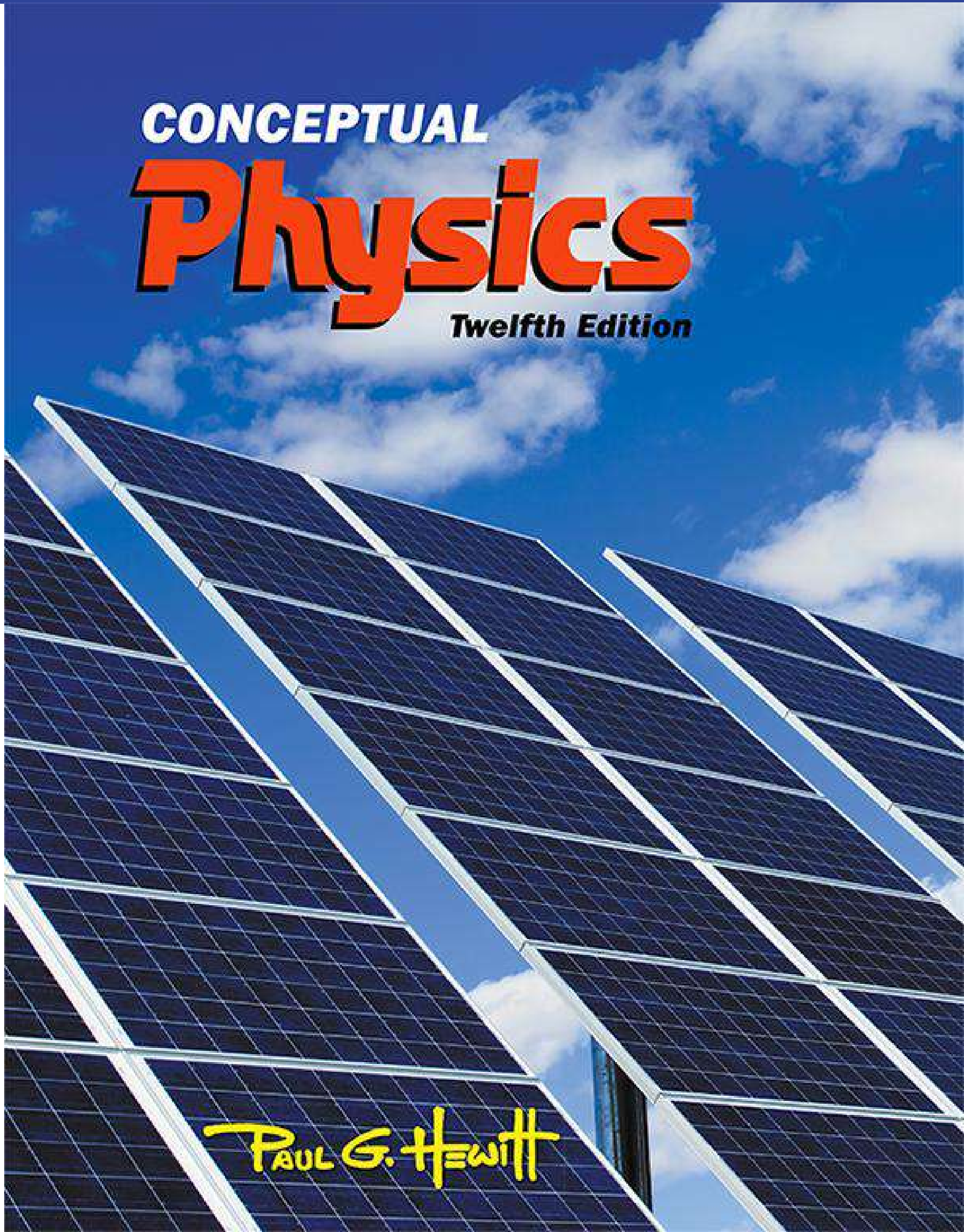
Lecture Outline

Magnetism
Ch 36.1-36.7



This lecture will help you understand:

- Magnetic Forces
- Magnetic Poles
- Magnetic Fields
- Magnetic Domains
- Electric Currents and Magnetic Fields
- Electromagnets
- Magnetic Force on Moving Charged Particles
- Magnetic Force on Current Carrying Wires
- Earth's Magnetic Field
- Biomagnetism

Magnetism

- The term *magnetism* comes from the name Magnesia, a coastal district of ancient Thessaly, Greece.
- Unusual stones were found by the Greeks more than 2000 years ago.
- These stones, called *lodestones*, had the intriguing property of attracting pieces of iron.
- Magnets were first fashioned into compasses and used for navigation by the Chinese in the 12th century.

Magnetic Forces

- The force between any two charged particles depends on the magnitude of the charge on each and their distance of separation, as specified in Coulomb's law. But Coulomb's law is not the whole story!
- When the charged particles are moving with respect to each other, the electrical force between electrically charged particles depends also, in a complicated way, on their motion.
- There is a force due to the motion of the charged particles that we call the **magnetic force.**

Magnetic Poles

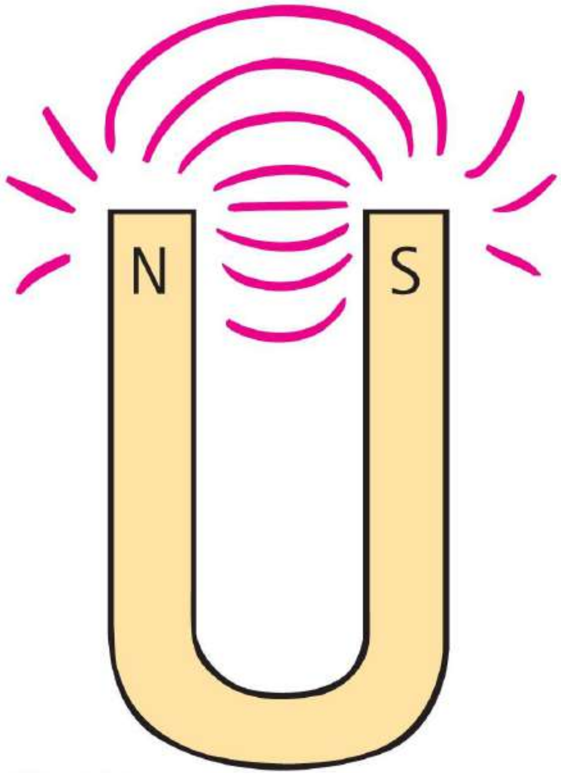
- Magnetic force between a pair of magnets
  - Force of attraction or repulsion between a pair of magnets depends on which end of the magnet is held near the other.
  - Behavior similar to electrical forces.
  - Strength of interaction depends on the distance between the two magnets.

Magnetic Poles, Continued

- Magnetic poles
  - Give rise to magnetic force
  - Two types interacting with each other
    - north pole (north-seeking pole)
    - south pole (south-seeking pole)
- Rule for magnetic forces between magnetic poles:
  - Like poles repel; opposite poles attract.

Magnetic Poles, Continued-1

- Magnetic poles (continued)
  - In all magnets—can't have one pole without the other
  - No single pole known to exist
  - Example:
    - simple bar magnet—poles at the two ends
    - horseshoe magnet: bent U shape—poles at ends



Magnetic Poles
CHECK YOUR NEIGHBOR

A weak and strong magnet repel each other. The greater repelling force is by the

A. stronger magnet.
B. weaker magnet.
C. Both the same.
D. None of the above.

Magnetic Poles
CHECK YOUR ANSWER

A weak and strong magnet repel each other. The greater repelling force is by the

C. **Both the same.**

Explanation:

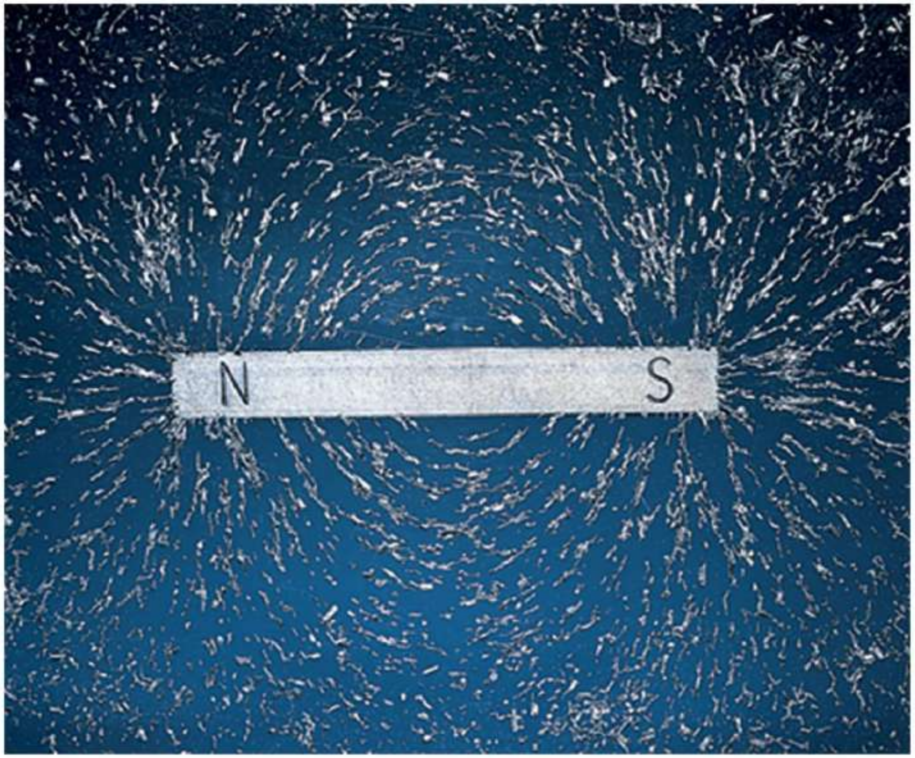
Remember Newton's third law!

Magnetic Fields

- Magnetic fields
  - Region of magnetic influence surrounding magnetic poles
  - Shape revealed by lines that spread from one pole to the other
  - By convention, direction is from the north pole to the south pole, produced by motions of electric charge in atoms

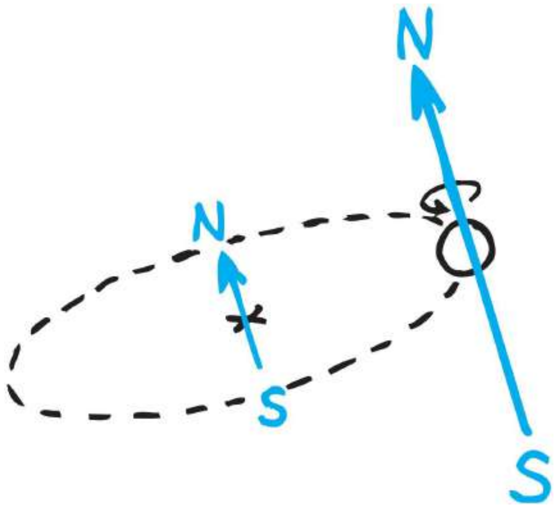
Magnetic Fields, Continued

- Magnetic fields (continued)
  - Strength indicated by closeness of the lines
    - lines close together; strong magnetic field
    - lines farther apart; weak magnetic field



Magnetic Fields, Continued-1

- Magnetic fields (continued)
  - Produced by two kinds of electron motion
    - electron spin
      - main contributor to magnetism
      - pair of electrons spinning in same direction creates a stronger magnet
      - pair of electrons spinning in opposite direction cancels magnetic field of the other
    - electron revolution



Magnetic Fields
CHECK YOUR NEIGHBOR

The source of all magnetism is

A. electrons rotating around an atomic nucleus.
B. electrons spinning around internal axes.
C. either or both A and B.
D. tiny bits of iron.

Magnetic Fields
CHECK YOUR ANSWER

The source of all magnetism is

C. **either or both A and B.**

Magnetic Fields
CHECK YOUR NEIGHBOR, Continued

Where magnetic field lines are more dense, the field there is

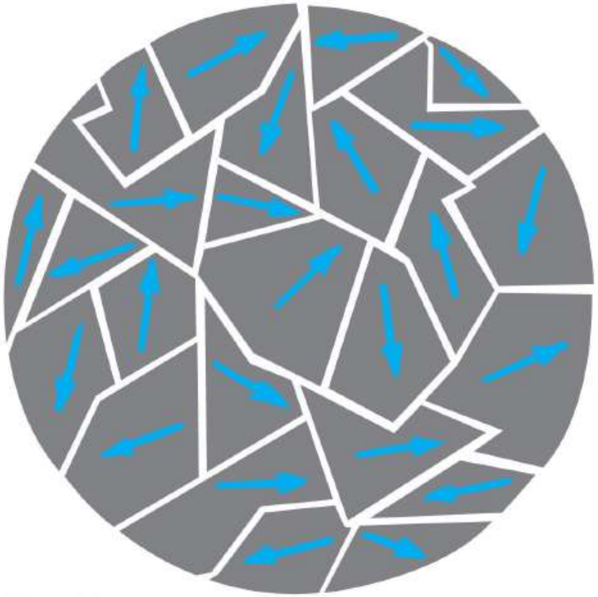
A. weaker.
B. stronger.
C. Both A and B.
D. Neither A nor B.

Magnetic Fields
CHECK YOUR ANSWER, Continued

Where magnetic field lines are more dense, the field there is

B. **stronger.**

Magnetic Domains

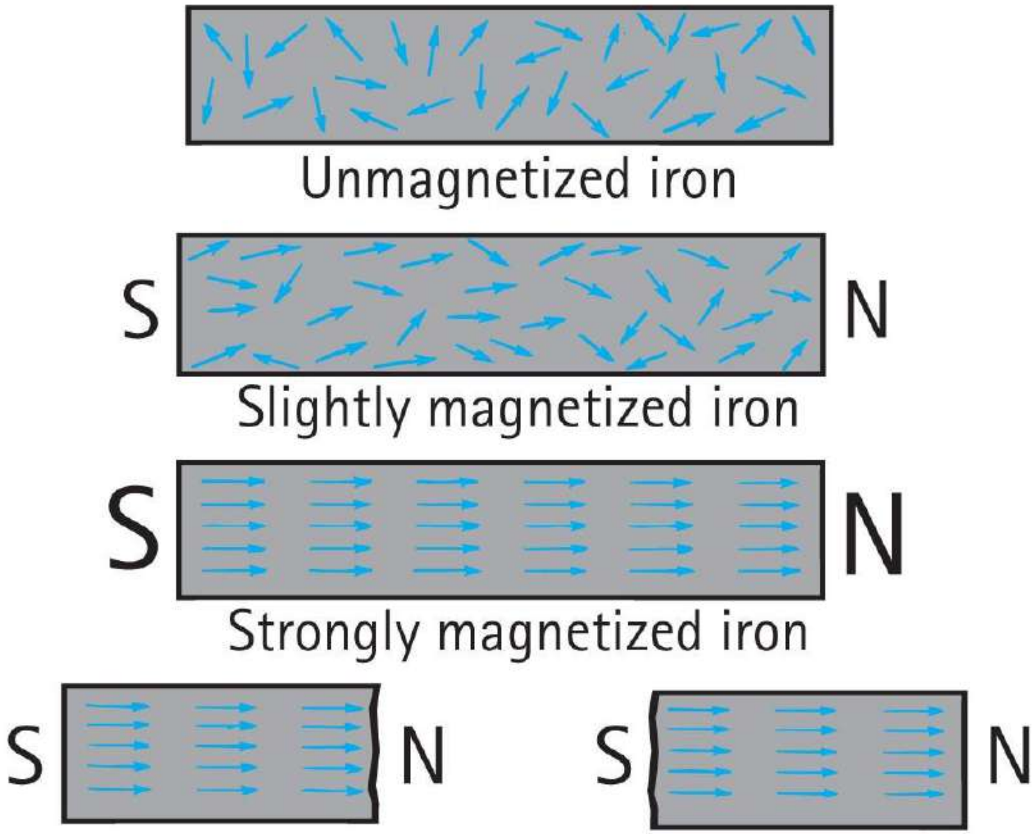


- Magnetic domains
  - Magnetized clusters of aligned magnetic atoms
- Permanent magnets made by
  - placing pieces of iron or similar magnetic materials in a strong magnetic field.
  - stroking material with a magnet to align the domains.

Magnetic Domains, Continued

- Difference between permanent magnet and temporary magnet
  - Permanent magnet
    - alignment of domains remains once external magnetic field is removed
  - Temporary magnet
    - alignment of domains returns to random arrangement once external magnetic field is removed

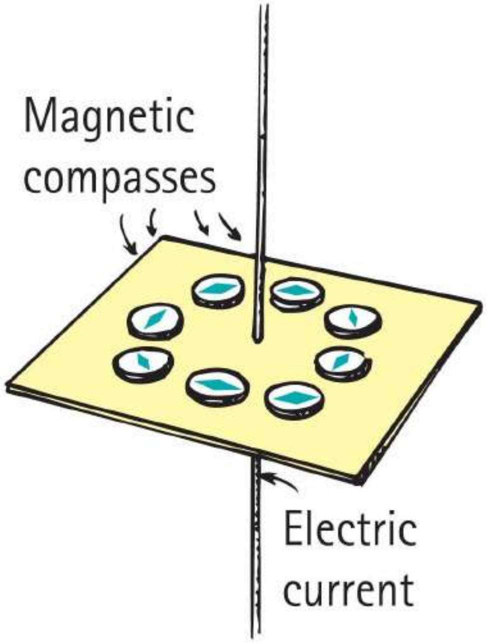
Magnetic Domains, Continued-1



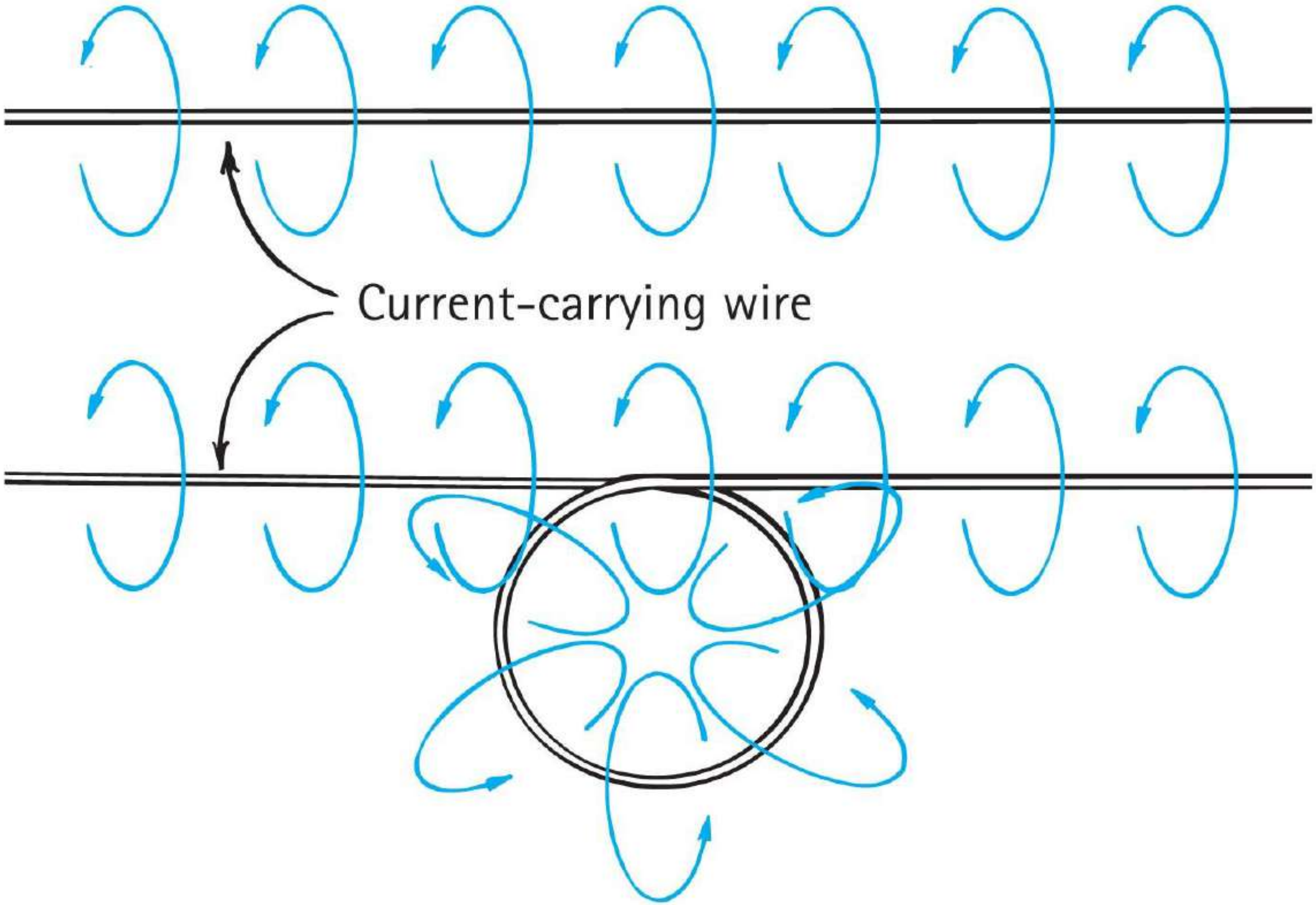
When a magnet is broken
into two pieces, each piece
is an equally strong magnet

Electric Currents and Magnetic Fields

- Connection between electricity and magnetism
  - Magnetic field forms a pattern of concentric circles around a current-carrying wire.
  - When current reverses direction, the direction of the field lines reverse.

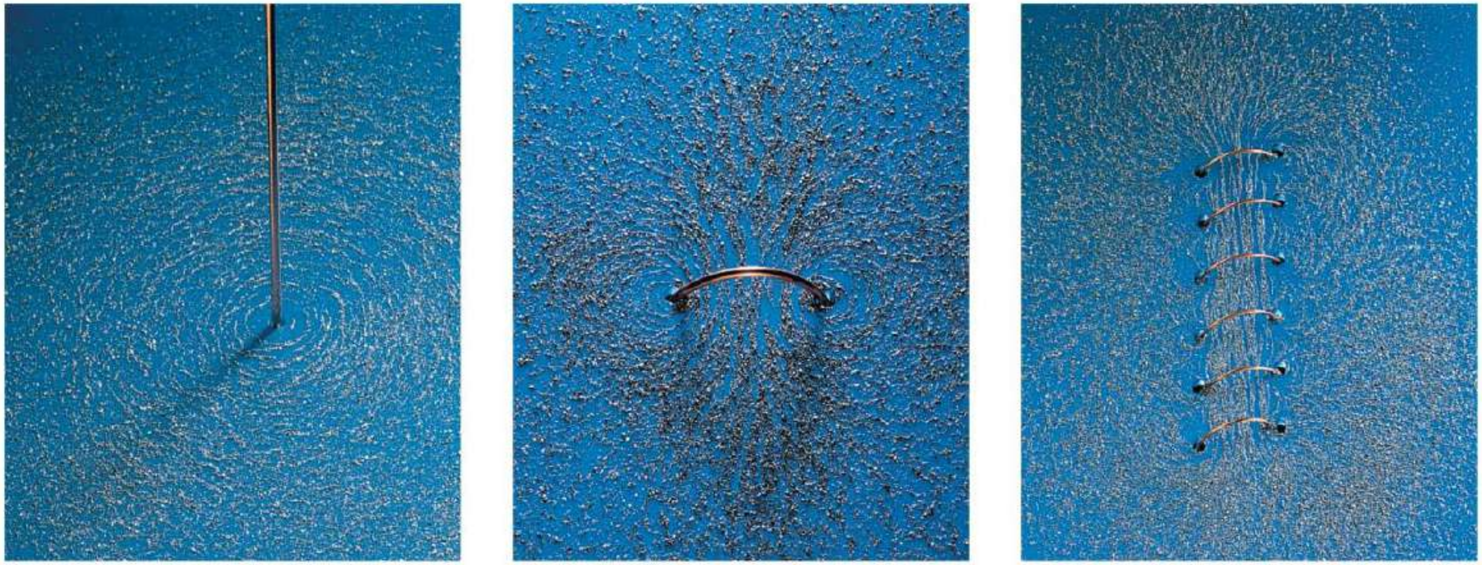


Electric Currents and Magnetic Fields, Continued



Electric Currents and Magnetic Fields, Continued-1

- Magnetic field intensity
  - increases as the number of loops increase in a current-carrying coil temporary magnet.



(a) (b) (c)

Electric Currents and Magnetic Fields, Continued-2

- Electromagnet
  - Iron bar placed in a current-carrying coil
  - Most powerful—employs superconducting coils that eliminate the core
  - Applications
    - control charged-particle beams in high-energy accelerators
    - lift automobiles and other iron objects
    - levitate and propel high-speed trains

Electric Currents and Magnetic Fields
CHECK YOUR NEIGHBOR

An electromagnet can be made stronger by

A. increasing the number of turns of wire.
B. increasing the current in the coil.
C. Both A and B.
D. None of the above.

Electric Currents and Magnetic Fields
CHECK YOUR ANSWER

An electromagnet can be made stronger by

C. **Both A and B.**

Electromagnets

- A current-carrying coil of wire is an **electromagnet.**
- The strength of an electromagnet is increased by
  - increasing the current through the coil and
  - increasing the number of turns in the coil.

    Industrial magnets gain additional strength by
  - having a piece of iron within the coil.
- Magnetic domains in the iron core are induced into alignment, adding to the field.

Electromagnets, Continued

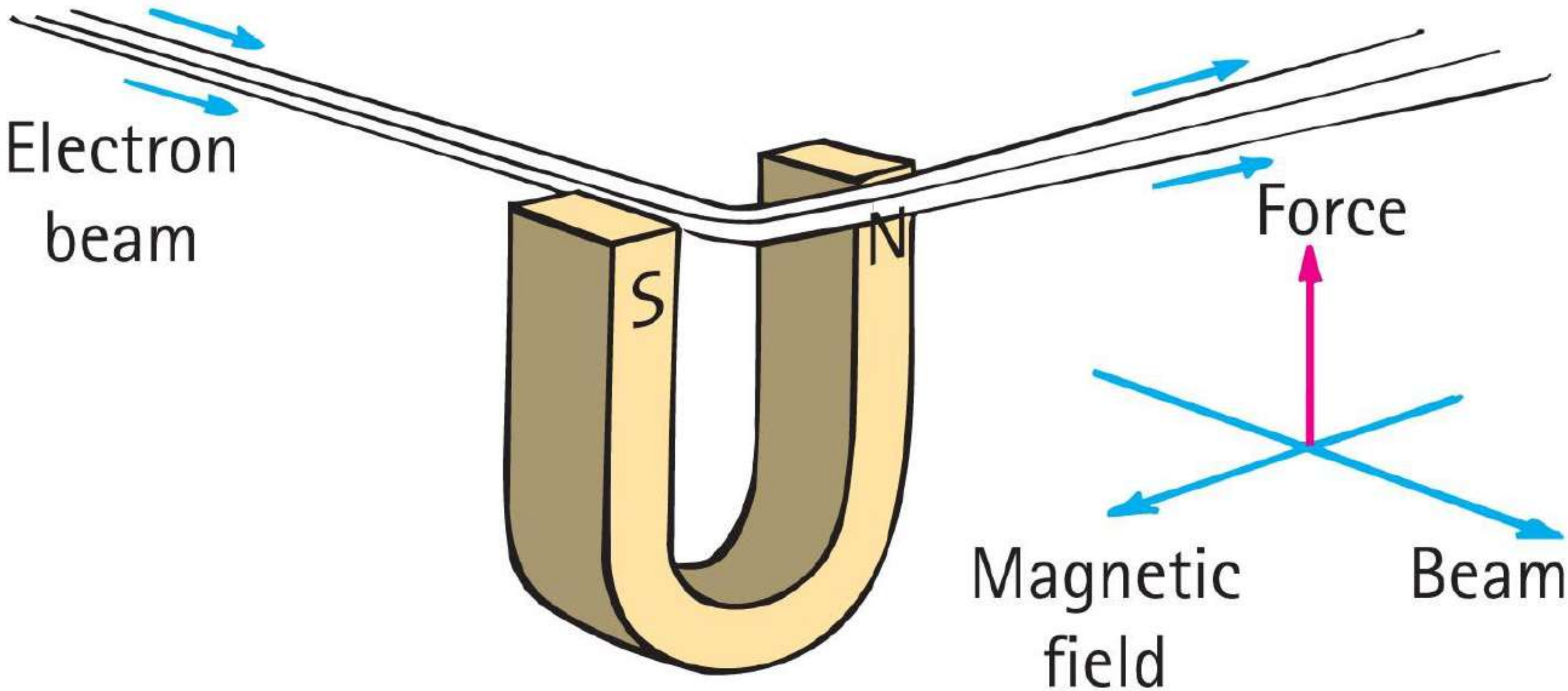
- Electromagnets without iron cores are used in magnetically levitated, or "maglev," transportation.
- Levitation is accomplished by magnetic coils that run along the track, called a guideway.
  - The coils repel large magnets on the train's undercarriage.
  - Continually alternating electric current fed to the coils continually alternates their magnetic polarity, pulling and pushing the train forward.
- Electromagnets that utilize superconducting coils produce extremely strong magnetic fields—and they do so very economically because there are no heat losses.

Magnetic Forces on Moving Charges

- Moving charges in a magnetic field experience a deflecting force.
  - Greatest force
    - particle movement in direction perpendicular to the magnetic field lines
  - Least force
    - particle movement other than perpendicular to the magnetic field lines
  - No force
    - particle movement parallel to the magnetic field lines

Magnetic Forces on Moving Charges, Continued

- Moving charges in a magnetic field experience a deflecting force. (continued)



Magnetic Force on Moving Charges CHECK YOUR NEIGHBOR

The reason that an electron moving in a magnetic field doesn't pick up speed is

A. magnets only divert them.
B. only electric fields can change the speed of a charged particle.
C. the magnetic force is always perpendicular to its motion.
D. All of the above.

Magnetic Force on Moving Charges
CHECK YOUR ANSWER

The reason that an electron moving in a magnetic field doesn't pick up speed is

C. **the magnetic force is always perpendicular to its motion.**

Explanation:

Although all statements are true, the reason is given only by C. With no component of force in the direction of motion, speed doesn't change.

Magnetic Force on Moving Charges CHECK YOUR NEIGHBOR, Continued

The magnetic force on a moving charged particle can change the particle's

A. speed.
B. direction.
C. Both A and B.
D. Neither A nor B.

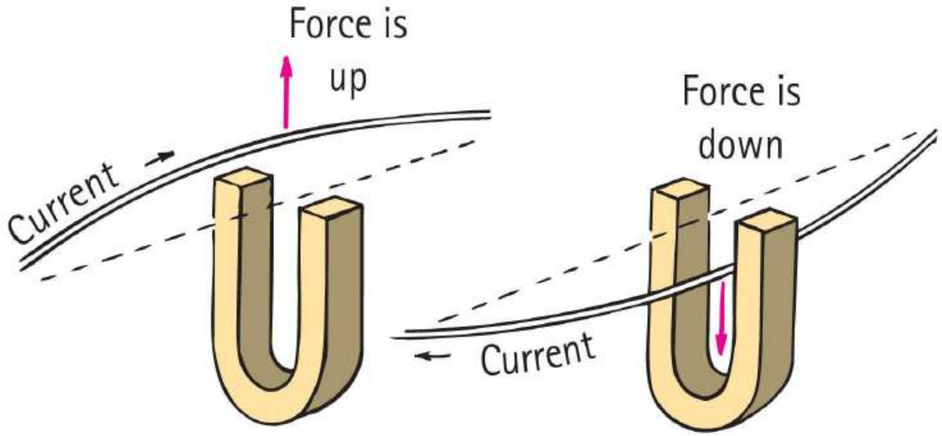
Magnetic Force on Moving Charges CHECK YOUR ANSWER, Continued

The magnetic force on a moving charged particle can change the particle's

B. **direction.**

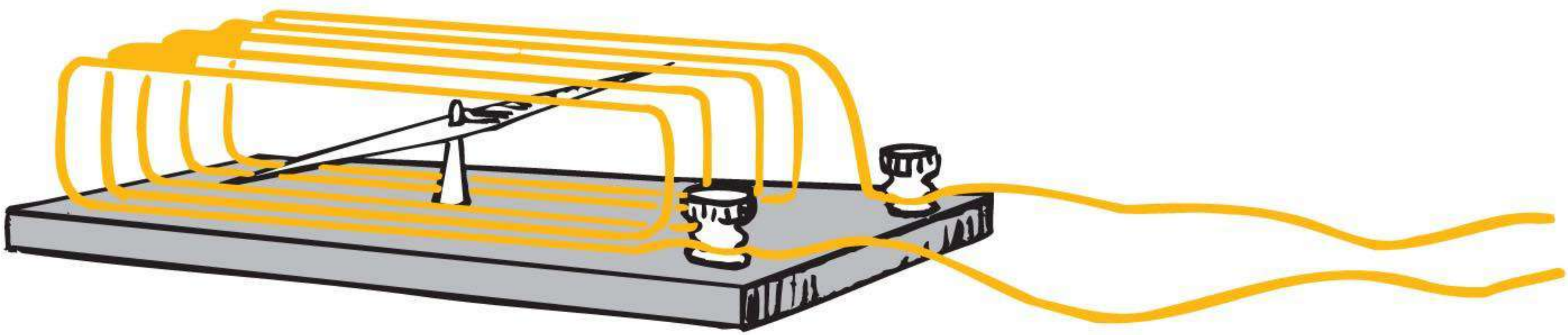
Magnetic Force on Current-Carrying Wires

- Magnetic force on current-carrying wires
  - Current of charged particles moving through a magnetic field experiences a deflecting force.
    - Direction is perpendicular to both magnetic field lines and current (perpendicular to wire).
    - Strongest when current is perpendicular to the magnetic field lines.



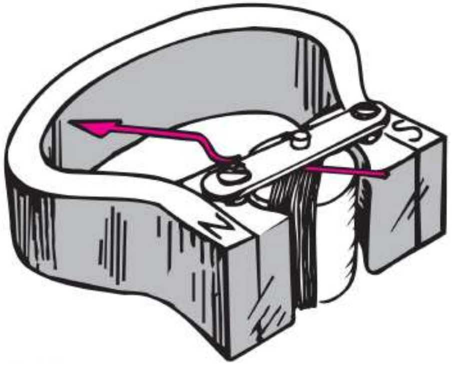
Magnetic Force on Current-Carrying Wires, Continued

- Electric meters detect electric current
  - Example:
    - magnetic compass
    - compass in a coil of wires



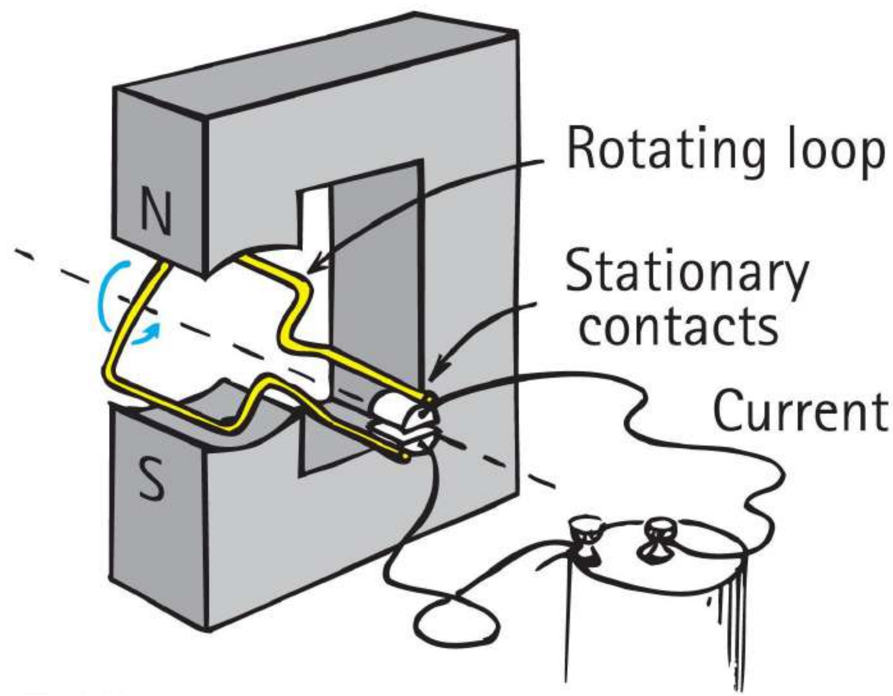
Magnetic Force on Current-Carrying Wires, Continued-1

- Galvanometer
  – Current-indicating device named after Luigi Galvani
  – Called ammeter when calibrated to measure current (amperes)
  – Called voltmeter when calibrated to measure electric potential (volts)



Magnetic Force on Current-Carrying Wires, Continued-2

- Electric motor
  - Different from galvanometer in that each time the coil makes a half rotation, the direction of the current changes in cyclic fashion to produce continuous rotation



Magnetic Force on Current-Carrying Wires
CHECK YOUR NEIGHBOR

A motor and a generator are

A. similar devices.
B. very different devices with different applications.
C. forms of transformers.
D. energy sources.

Magnetic Force on Current-Carrying Wires
CHECK YOUR ANSWER

A motor and a generator are

A. **similar devices.**