}} \hat{k}$$

All contributions are in the same direction

$$B = \int_{-\infty}^{\infty} \frac{\mu_0}{4\pi} \frac{i x dy}{\left(x^2 + y^2\right)^{3/2}}$$

Can just worry about the magnitude

$$\boxed{B_{wire} = \frac{\mu_0 i}{2\pi x}}$$

Magnetic field strength of a long straight wire. Direction from RHR

TopHat Question