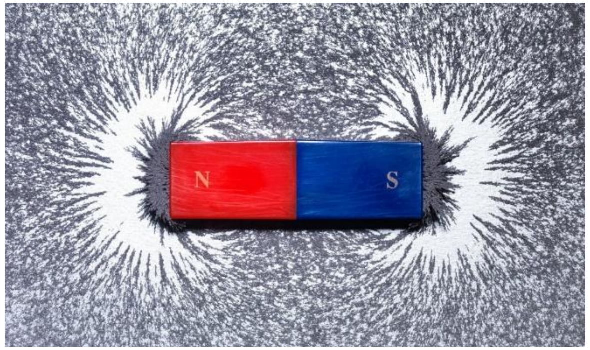
Chapter 11.6-11.7, 12.1-12.3

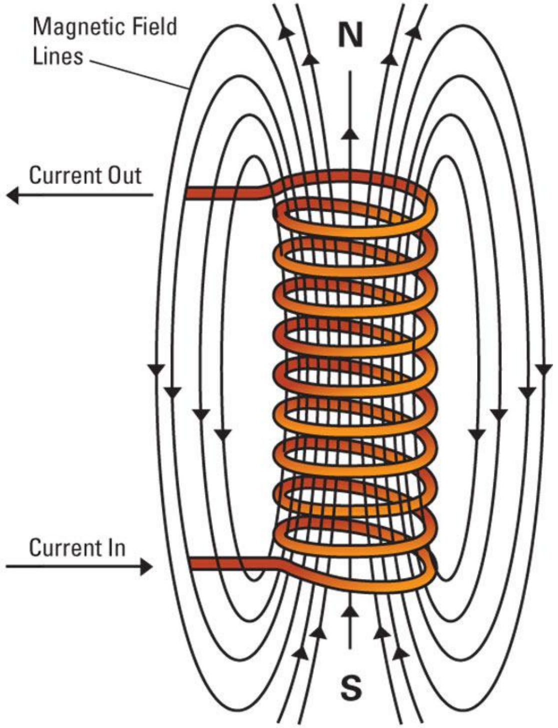
Magnetism and electricity

Outline of electromagnetism

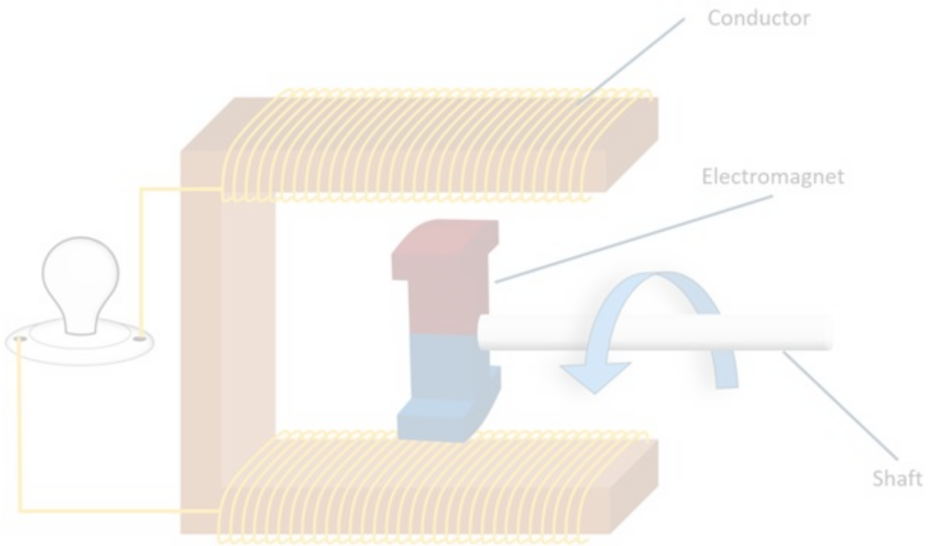
Electricity



Magnetism



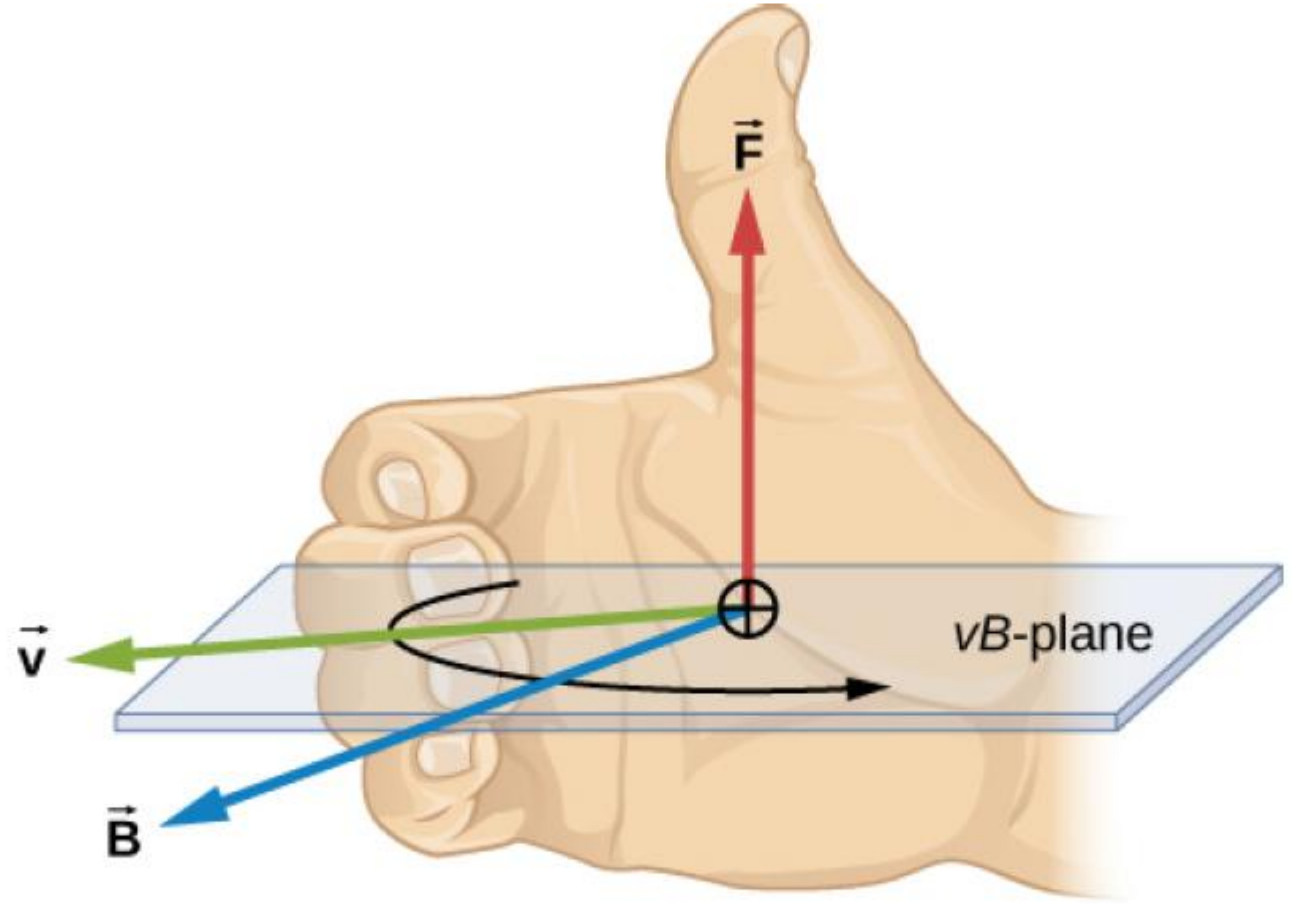
Electricity generating magnetism



Moving fields

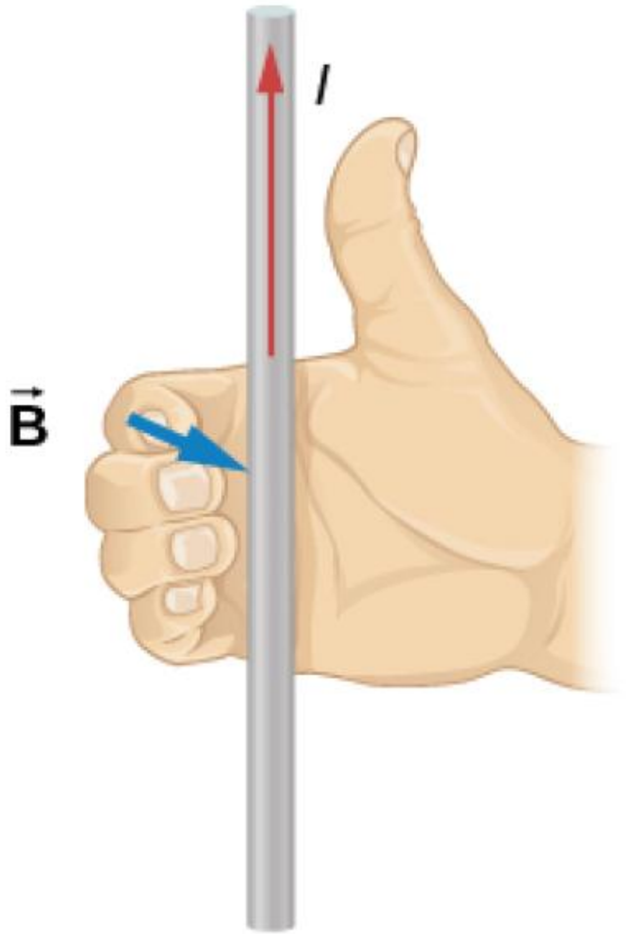
Lorentz force from the magnetic field

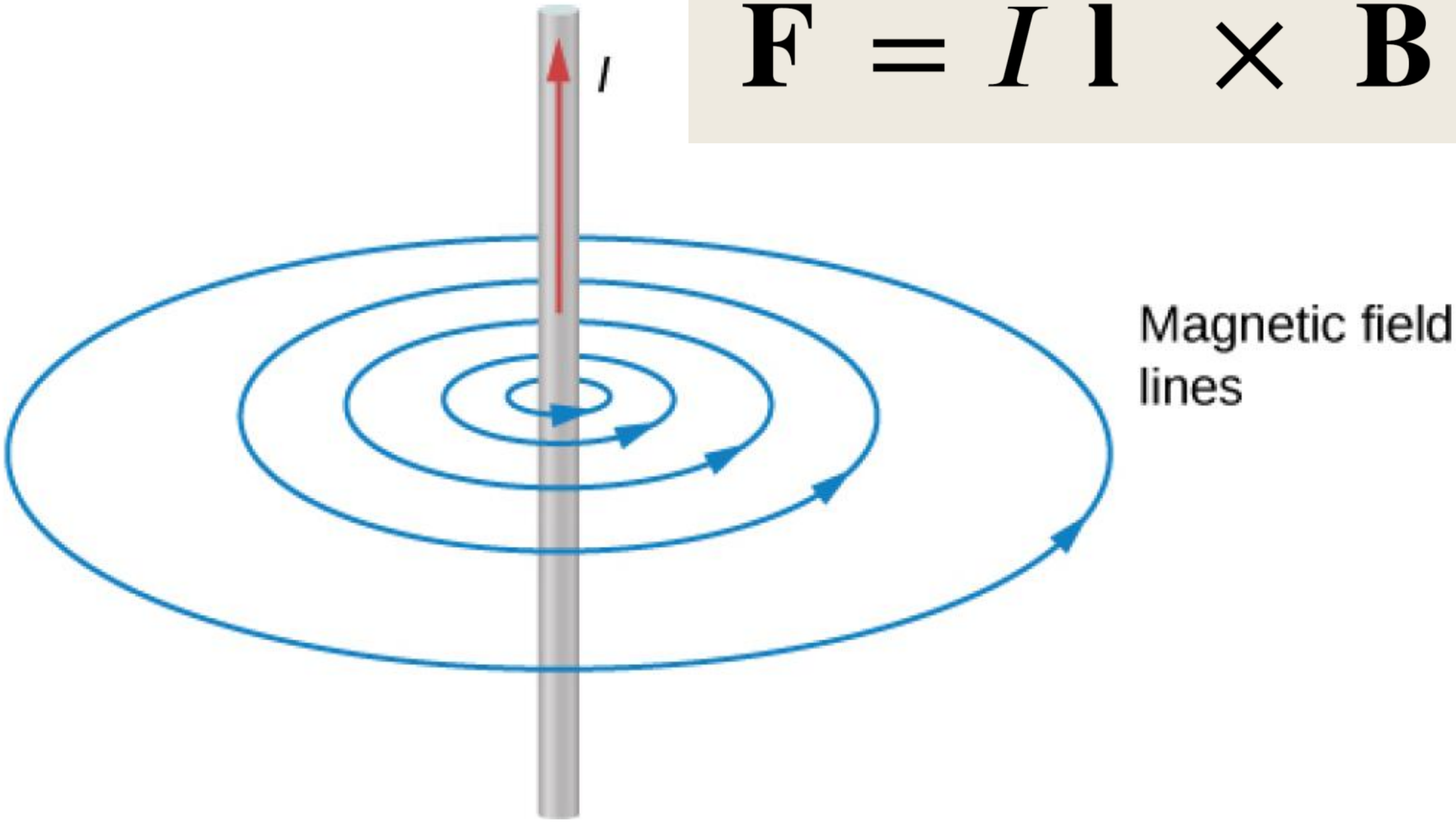
$$\vec{\mathbf{F}} = q\vec{\mathbf{v}} \times \vec{\mathbf{B}}.$$



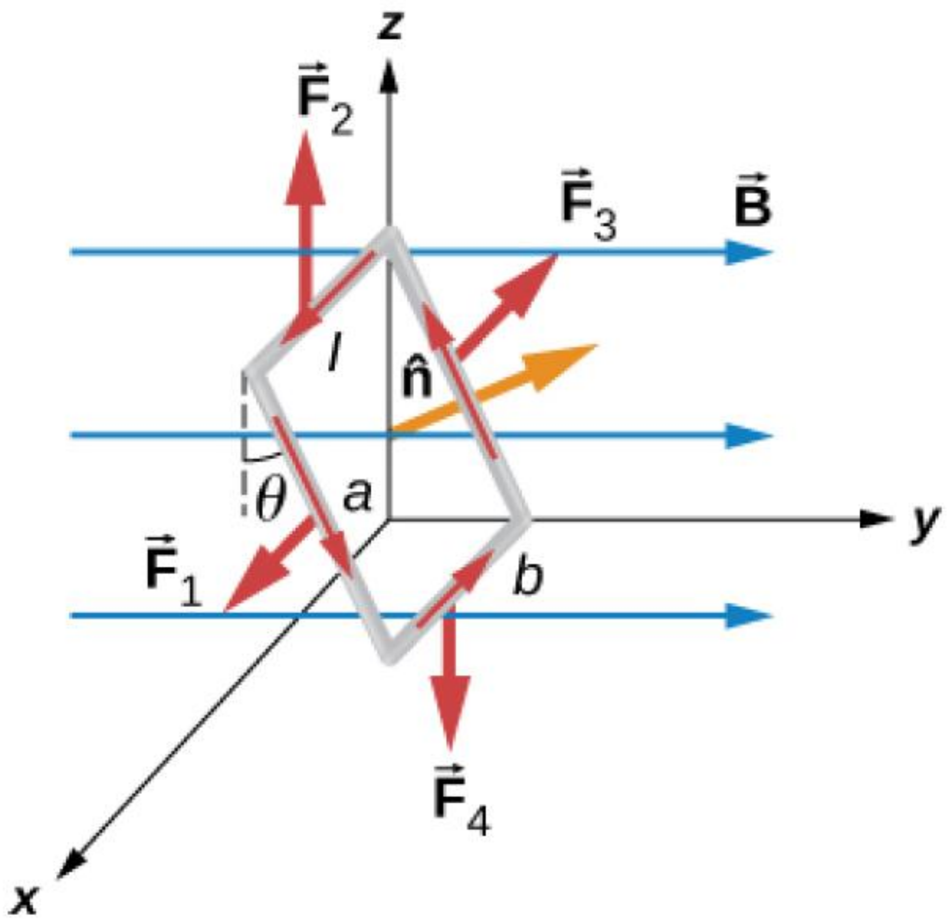
Magnetic field from a wire

$$\vec{\mathbf{F}} = I\,\vec{\mathbf{l}} \times \vec{\mathbf{B}}.$$





Current-carrying loop = dipole moment



$$\vec{\mu} = IA\hat{n}$$

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

$$\vec{\tau} = \vec{\mu} \times \vec{B}.$$

The sum-up slide

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

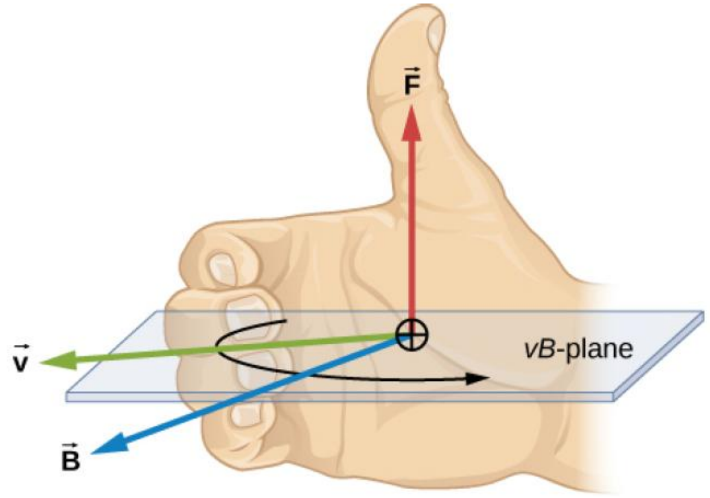
$$U(r) = k\frac{qQ}{r}$$

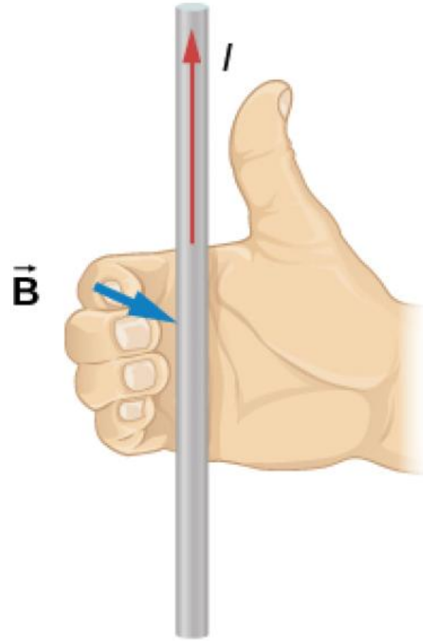
$$\vec{E} = -\vec{\nabla} V,$$

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

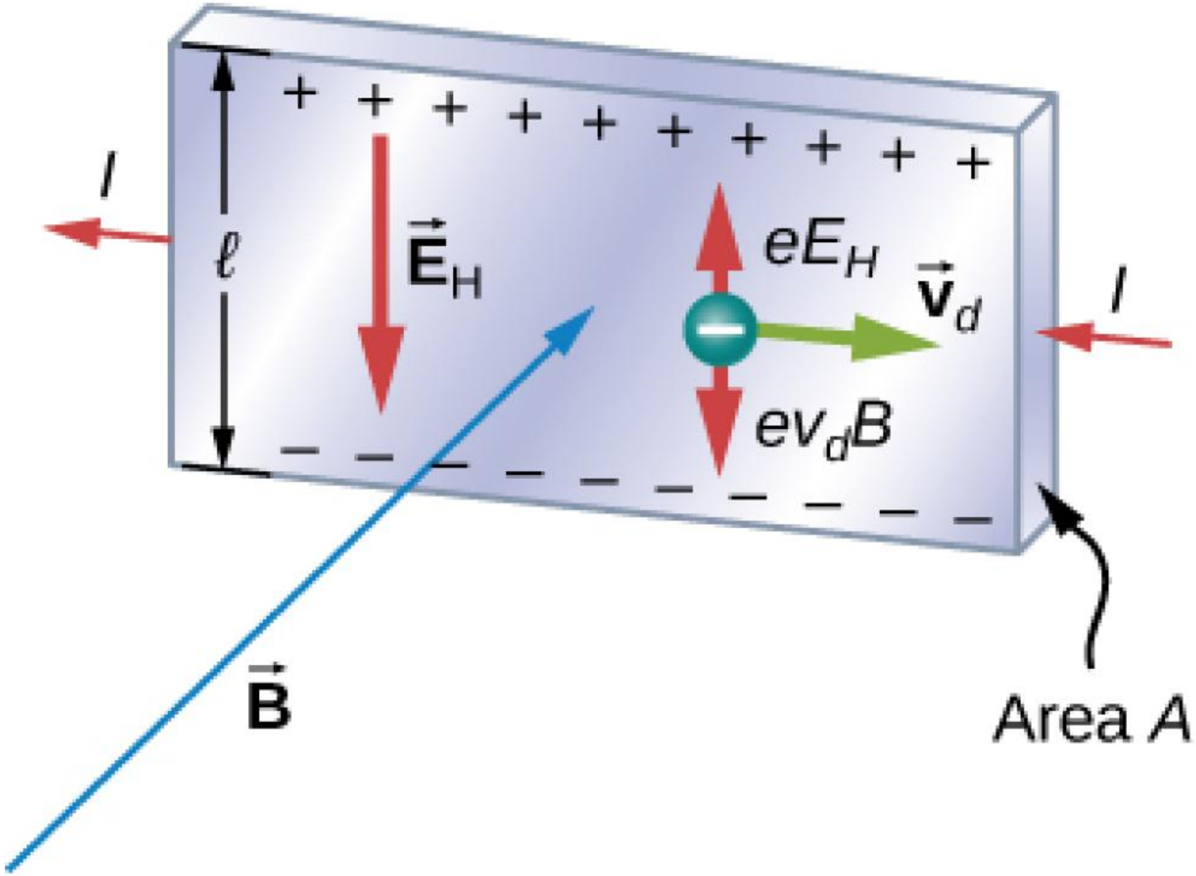
$$V = \frac{U}{q}.$$

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





The Hall effect



$$v_d = \frac{E}{B}.$$

$$V = Blv_d.$$

Example exercise

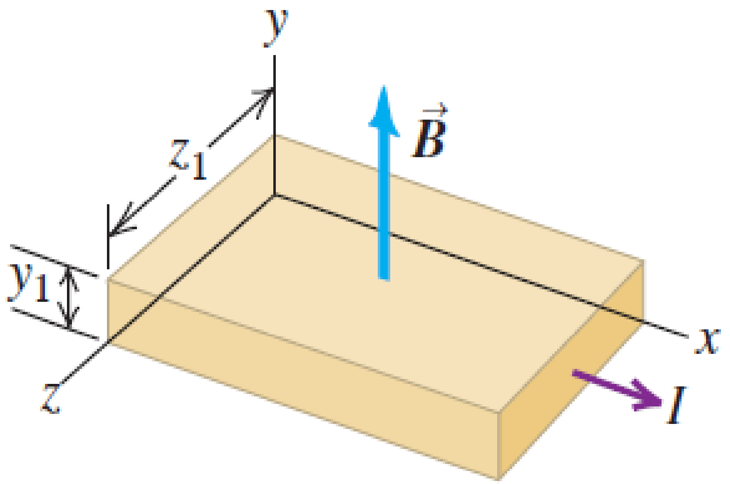
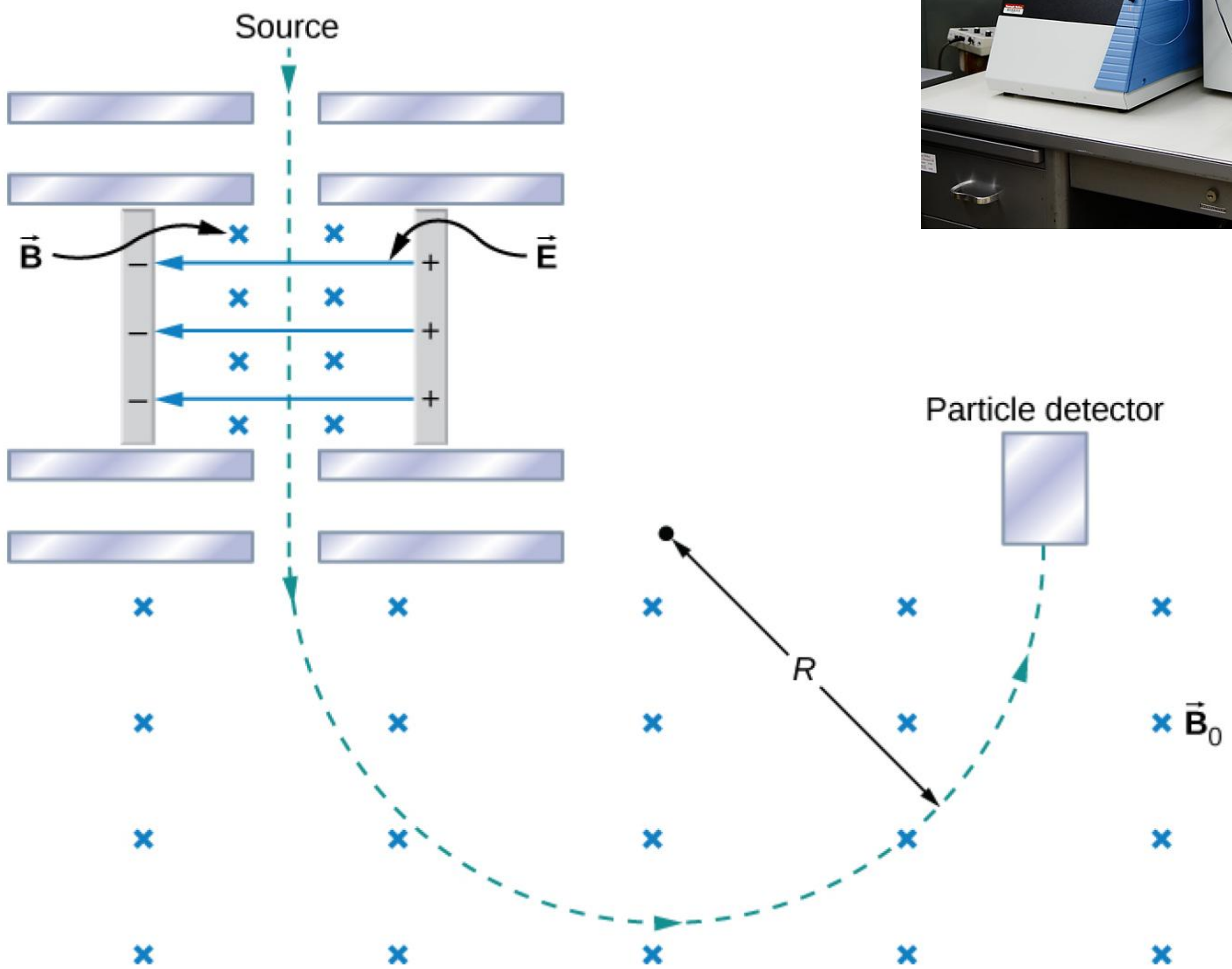


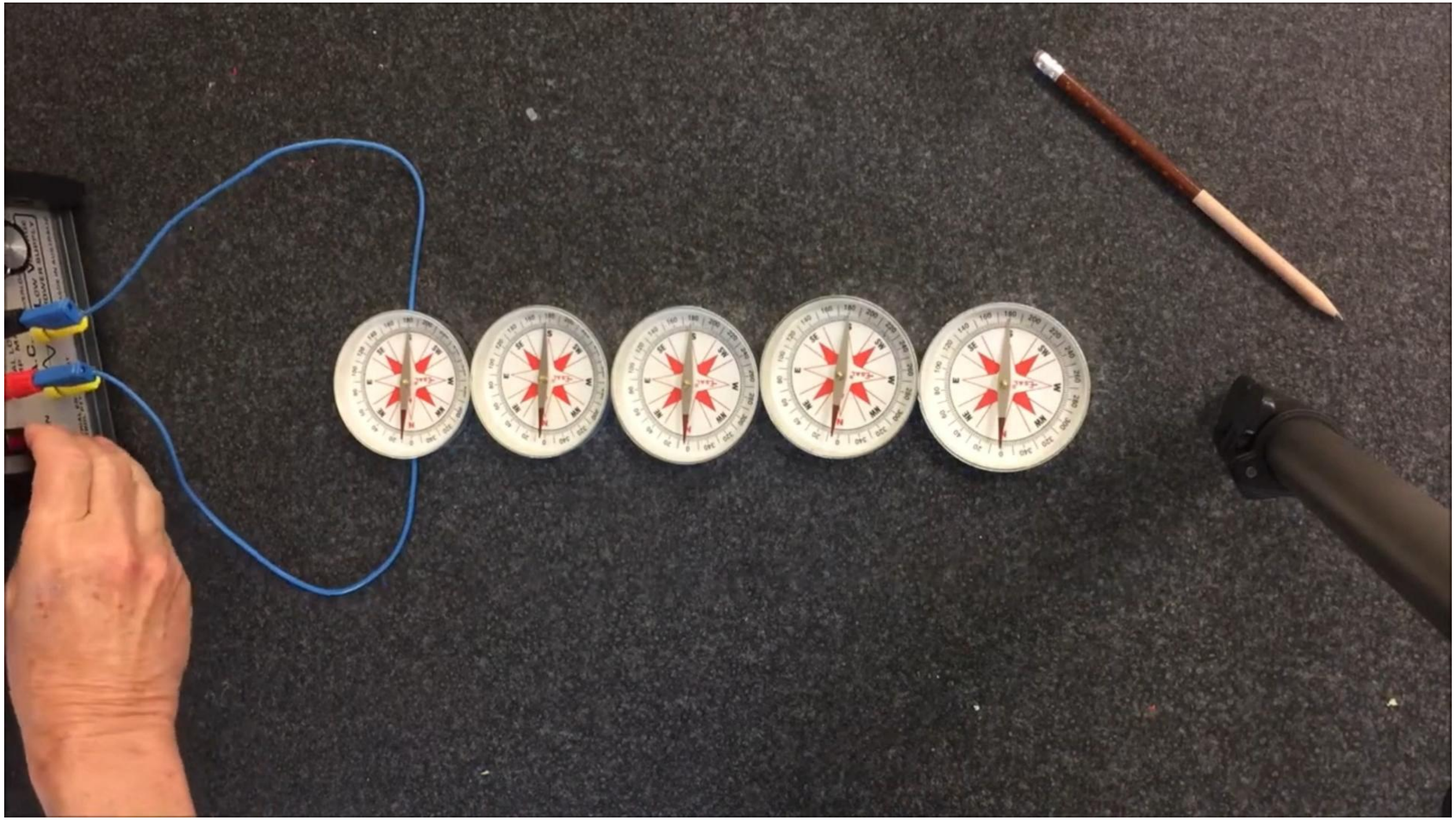
Figure E27.45 shows a portion of a silver ribbon with $z_1 = 11.8$ mm and $y_1 = 0.23$ mm

When the magnetic field is 2.29 T and the current is 78.0 A, the Hall emf is found to be 131 μV. What does the simplified model of the Hall voltage presented in Section 27.9 give for the density of free electrons in the unknown metal?

The mass spectrometer

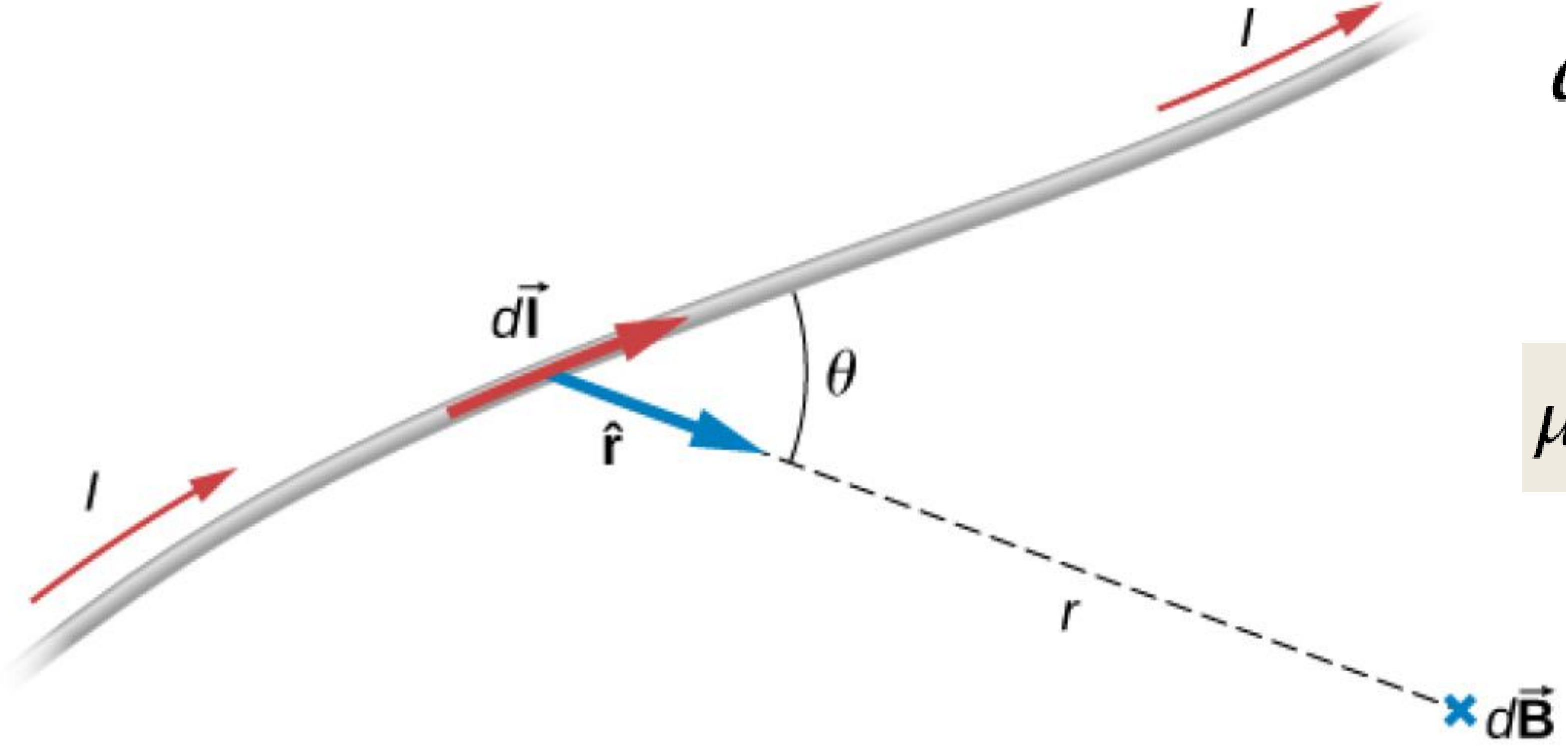


Ørsteds experiment in 1820!



Credit Dr. Richard Walding

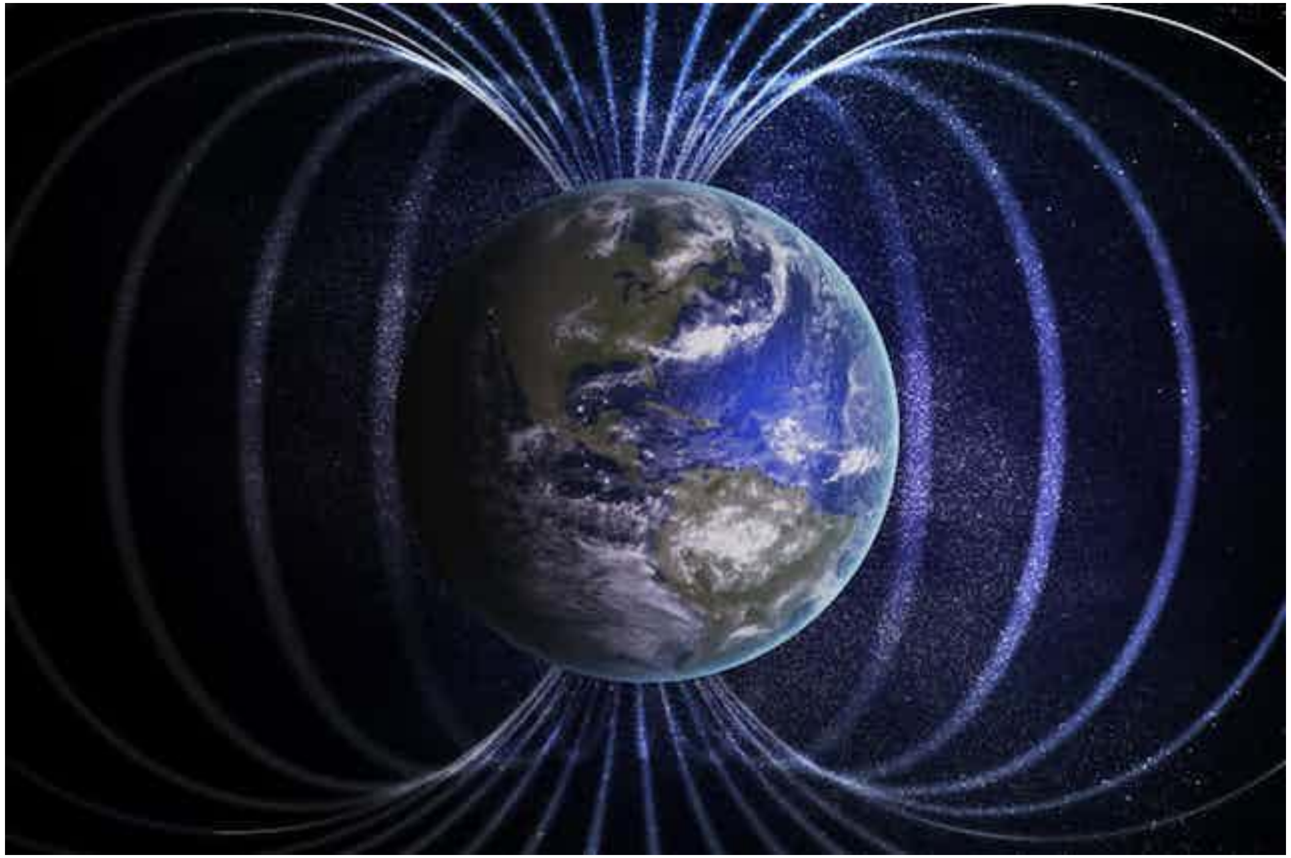
Biot-Savart law



$$d\vec{\mathbf{B}} = \frac{\mu_0}{4\pi} \frac{I d\vec{\mathbf{l}} \times \hat{\mathbf{r}}}{r^2}.$$

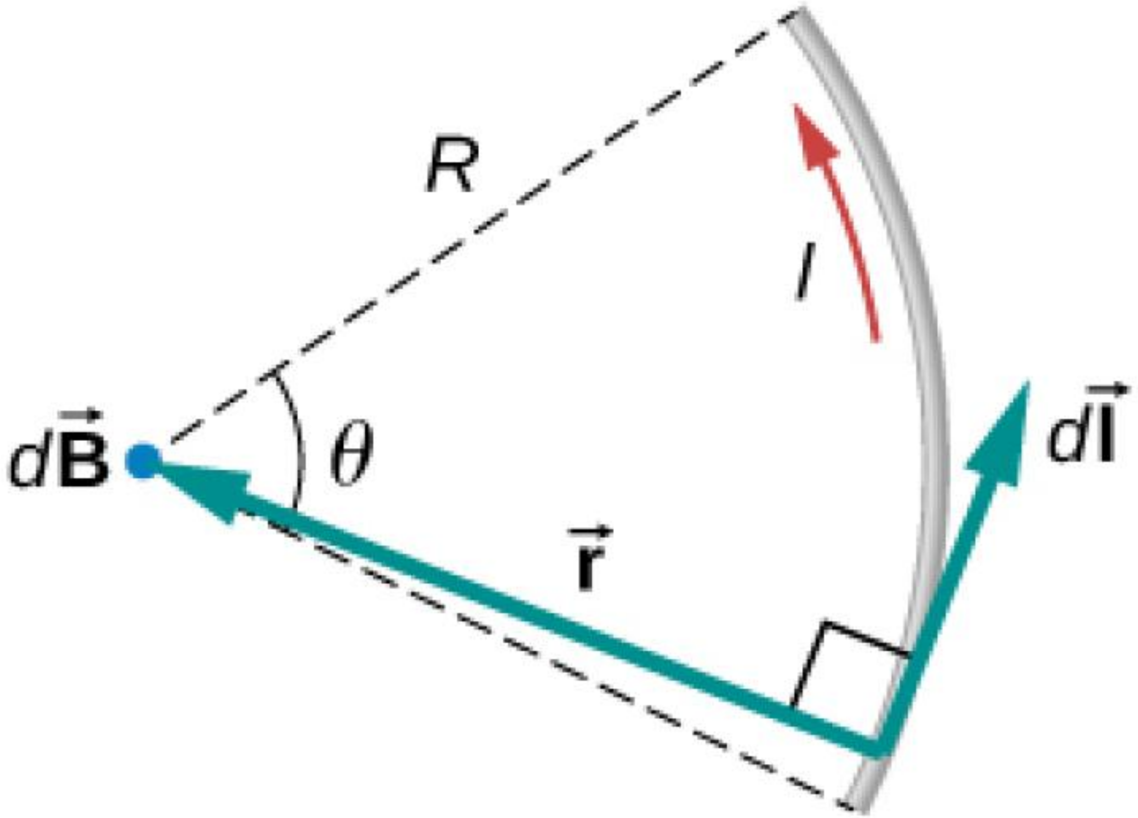
$$\mu_0 = 4\pi \times 10^{-7} \mathrm{T} \cdot \mathrm{m/A}$$

Size of magnetic fields



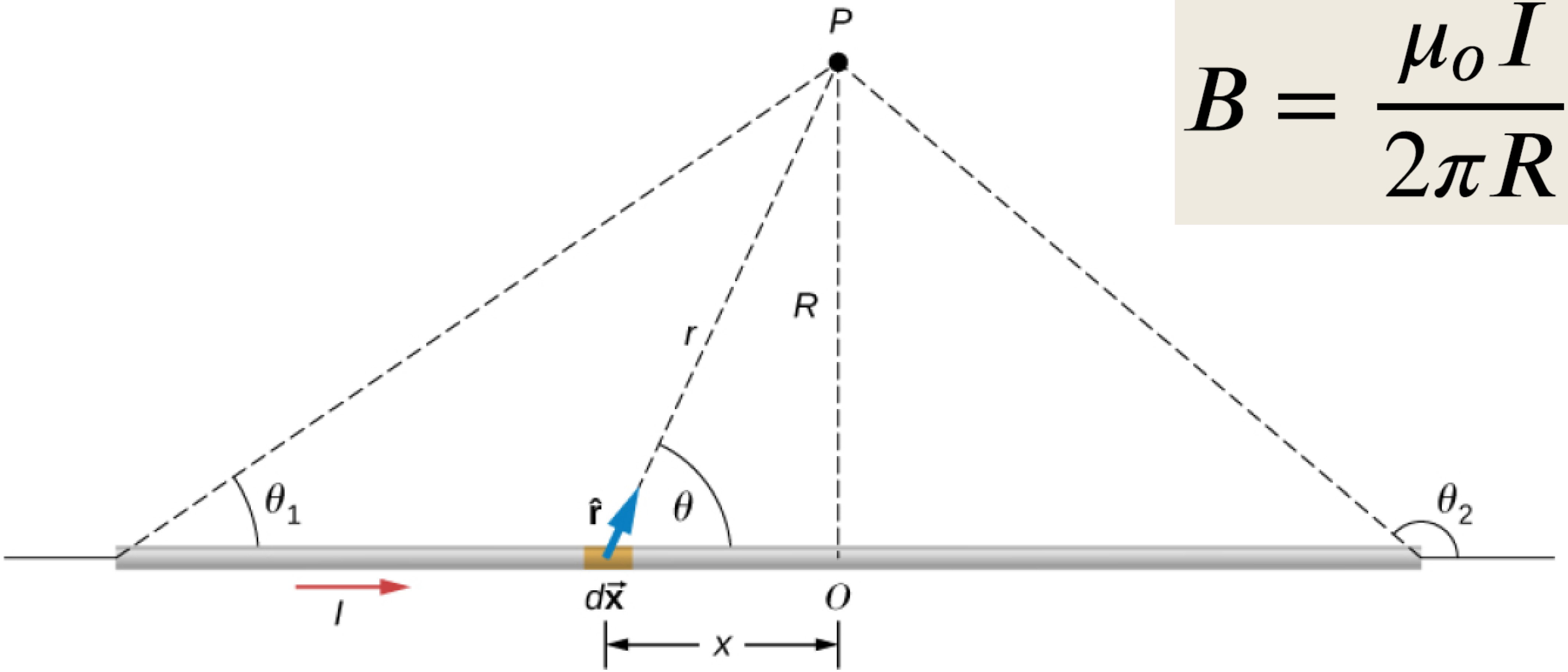
The magnitude of Earth's magnetic field at its surface ranges from 25 to 65 μT

Magnetic field from a circular wire



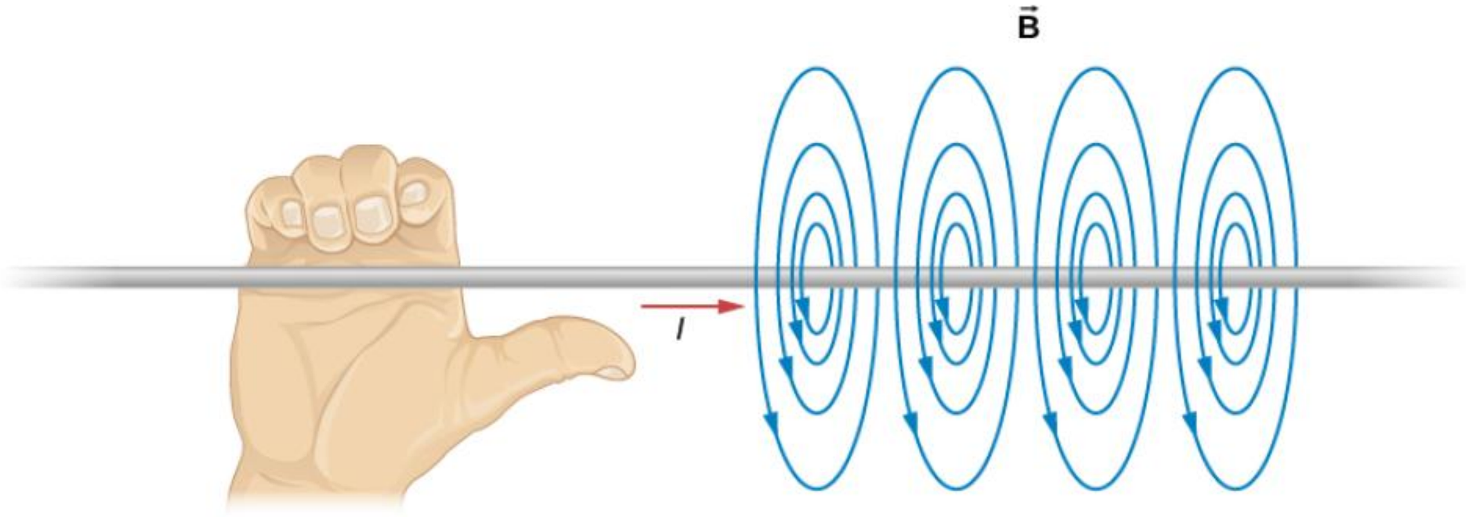
$$B = \frac{\mu_0 I \theta}{4\pi r}.$$

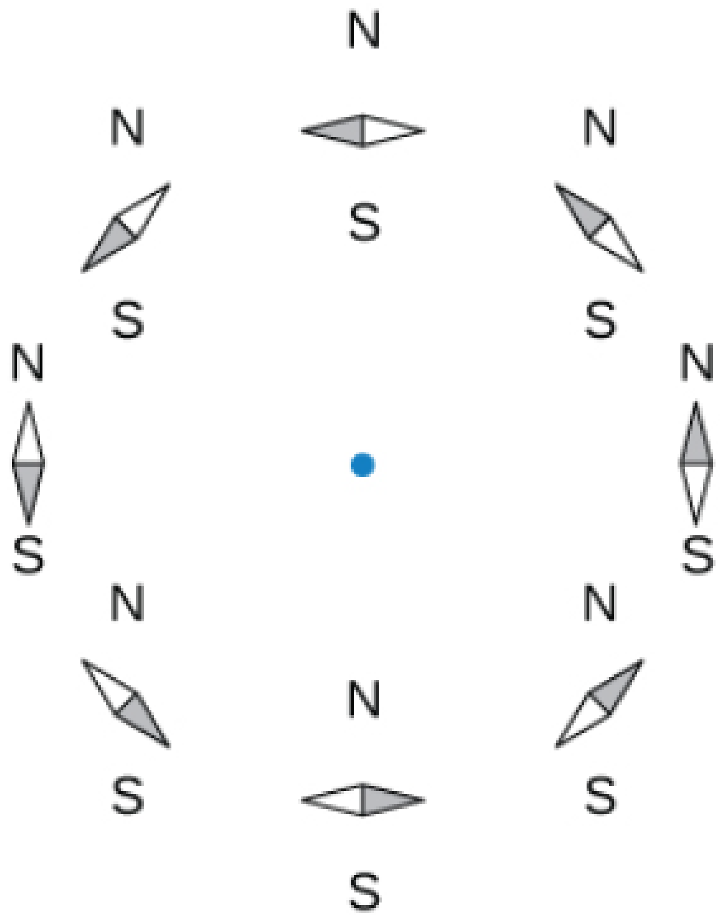
Magnetic field from a straight wire



$$B = \frac{\mu_0 I}{2\pi R}.$$

The right-hand rule

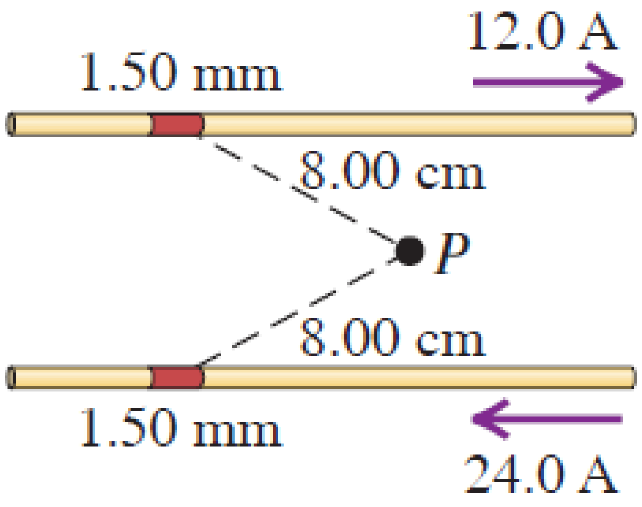




Magnetic field from a straight wire

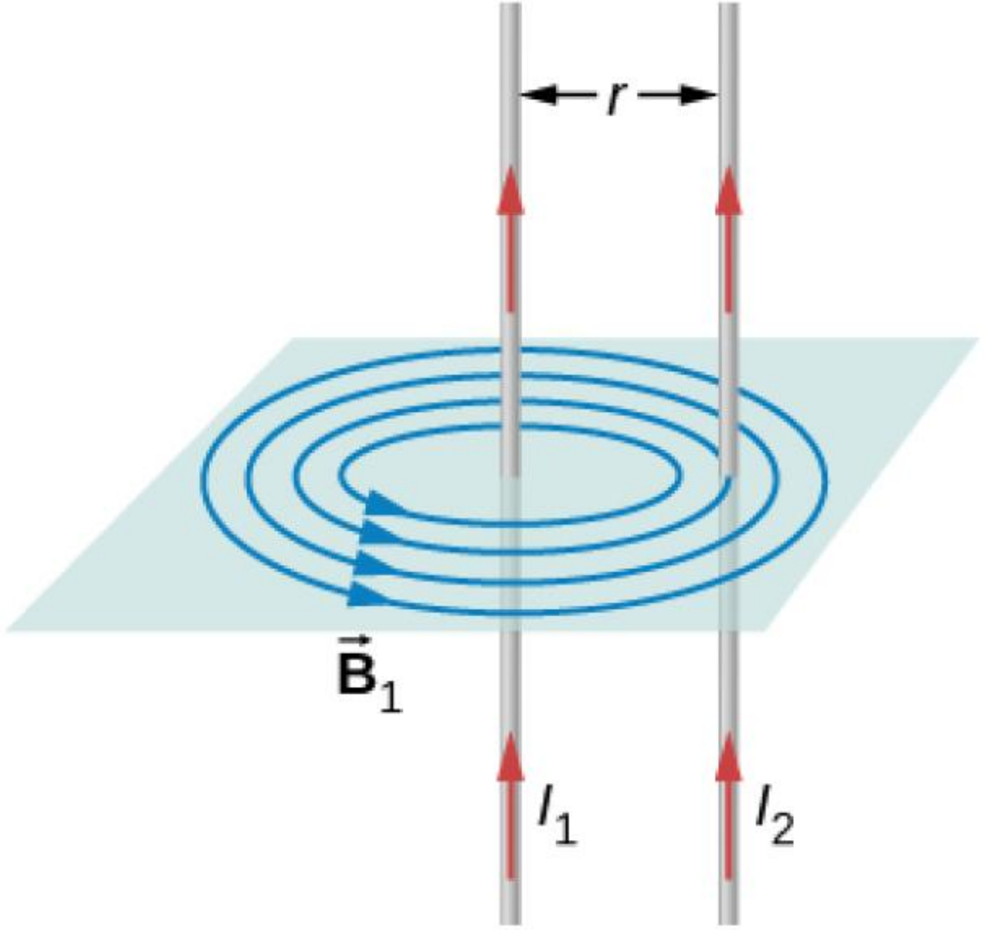
Example exercise

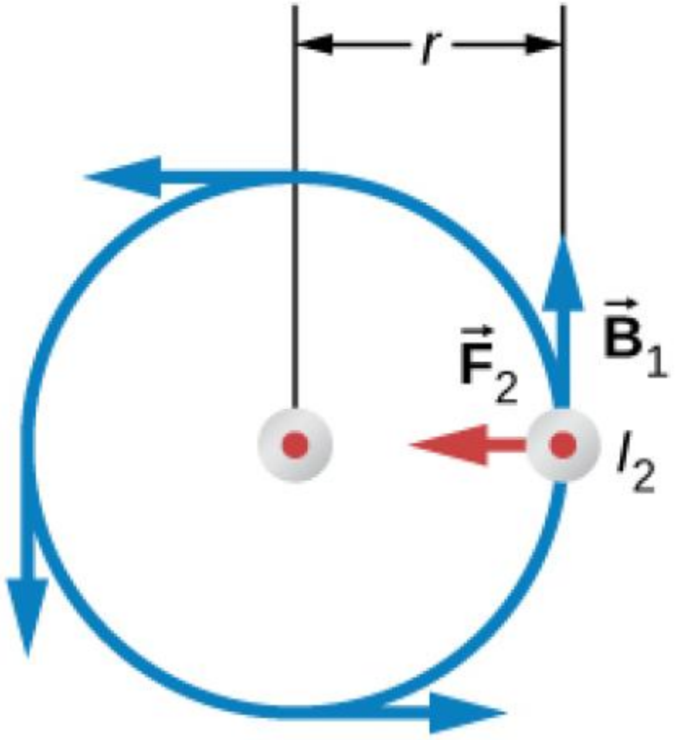
Two parallel wires are 5.80 cm apart and carry currents in opposite directions, as shown in **Fig. E28.12**. Find the magnitude and direction of the magnetic field at point P due to two 1.50 mm segments of wire that are opposite each other and each 8.00 cm from P.



Force between two wires

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}.$$

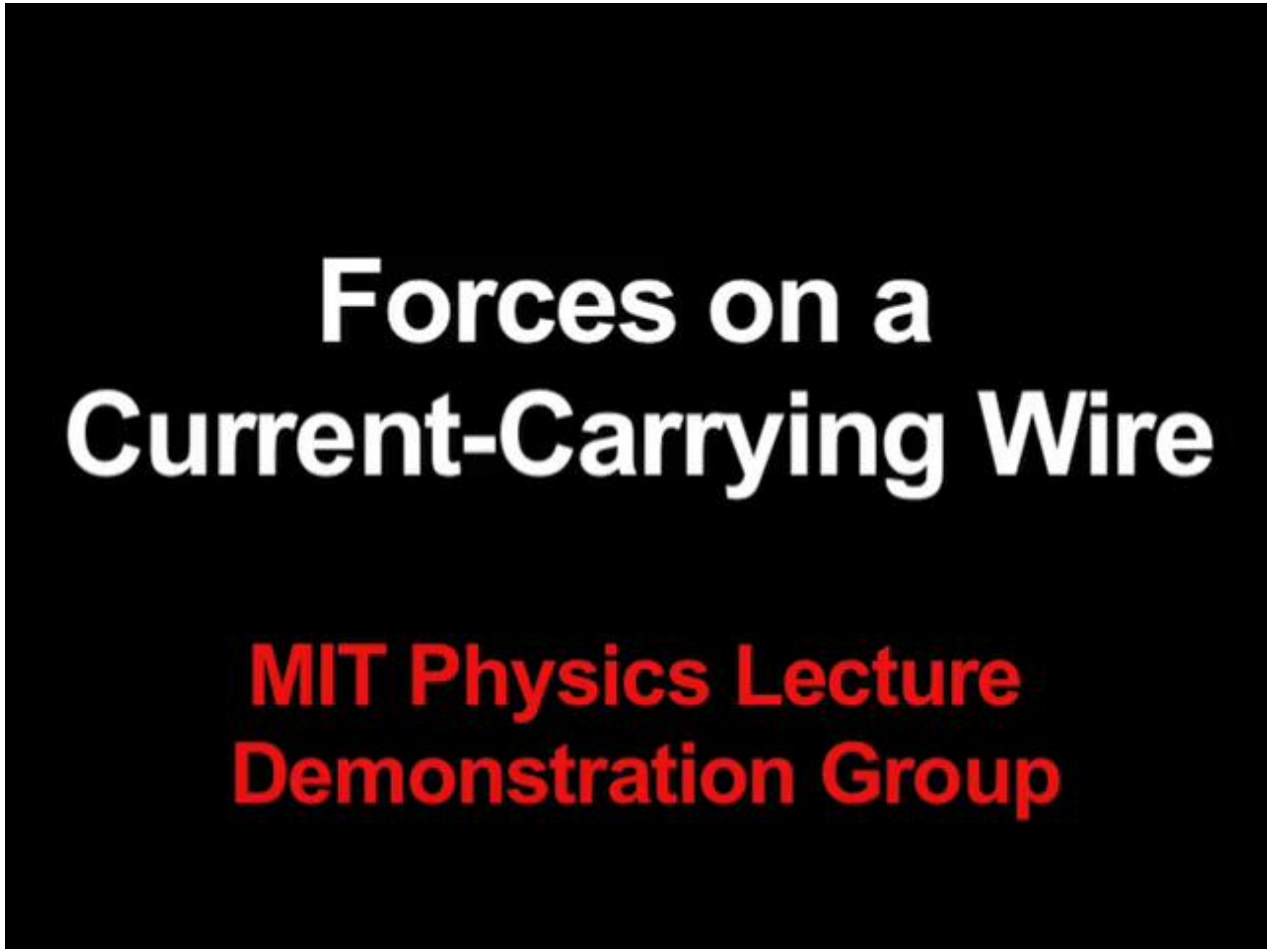




Example exercise

Two long, parallel wires are separated by a distance of 2.50 cm. The force per unit length that each wire exerts on the other is 4.00×10^{-5} N/m, and the wires repel each other. The current in one wire is 0.600 A. (a) What is the current in the second wire? (b) Are the two currents in the same direction or in opposite directions?

Demonstration



Exercise 27.46 09/24 2B

The Hall-voltage is

$$V = \frac{IBl}{neA}$$

So the density of free electrons is

$$n = \frac{IBl}{VeA} = \frac{IBl}{Vel \cdot h} = \frac{IB}{Veh}$$

We have $h = 0{,}23$ mm so

$$n = \frac{78\,A \cdot 2.29\,T}{131 \cdot 10^{-6}\,V \cdot 1{,}6 \cdot 10^{-19}\,C \cdot 0{,}23 \cdot 10^{-3}\,m}$$

$$= 3{,}7 \cdot 10^{28} \text{ electrons}/m^3$$

Exercise 28.12 09/24 7B

We use the Biot - Savart law.

Both fields are into the page - right hand rule - so their magnitudes add

The field from the 12.0 A segment is

$$dB_1 = \frac{\mu_0}{4\pi} \frac{I\, dl \sin\theta}{r^2} \qquad \frac{5.8\,\text{cm}}{2} \downarrow$$

$$= \frac{4 \cdot \pi \cdot 10^{-7}\ \text{T} \cdot \text{m/A}}{4\pi} \cdot \frac{12\ \text{A} \cdot 0{,}0015\ \text{m} \cdot \frac{2{,}90\ \text{cm}}{8{,}00\ \text{cm}}}{(0{,}08\ \text{m})^2}$$

$$= 1{,}02 \cdot 10^{-7}\ \text{T}$$

The field from the 24 A wire is twice this, so the total field is

$$B = \underline{\underline{3{,}06 \cdot 10^{-7}\ \text{T}}}$$

Exercise 28.30

09/24 8B

We know that

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2 \cdot \pi \cdot r}$$

So

$$I_2 = \frac{F}{l} \frac{2\pi r}{\mu_0 I_1}$$

$$= 4{,}0 \cdot 10^{-5}\ N/m \cdot \frac{2 \cdot \pi \cdot 0{,}025\ m}{4 \cdot \pi \cdot 10^{-7}\ T \cdot m/A \cdot 0{,}60\ A}$$

$$= \underline{\underline{8{,}33\ A}}$$

The wires repel so the currents are in opposite directions.