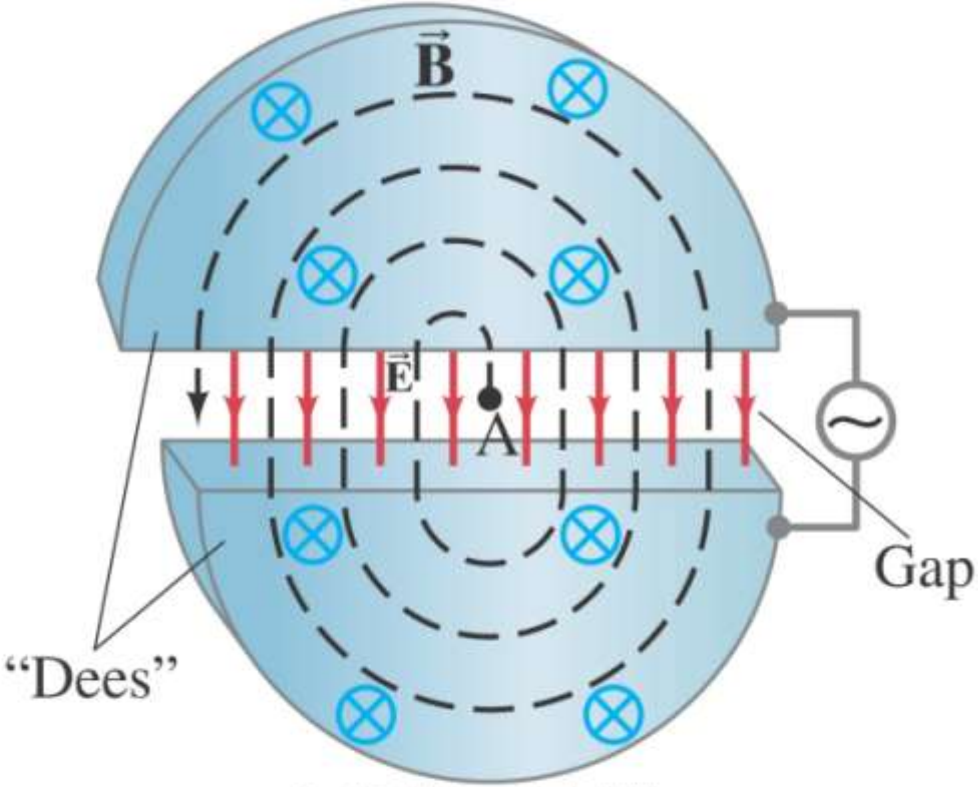
Chapter 20

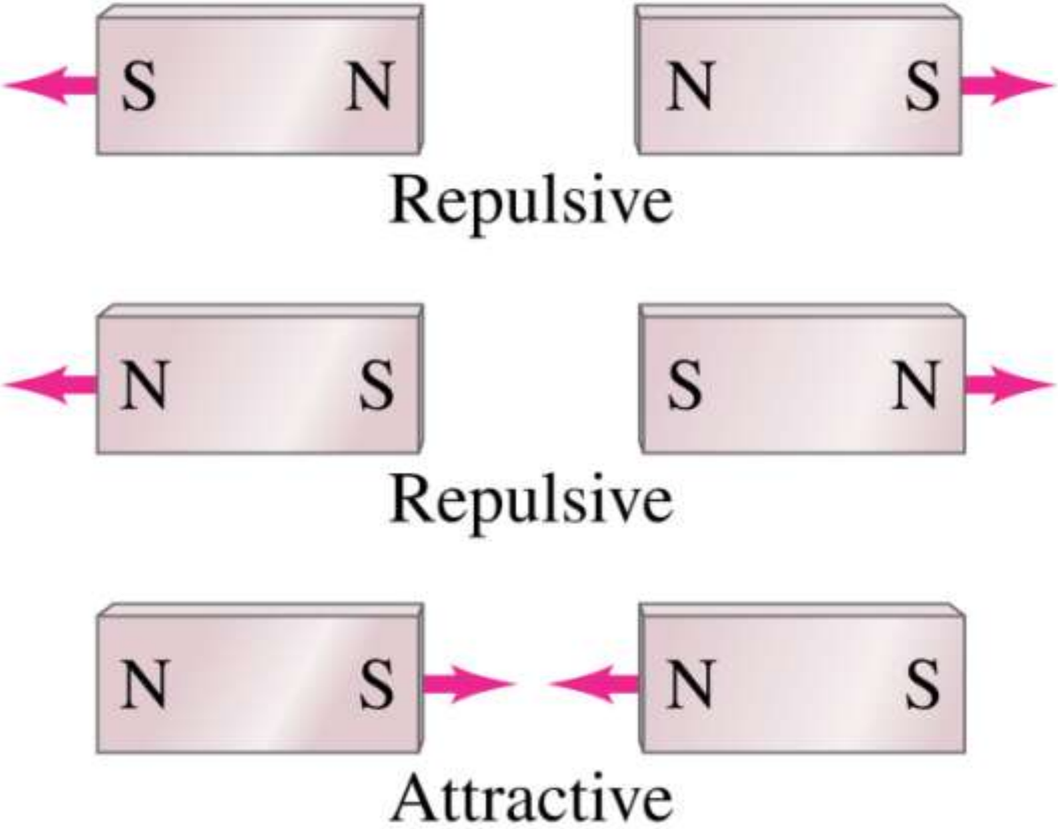
Magnetism



20.1 Magnets and Magnetic Fields

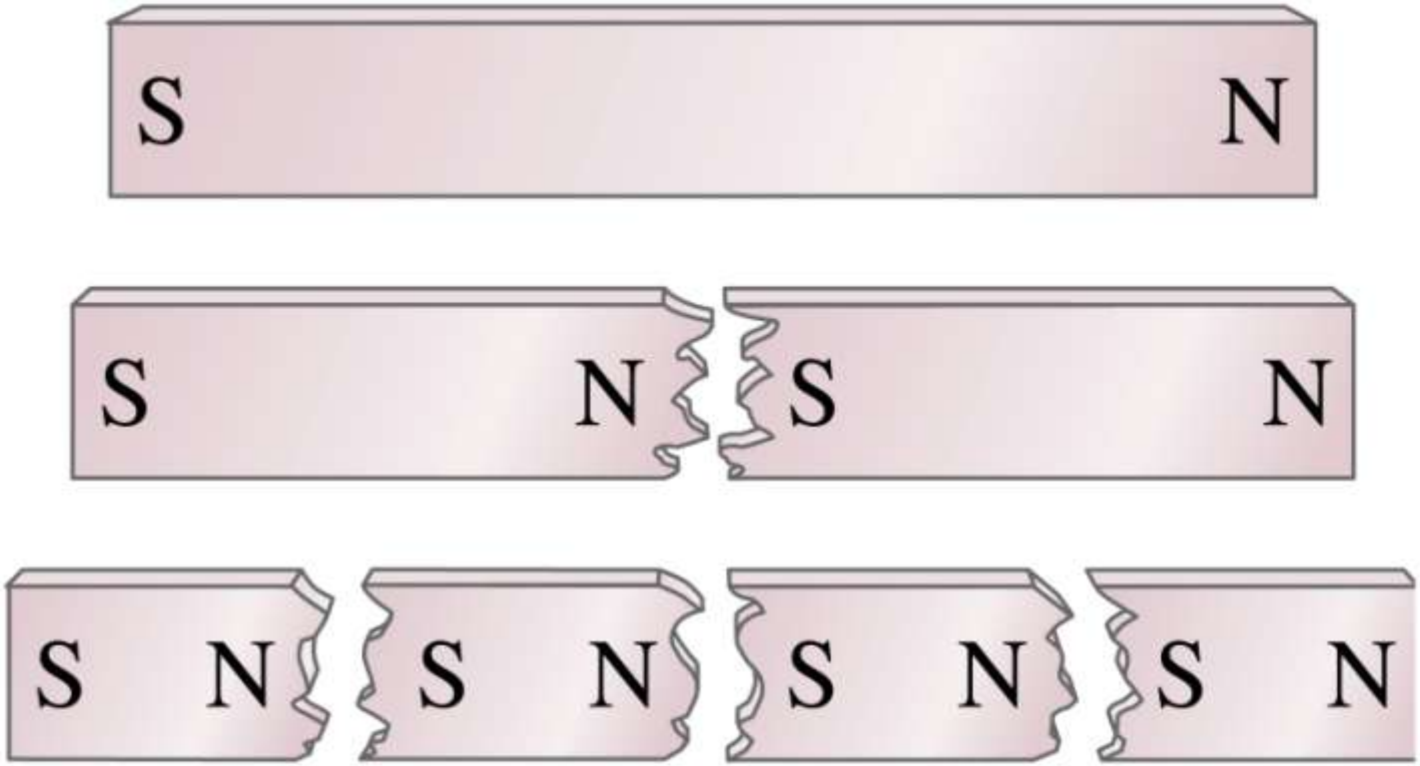
Magnets have two ends – poles – called north and south.

Like poles repel; unlike poles attract.



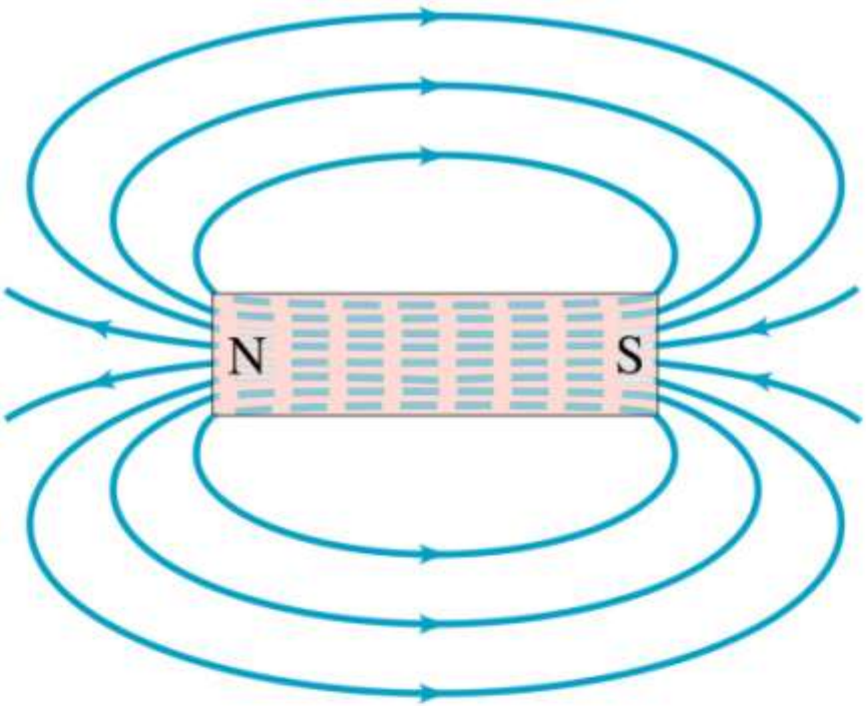
20.1 Magnets and Magnetic Fields

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



20.1 Magnets and Magnetic Fields

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



(b)

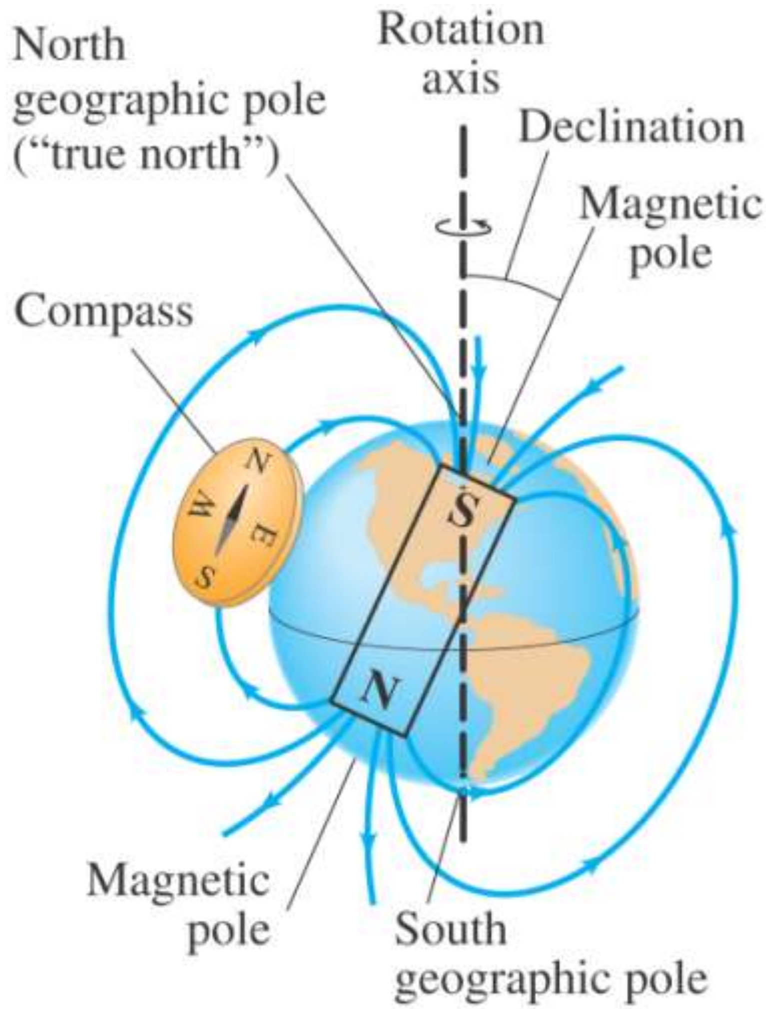
20.1 Magnets and Magnetic Fields

Time for a Gizmo!

20.1 Magnets and Magnetic Fields

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

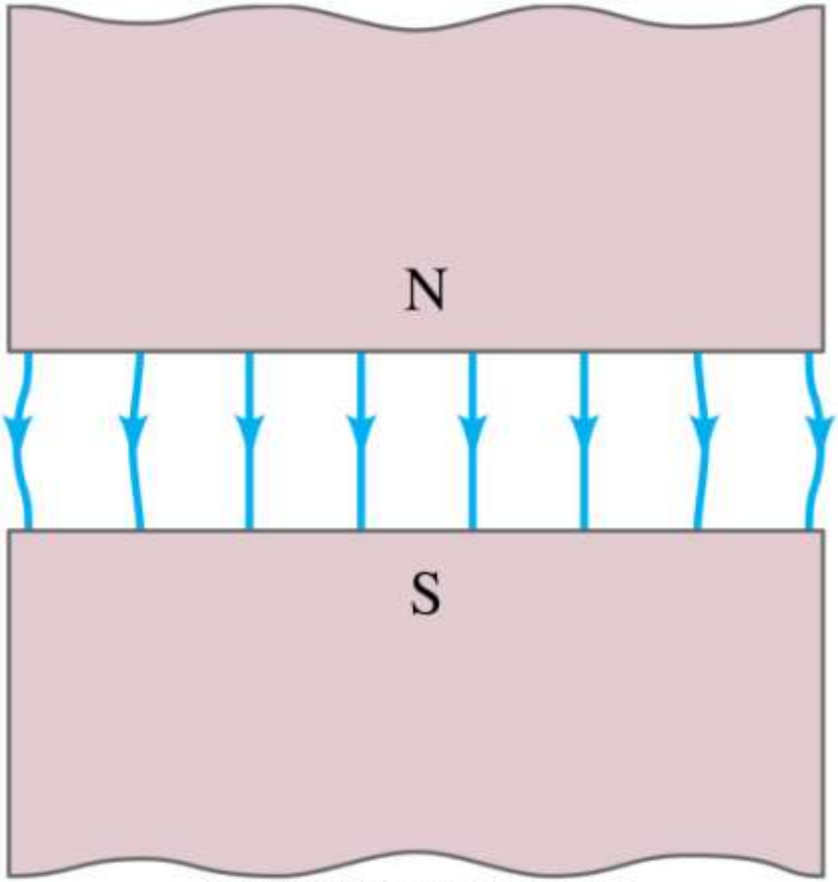
Note that the Earth's "North Pole" is really a south magnetic pole, as the north ends of magnets are attracted to it.



20.1 Magnets and Magnetic Fields

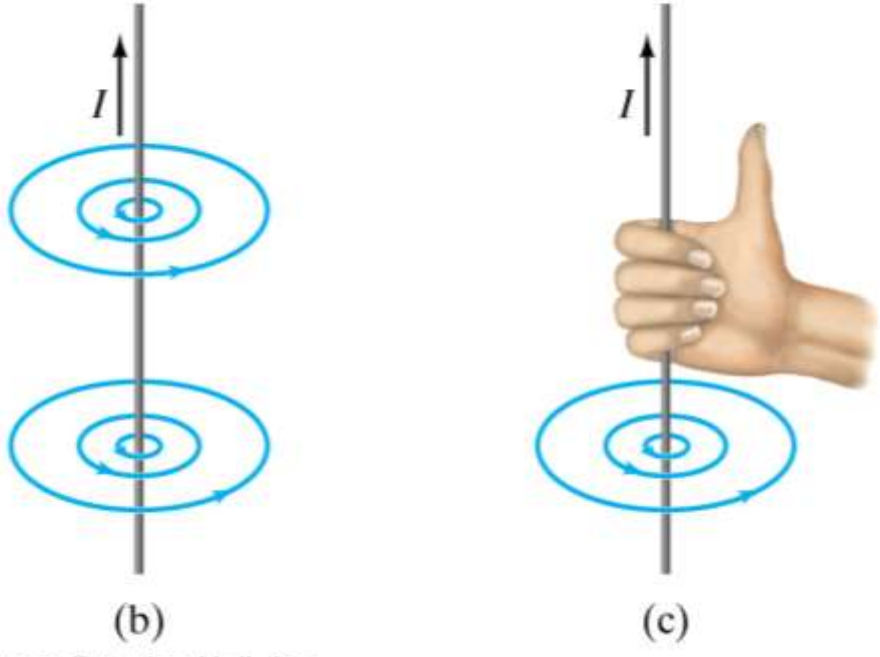
A uniform magnetic field is constant in magnitude and direction.

The field between these two wide poles is nearly uniform.



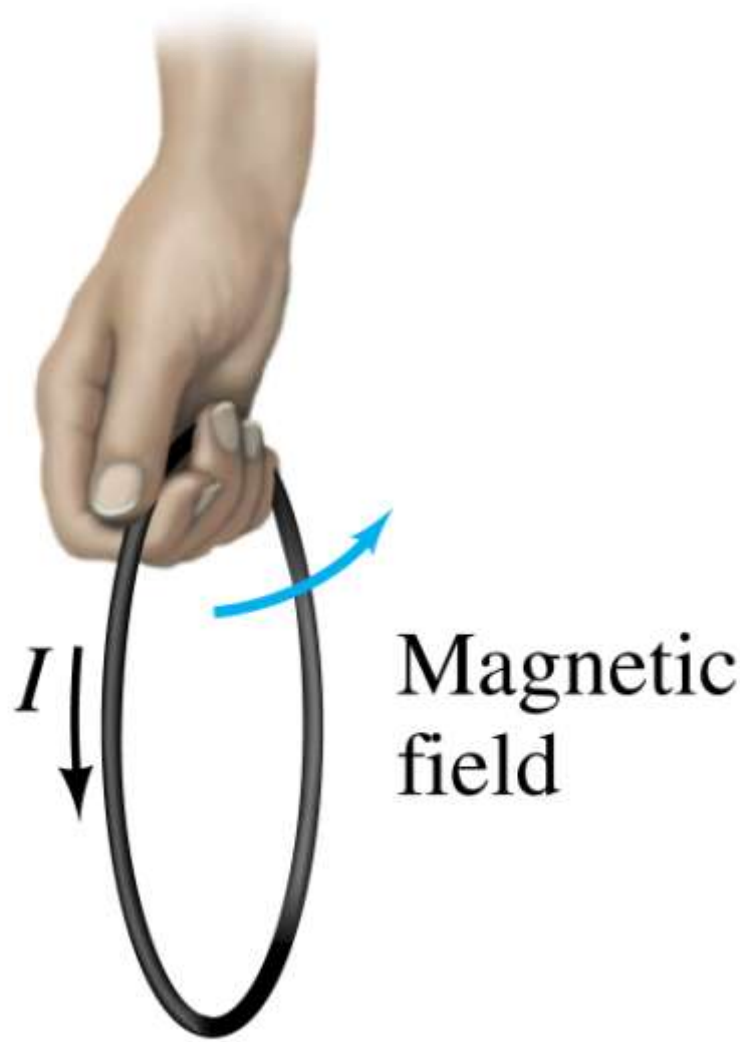
20.2 Electric Currents Produce Magnetic Fields

Experiment shows that an electric current produces a magnetic field.



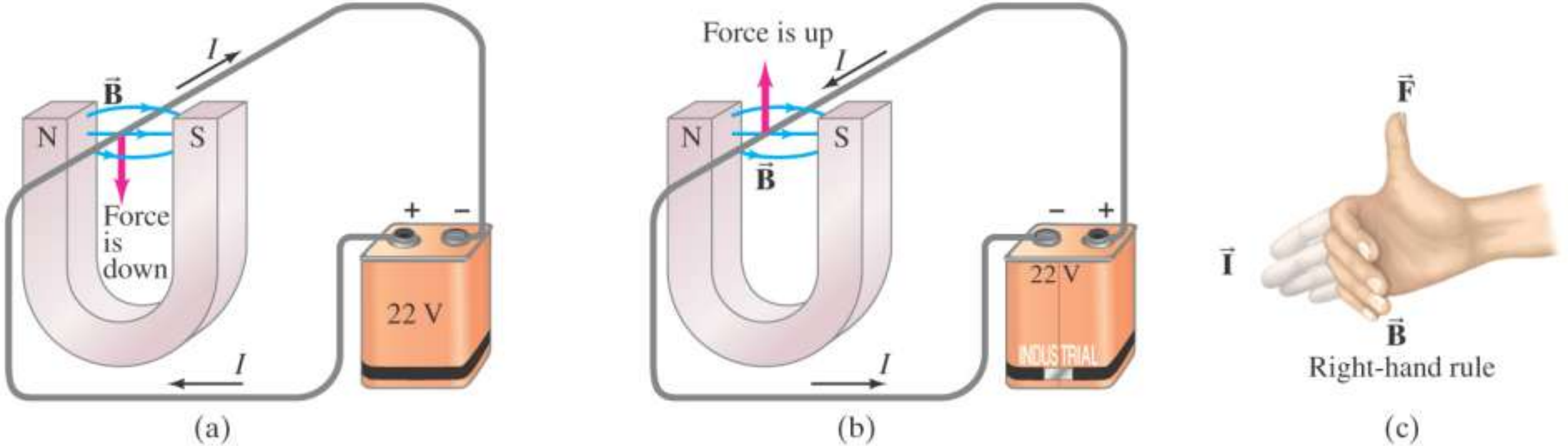
20.2 Electric Currents Produce Magnetic Fields

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



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.



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).

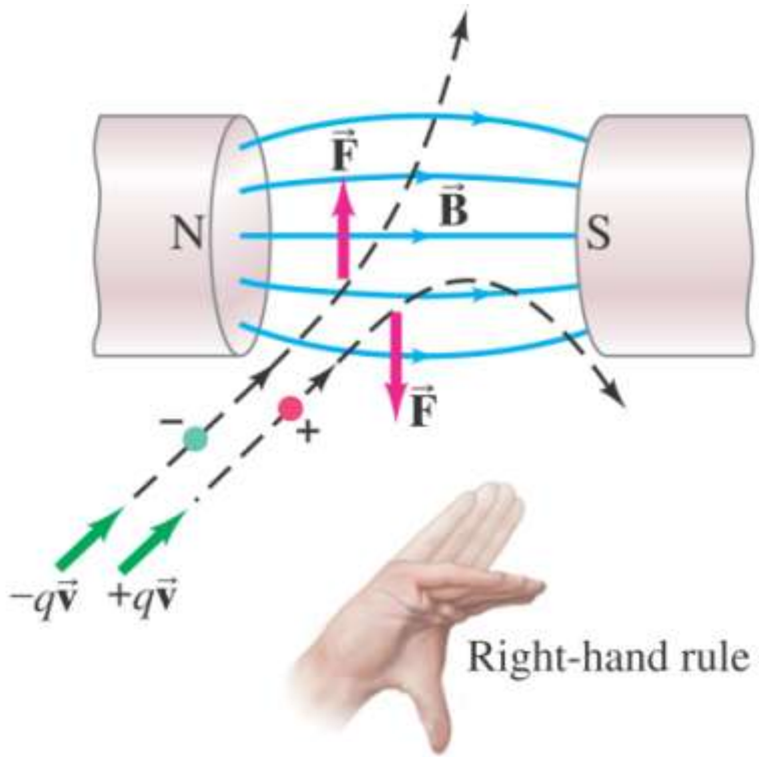
1 G = 10^{-4} T.

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.

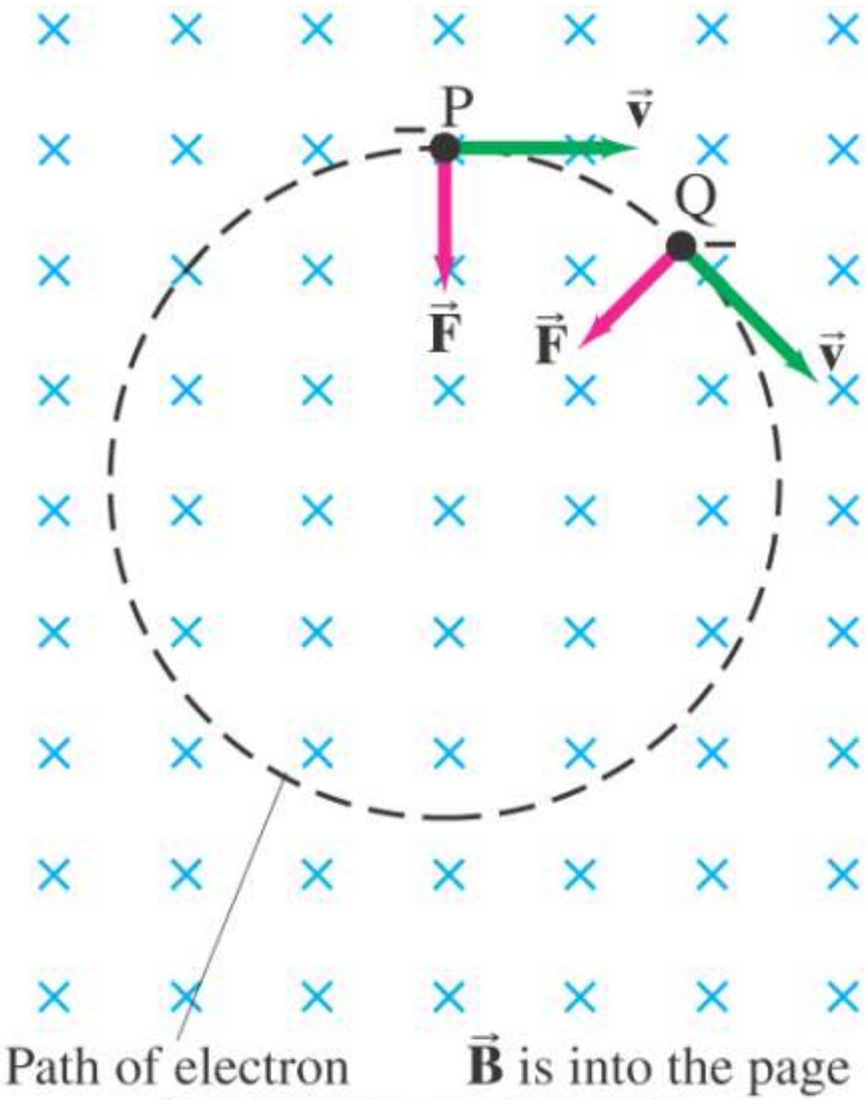


20.4 Force on Electric Charge Moving in a Magnetic Field

Time for a Gizmo!

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.



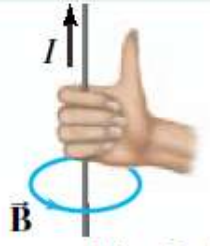
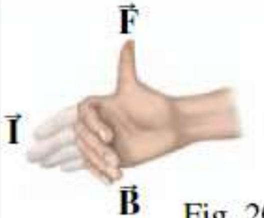
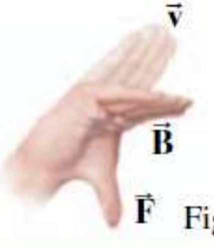
20.4 Force on Electric Charge Moving in a Magnetic Field

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.

20.4 Force on Electric Charge Moving in a Magnetic Field

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

20.5 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:

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

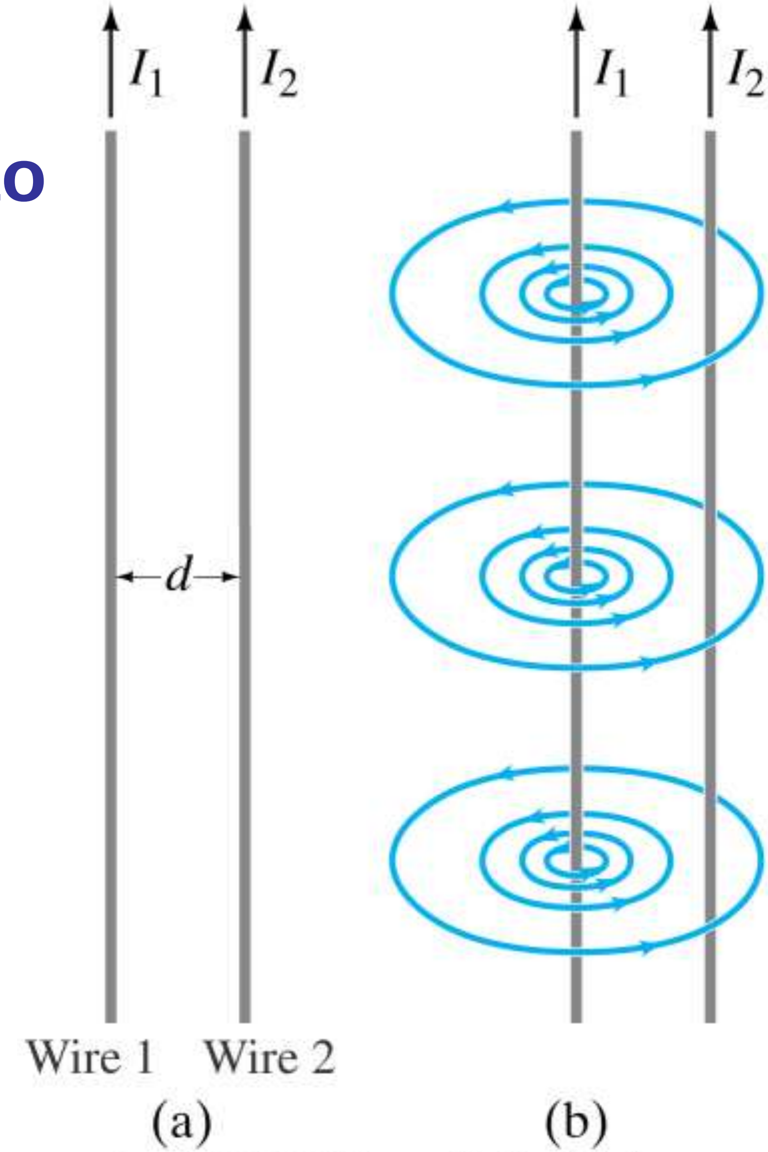
20.6 Force between Two Parallel Wires

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

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

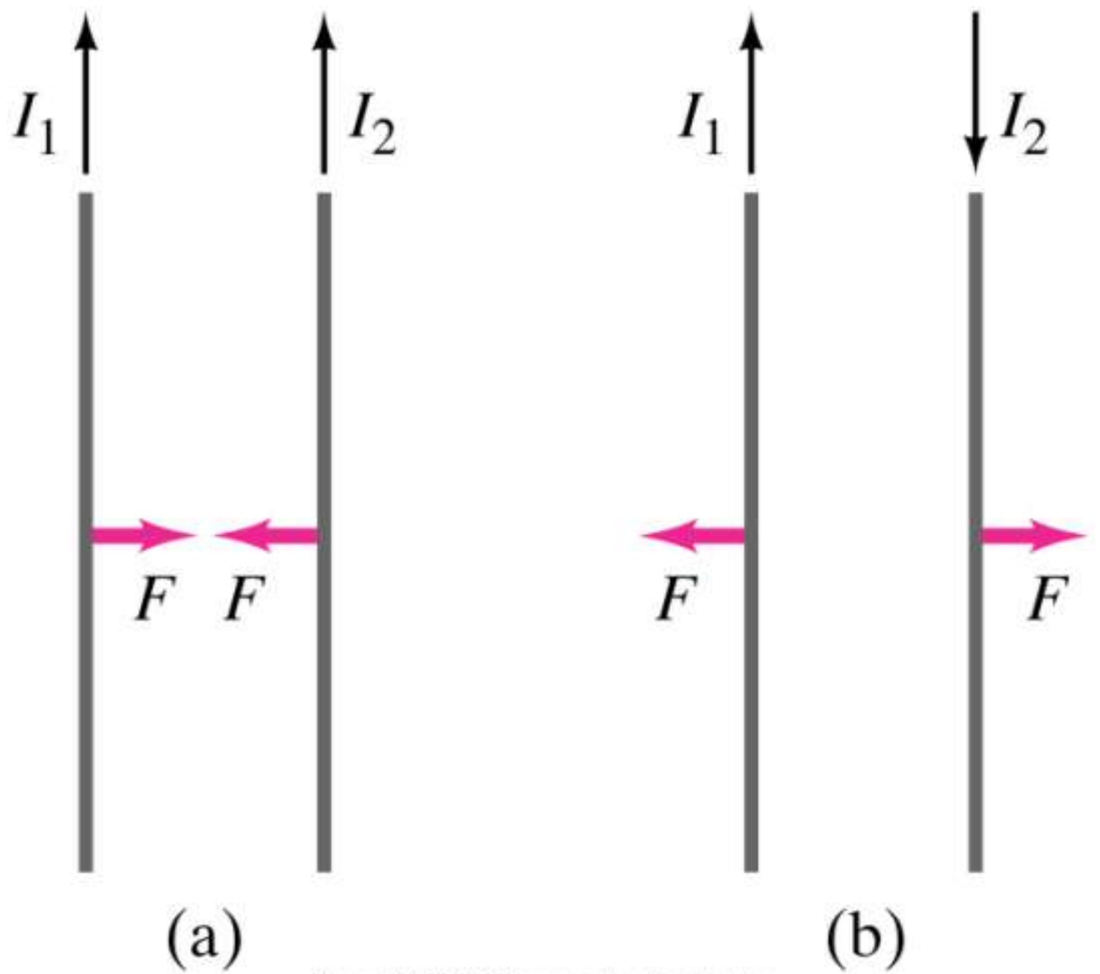
The force this field exerts on a length l_2 of wire 2 is:

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



20.6 Force between Two Parallel Wires

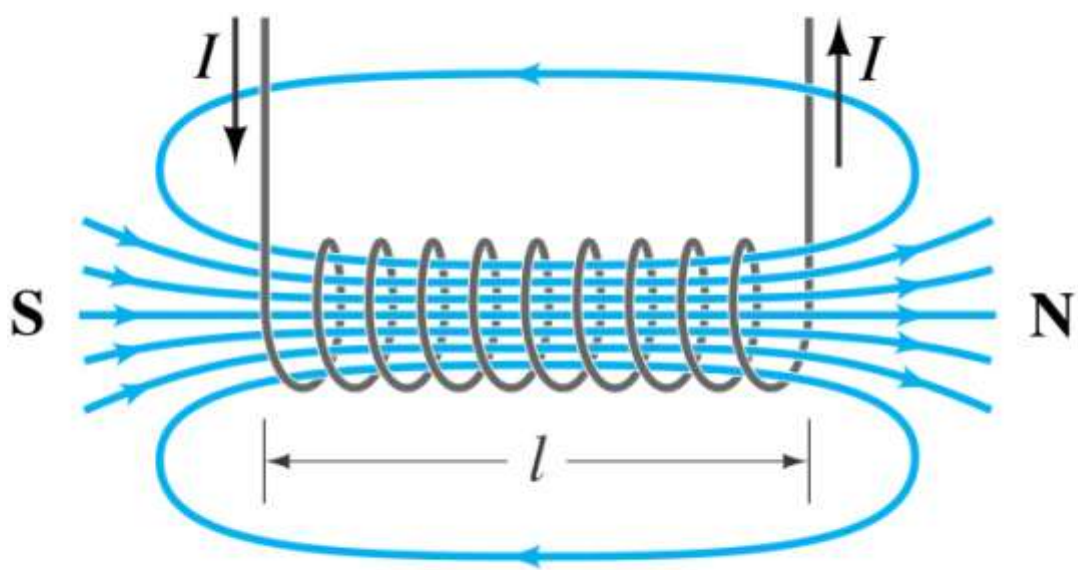
Parallel currents attract; antiparallel currents repel.



20.7 Solenoids and Electromagnets

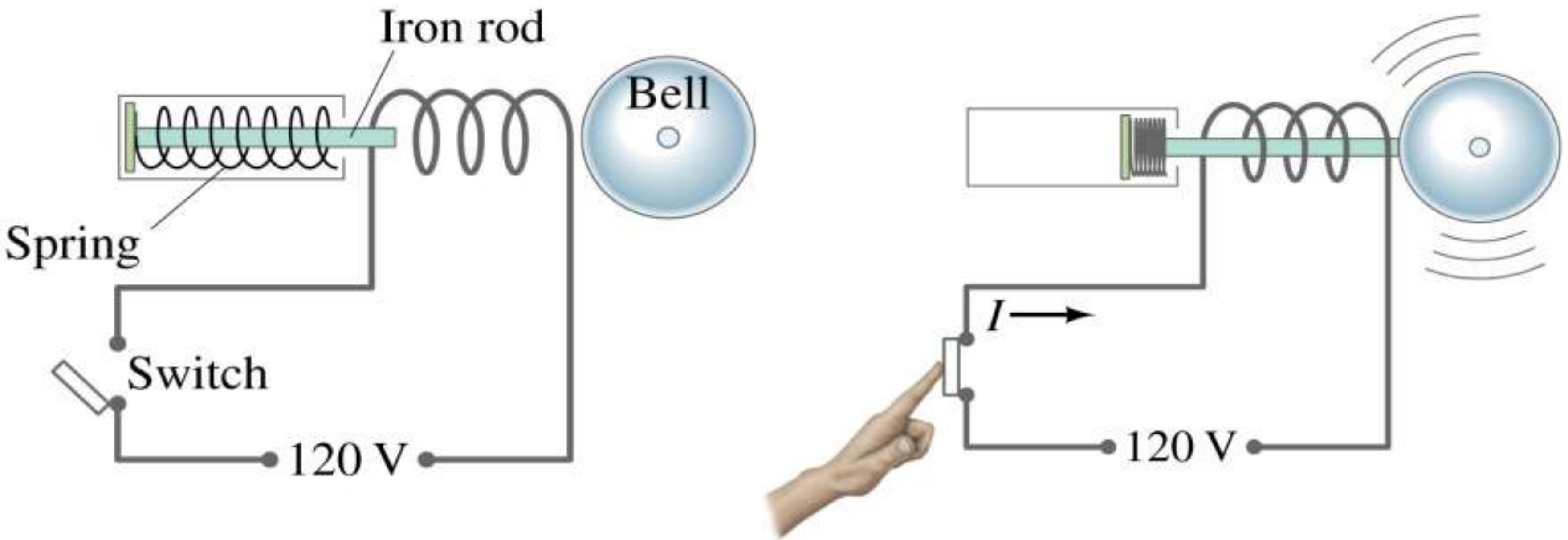
A solenoid is a long coil of wire. If it is tightly wrapped, the magnetic field in its interior is almost uniform:

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



20.7 Solenoids and Electromagnets

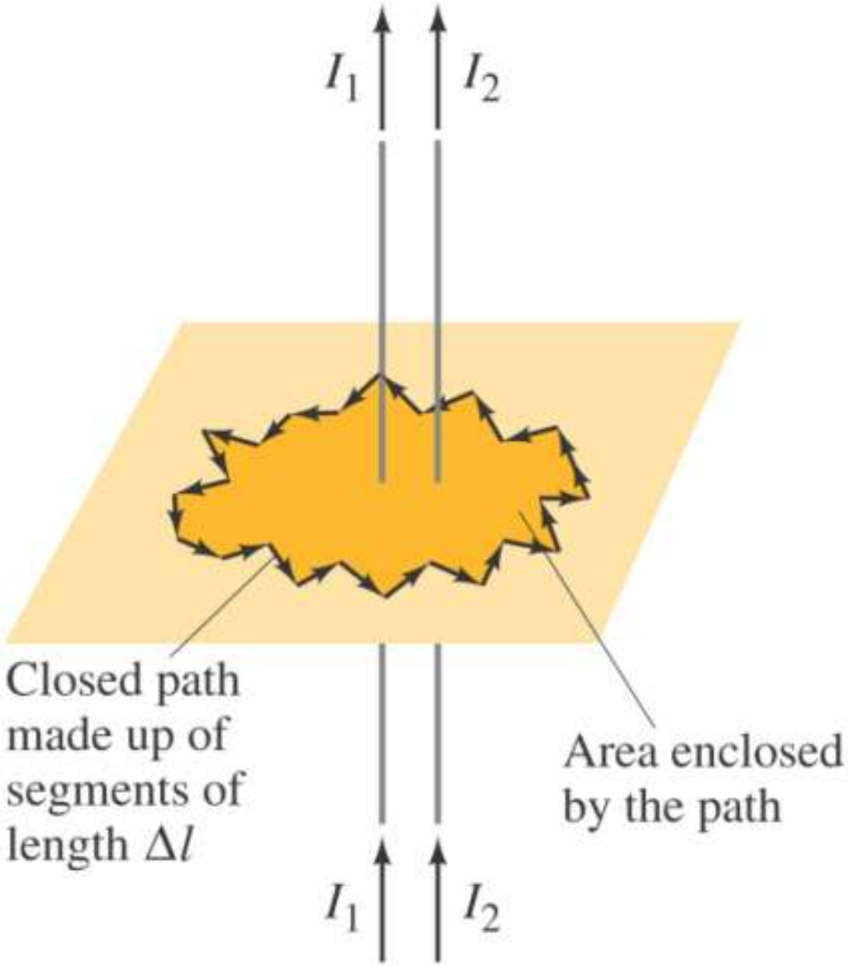
If a piece of iron is inserted in the solenoid, the magnetic field greatly increases. Such electromagnets have many practical applications.



20.8 Ampère's Law

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

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



20.8 Ampère's Law

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