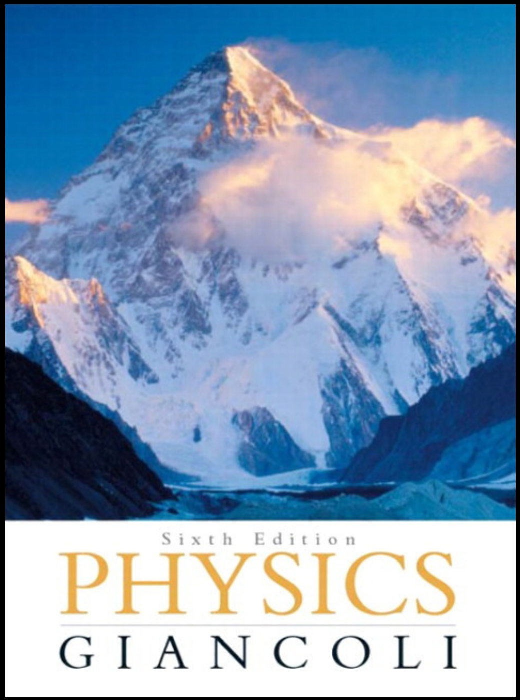

Lecture PowerPoints

Chapter 20

Physics: Principles with Applications, 6th edition

Giancoli

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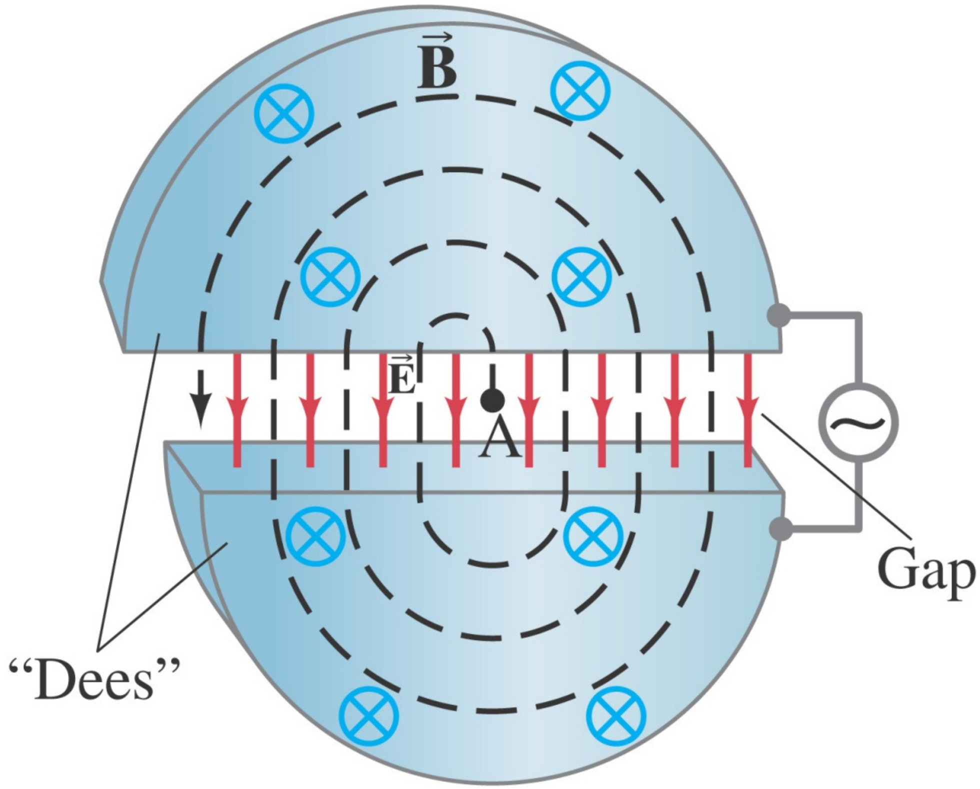
Chapter 20

Magnetism



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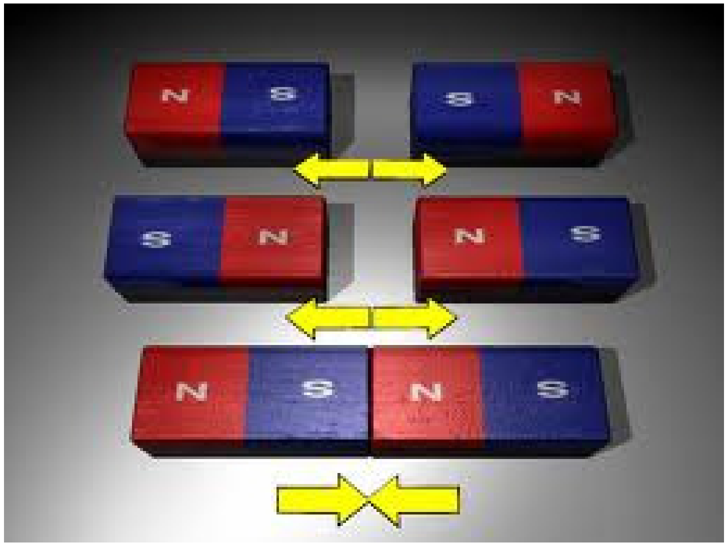
Units of Chapter 20

- Magnets and Magnetic Fields
- Electric Currents Produce Magnetic Fields
- Force on an Electric Current in a Magnetic Field; Definition of B
- Force on Electric Charge Moving in a Magnetic Field
- Magnetic Field Due to a Long Straight Wire
- Force between Two Parallel Wires
- Solenoids and Electromagnets
- Applications: Galvanometers, Motors, Loudspeakers
- Mass Spectrometer

Basic Observations about Magnets

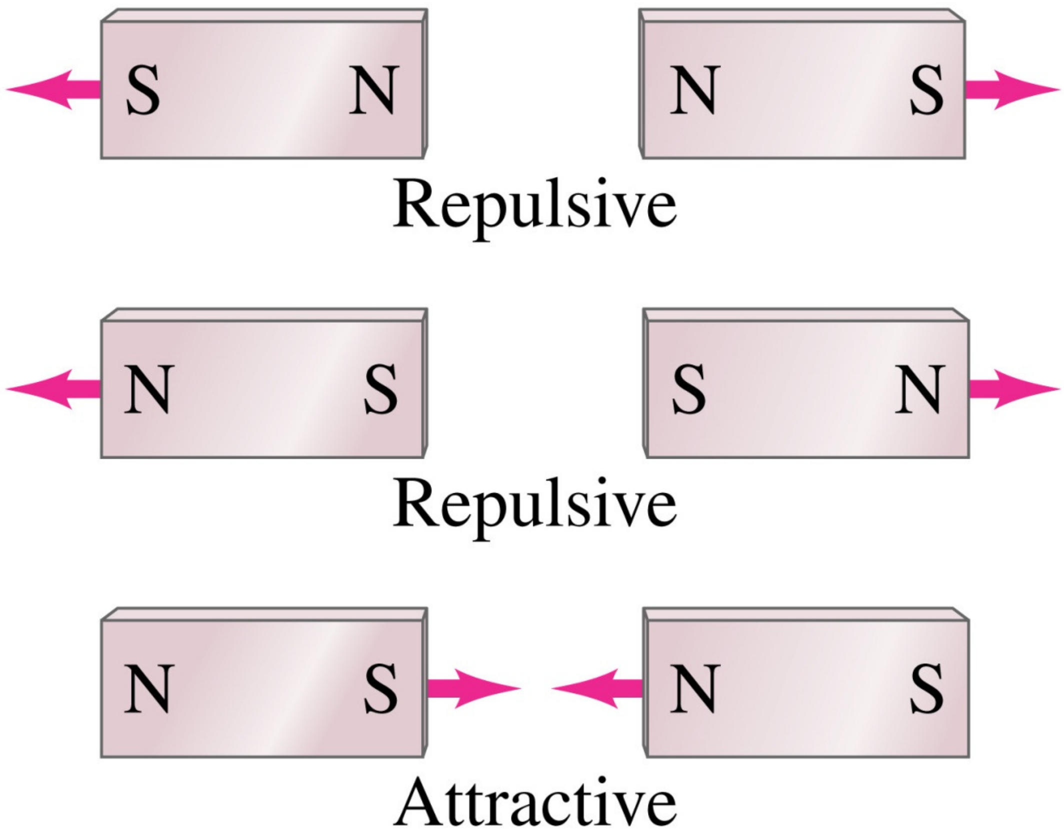
- Magnets have two ends – poles – called north and south.
- Like poles repel; unlike poles attract.
- Compasses point North
- Compasses also respond to magnets and electric wires
- Thus electric currents must produce magnetic fields
- Wire coils carrying a current are electromagnets, and can magnetize things.
- Magnets attract Iron, but not usually other metals -what's going on?



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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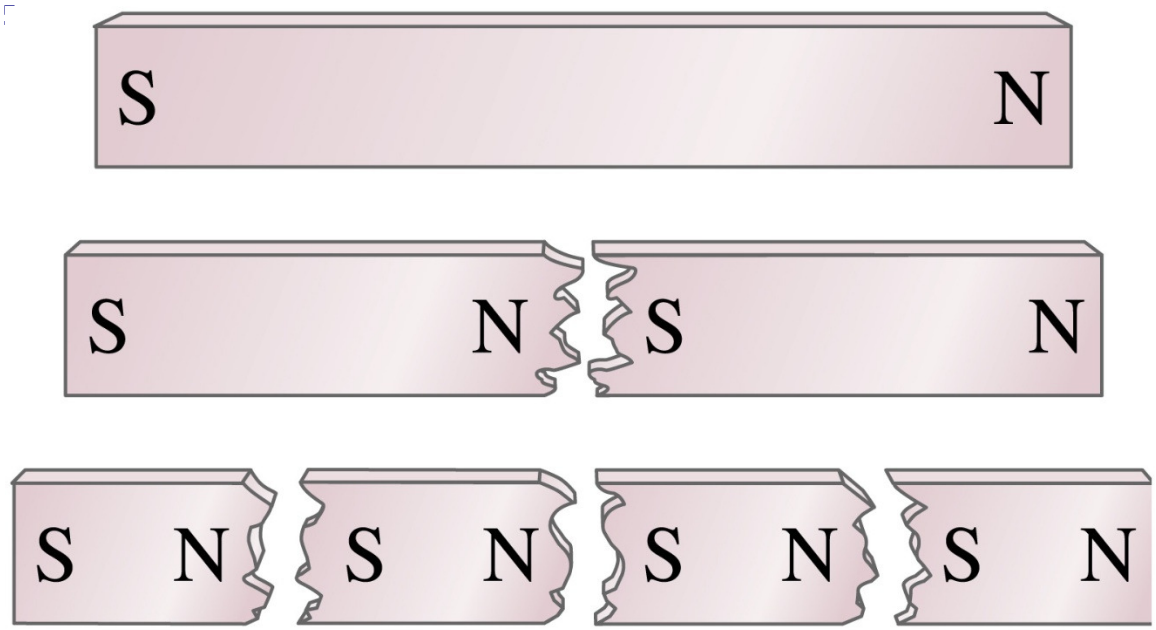
Magnets Always have at least 2 poles

- Typical magnets are Dipoles
- Magnet poles cannot be isolated
- This is unlike electric charges
- If you cut a magnet in half, you don't get a north pole and a south pole
- You get two smaller magnets.
- No "Monopoles"



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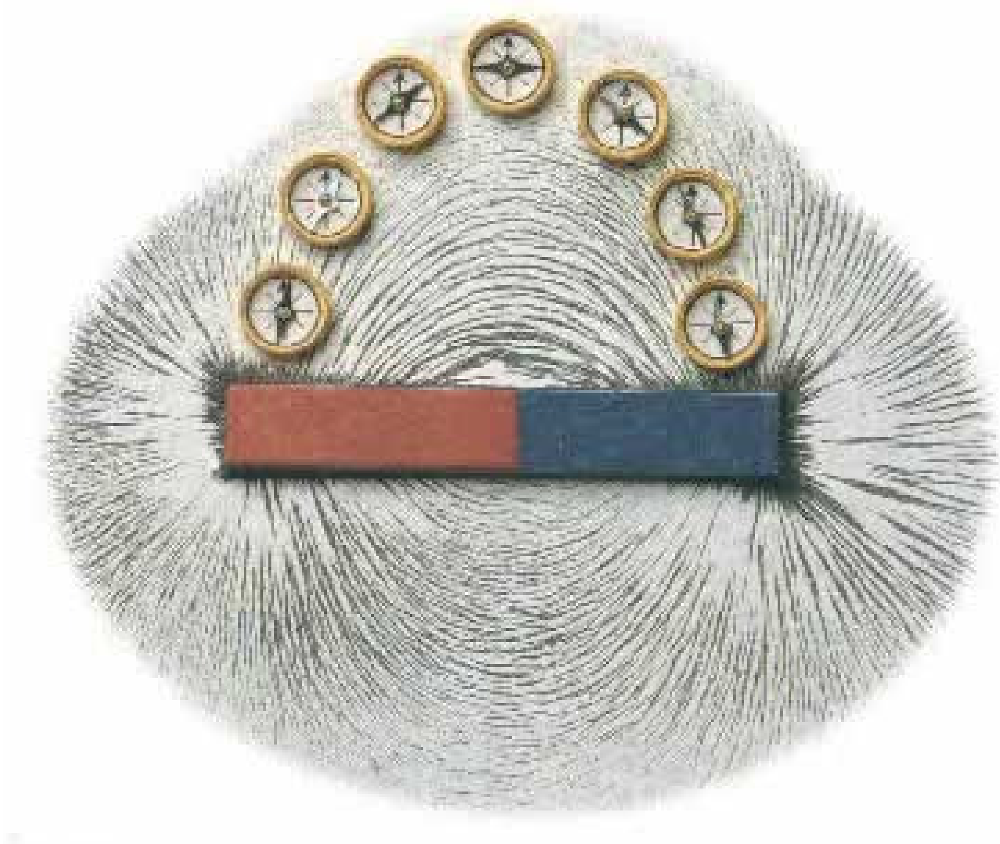
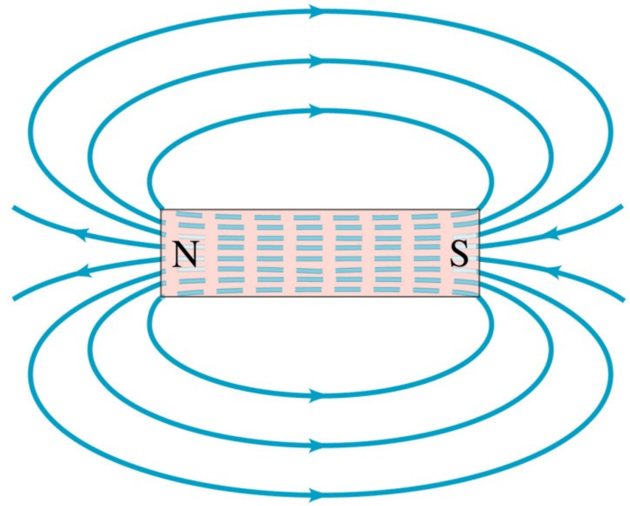
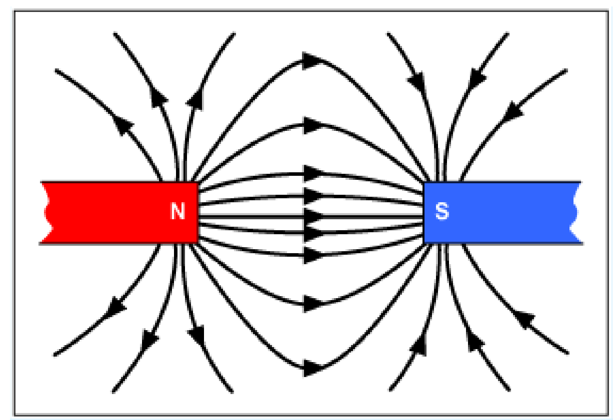
20.1 Magnets and Magnetic Fields

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



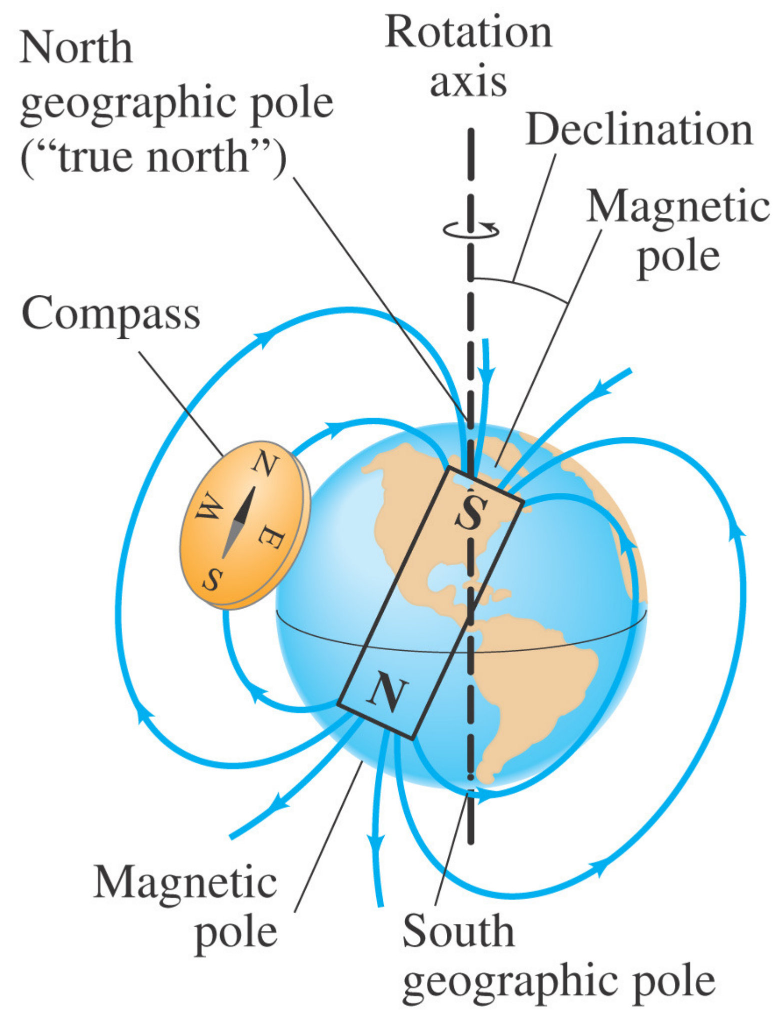




20.1 Magnets and Magnetic Fields

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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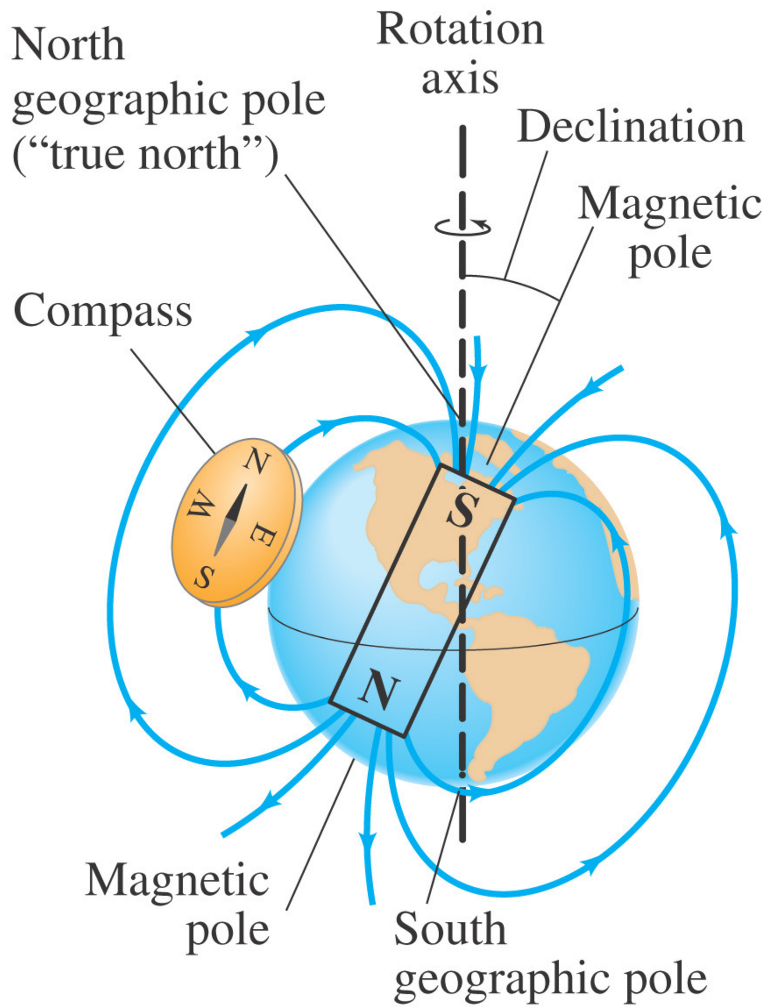
The Earth's Magnetic field

- Dipole: Similar to that of a bar magnet
- Strength: $B_{Earth} = 0.5 \times 10^{-4}$ Tesla
- Generated by circulating currents in the Earth's molten iron core
- Offset from the rotation axis,
- Moves! (many km/yr)
- Locally warped (Magnetic variation: up to 20°in New England)
- The Earth's "North Pole" is really a south magnetic pole, as the north ends of magnets are attracted to it.
- Currently weakening
- Reverses roughly every 300,000 yrs
- Responsible for the Aurora



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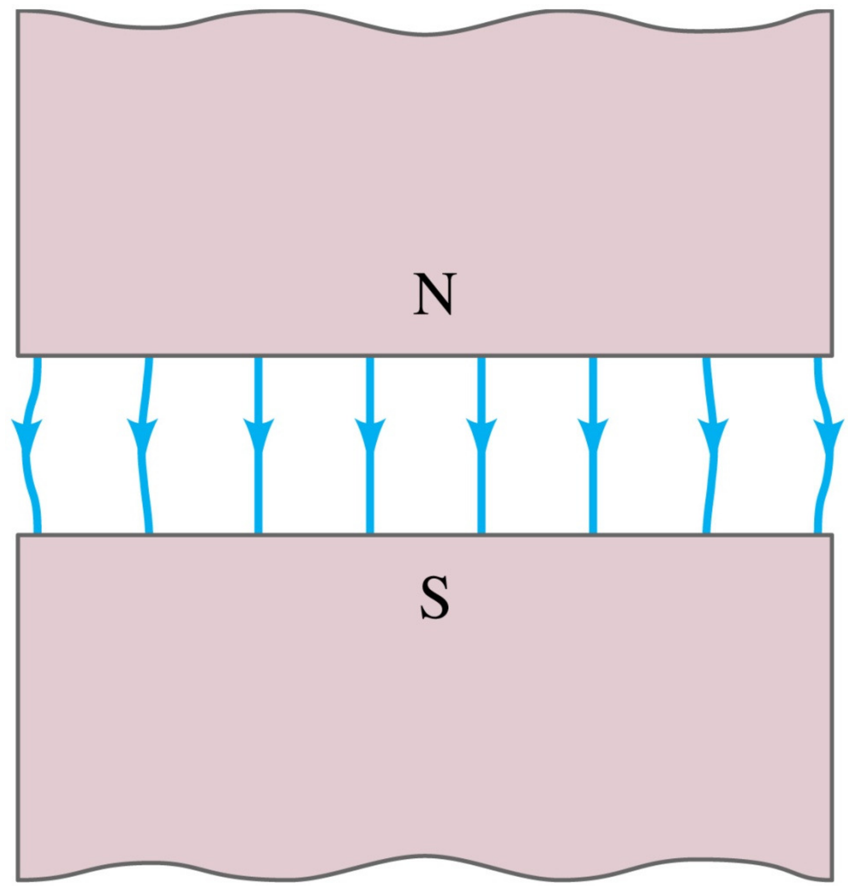
20.1 Magnets and Magnetic Fields

A uniform magnetic field is constant in magnitude and direction.

The field between these two wide poles is nearly uniform.



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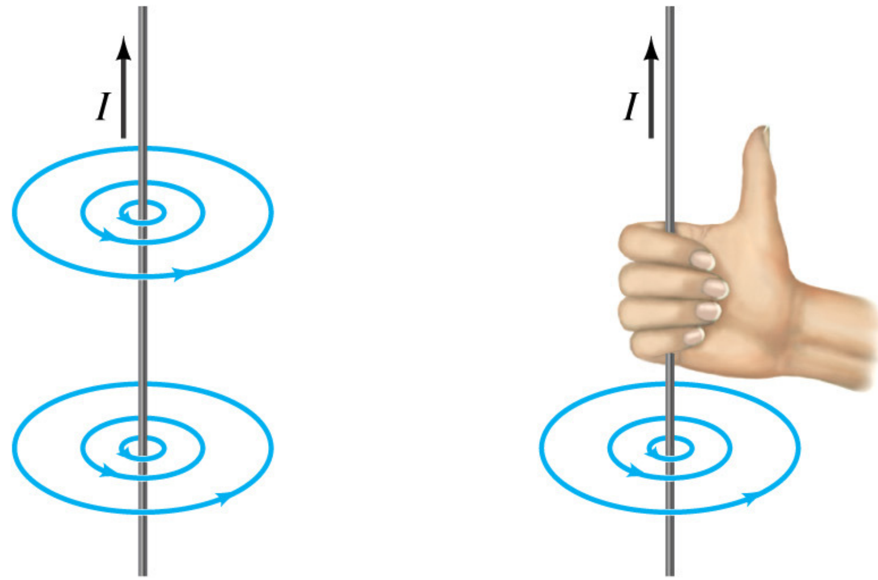
20.2 Electric Currents Produce Magnetic Fields

Experiment shows that an electric current produces a magnetic field.

Right hand Grip Rule for Current and Magnetic Field



(b) (c)

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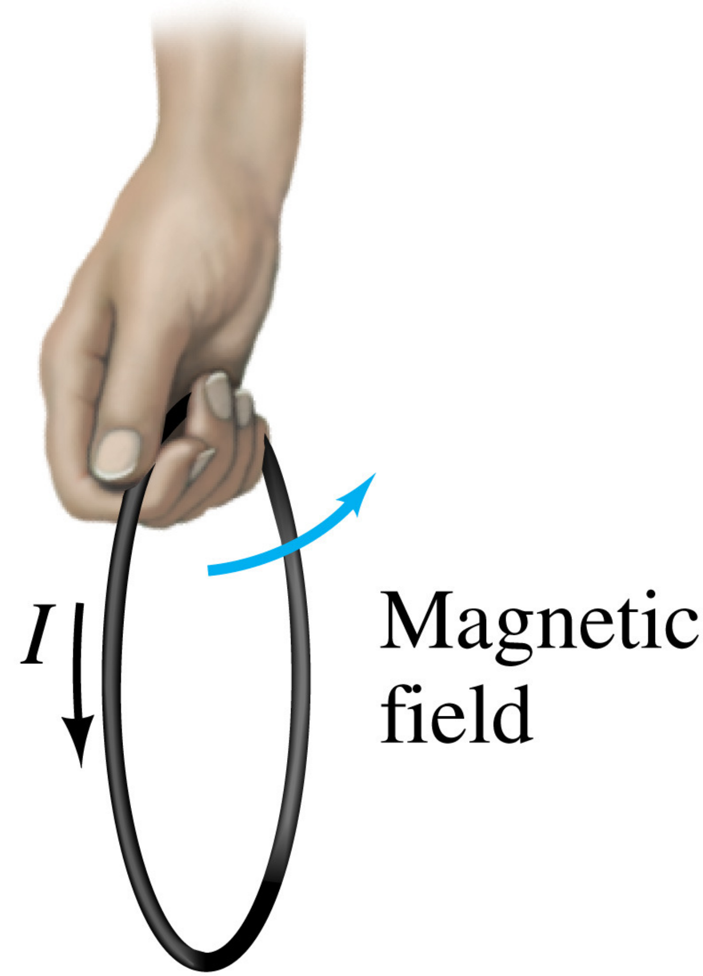
20.2 Electric Currents Produce Magnetic Fields

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

It applies in all kinds of situations: Wires, Loops, Coils, nerve fibers, medical sensors, the solar wind, etc…..



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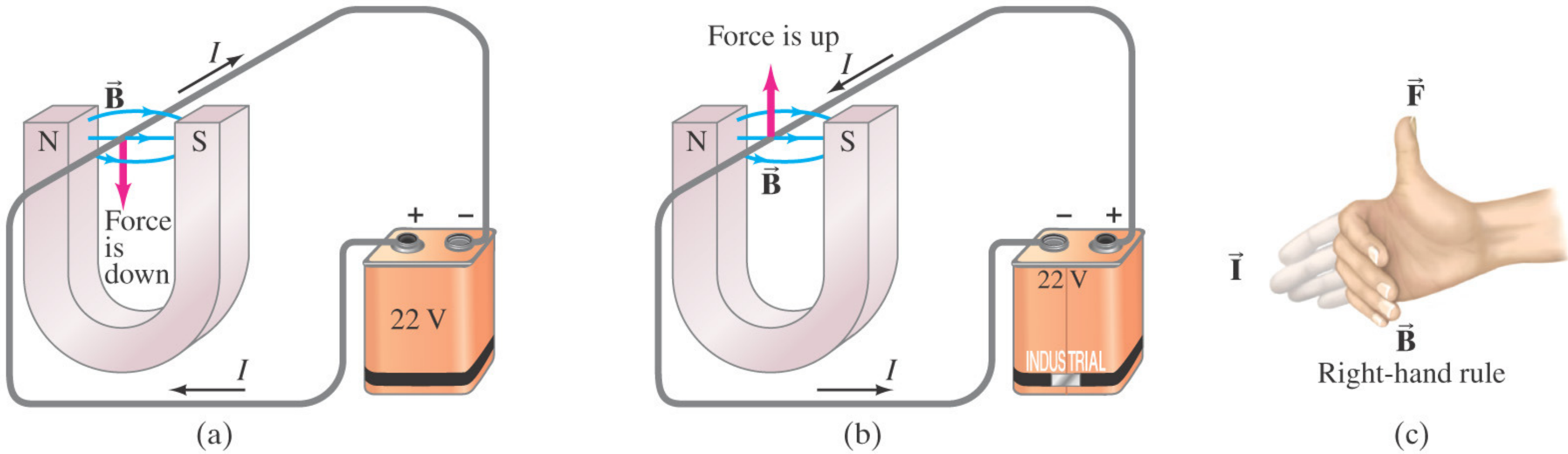
20.3 Force on an Electric Current in a Magnetic Field; Definition of B

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

Force, Field, and Current for a "right-handed Triad" (they are orthogonal like vector components)

One version of the Right Hand Rule is the F-B-I rule



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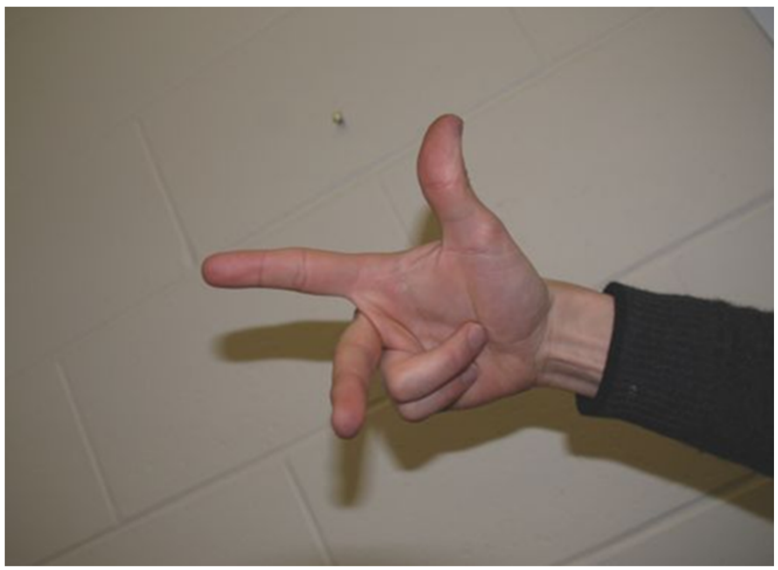
Right Hand Rule for deflection of charged particles and current carrying wires by a Magnetic Field

I (current)

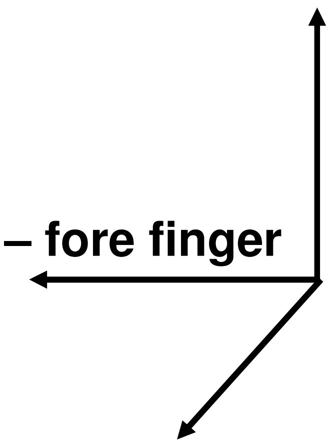
B (field)



F (force)

I (current) - thumb

B (field) – fore finger

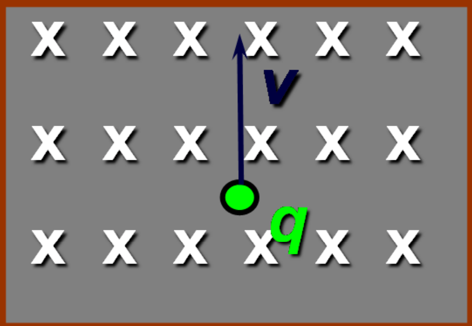


F (force) – middle finger

ConcepTest 20.1a Magnetic Force I

A positive charge enters a uniform magnetic field as shown. What is the direction of the magnetic force?

1) out of the page
2) into the page
3) downwards
4) to the right
5) to the left

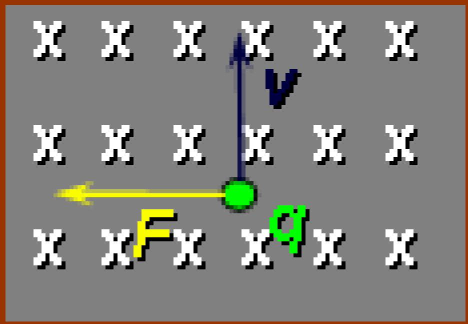


ConcepTest 20.1a Magnetic Force I

A positive charge enters a uniform magnetic field as shown. What is the direction of the magnetic force?

1) out of the page
2) into the page
3) downwards
4) to the right
5) to the left

Using the right-hand rule, you can see that the magnetic force is directed **to the left**. Remember that the magnetic force must be **perpendicular to BOTH the *B* field and the velocity**.



How to calculate the Force on a Current-carrying wire

- Symbol for Magnetic Field: B
- Units: Tesla (T) or Gauss (10^{-4} T)
- The force on the wire depends on the current, the length of the wire, the magnetic field, and its orientation.

$$F = IlB \sin\theta$$

F = qvB sinθ **(think why this is the same thing)**

This equation defines the magnetic field B.

If the wire is a right-angles to the field, then the maximum force is felt

$$F_{max} = IlB$$

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.

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

This equation defines the magnetic field **B**.

Unit of B: Tesla, T 1 T = 1 N/A·m

Another unit sometimes used: gauss (G)

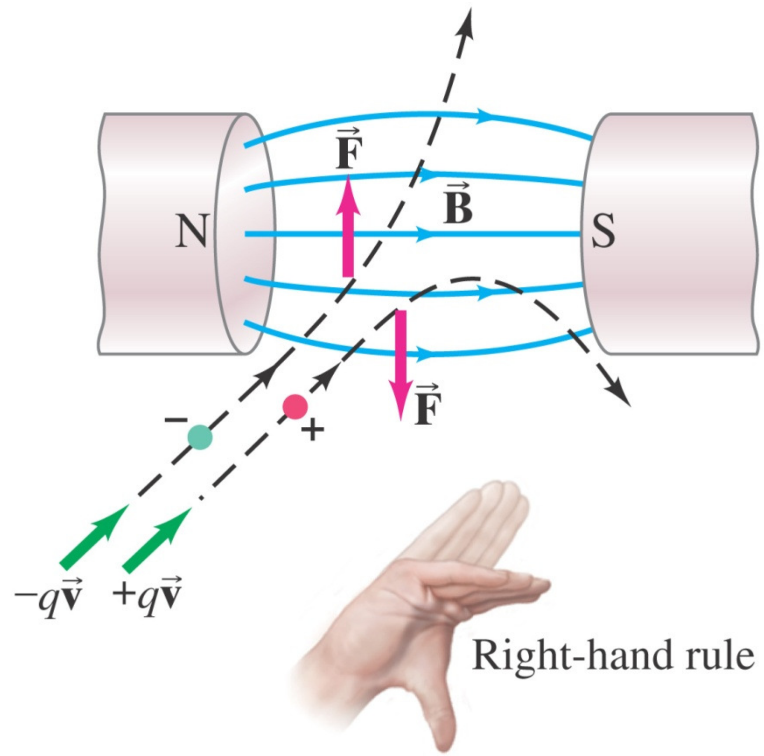
1 G = 10^{-4} T.

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:

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

- Once again, the direction is given by a right-hand rule (FBI).
- Maximum force occurs when the charge moves orthogonally to the Field
- The "current" direction depends on the charge carrier (+/-)
- Application: TV tube, Mass Spectrometer



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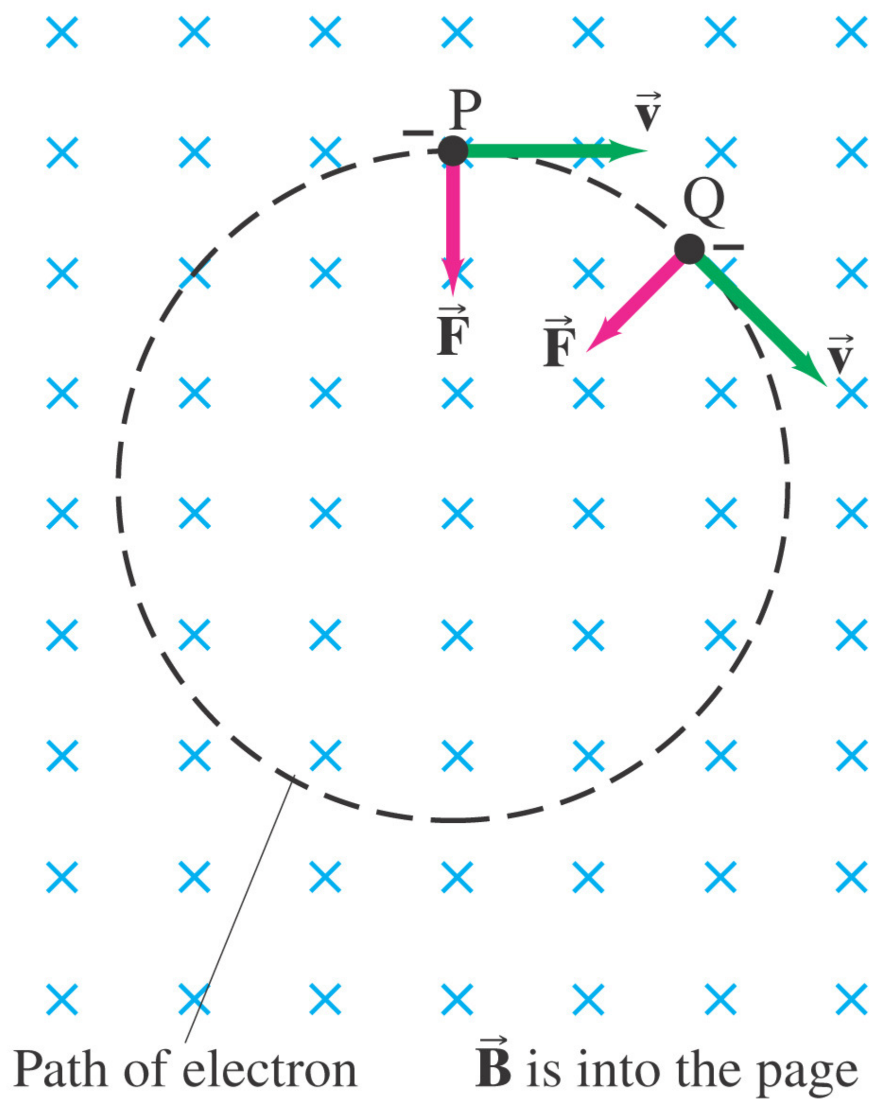
20.4 Force on Electric Charge Moving in a Magnetic Field

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

Can be demonstrated in the so-called E-by-M experiment.



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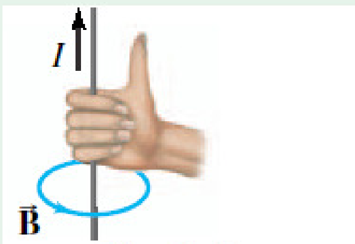
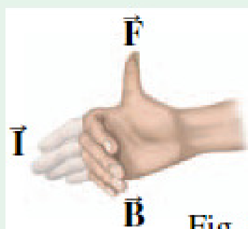
20.4 Force on Electric Charge Moving in a Magnetic Field

Problem solving: Magnetic fields – things to remember

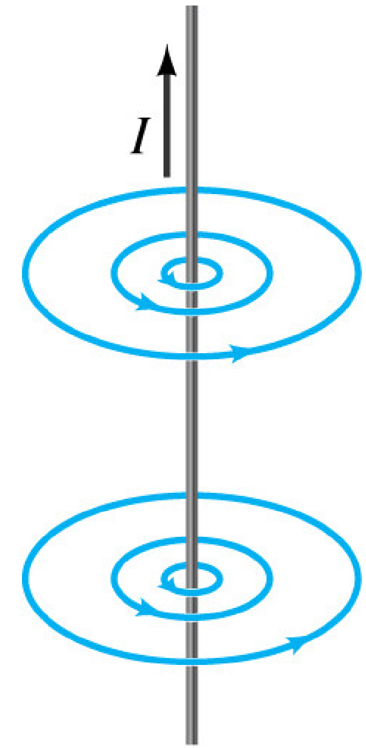
1. The magnetic force is perpendicular to the magnetic field direction.
2. The right-hand rule is useful for determining directions.
3. Equations in this chapter give magnitudes only. The right-hand rule gives the direction.

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



- If a current produces B-field, how to calculate it:
- Field is proportional to the Current
- Field is inversely proportional to the distance from the wire.

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

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

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

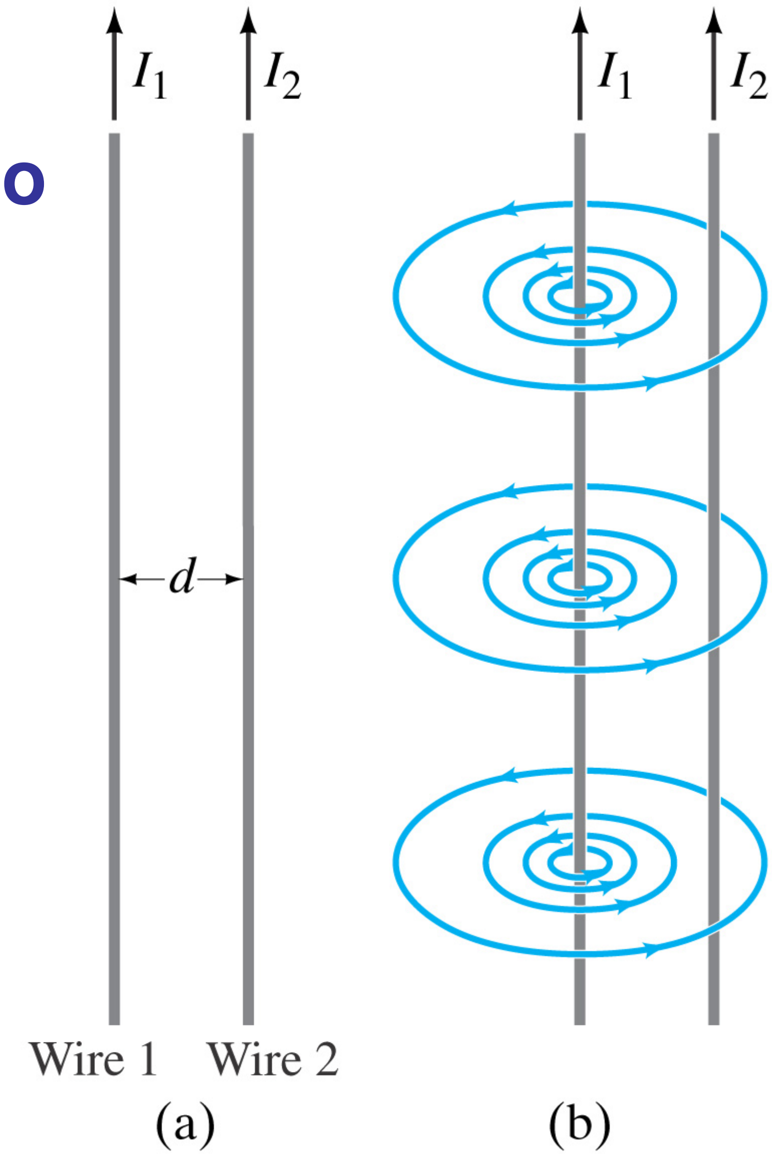
20.6 Force between Two Parallel Wires

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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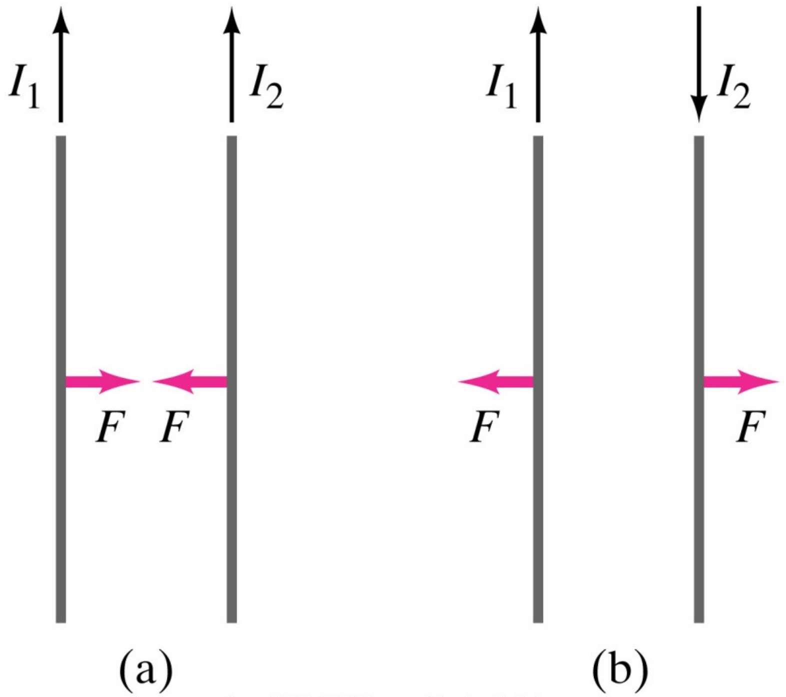
20.6 Force between Two Parallel Wires

Parallel currents attract; antiparallel currents repel.



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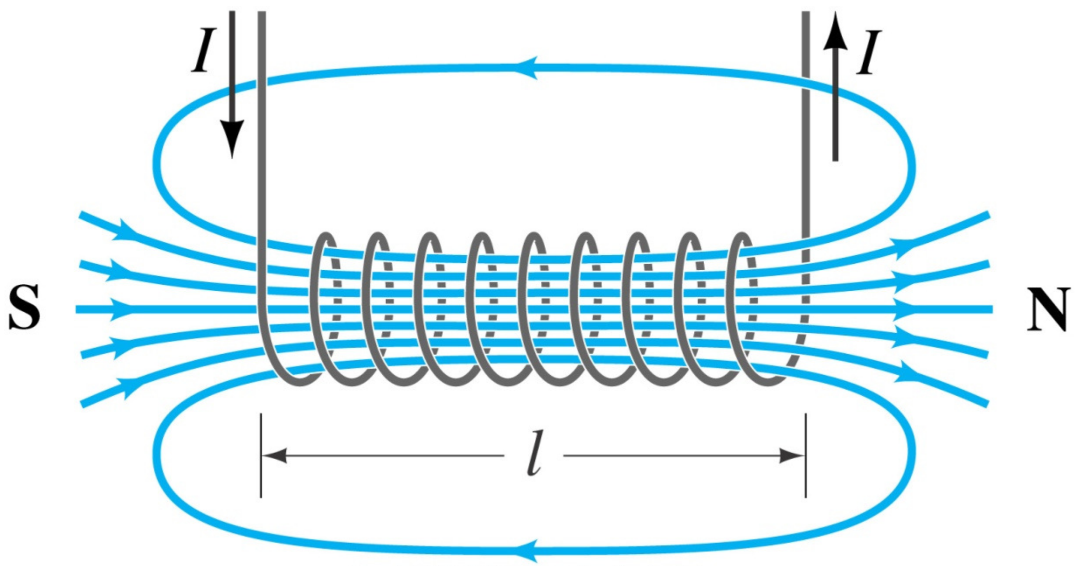
If you can remember the Right Hand Grip Rule, then the force between parallel wires is like a handshake

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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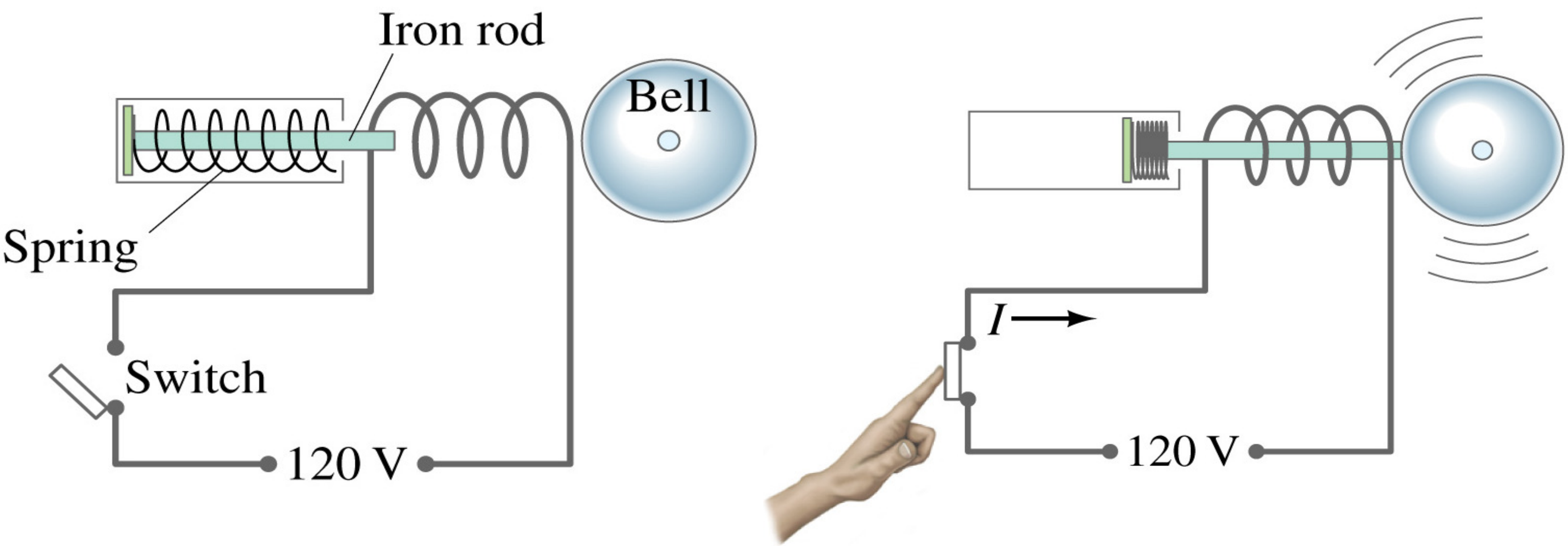
20.7 Solenoids and Electromagnets

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



20.9 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:

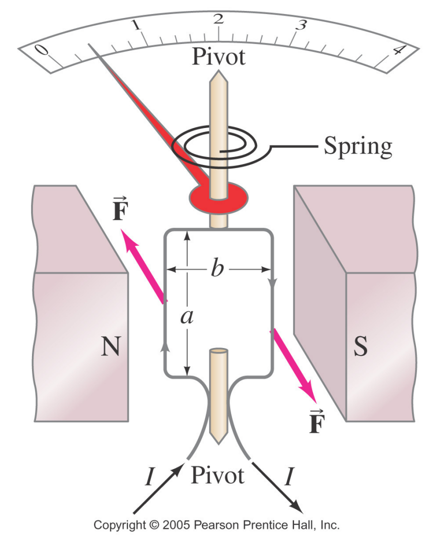
$$\tau = NIAB\sin\theta \qquad \textbf{(20-10)}$$

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

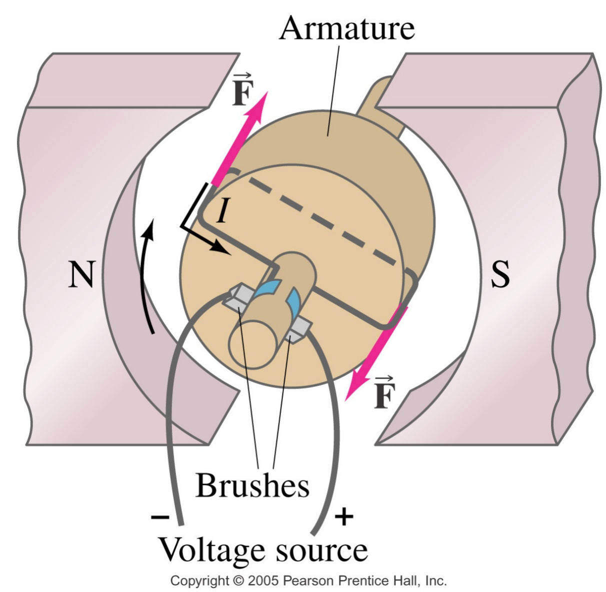
$$M = NIA \qquad \textbf{(20-11)}$$

20.10 Applications: Galvanometers, Motors, Loudspeakers

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

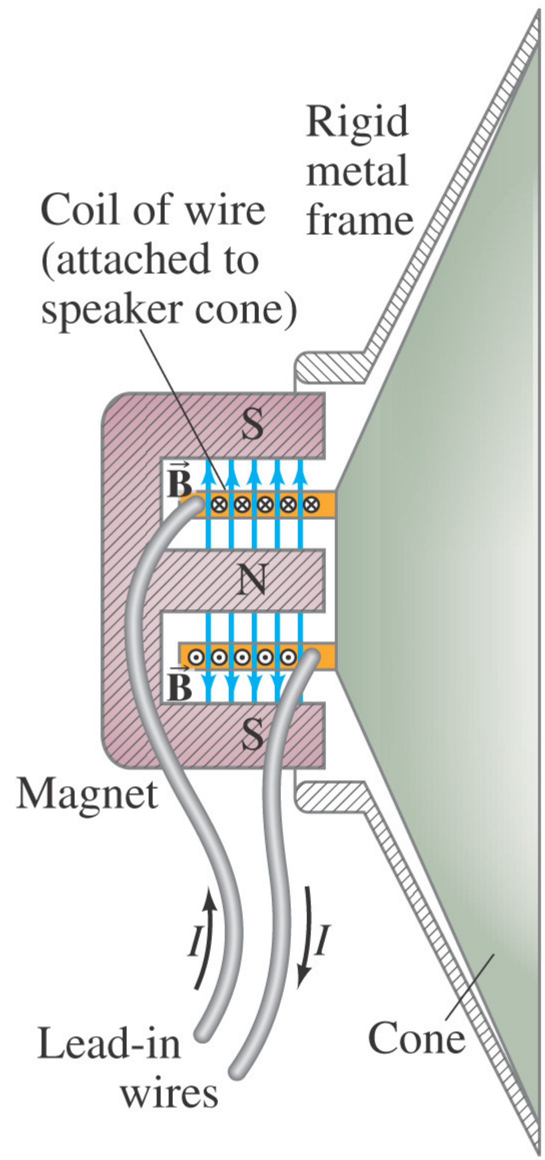


An electric motor also takes advantage of the torque on a current loop, to change electrical energy to mechanical energy.



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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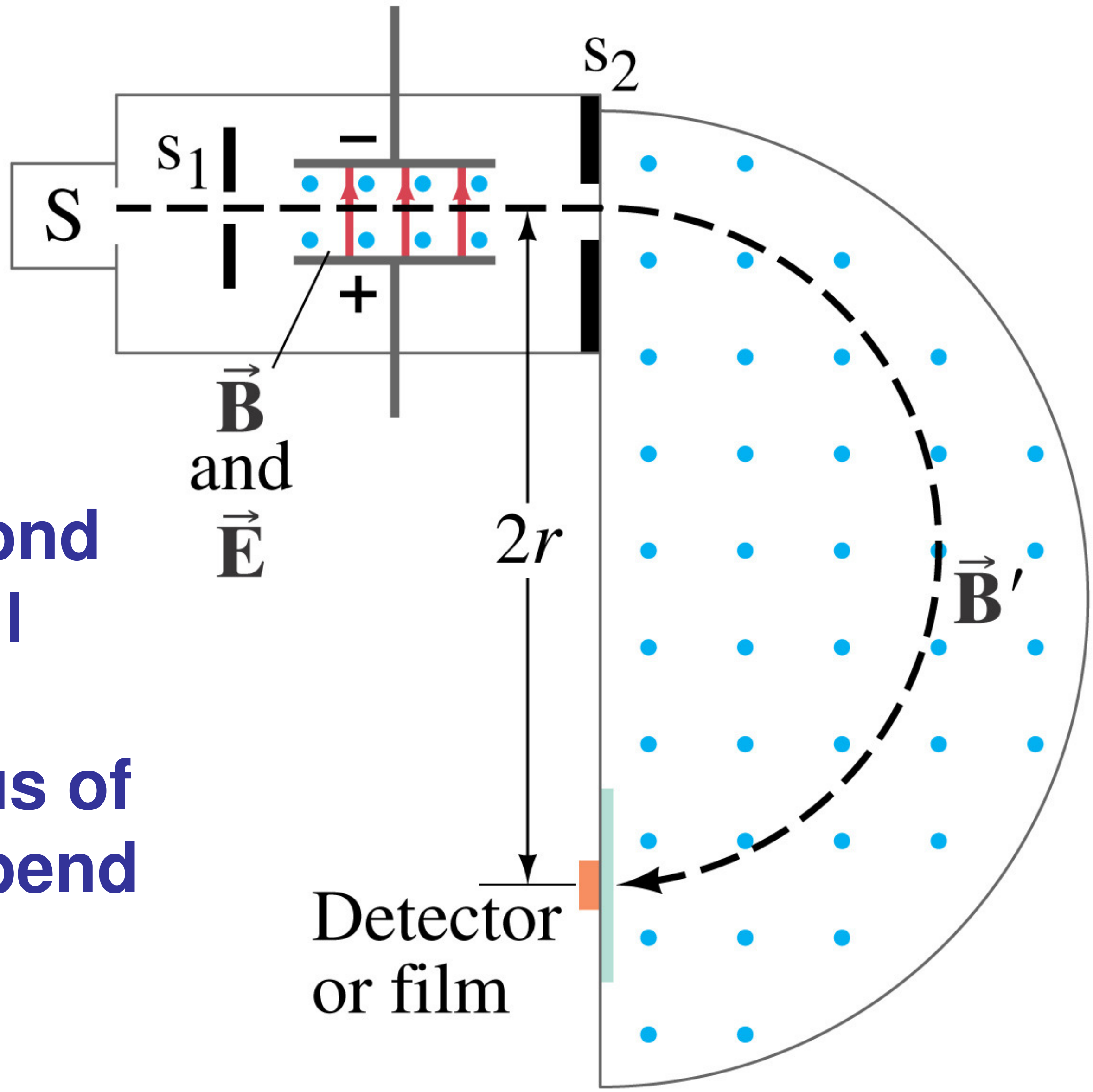
20.11 Mass Spectrometer

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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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:**

$$B = \mu_0 I N / l$$

- **Ampère's law:**

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

- **Torque on a current loop:**

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