Storyline

Sources of the Magnetic Field

Physics for Scientists and Engineers, 10e
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BROOKS/COLE
CENGAGE Learning

Relationship between Magnetism and Electricity

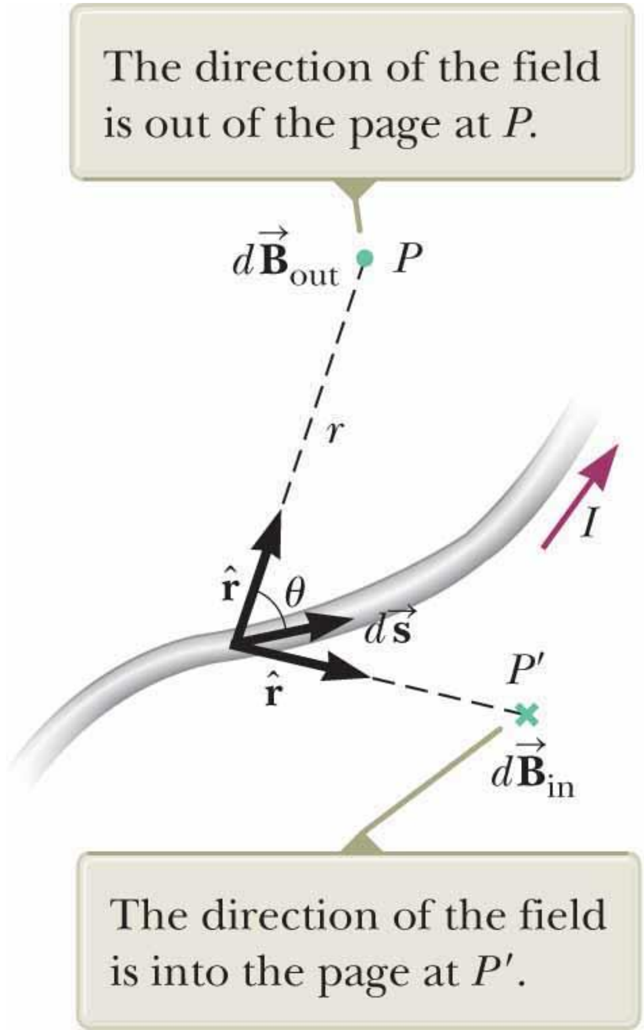
The Biot–Savart Law

$$d\vec{\mathbf{B}} = \frac{\mu_0}{4\pi}\frac{Id\vec{\mathbf{s}}\times\hat{\mathbf{r}}}{r^2}$$

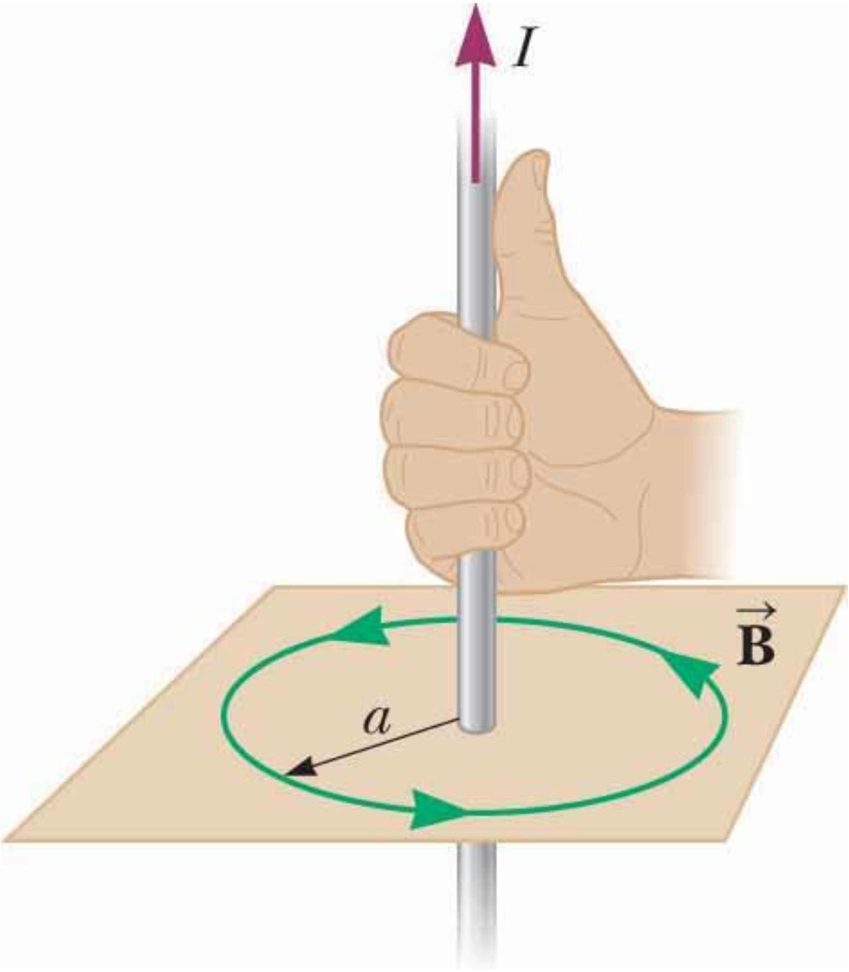
$$\mu_0 = 4\pi\times10^{-7}\ \mathrm{T\cdot m/A}$$

$$\vec{\mathbf{E}} = k_e\frac{q}{r^2}\hat{\mathbf{r}}$$

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

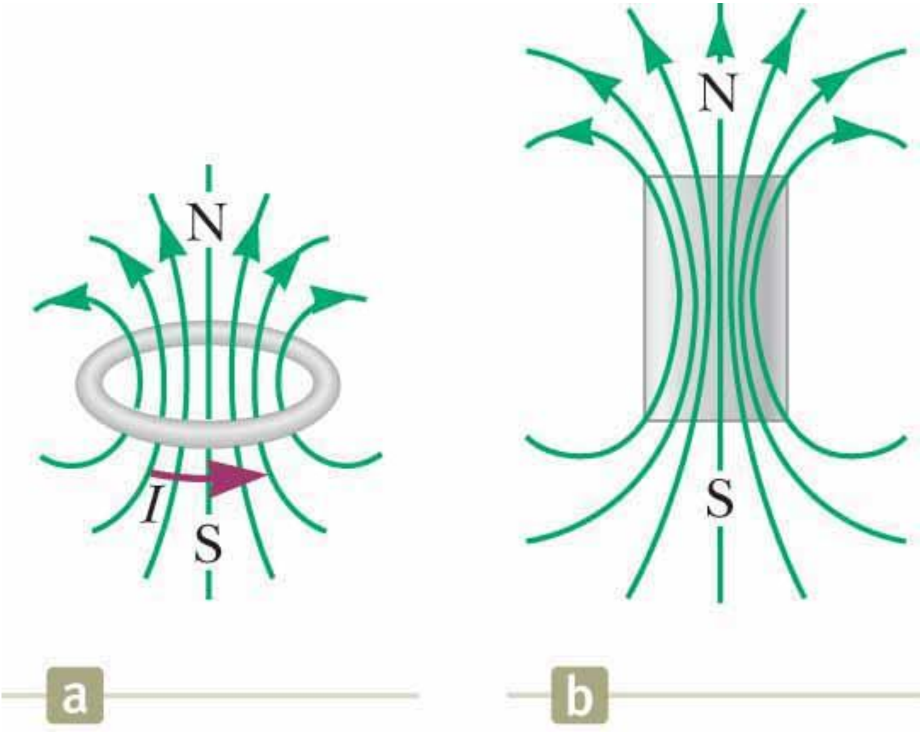


Magnetic Fields Due to Currents

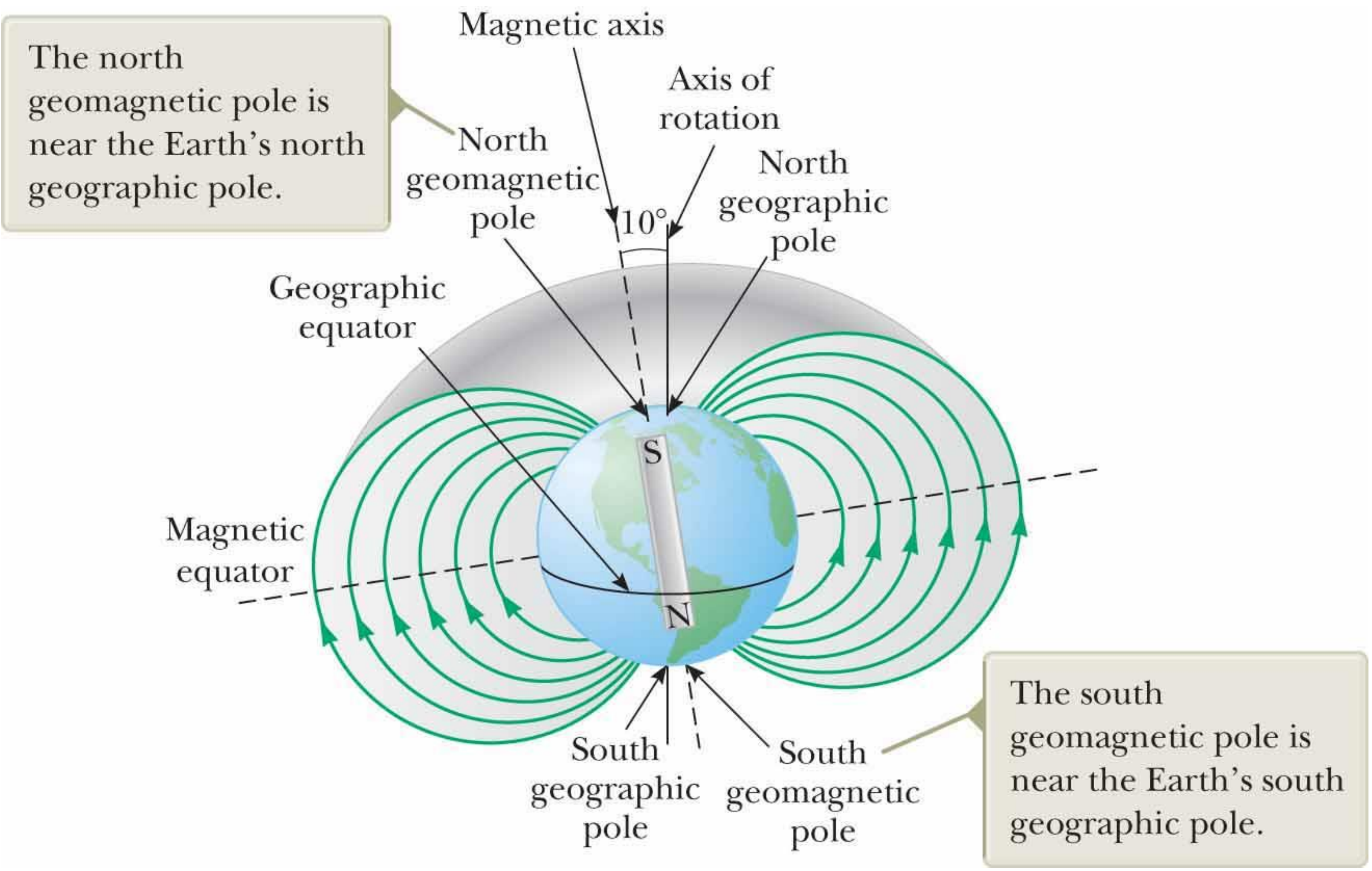


Example 29.3: Magnetic Field on the Axis of a Circular Current Loop

$$B = \frac{\mu_0 I}{2a} \quad \text{(at center of loop)}$$



Source of Earth's Magnetic Field



The Magnetic Force Between Two Parallel Conductors

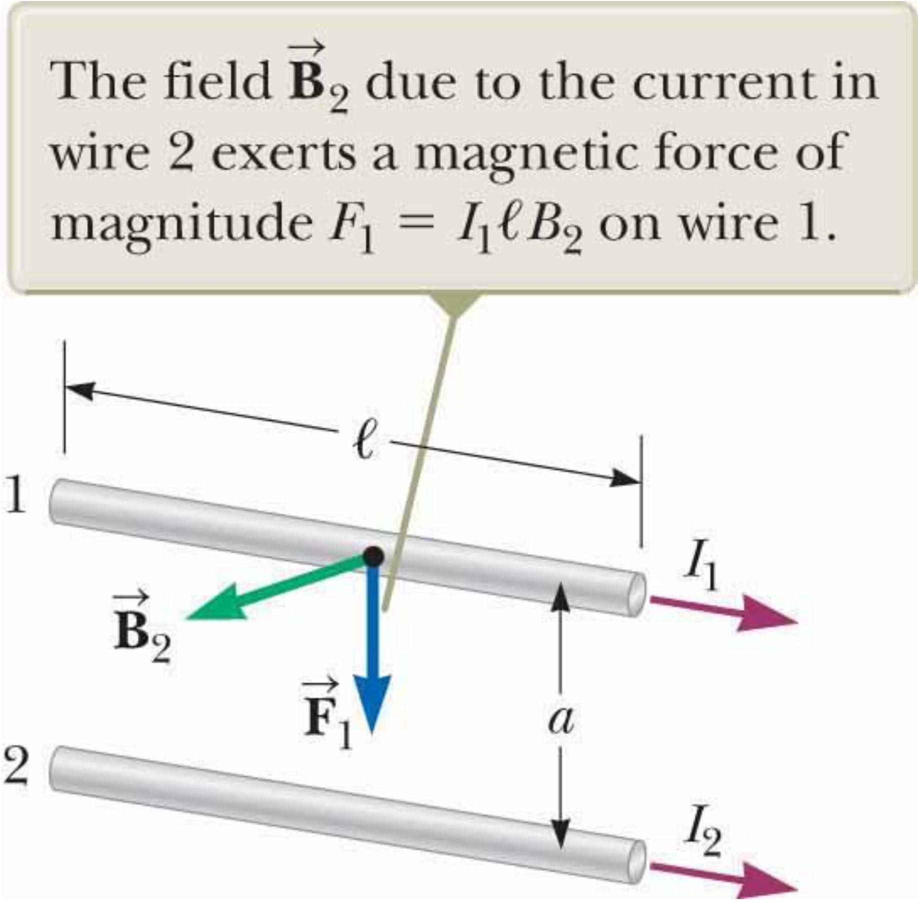
$$\vec{\mathbf{F}}_1 = I_1 \vec{\ell} \times \vec{\mathbf{B}}_2 \qquad F_1 = I_1 \ell B_2$$

$$F_1 = I_1 \ell B_2$$

$$= I_1 \ell \left(\frac{\mu_0 I_2}{2\pi a} \right)$$

$$= \frac{\mu_0 I_1 I_2}{2\pi a} \ell$$

$$\frac{F_B}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi a}$$



The Magnetic Force Between Two Parallel Conductors

When the magnitude of the force per unit length between two long, parallel wires that carry identical currents and are separated by 1 m is 2×10^{-7} N/m, the current in each wire is defined to be 1 A.

$$\frac{F_B}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi a}$$

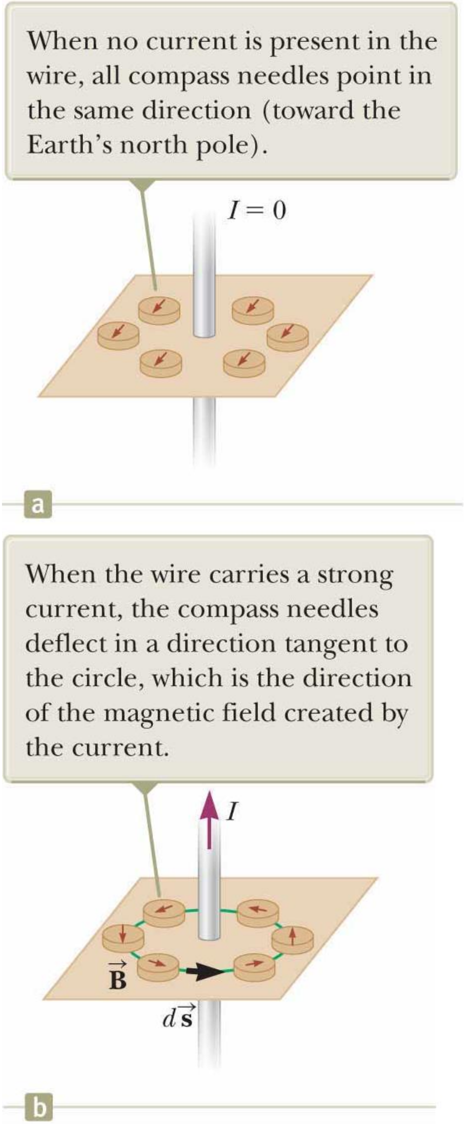
$$F_1 = \frac{\mu_0 I_1 I_2}{2\pi a} \ell$$

Ampère's Law

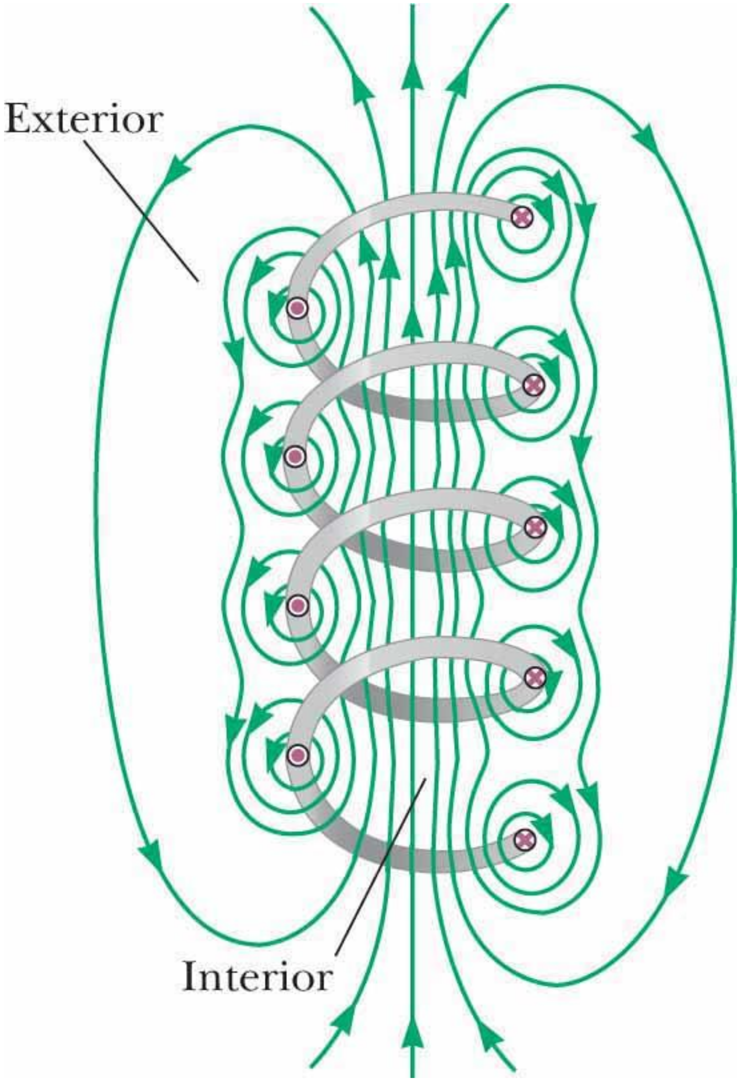
$$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} = B\oint ds = \frac{\mu_0 I}{2\pi r}(2\pi r) = \mu_0 I$$

The line integral of $\vec{\mathbf{B}} \cdot d\vec{\mathbf{s}}$ around any closed path equals $\mu_0 I$, where I is the total steady current passing through any surface bounded by the closed path:

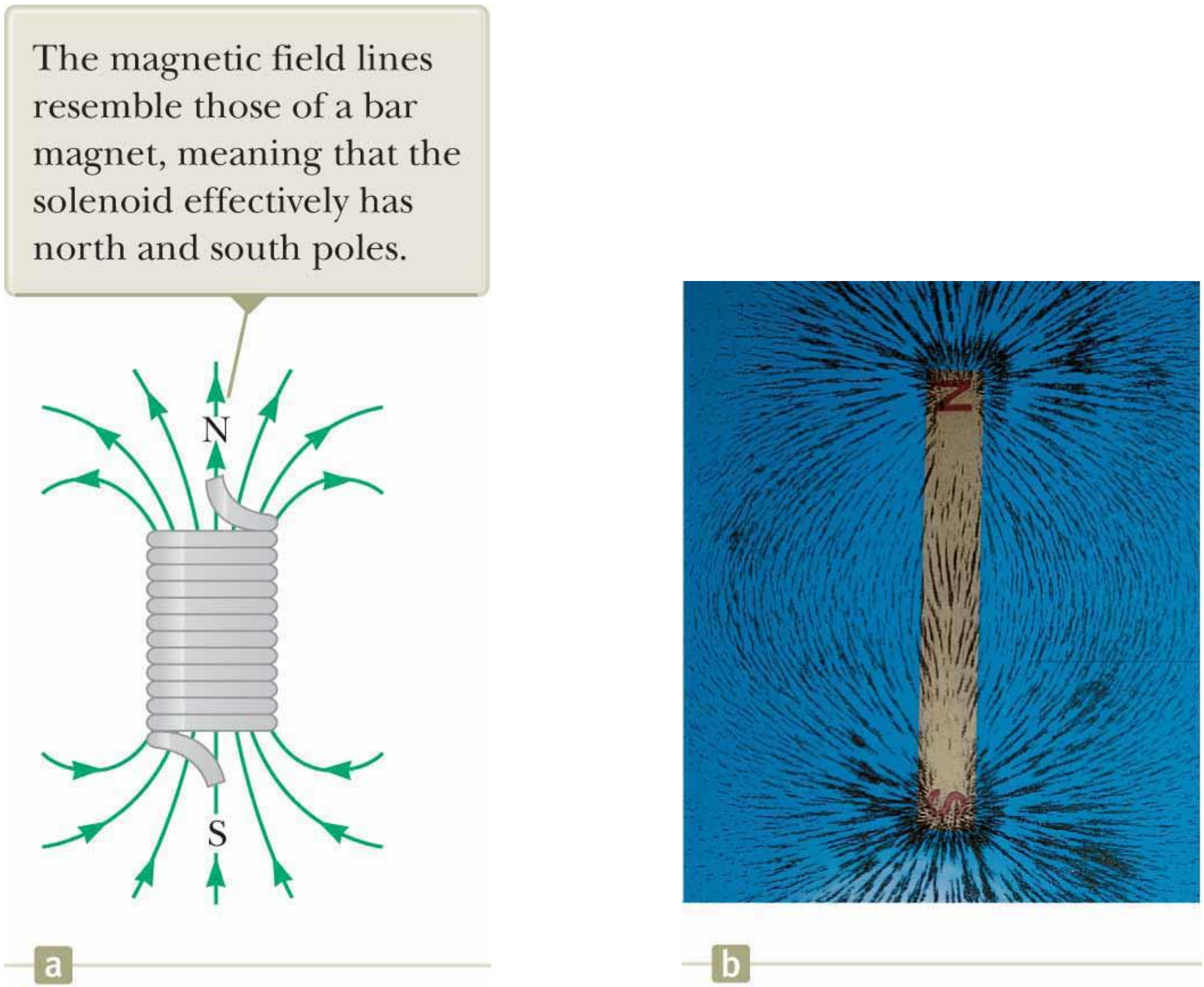
$$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} = \mu_0 I$$



The Magnetic Field of a Solenoid



The Magnetic Field of a Solenoid

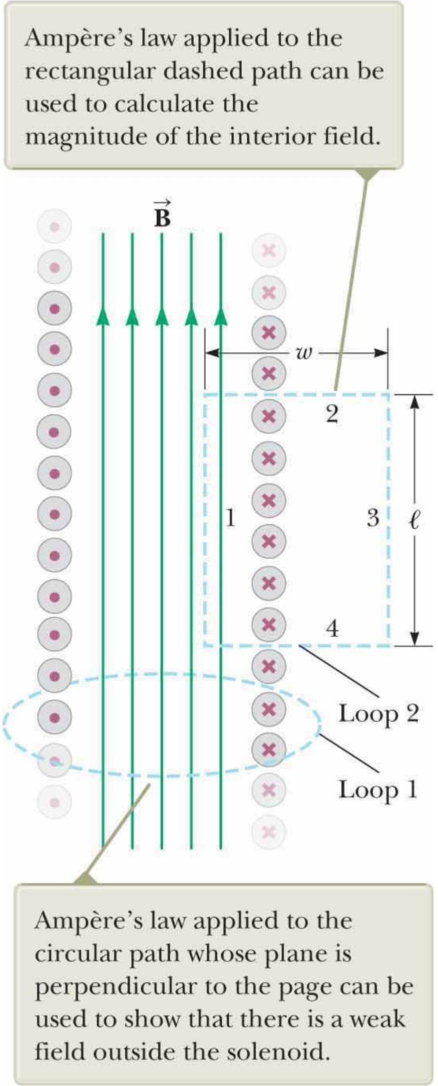


The Magnetic Field of a Solenoid

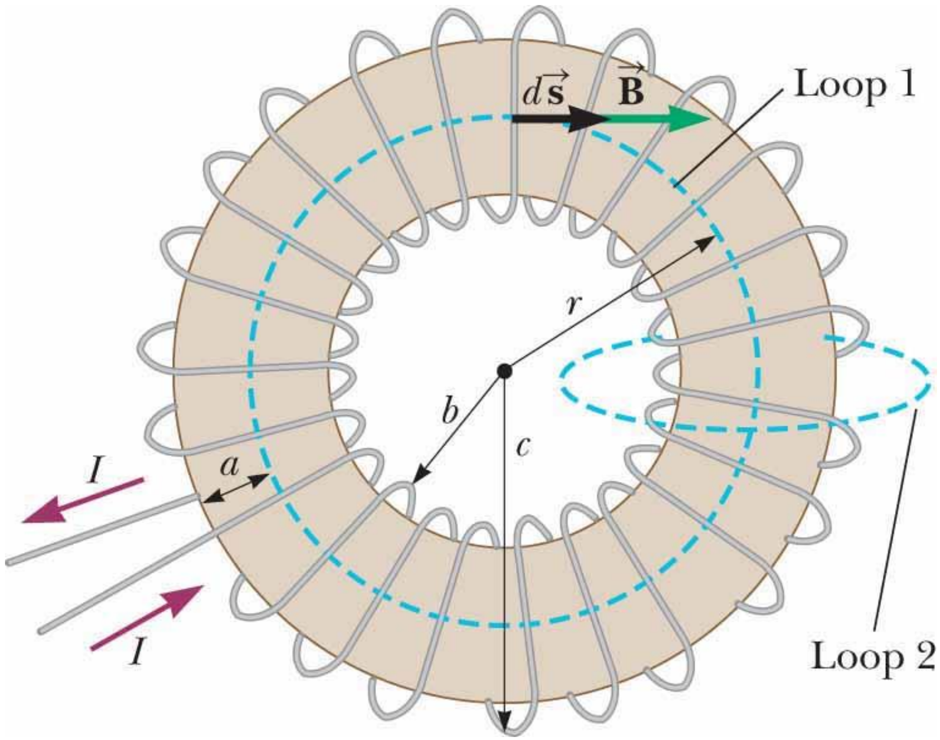
$$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} = \oint_{\text{path 1}} \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} + \oint_{\text{path 2}} \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} = B\ell$$

$$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} = B\ell = \mu_0 NI$$

$$B = \mu_0 \frac{N}{\ell} I = \mu_0 n I$$



The Magnetic Field of a Solenoid

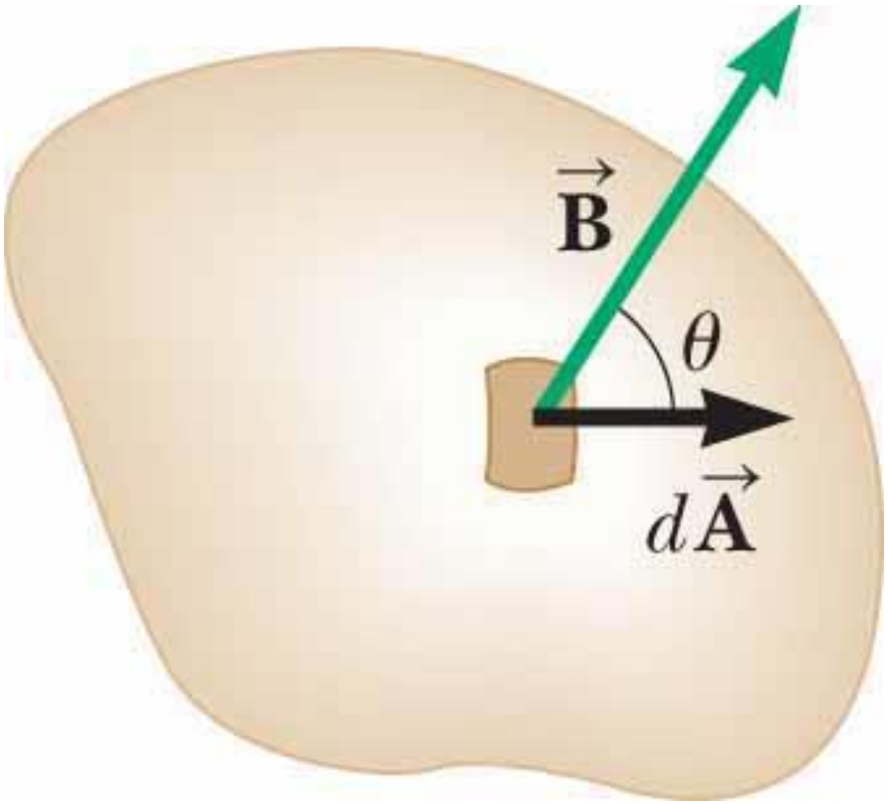


$$B_{\text{toroid}} = \frac{\mu_0 N I}{2\pi r} \qquad B_{\text{solenoid}} = \mu_0 n I \Rightarrow n = \frac{N}{2\pi r}$$

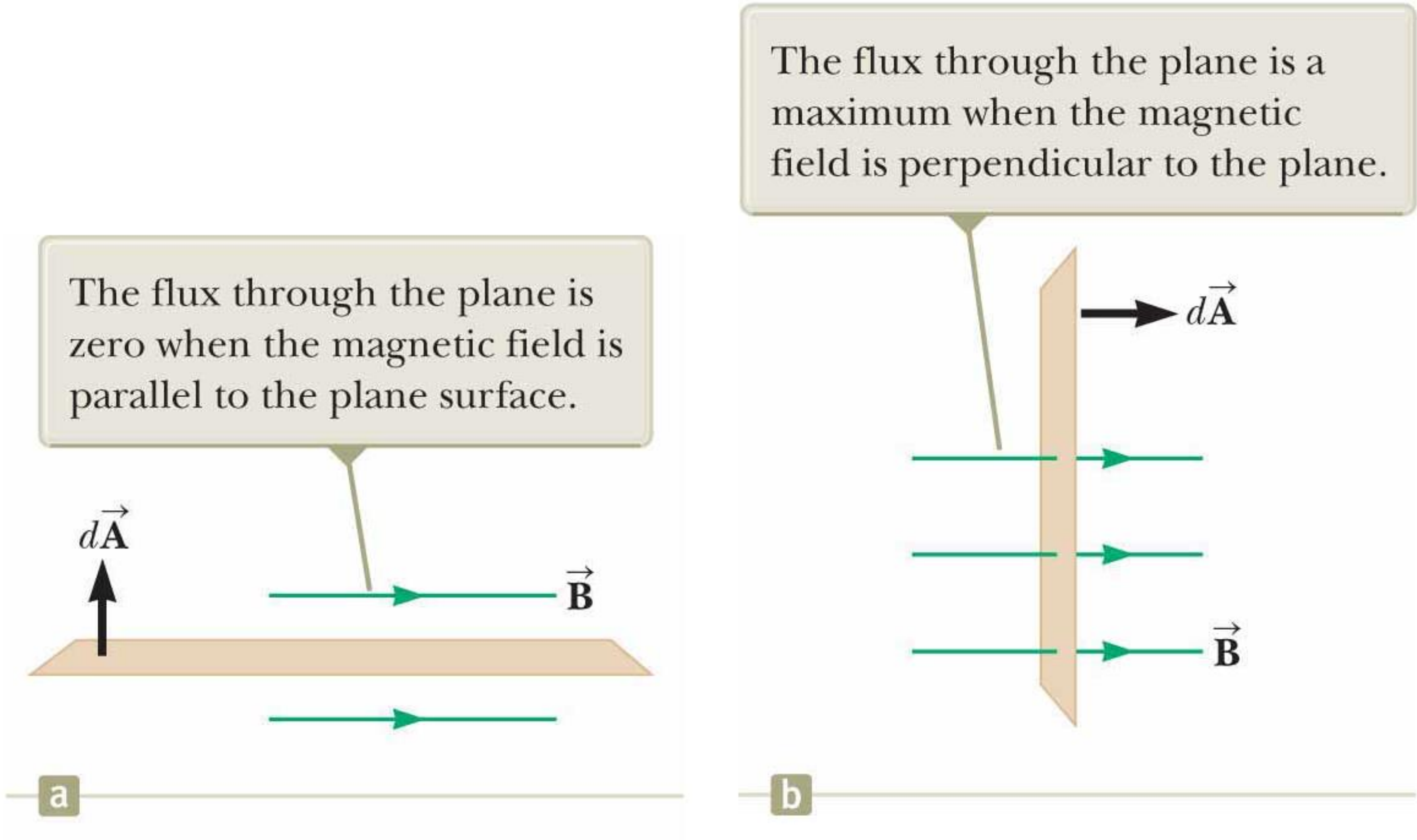
Gauss's Law in Magnetism

$$\Phi_B \equiv \int \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$

$$\Phi_B = BA\cos\theta$$



Gauss's Law in Magnetism

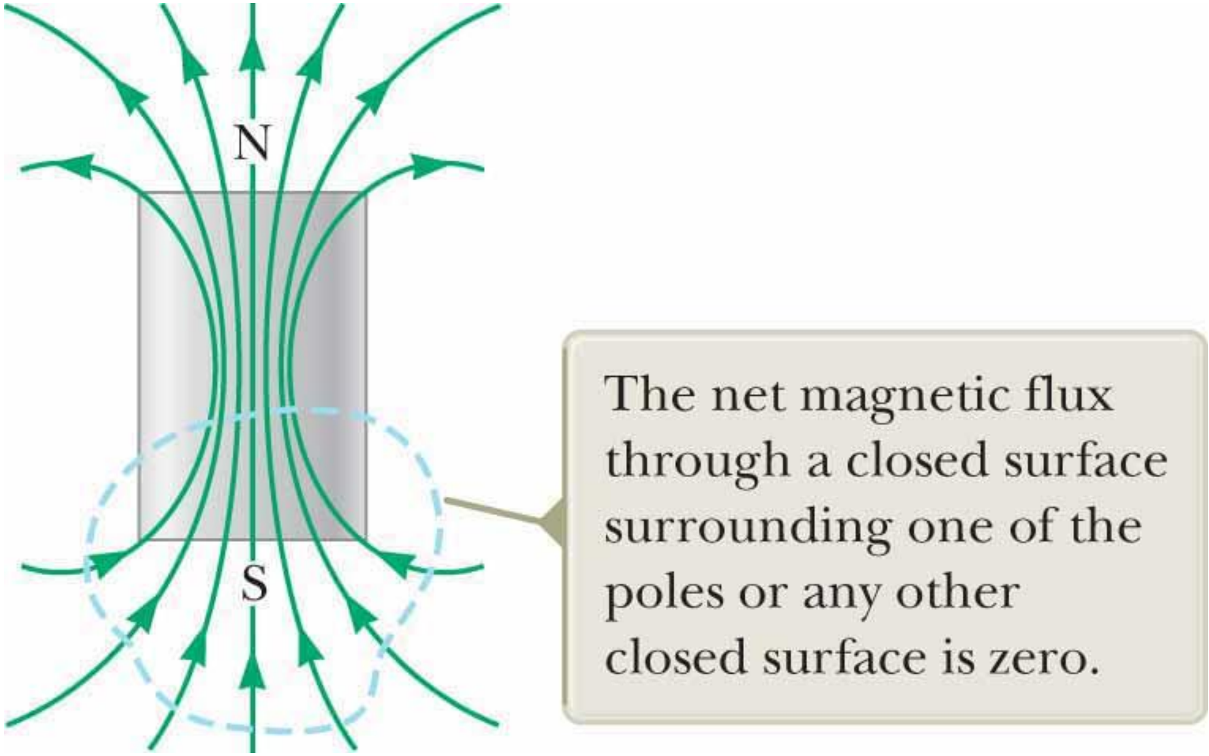


$$1\ \text{Wb} = 1\ \text{T} \cdot \text{m}^2$$

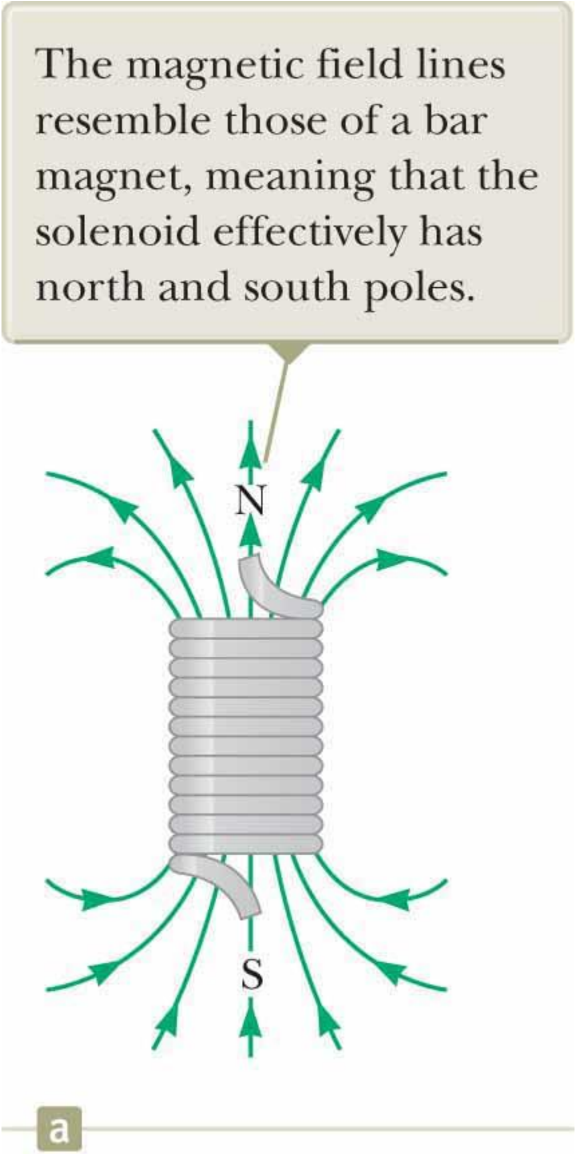
Gauss's Law in Magnetism

The net magnetic flux through any closed surface is always zero:

$$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$$



Magnetism in Matter



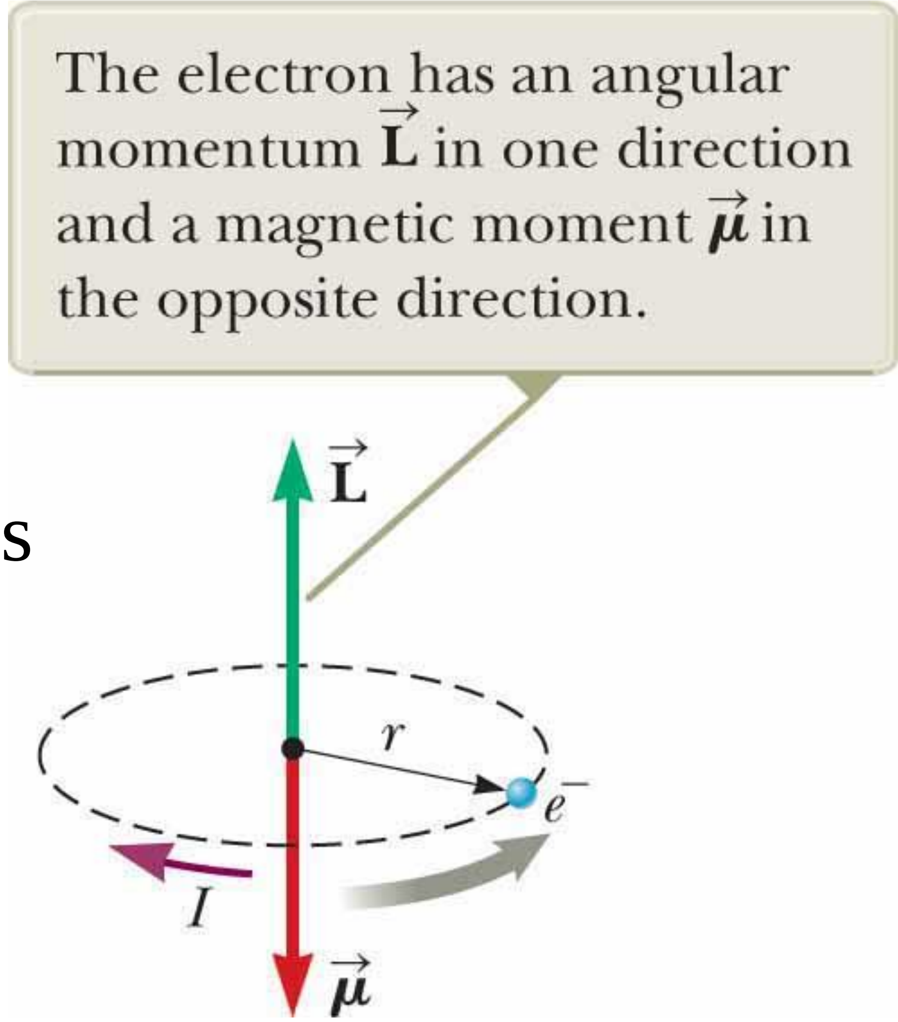
The Magnetic Moments of Atoms

$$\mu = IA$$

$$L = m_e v r$$

$$\hbar = \frac{h}{2\pi} = 1.05 \times 10^{-34}\ \text{J} \cdot \text{s}$$

$$\mu = \sqrt{2}\,\frac{e}{2m_e}\hbar$$

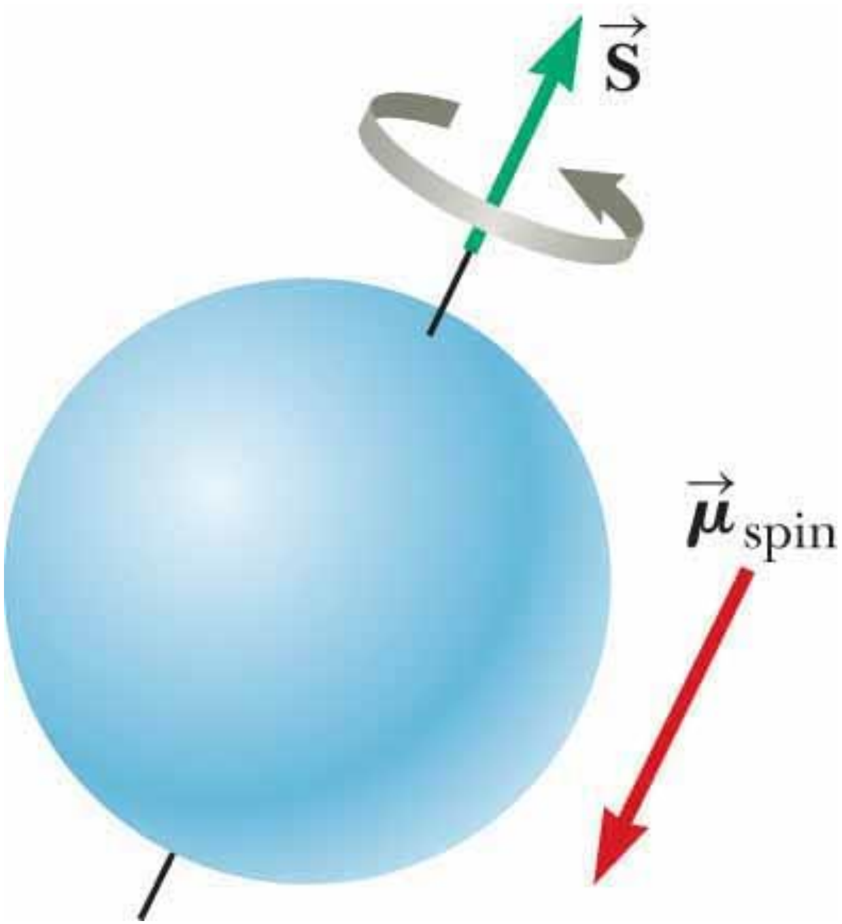


The Magnetic Moments of Atoms

$$S = \frac{\sqrt{3}}{2}\hbar$$

$$\mu_{\text{spin}} = \frac{e\hbar}{2m_e}$$

$$\mu_{\text{B}} = \frac{e\hbar}{2m_e} = 9.27\times10^{-24}\ \text{J/T}$$



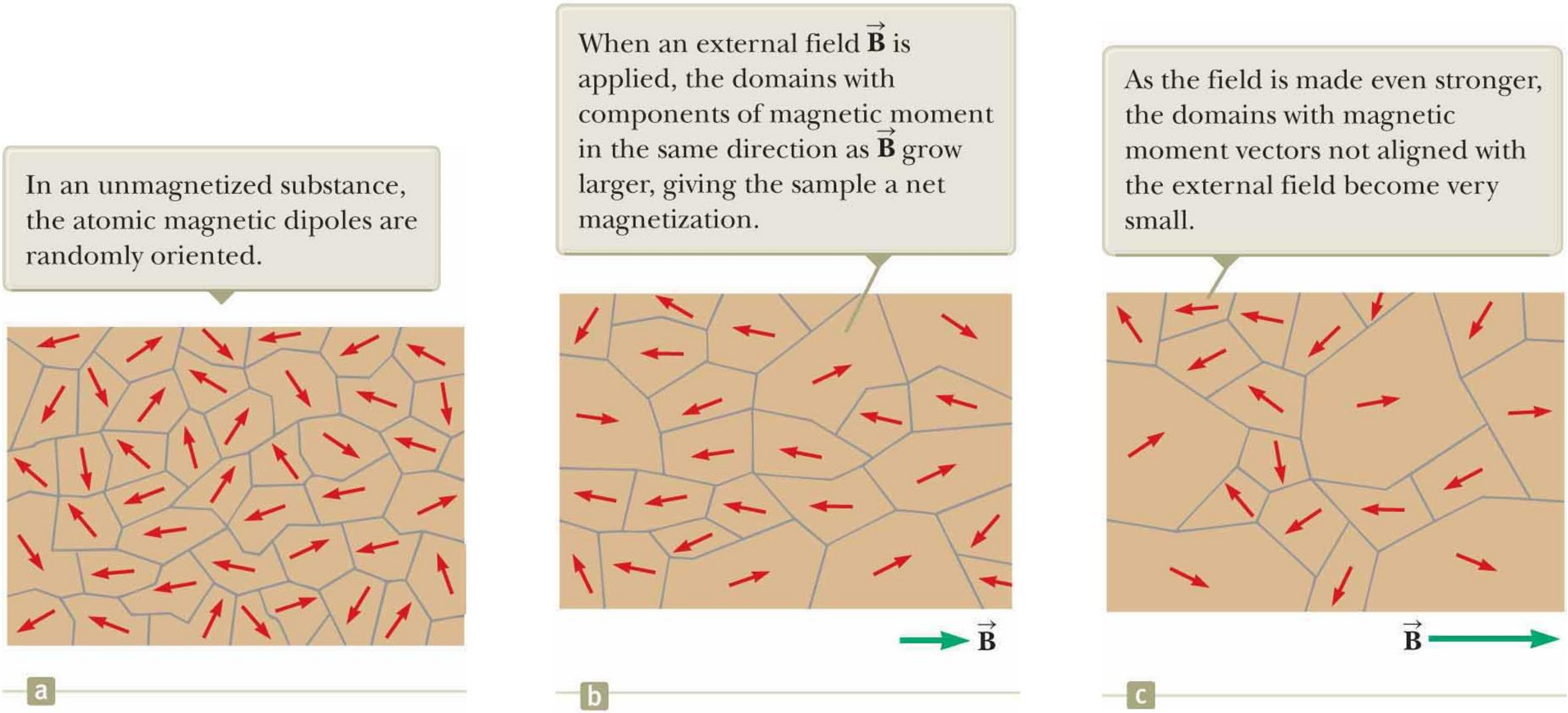
The Magnetic Moments of Atoms

TABLE 29.1 Magnetic Moments of Some Atoms and Ions

Atom or Ion	Magnetic Moment (10^{-24} J/T)
H	9.27
He	0
Ne	0
Ce^{3+}	19.8
Yb^{3+}	37.1

$$\mu_B = \frac{e\hbar}{2m_e} = 9.27\times10^{-24}\ \text{J/T}$$

Ferromagnetism

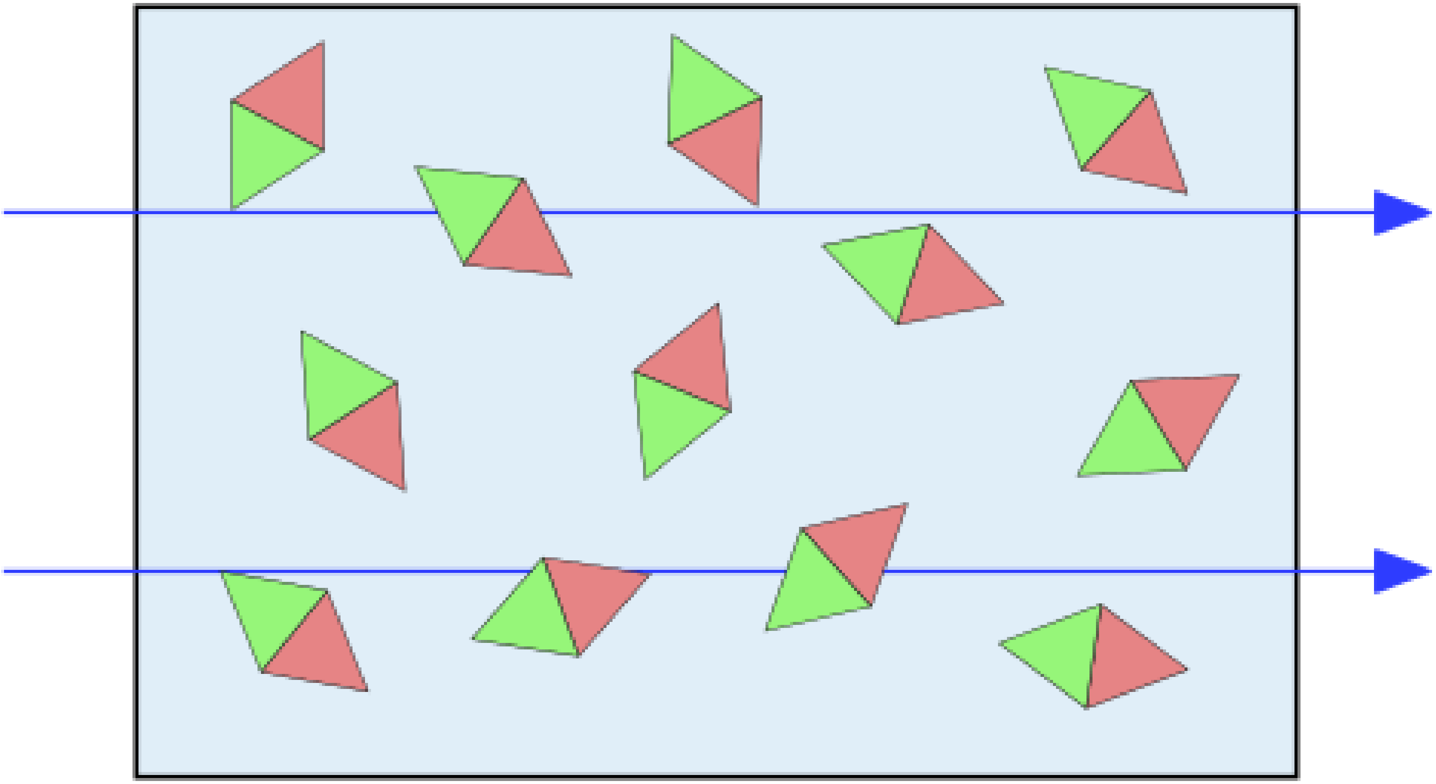


Ferromagnetism

TABLE 29.2 Curie Temperatures for Several Ferromagnetic Substances

Substance	T_{Curie} (K)
Iron	1 043
Cobalt	1 394
Nickel	631
Gadolinium	317
Fe_2O_3	893

Paramagnetism



Diamagnetism

In the Meissner effect, the small magnet at the top induces currents in the superconducting disk below, which is cooled to −321°F (77 K). The currents create a repulsive magnetic force on the magnet causing it to levitate above the superconducting disk.