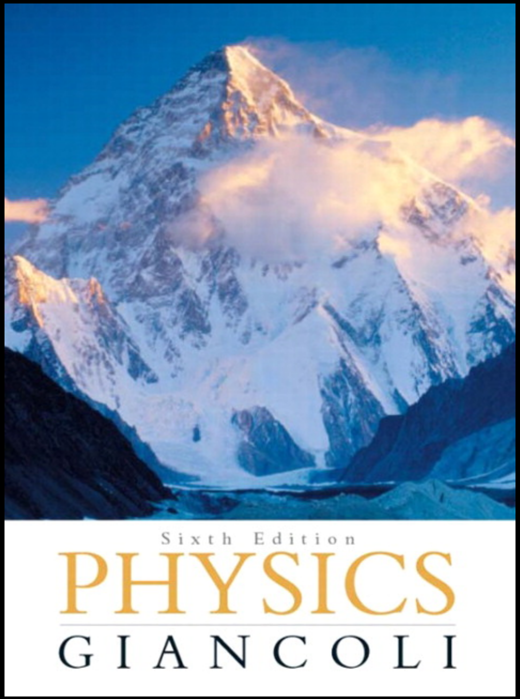

Lecture PowerPoints

Chapter 20

Physics: Principles with Applications, 6th edition

Giancoli

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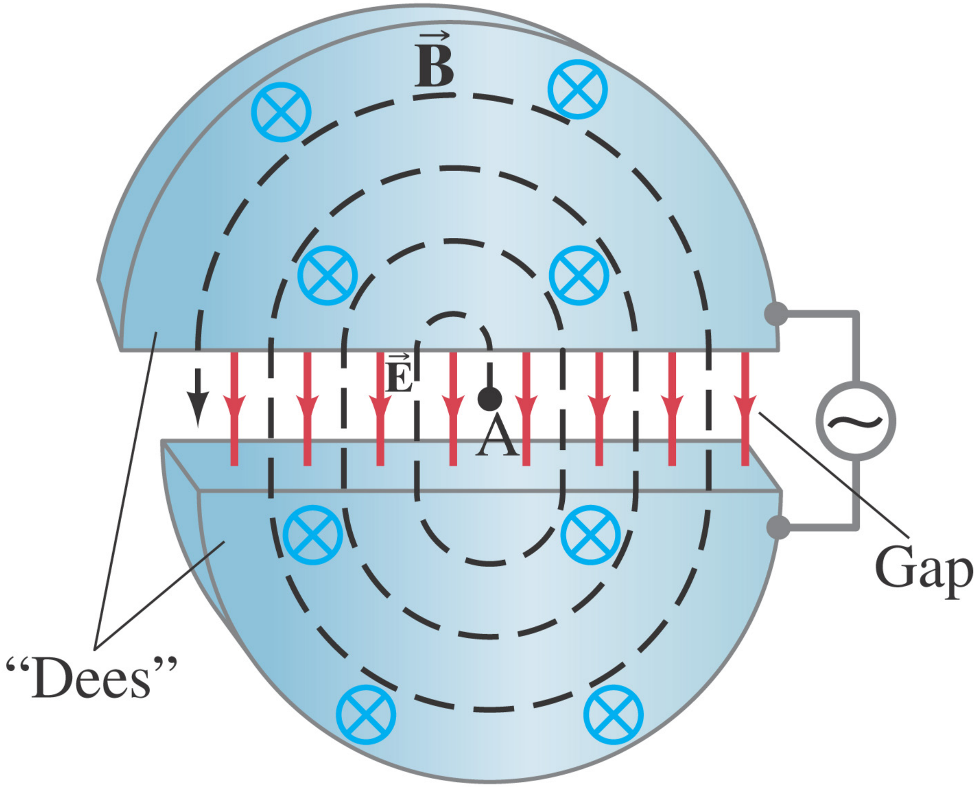
Chapter 20

Magnetism



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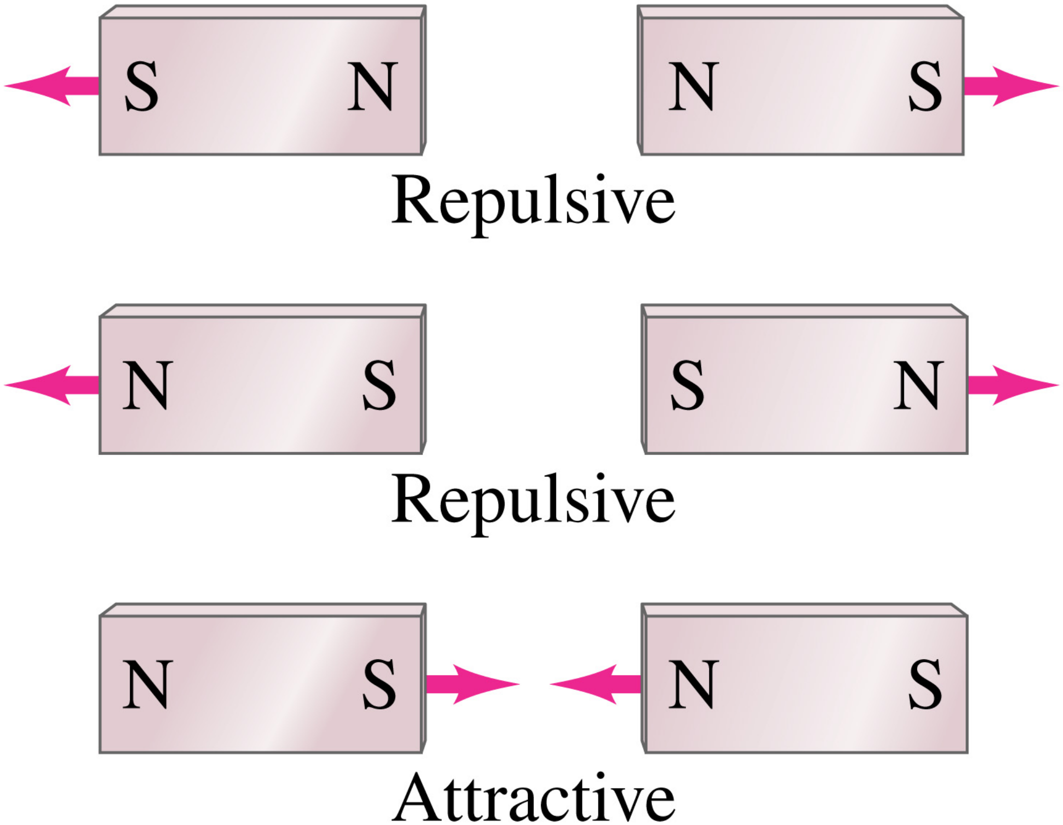
20.1 Magnets and Magnetic Fields

Magnets have two ends – poles – called north and south.

Like poles repel; unlike poles attract.



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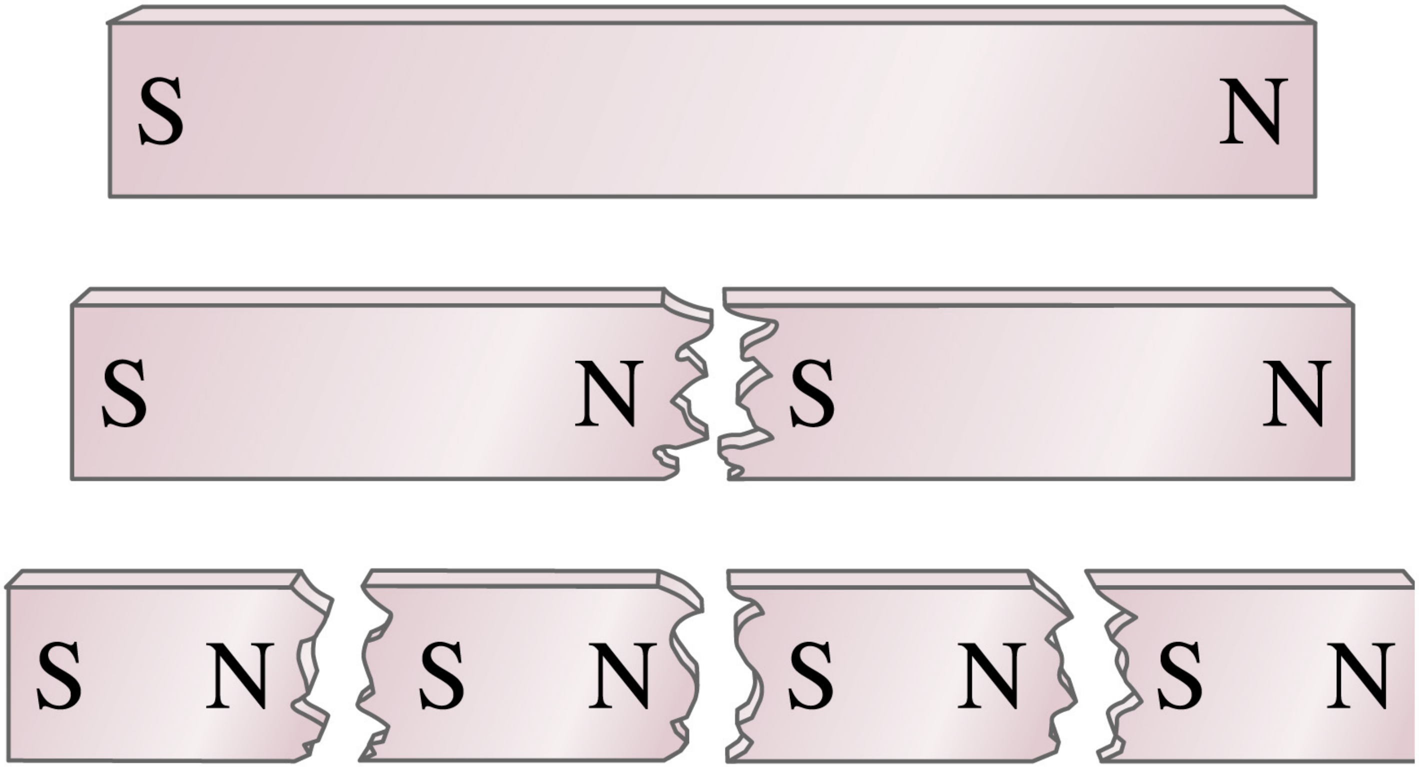
20.1 Magnets and Magnetic Fields

However, if you cut a magnet in half, you don't get a north pole and a south pole – you get two smaller magnets.



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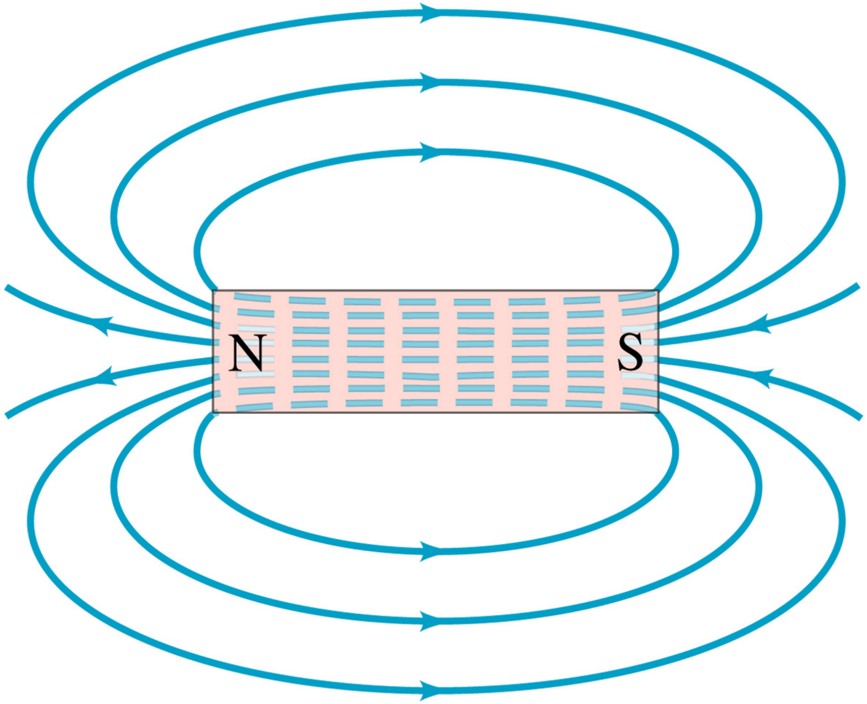
20.1 Magnets and Magnetic Fields

Magnetic fields can be visualized using magnetic field lines, which are always closed loops.



(b)

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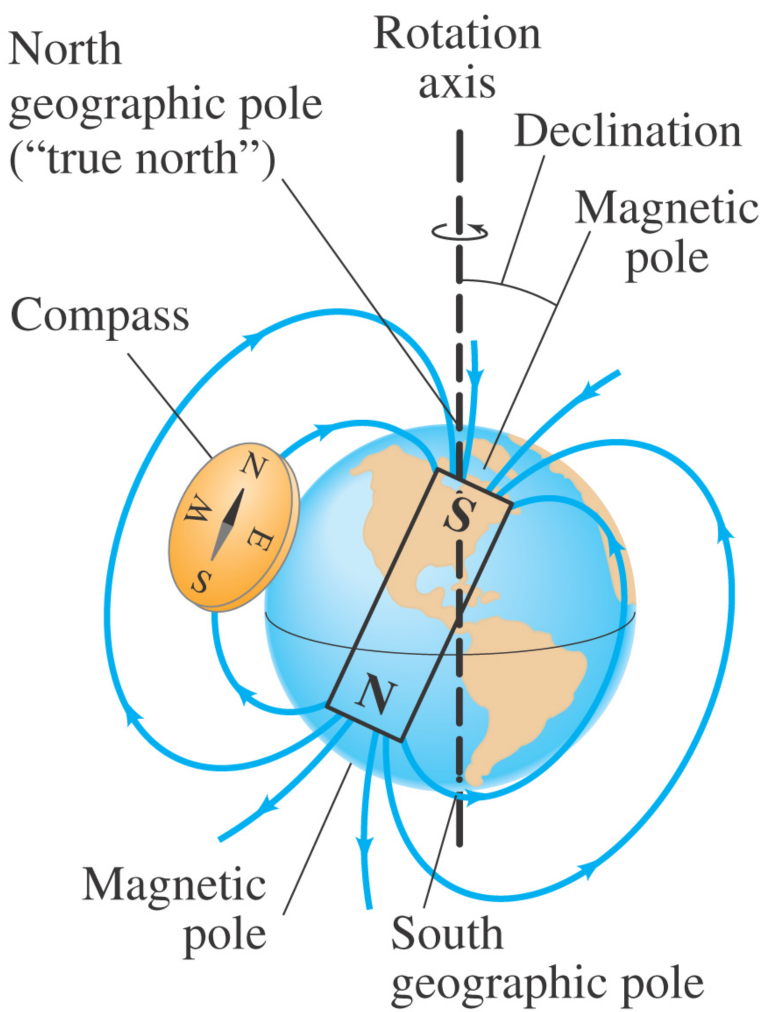
20.1 Magnets and Magnetic Fields

The Earth's magnetic field is similar to that of a bar magnet.

Note that the Earth's "North Pole" is really a south magnetic pole, as the north ends of magnets are attracted to it.



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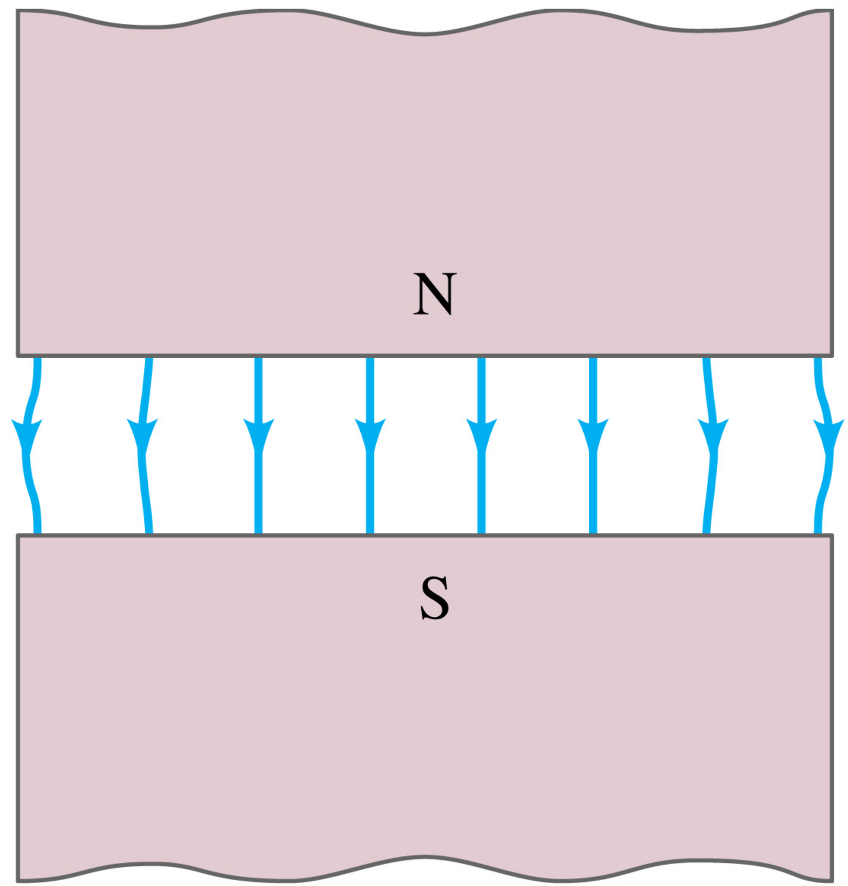
20.1 Magnets and Magnetic Fields

A uniform magnetic field is constant in magnitude and direction.

The field between these two wide poles is nearly uniform.



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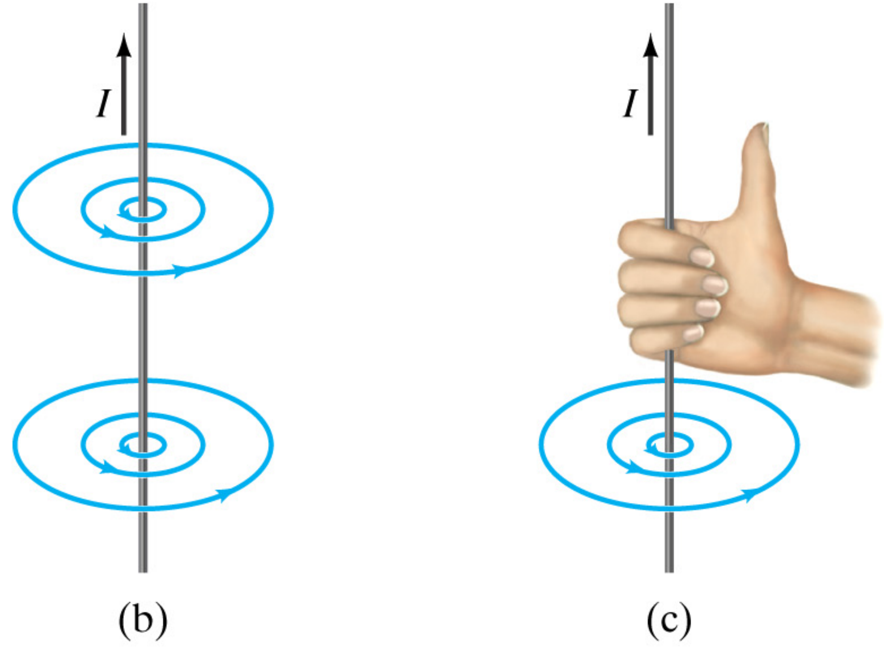
20.2 Electric Currents Produce Magnetic Fields

Experiments show that an electric current produces a magnetic field.



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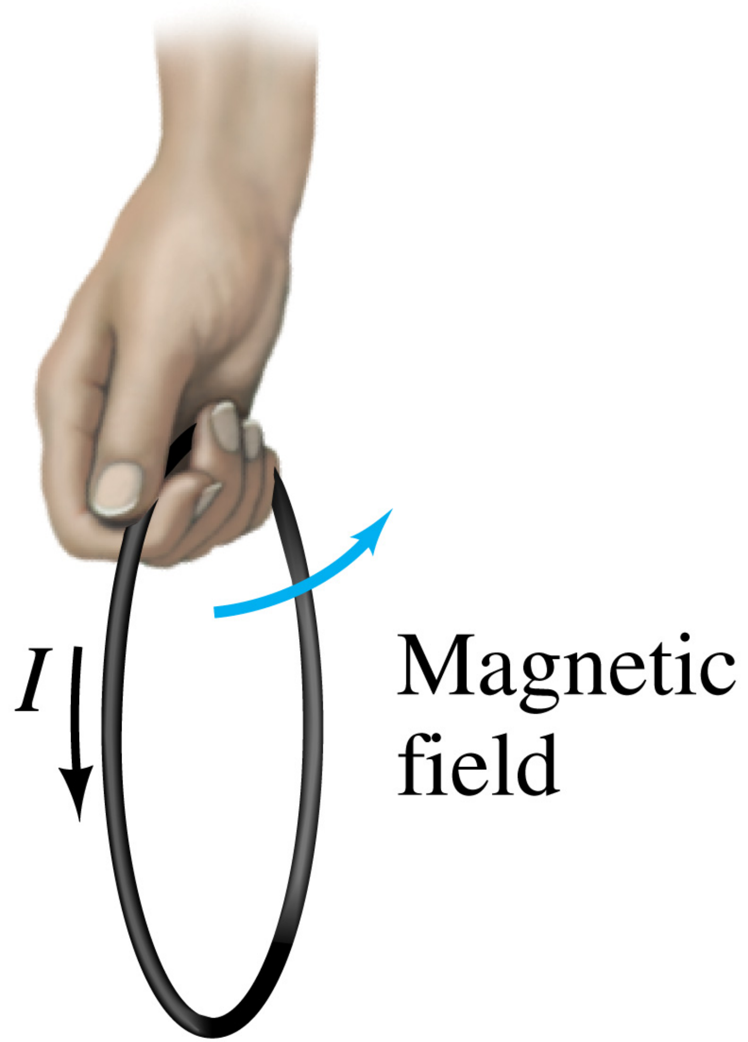
20.2 Electric Currents Produce Magnetic Fields

The direction of the field is given by a right-hand rule.



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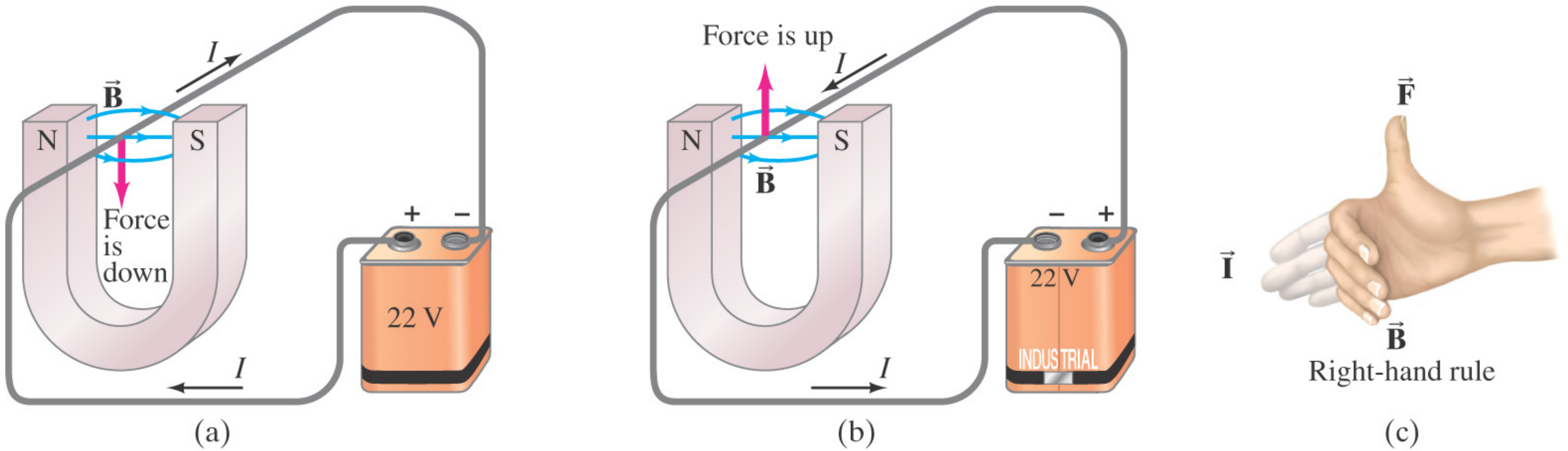
20.3 Force on an Electric Current in a Magnetic Field; Definition of B

A magnet exerts a force on a current-carrying wire. The direction of the force is given by a right-hand rule.



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20.3 Force on an Electric Current in a Magnetic Field; Definition of **B**

The force on the wire depends on the current, the length of the wire, the magnetic field, and its orientation.

$$F = IlB \sin\theta \qquad (20\text{-}1)$$

This equation defines the magnetic field B.

20.3 Force on an Electric Current in a Magnetic Field; Definition of B

Unit of **B**: the tesla, T.

1 T = 1 N/A·m.

Another unit sometimes used: the gauss (G).

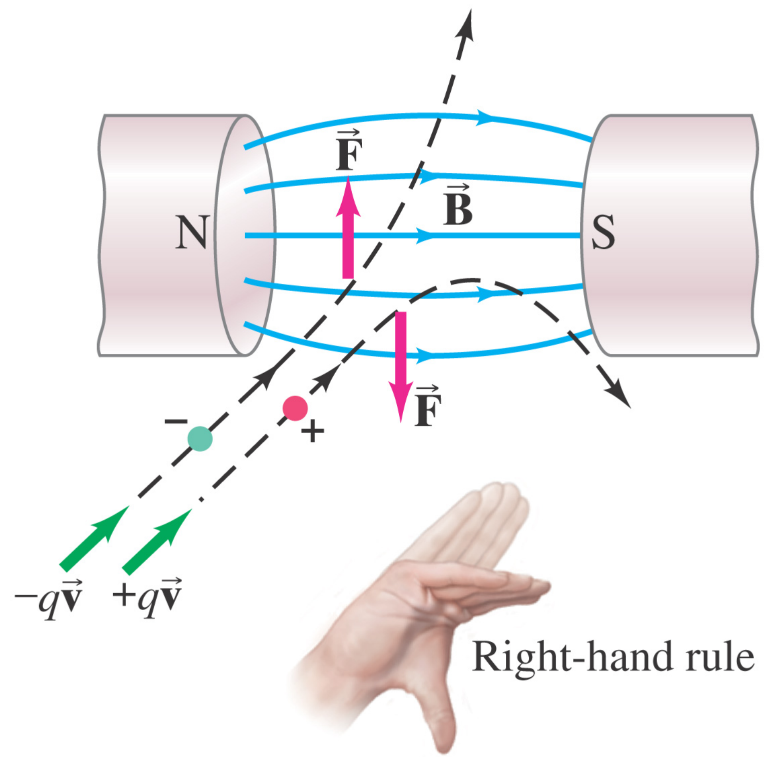
1 G = 10^{-4} T.

20.4 Force on Electric Charge Moving in a Magnetic Field

The force on a moving charge is related to the force on a current:

$$F = qvB\sin\theta \qquad (20\text{-}3)$$

Once again, the direction is given by a right-hand rule.



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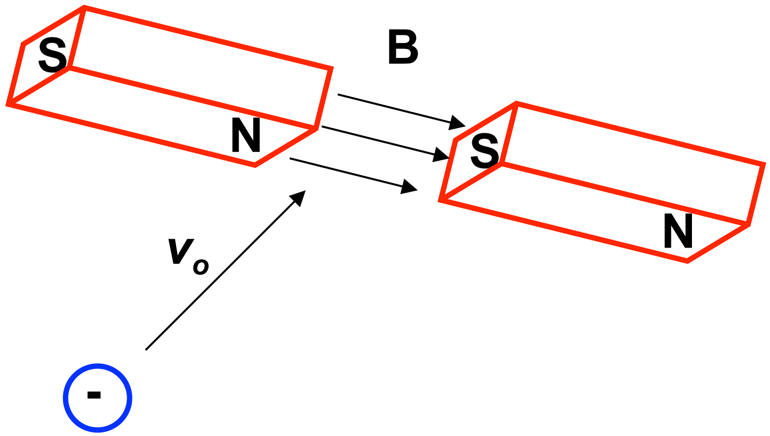
Magnetic Force on a moving charge



If a MOVING CHARGE moves into a magnetic field it will experience a MAGNETIC FORCE. This deflection is 3D in nature.

$$\vec{F}_B = q\vec{v} \otimes \vec{B}$$

$$F_B = qvB\sin\theta$$

The conditions for the force are:

- **Must have a magnetic field present**
- **Charge must be moving**
- **Charge must be positive or negative**
- **Charge must be moving PERPENDICULAR to the field.**

Example

A proton moves with a speed of $1.0x10^5$ m/s through the Earth's magnetic field, which has a value of 55μT at a particular location. When the proton moves eastward, the magnetic force is a maximum, and when it moves northward, no magnetic force acts upon it. What is the magnitude and direction of the magnetic force acting on the proton?

$$F_B = qvB, \theta = 90, \sin 90 = 1$$

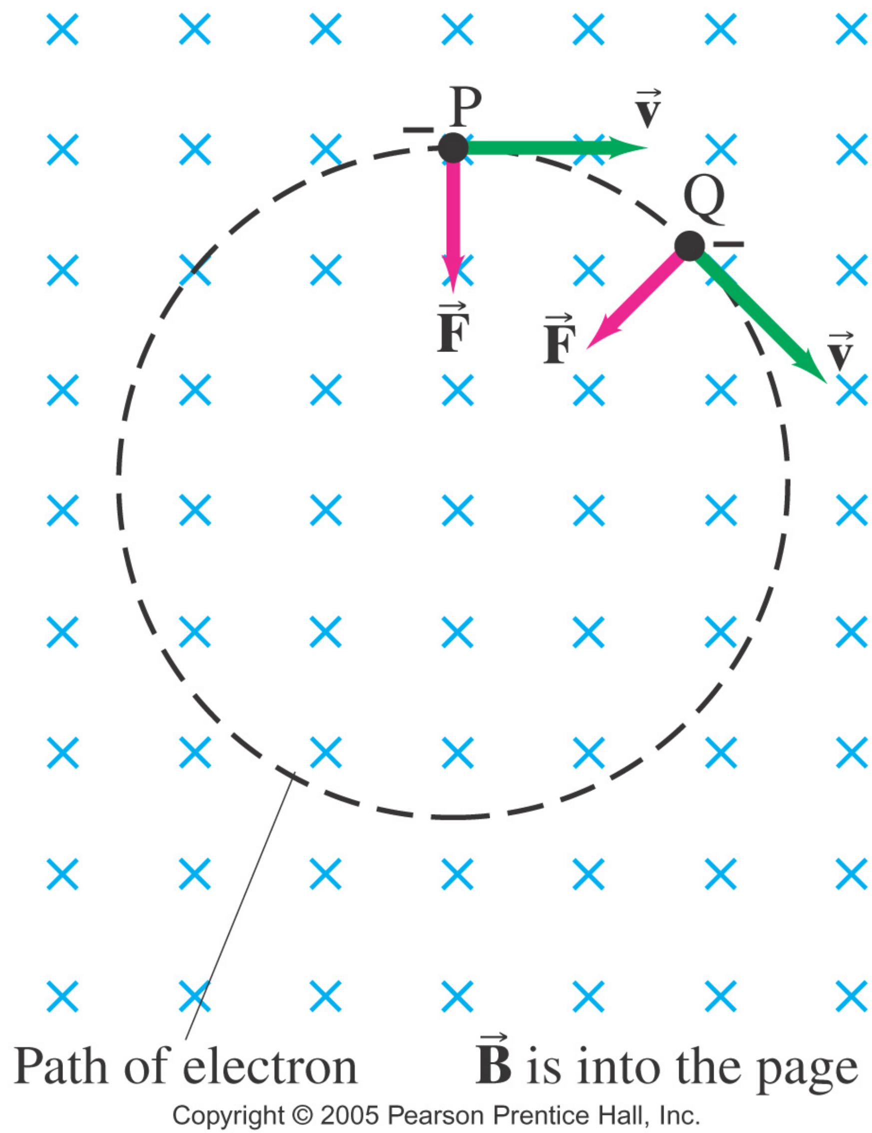
$$F_B = (1.6x10^{-19})(1.0x10^5)(55x10^{-6})$$

$$F_B = 8.8x10^{-19}\ \mathrm{N}$$

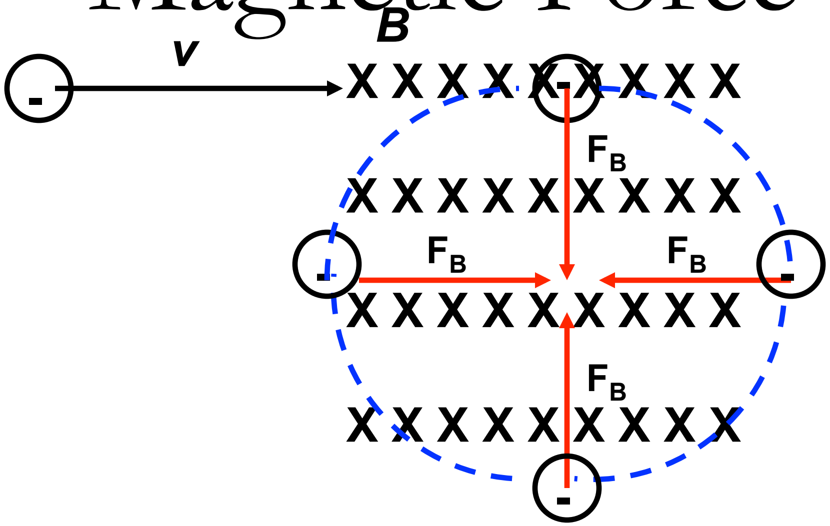
The direction cannot be determined precisely by the given information. Since no force acts on the proton when it moves northward (meaning the angle is equal to ZERO), we can infer that the magnetic field must either go northward or southward.

20.4 Force on Electric Charge Moving in a Magnetic Field

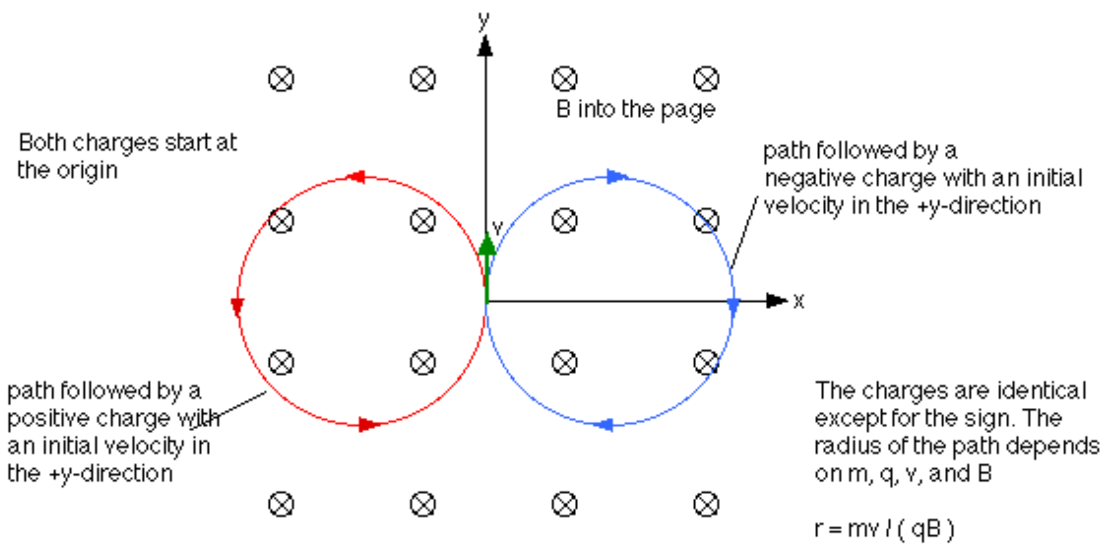
If a charged particle is moving perpendicular to a uniform magnetic field, its path will be a circle.



Magnetic Force and Circular Motion

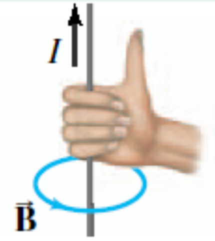
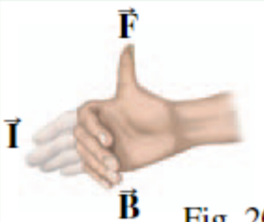
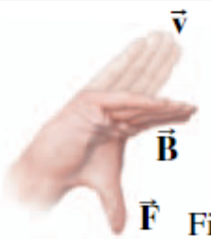


Suppose we have an electron traveling at a velocity , *v*, entering a magnetic field, *B*, directed into the page. What happens after the initial force acts on the charge?



Right Hand Rule

TABLE 20–1 Summary of Right-hand Rules (= RHR)

Physical Situation	Example	How to Orient Right Hand	Result
1. Magnetic field produced by current (RHR-1)	 Fig. 20–8c	Wrap fingers around wire with thumb pointing in direction of current I	Fingers point in direction of $\vec{\mathbf{B}}$
2. Force on electric current I due to magnetic field (RHR-2)	 Fig. 20–11c	Fingers point straight along current I, then bent along magnetic field $\vec{\mathbf{B}}$	Thumb points in direction of force
3. Force on electric charge $+q$ due to magnetic field (RHR-3)	 Fig. 20–14	Fingers point along particle's velocity $\vec{\mathbf{v}}$, then along $\vec{\mathbf{B}}$	Thumb points in direction of force

20.4 Force on Electric Charge Moving in a Magnetic Field

Problem solving: Magnetic fields – things to remember

1. The magnetic force is perpendicular to the magnetic field direction.
2. The right-hand rule is useful for determining directions.
3. Equations in this chapter give magnitudes only. The right-hand rule gives the direction.

20.5 Magnetic Field Due to a Long Straight Wire

The field is inversely proportional to the distance from the wire:

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} \qquad \textbf{(20-6)}$$

The constant μ_0 is called the permeability of free space, and has the value:

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

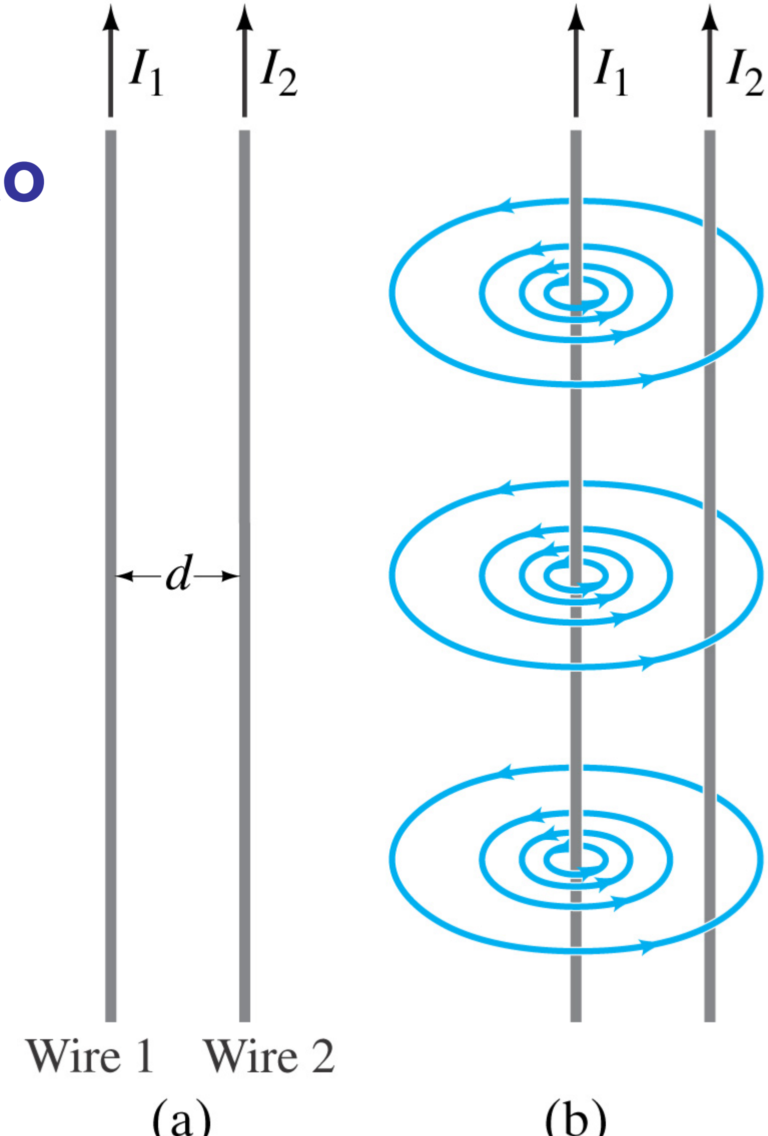
20.6 Force between Two Parallel Wires

The magnetic field produced at the position of wire 2 due to the current in wire 1 is:

$$B_1 = \frac{\mu_0}{2\pi}\frac{I_1}{d}$$

The force this field exerts on a length l_2 of wire 2 is:

$$F_2 = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d} l_2 \qquad \textbf{(20-7)}$$



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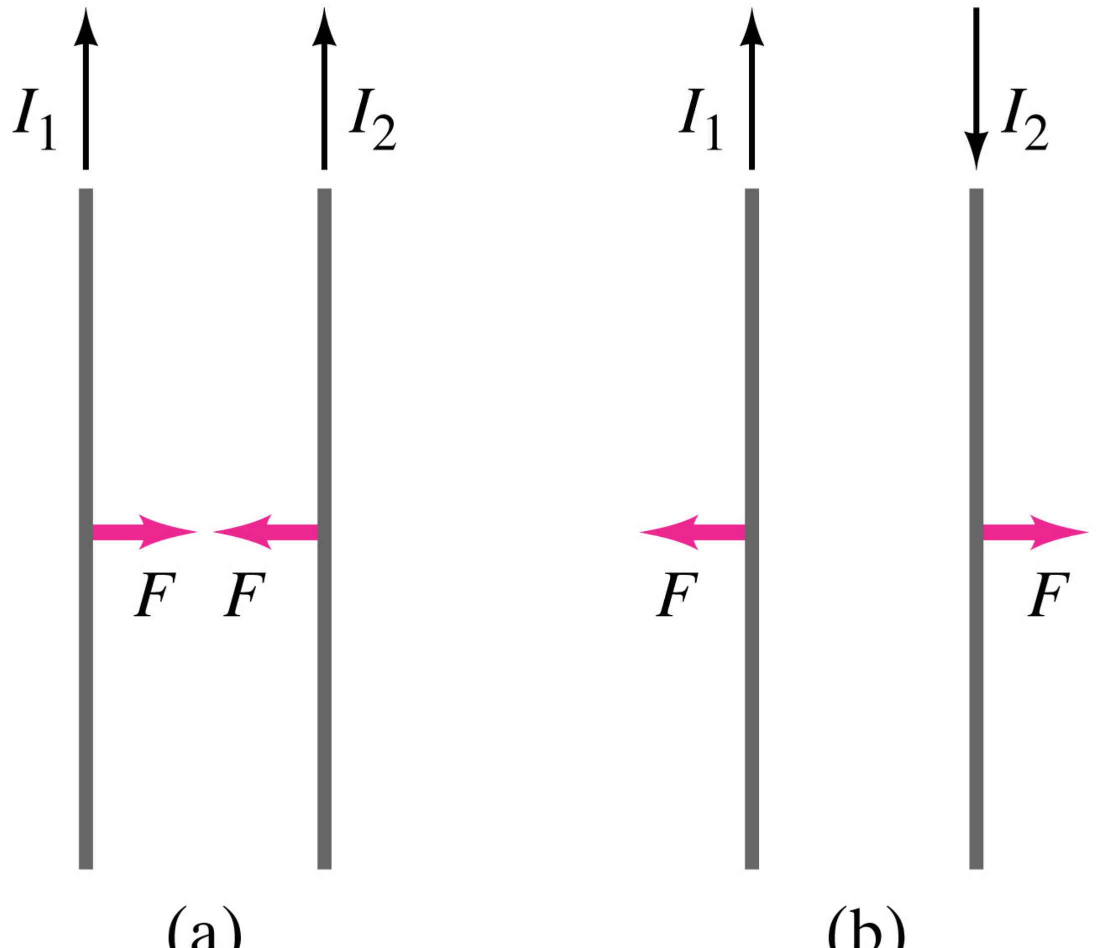
20.6 Force between Two Parallel Wires

Parallel currents attract; antiparallel currents repel.



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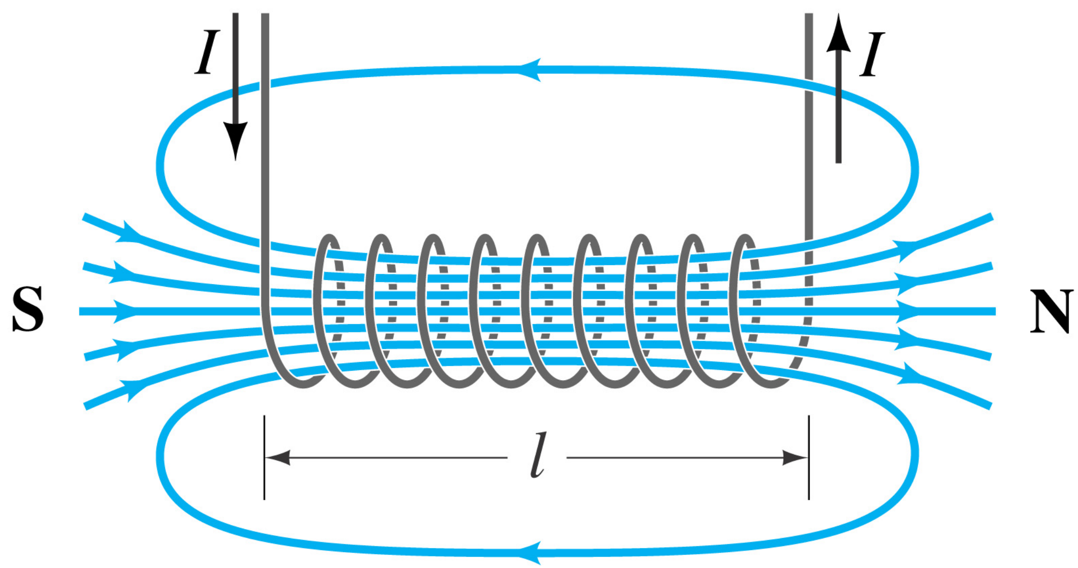
20.7 Solenoids and Electromagnets

A solenoid is a long coil of wire. If it is tightly wrapped, the magnetic field in its interior is almost uniform:

$$B = \mu_0 I N / l \qquad \text{(20-8)}$$



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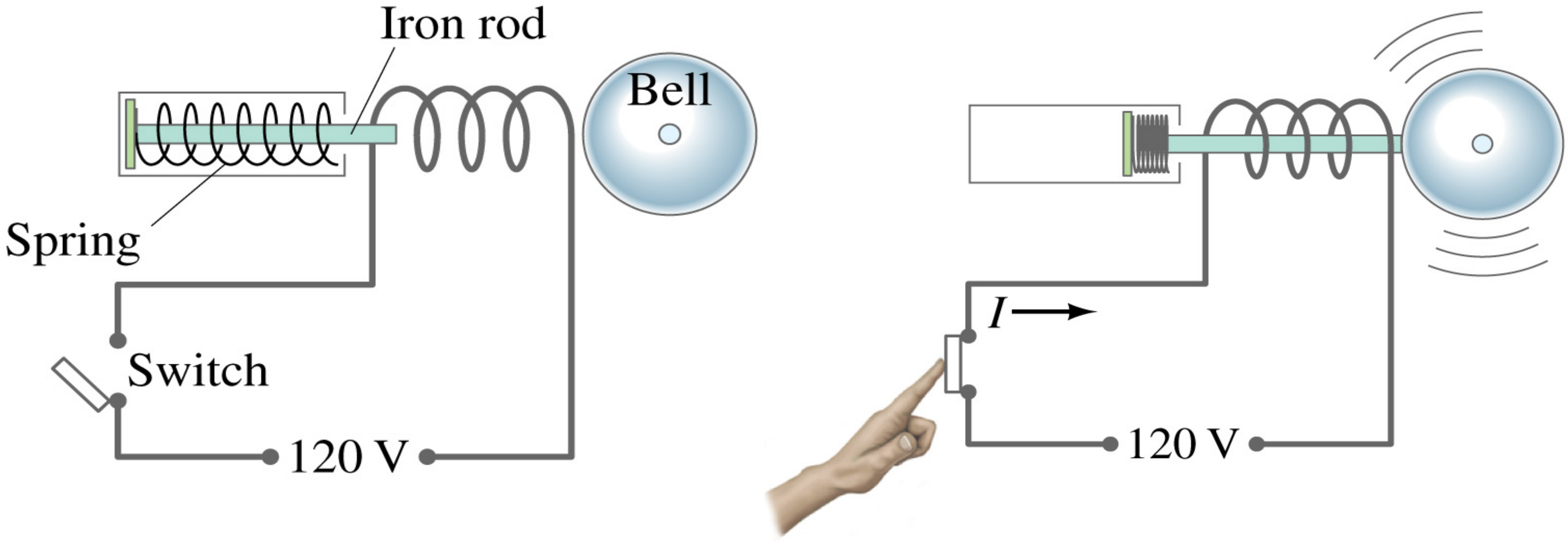
20.7 Solenoids and Electromagnets

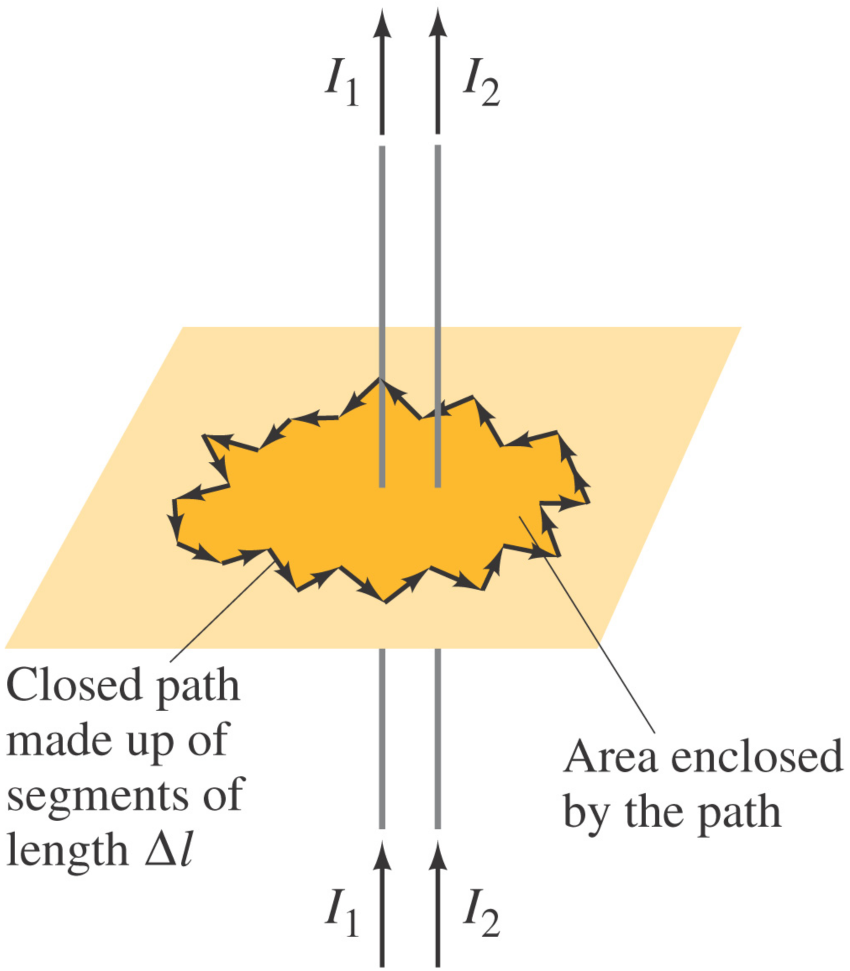
If a piece of iron is inserted in the solenoid, the magnetic field greatly increases. Such electromagnets have many practical applications.



20.8 Ampère's Law

Ampère's law relates the magnetic field around a closed loop to the total current flowing through the loop.

$$\Sigma B_{\|}\,\Delta l = \mu_0 I_{\text{encl}} \qquad \textbf{(20-9)}$$



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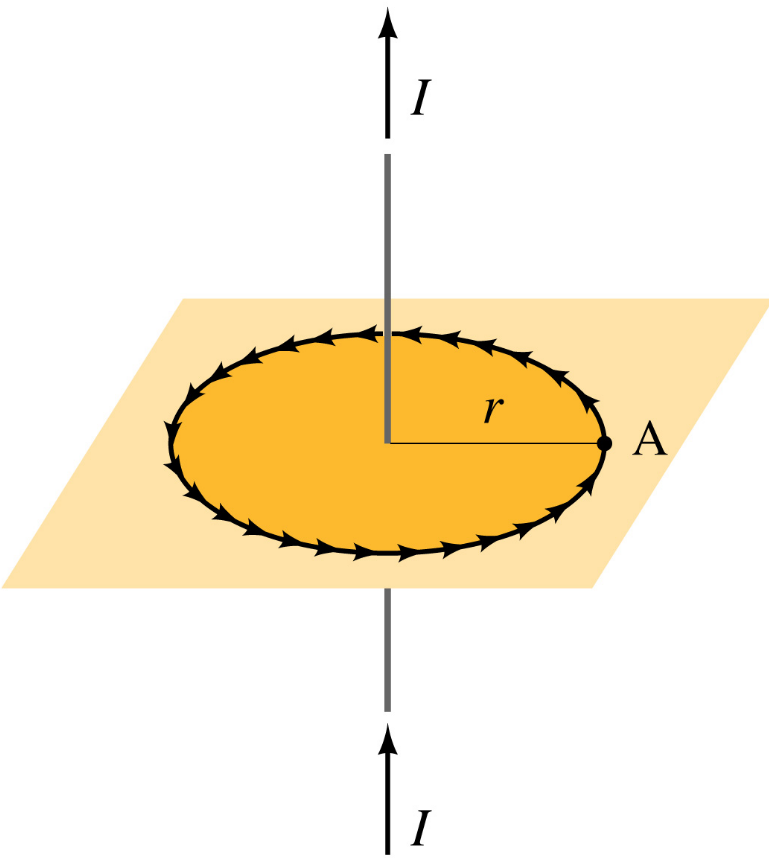
20.8 Ampère’s Law

Ampère’s law can be used to calculate the magnetic field in situations with a high degree of symmetry.



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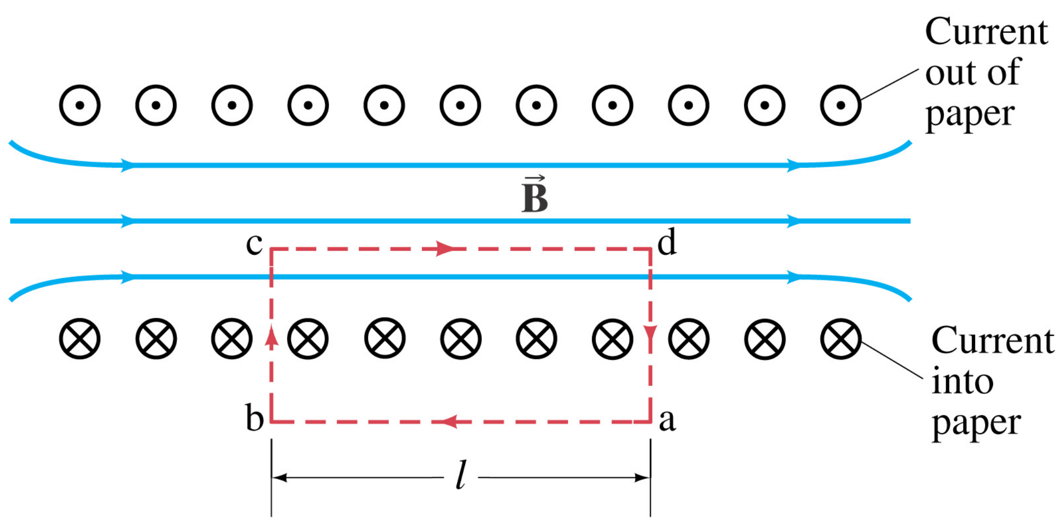

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20.9 Torque on a Current Loop; Magnetic Moment

The forces on opposite sides of a current loop will be equal and opposite (if the field is uniform and the loop is symmetric), but there may be a torque.

The magnitude of the torque is given by:

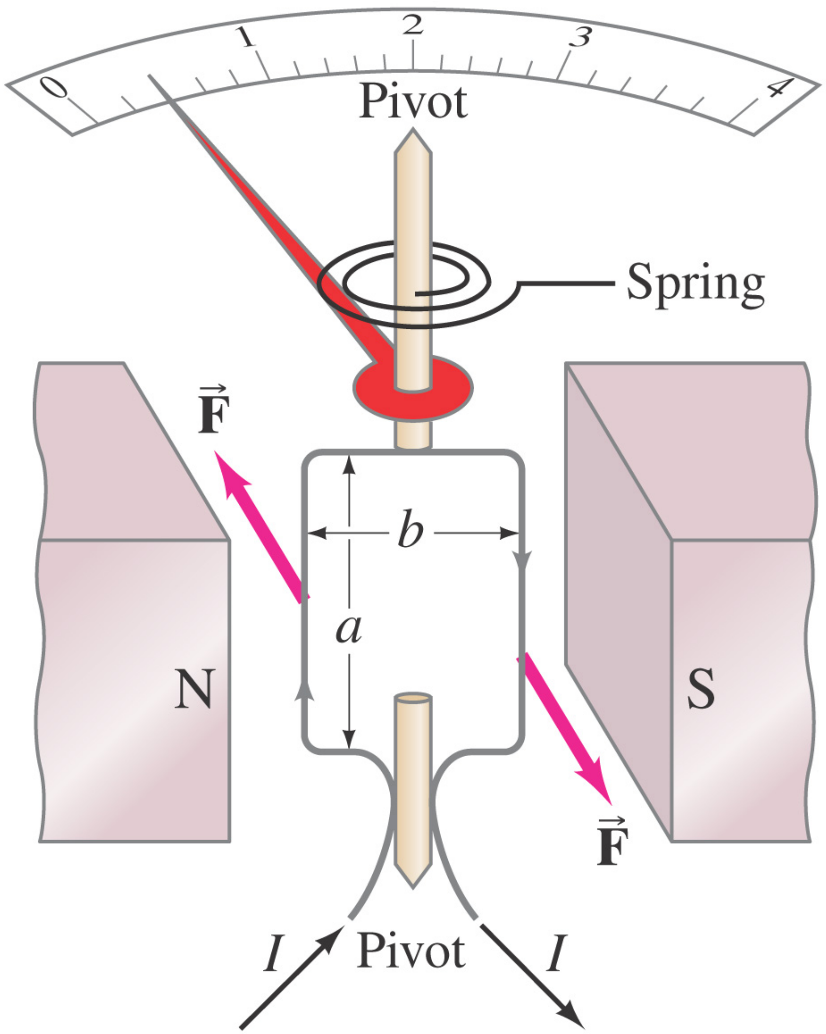
$$\tau = NIAB\sin\theta \qquad \textbf{(20-10)}$$

The quantity NIA is called the magnetic dipole moment, M:

$$M = NIA \qquad \textbf{(20-11)}$$

20.10 Applications: Galvanometers, Motors, Loudspeakers

A galvanometer takes advantage of the torque on a current loop to measure current.



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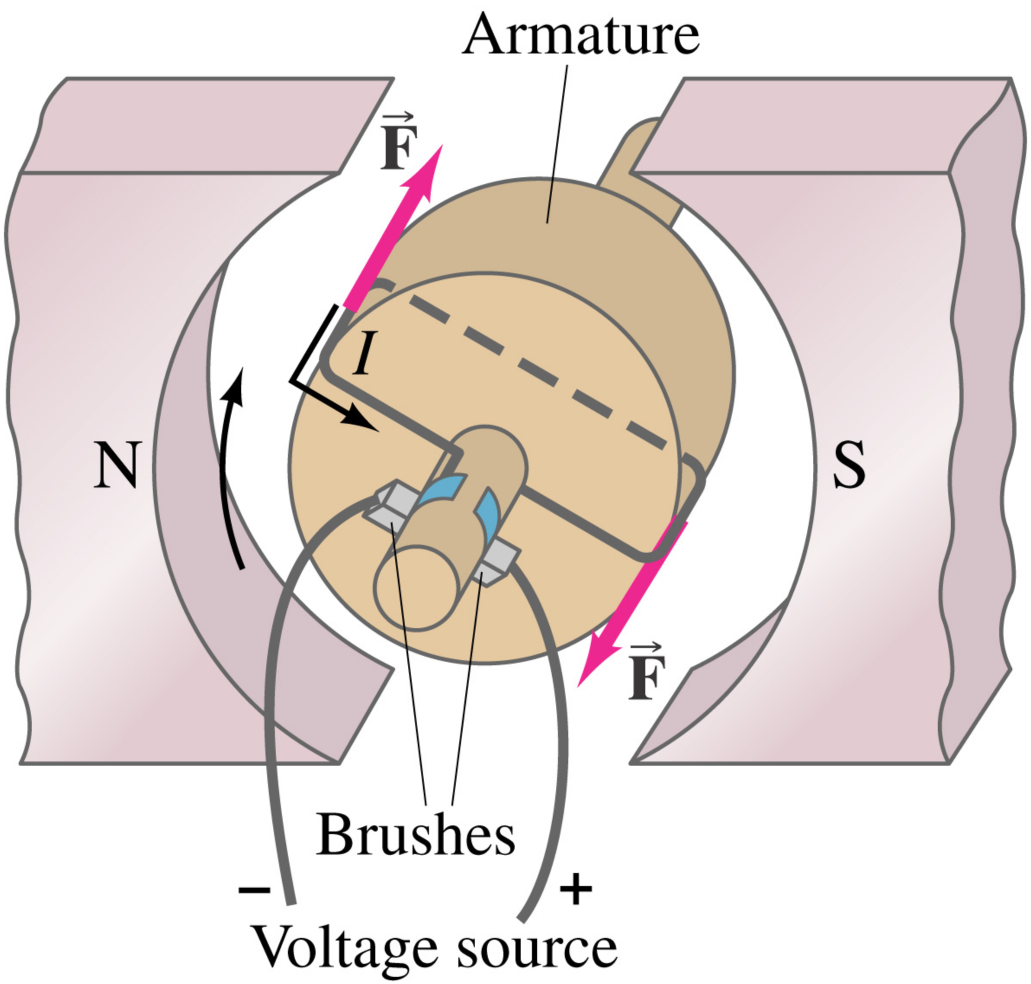
20.10 Applications: Galvanometers, Motors, Loudspeakers

An electric motor also takes advantage of the torque on a current loop, to change electrical energy to mechanical energy.



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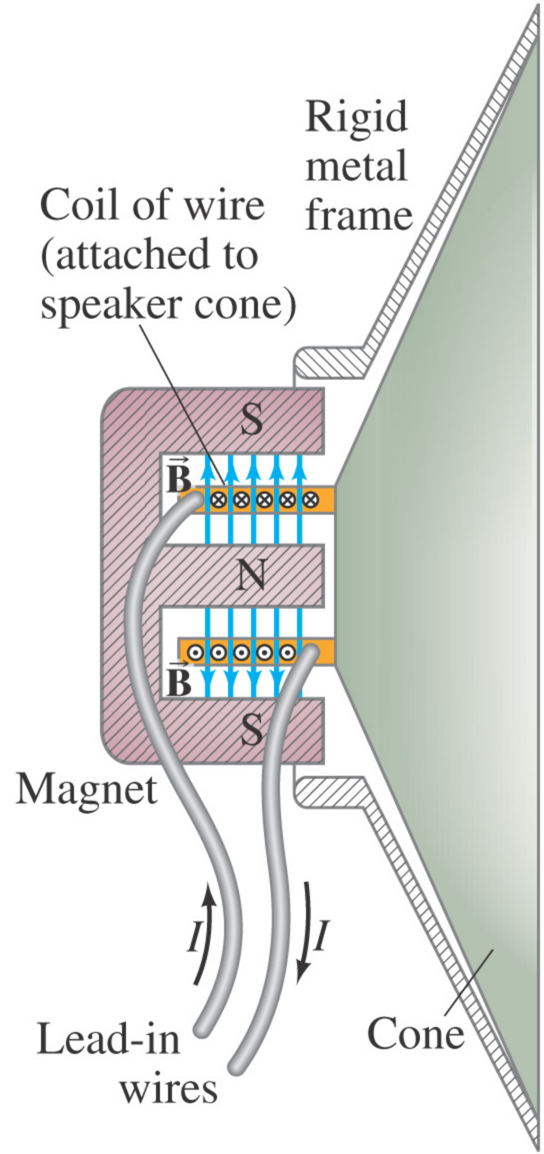
20.10 Applications: Galvanometers, Motors, Loudspeakers

Loudspeakers use the principle that a magnet exerts a force on a current-carrying wire to convert electrical signals into mechanical vibrations, producing sound.



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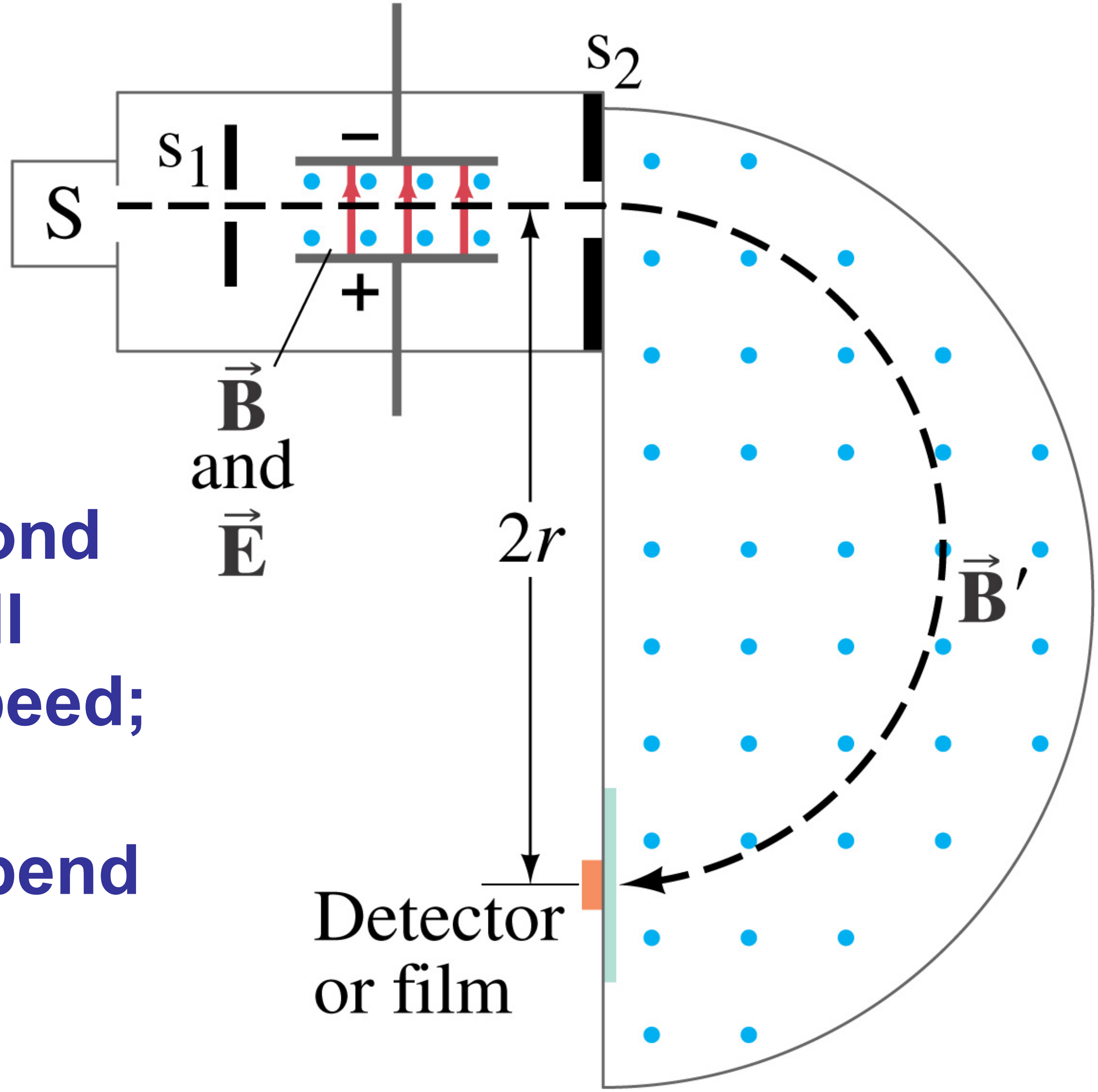
20.11 Mass Spectrometer

A mass spectrometer measures the masses of atoms. If a charged particle is moving through perpendicular electric and magnetic fields, there is a particular speed at which it will not be deflected:

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

20.11 Mass Spectrometer

All the atoms reaching the second magnetic field will have the same speed; their radius of curvature will depend on their mass.



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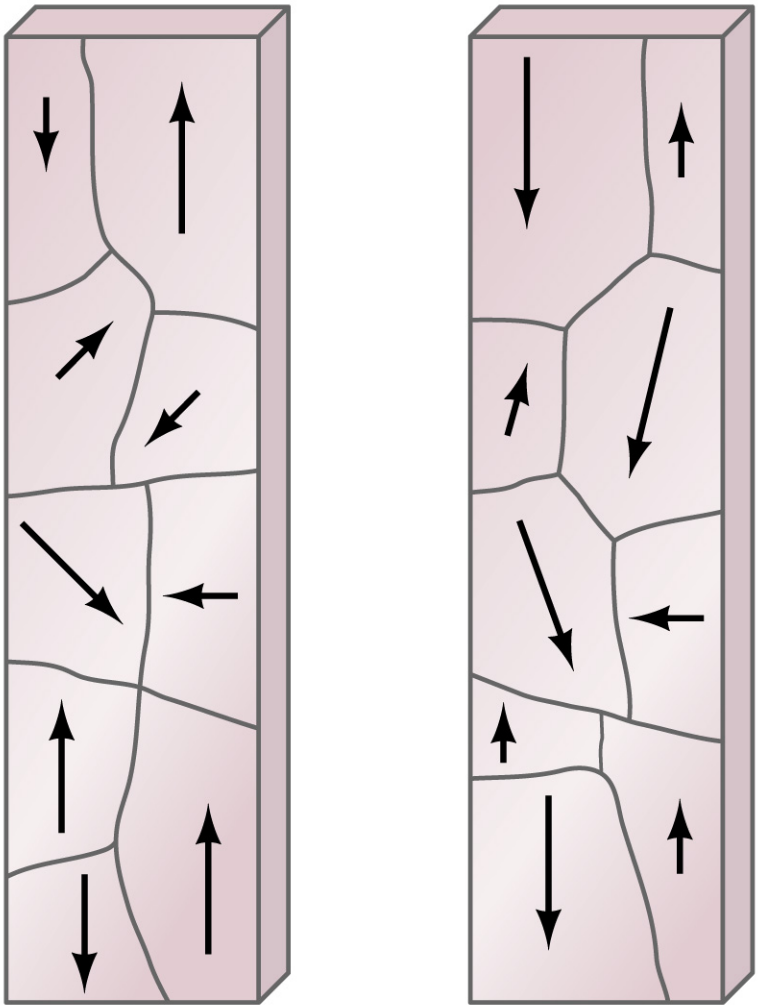
20.12 Ferromagnetism: Domains and Hysteresis

Ferromagnetic materials are those that can become strongly magnetized, such as iron and nickel.

These materials are made up of tiny regions called domains; the magnetic field in each domain is in a single direction.

20.12 Ferromagnetism: Domains and Hysteresis

When the material is unmagnetized, the domains are randomly oriented. They can be partially or fully aligned by placing the material in an external magnetic field.



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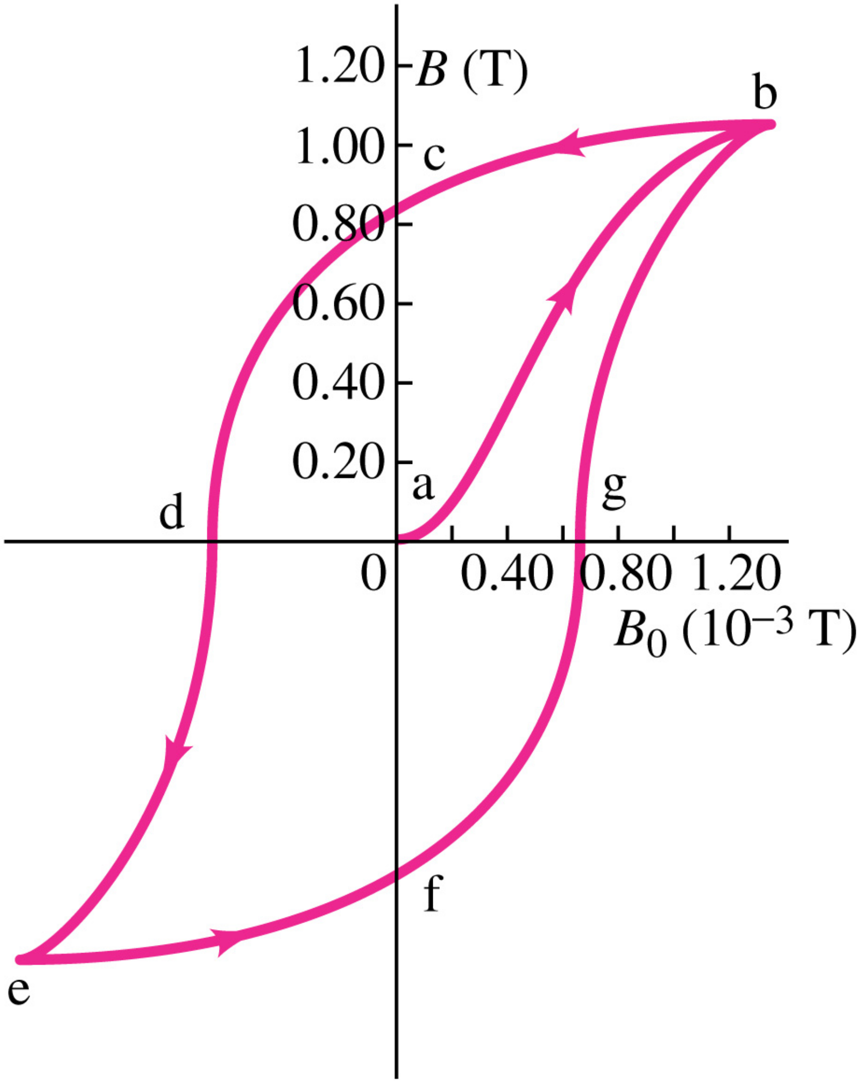
20.12 Ferromagnetism: Domains and Hysteresis

A magnet, if undisturbed, will tend to retain its magnetism. It can be demagnetized by shock or heat.

The relationship between the external magnetic field and the internal field in a ferromagnet is not simple, as the magnetization can vary.

20.12 Ferromagnetism: Domains and Hysteresis

Starting with unmagnetized material and no magnetic field, the magnetic field can be increased, decreased, reversed, and the cycle repeated. The resulting plot of the total magnetic field within the ferromagnet is called a hysteresis curve.



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Summary of Chapter 20

- Magnets have north and south poles
- Like poles repel, unlike attract
- Unit of magnetic field: tesla
- Electric currents produce magnetic fields
- A magnetic field exerts a force on an electric current:

$$F = IlB \sin\theta$$

Summary of Chapter 20

- **A magnetic field exerts a force on a moving charge:**

$$F = qvB\sin\theta$$

- **Magnitude of the field of a long, straight current-carrying wire:**

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

- **Parallel currents attract; antiparallel currents repel**

Summary of Chapter 20

- **Magnetic field inside a solenoid:**

$$B = \mu_0 IN/l$$

- **Ampère's law:**

$$\Sigma B_{||}\,\Delta l = \mu_0\, I_{\text{encl}}$$

- **Torque on a current loop:**

$$\tau = NIAB\sin\theta$$