Chapter 19

Magnetism

Magnets

- *Poles* of a magnet are the ends where objects are most strongly attracted
  - Two poles, called *north* and *south*
- Like poles repel each other and unlike poles attract each other
  - Similar to electric charges
- Magnetic poles cannot be isolated
  - If a permanent magnetic is cut in half repeatedly, you will still have a north and a south pole
  - This differs from electric charges
  - There is some theoretical basis for monopoles, but none have been detected

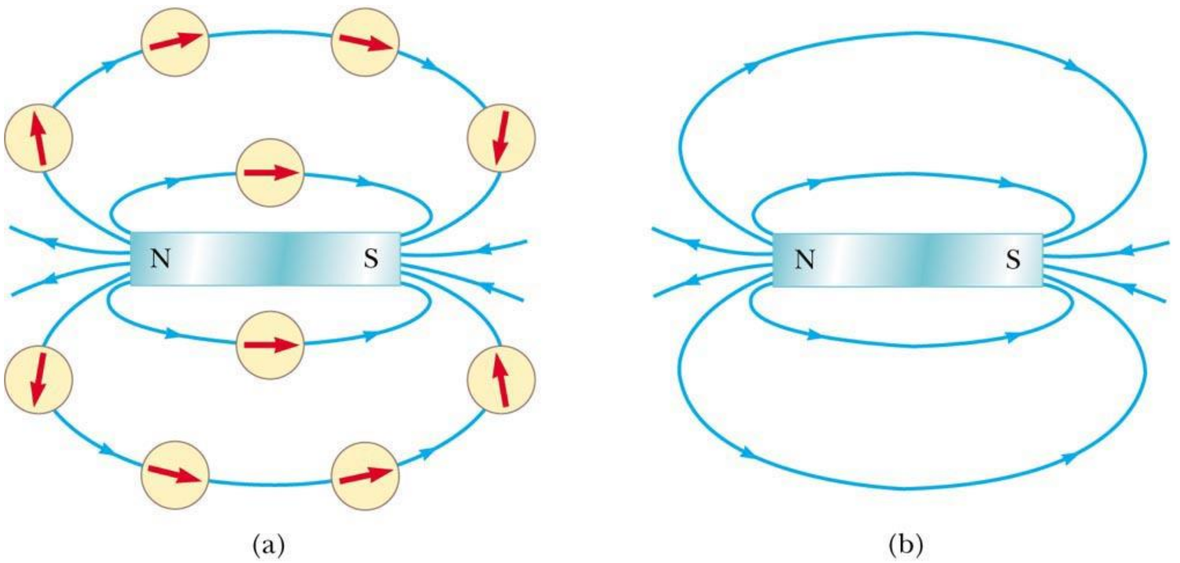
Sources of Magnetic Fields

- The region of space surrounding a *moving* charge includes a magnetic field
  - The charge will also be surrounded by an electric field
- A magnetic field surrounds a properly magnetized magnetic material

Magnetic Fields

- A vector quantity
- Symbolized by $\vec{\mathbf{B}}$
- Direction is given by the direction a *north pole* of a compass needle points in that location
- *Magnetic field lines* can be used to show how the field lines, as traced out by a compass, would look

Magnetic Field Lines, sketch



- A compass can be used to show the direction of the magnetic field lines (a)
- A sketch of the magnetic field lines (b)

About the Earth's Magnetic Poles

- The magnetic and geographic poles are not in the same exact location
  - The difference between true north, at the geographic north pole, and magnetic north is called the *magnetic declination*
    - The amount of declination varies by location on the earth's surface

Source of the Earth’s Magnetic Field

- There cannot be large masses of permanently magnetized materials since the high temperatures of the core prevent materials from retaining permanent magnetization
- The most likely source of the Earth’s magnetic field is believed to be electric currents in the liquid part of the core

Reversals of the Earth's Magnetic Field

- The direction of the Earth's magnetic field reverses every few million years
  - Evidence of these reversals are found in basalts resulting from volcanic activity
  - The origin of the reversals is not understood

Magnetic Fields

- When moving through a magnetic field, a charged particle experiences a magnetic force
  - This force has a maximum value when the charge moves perpendicularly to the magnetic field lines
  - This force is zero when the charge moves along the field lines

Magnetic Fields, cont

- One can define a magnetic field in terms of the magnetic force exerted on a test charge moving in the field with velocity $\vec{\mathbf{v}}$
  - Similar to the way electric fields are defined
- $F = qvB\sin\theta$

Units of Magnetic Field

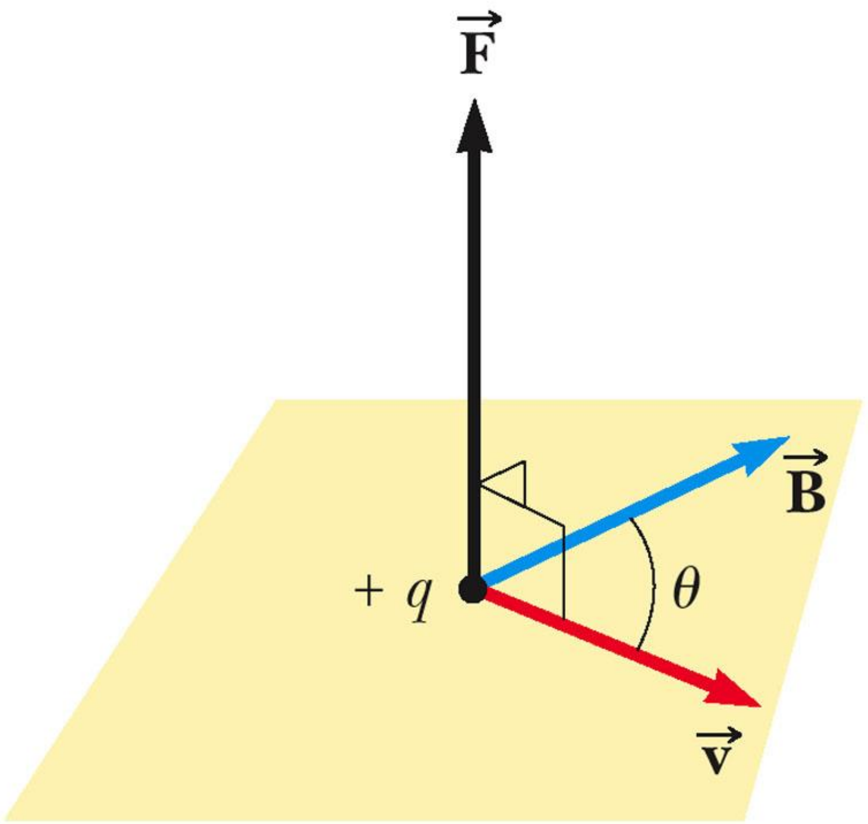
- The SI unit of magnetic field is the *Tesla* (T)

$$T = \frac{Wb}{m^2} = \frac{N}{C \cdot (m/s)} = \frac{N}{A \cdot m}$$

  - Wb is a Weber
- The cgs unit is a *Gauss* (G)
  - 1 T = 10^4 G

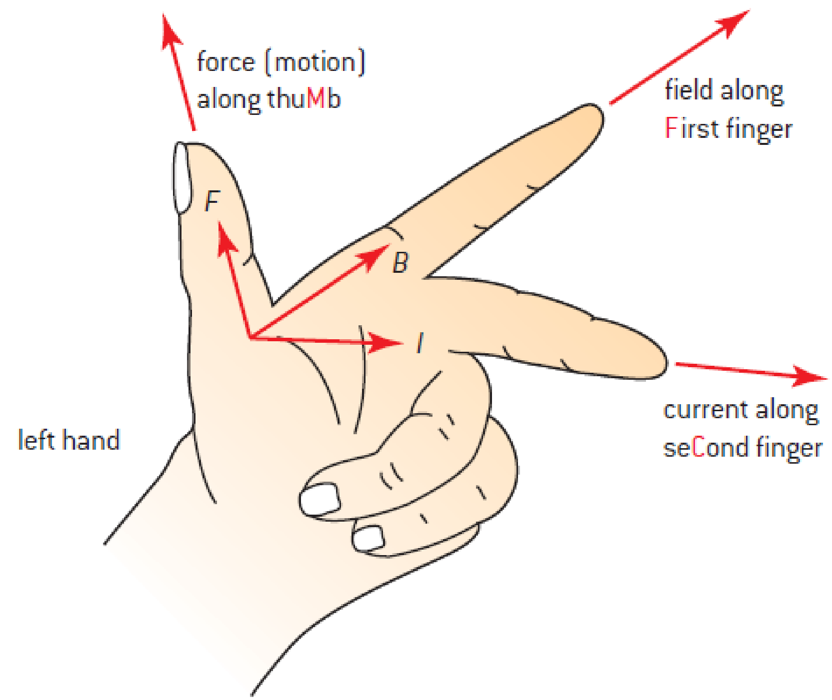
Finding the Direction of Magnetic Force

- Experiments show that the direction of the magnetic force is always perpendicular to both $\vec{\mathbf{v}}$ and $\vec{\mathbf{B}}$
- F_{max} occurs when $\vec{\mathbf{v}}$ is perpendicular to $\vec{\mathbf{B}}$
- $F = 0$ when $\vec{\mathbf{v}}$ is parallel to $\vec{\mathbf{B}}$



Left Hand Rule

- Your first (index) finger in the direction of the magnetic field, $\vec{\mathbf{B}}$
- Place your second (middle) finger in the direction of current or velocity
- Your thumb points in the direction of the force, $\vec{\mathbf{F}}$, on a positive charge
  - If the charge is negative, the force is opposite that determined by the right hand rule



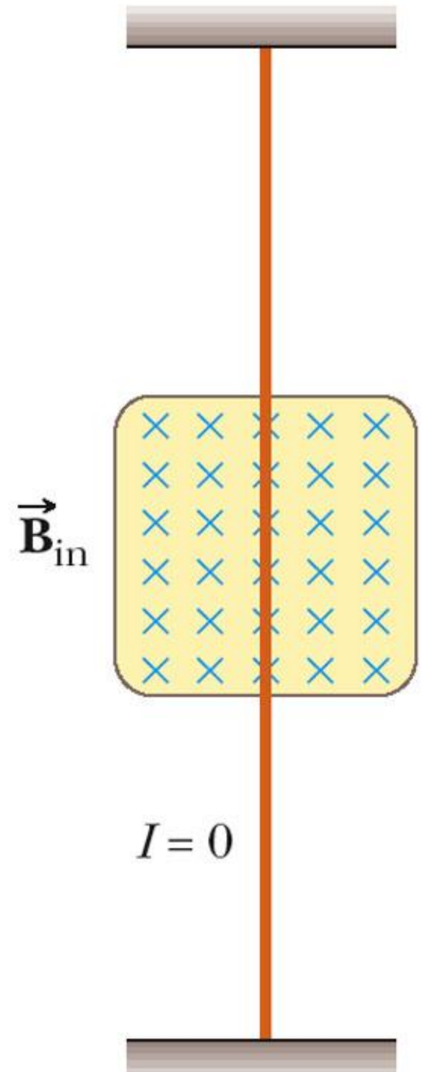
▲ Figure 9 Fleming's left-hand rule.

Magnetic Force on a Current Carrying Conductor

- A force is exerted on a current-carrying wire placed in a magnetic field
  - The current is a collection of many charged particles in motion
- The direction of the force is given by left hand rule

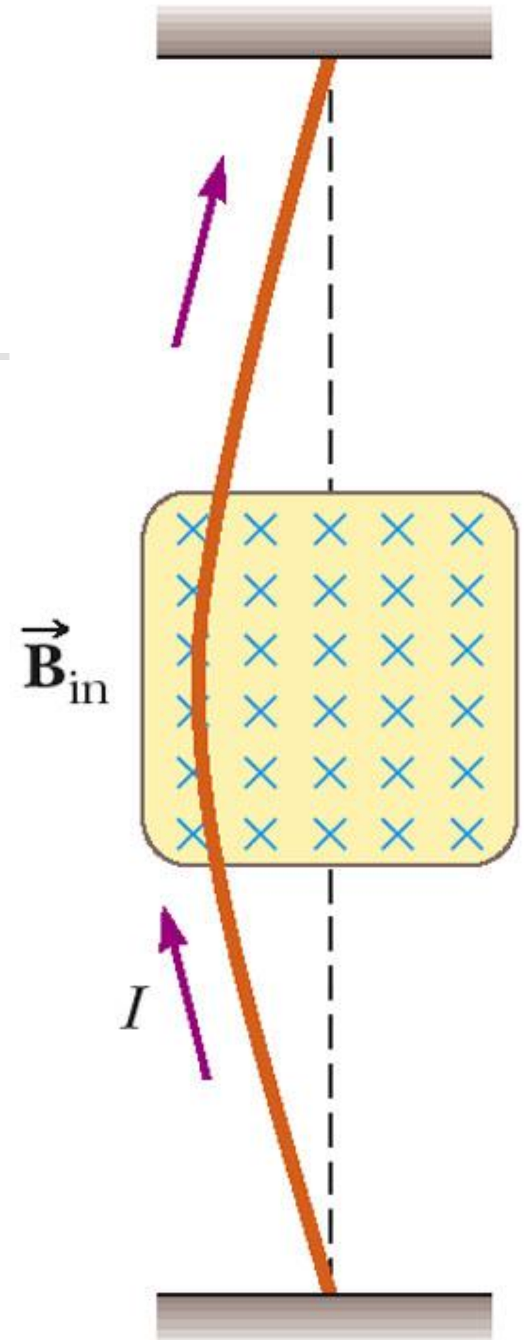
Force on a Wire

- The blue x's indicate the magnetic field is directed *into* the page
  - The x represents the tail of the arrow
- Blue dots would be used to represent the field directed *out of* the page
  - The • represents the head of the arrow
- In this case, there is no current, so there is no force



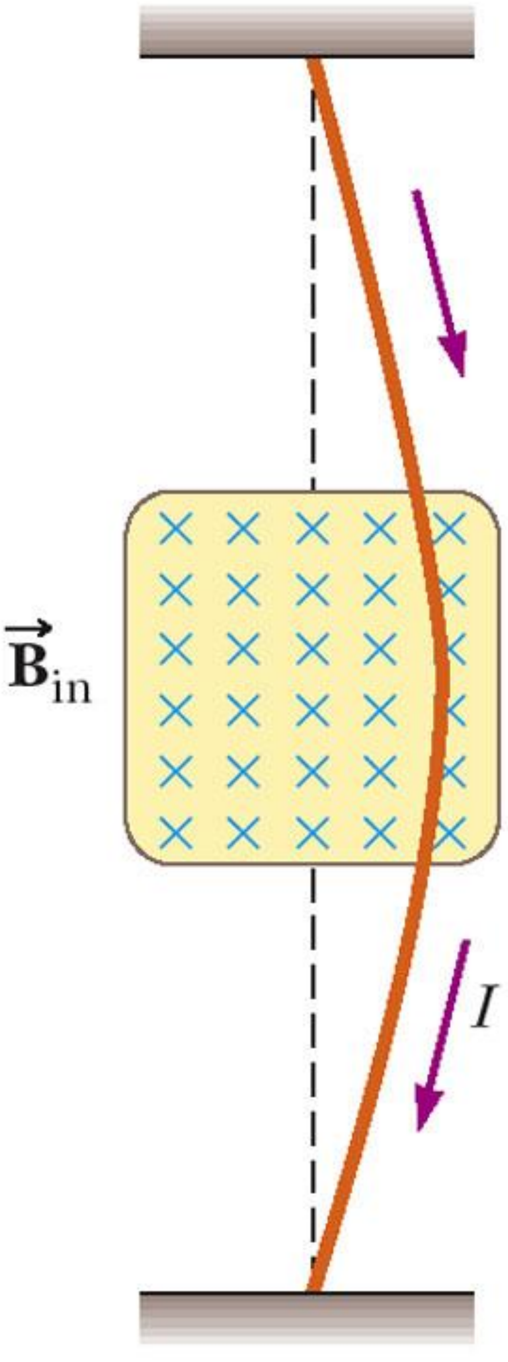
Force on a Wire, cont

- B is into the page
- The current is up the page
- The force is to the left



Force on a Wire, final

- B is into the page
- The current is down the page
- The force is to the right

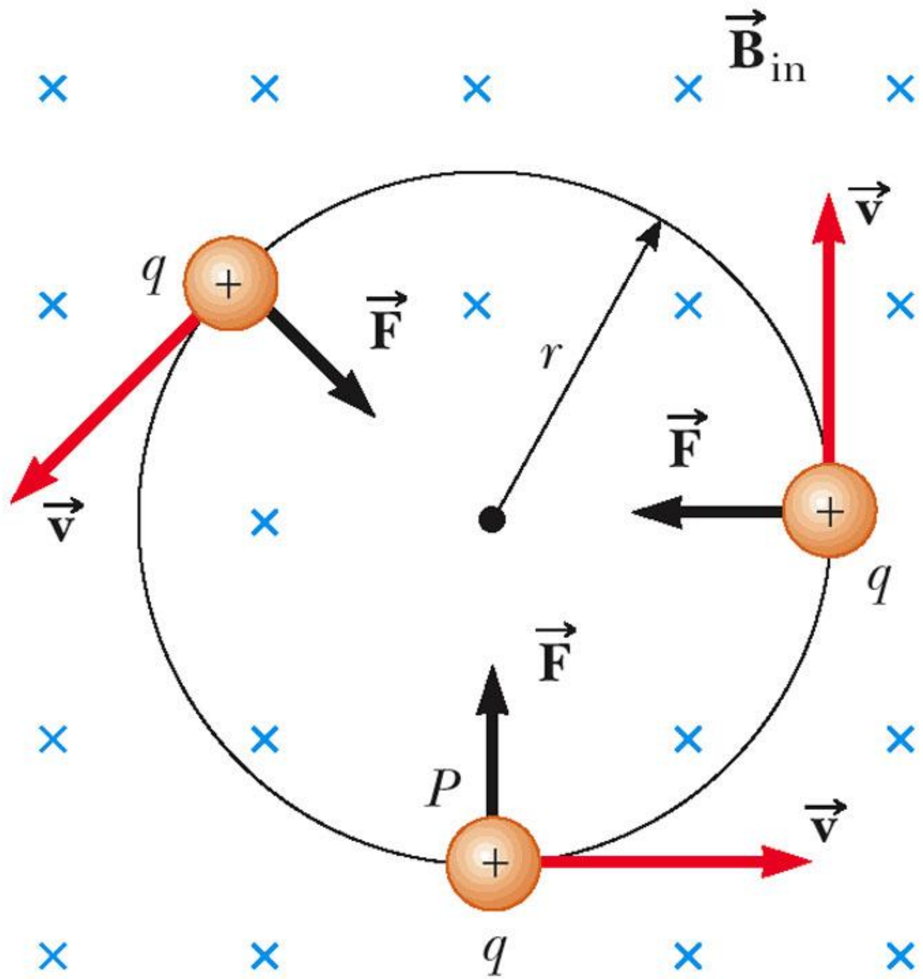


Force on a Wire, equation

- The magnetic force is exerted on each moving charge in the wire
- The total force is the sum of all the magnetic forces on all the individual charges producing the current
- F = $B\ I\ L \sin\theta$
  - θ is the angle between $\vec{\mathbf{B}}$ and the direction of I
  - The direction is found by the right hand rule, placing your fingers in the direction of I instead of $\vec{\mathbf{v}}$

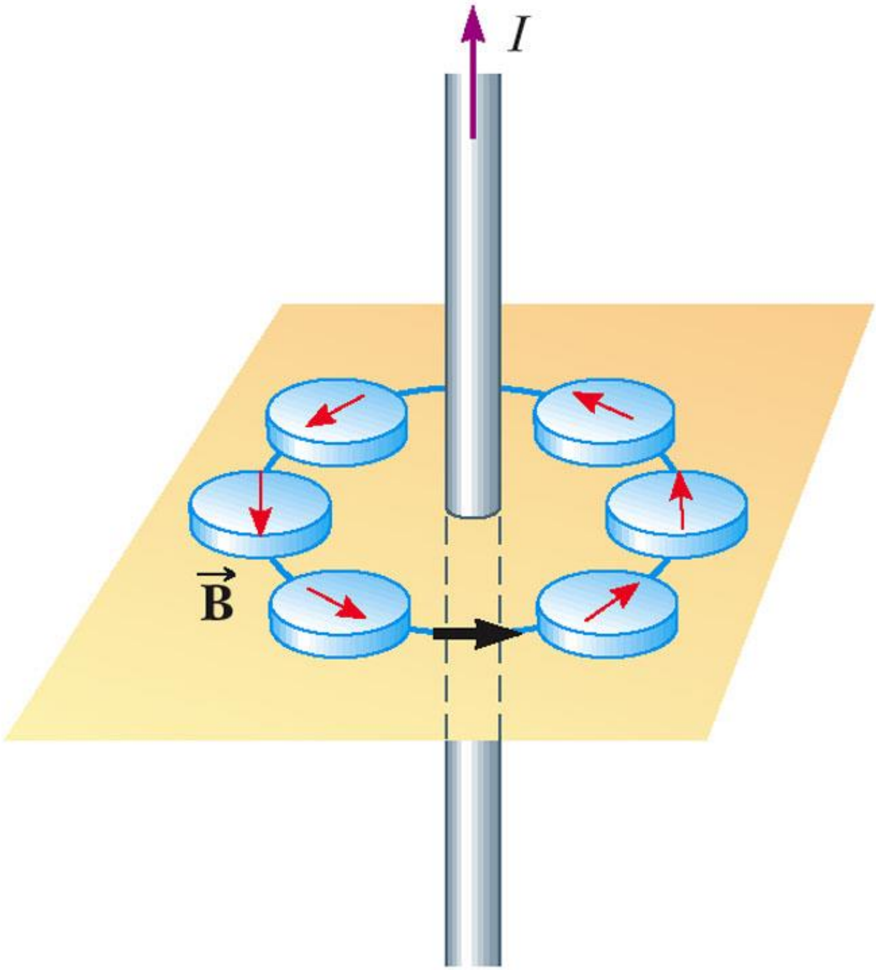
Force on a Charged Particle in a Magnetic Field

- Consider a particle moving in an external magnetic field so that its velocity is perpendicular to the field
- The force is always directed toward the center of the circular path
- The magnetic force causes a centripetal acceleration, changing the direction of the velocity of the particle



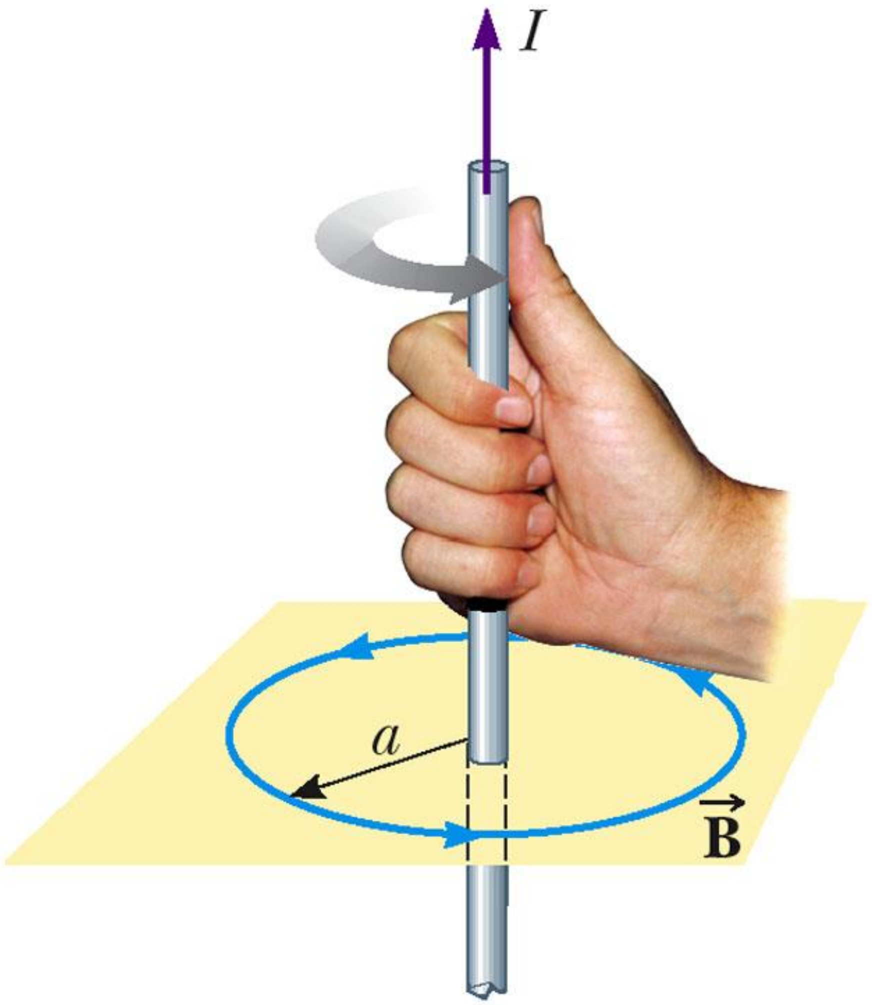
Magnetic Fields – Long Straight Wire

- A current-carrying wire produces a magnetic field
- The compass needle deflects in directions tangent to the circle
  - The compass needle points in the direction of the magnetic field produced by the current



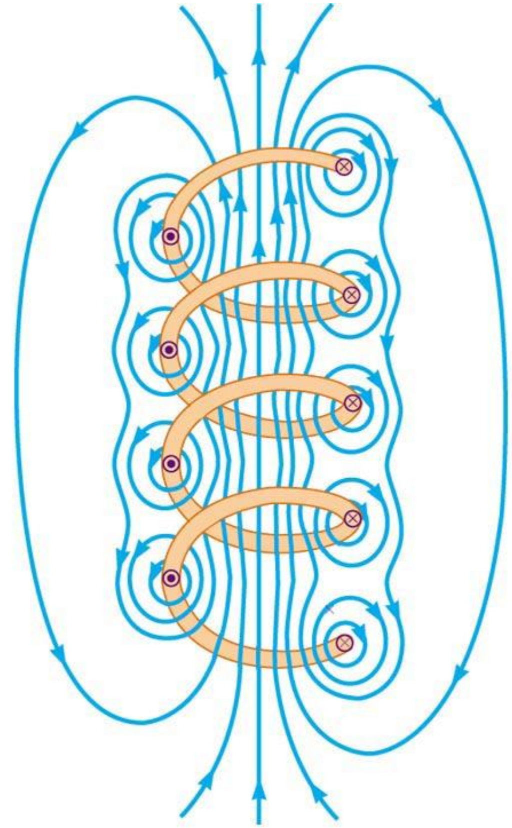
Direction of the Field of a Long Straight Wire

- Right Hand Rule
  - Grasp the wire in your right hand
  - Point your thumb in the direction of the current
  - Your fingers will curl in the direction of the field



Magnetic Field of a Solenoid

- If a long straight wire is bent into a coil of several closely spaced loops, the resulting device is called a solenoid
- It is also known as an electromagnet since it acts like a magnet only when it carries a current

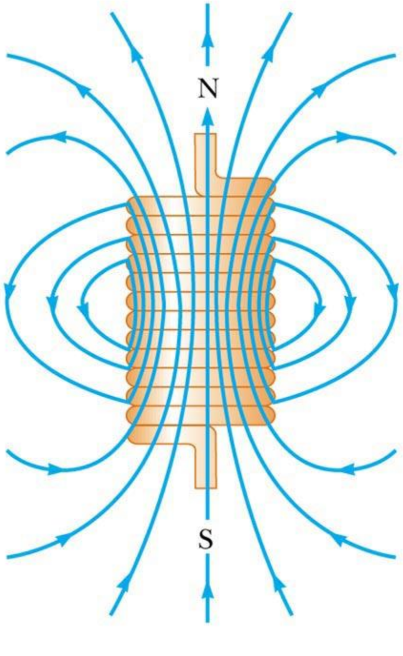


Magnetic Field of a Solenoid, 2

- The field lines inside the solenoid are nearly parallel, uniformly spaced, and close together
  - This indicates that the field inside the solenoid is nearly uniform and strong
- The exterior field is nonuniform, much weaker, and in the opposite direction to the field inside the solenoid

Magnetic Field in a Solenoid, 3

- The field lines of the solenoid resemble those of a bar magnet



(a)