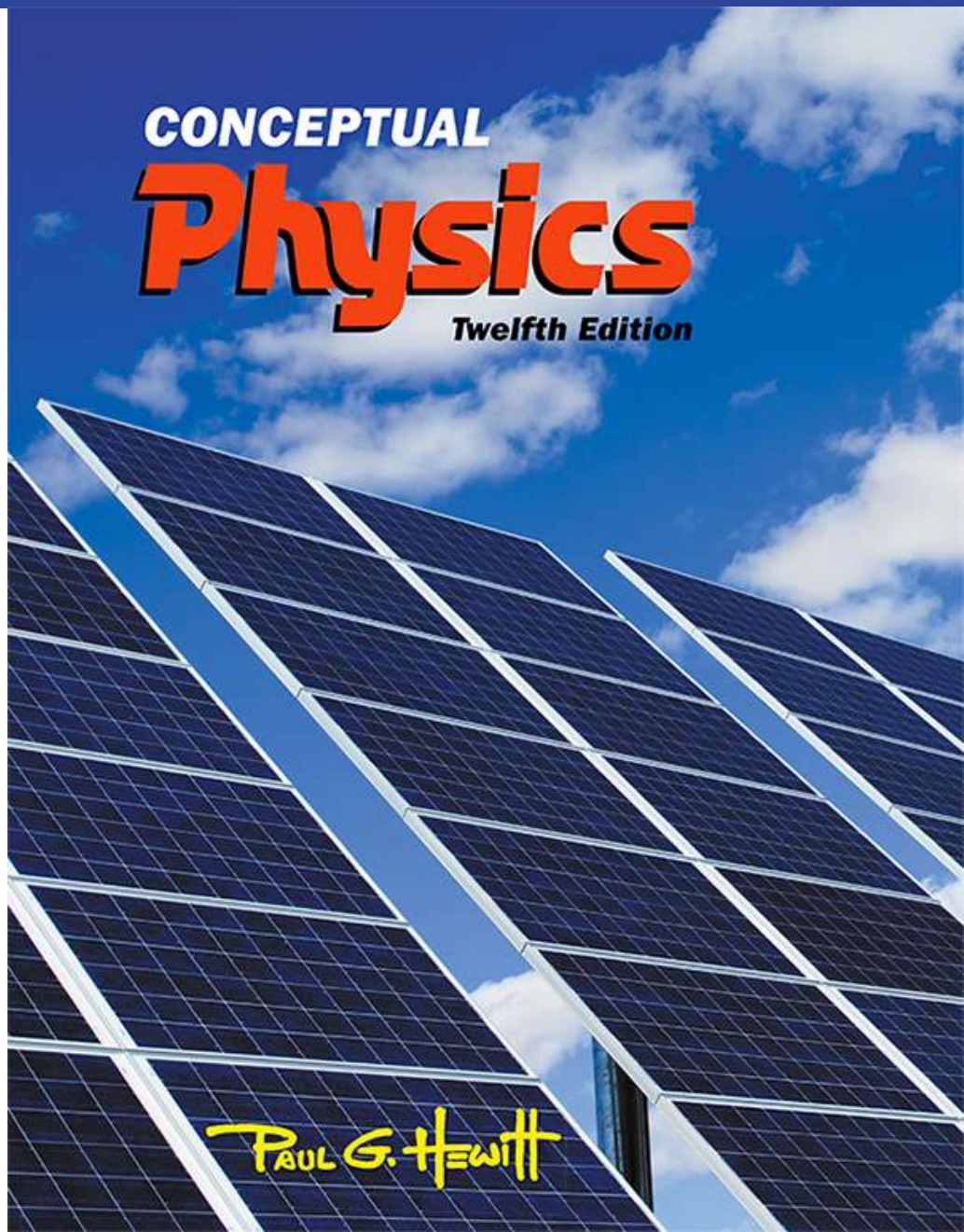
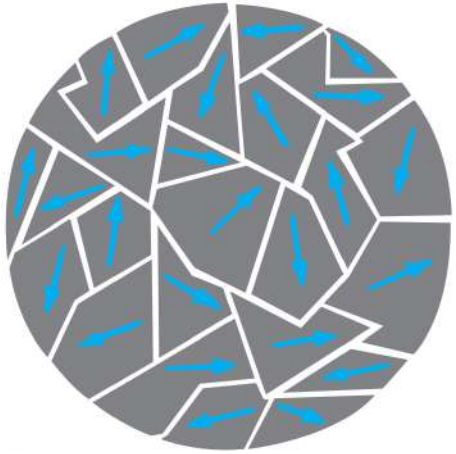
# Lecture Outline

## Chapter 24: Magnetism

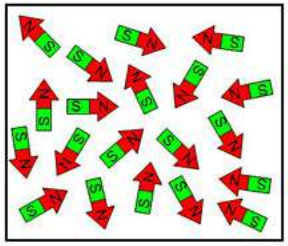
## Sections 4-6

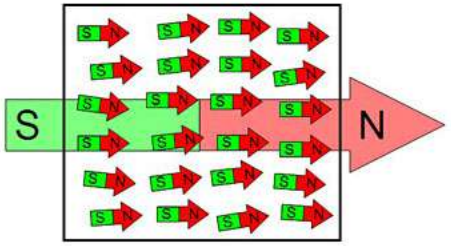


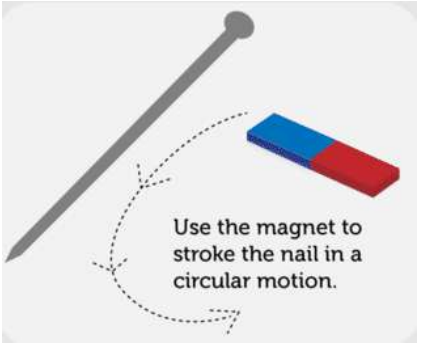
- Magnetic *domains*
  - Magnetized clusters of billions of aligned magnetic atoms
  - spin direction same in each domain.



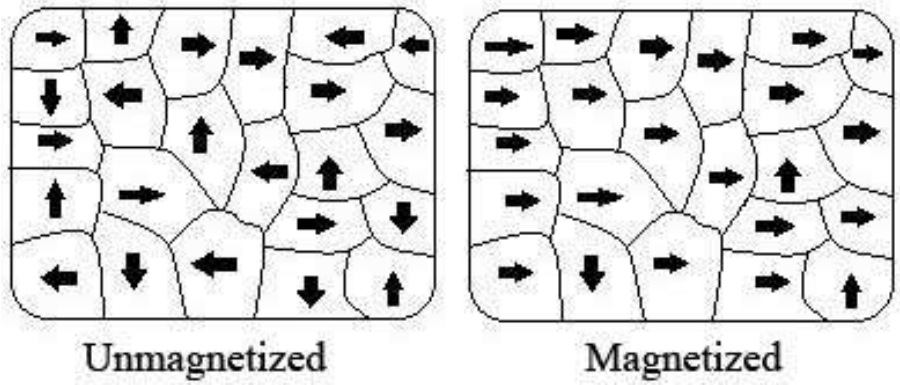
- *Permanent* magnets made by
  - placing pieces of iron or similar magnetic materials in a strong magnetic field.
  - stroking material with a magnet to align the domains.





- Permanent vs. 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

# Not all materials have domains.

Among metals:

Iron Fe, nickel Ni and cobalt Co have domains.

They are called *ferromagnetic* materials.

Iron Nickel Cobalt

Other materials do not have domains:

No domains → Cannot be magnetized.

Examples:

wood, glass, aluminum, plastic

# Magnetic Domains, Continued-1

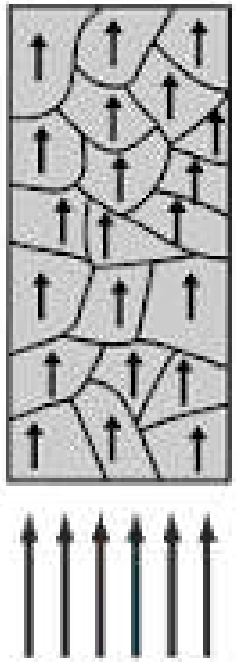
Unmagnetized iron

domains random
magnetism cancels

domains aligned
magnetism adds up

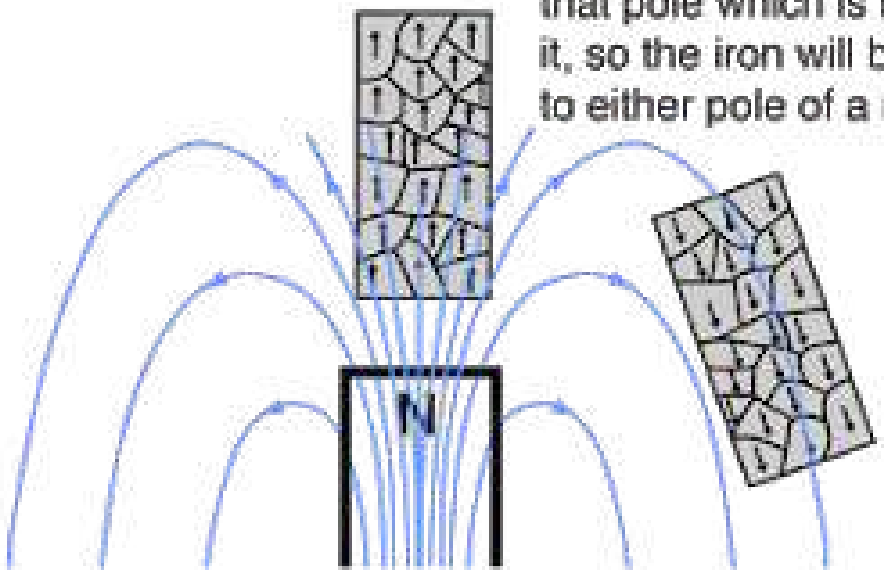
# How to get domains to line up:

In bulk material the domains usually cancel, leaving the material unmagnetized.



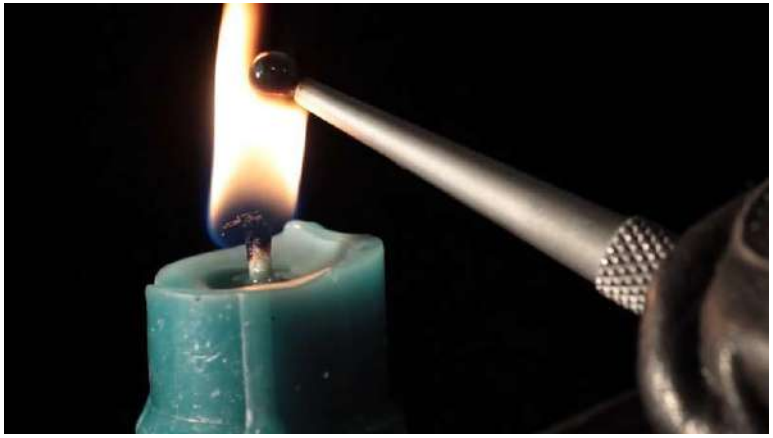
Externally applied magnetic field.

Iron will become magnetized in the direction of any applied magnetic field. This magnetization will produce a magnetic pole in the iron opposite to that pole which is nearest to it, so the iron will be attracted to either pole of a magnet.



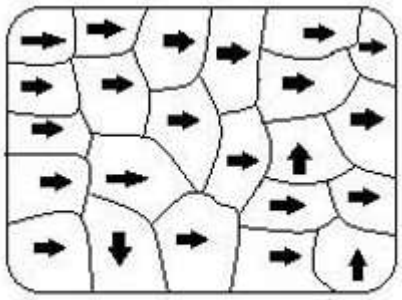
# How to lose your magnetization:

Heat to high temp:

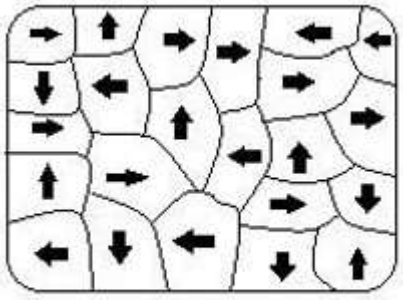


Drop it:

Changes the domains from this:




To this:



9. What is a magnetic domain?

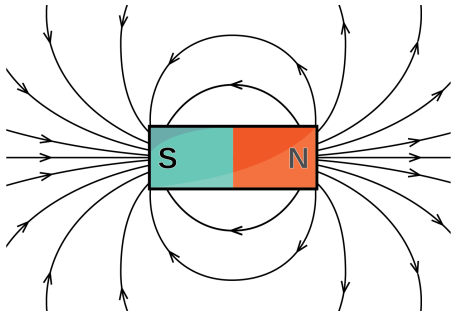
10. At the micro level, what is the difference between an unmagnetized iron nail and a magnetized iron nail?

11. Why is iron magnetic and wood is not?

12. Why will dropping an iron magnet on a concrete sidewalk make it a weaker magnet?

Connection between electricity and magnetism:

1. Magnets produce magnetic fields:
2. A compass near the magnet will point in the direction of the field lines.




3. Currents in wires produce magnetic fields.

→ What is the magnetic field of a straight wire?

- Arrange compasses around wire.
  Turn current on.
  Compasses show direction of the magnetic field.

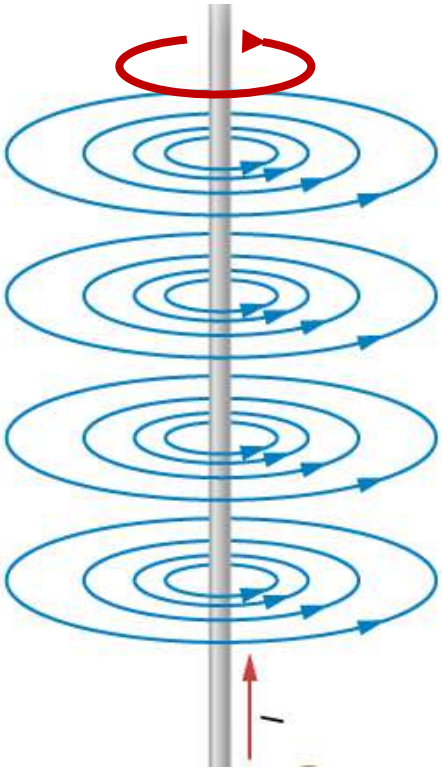


(a)

- Magnetic field forms a pattern of concentric circles around a current-carrying wire.
- When current I reverses direction, the direction of the field lines (shown in **blue**) reverse.

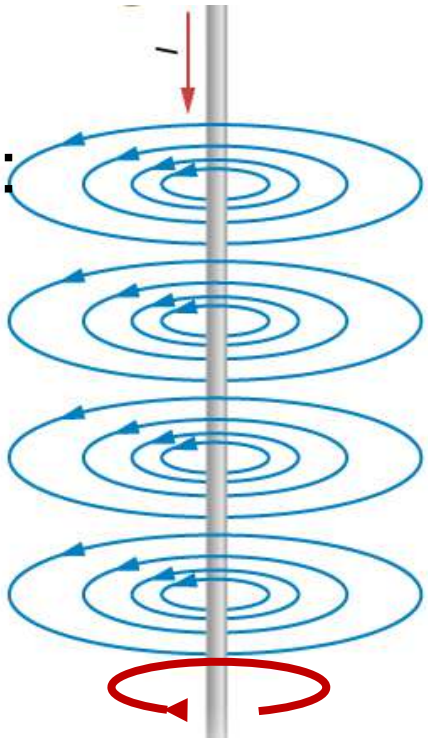
Current I upwards:

Magnetic field curls one way



Current I downwards:

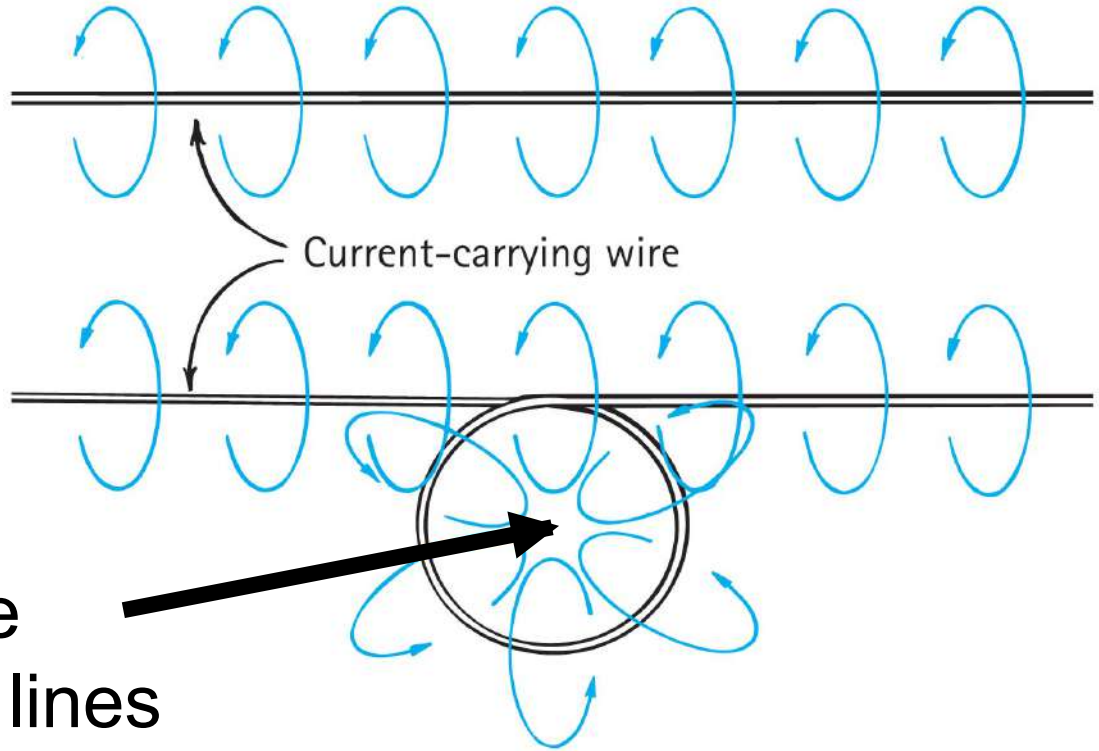
Magnetic field curls other way



Magnetic field is **concentric circles**.

# Bend the wire to form a loop:

straight wire:

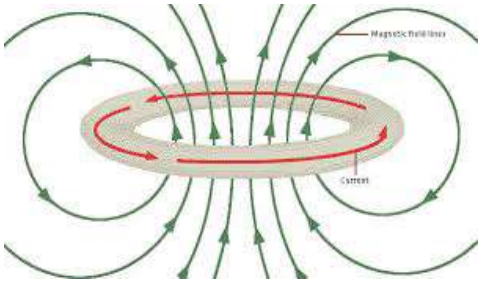



In the loop, the magnetic field lines bunch together:

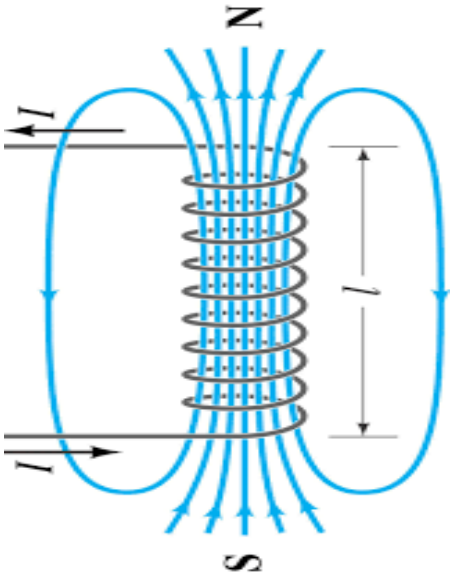
so the field is stronger there

# More loops → increased magnetic field

single loop:



many loops:

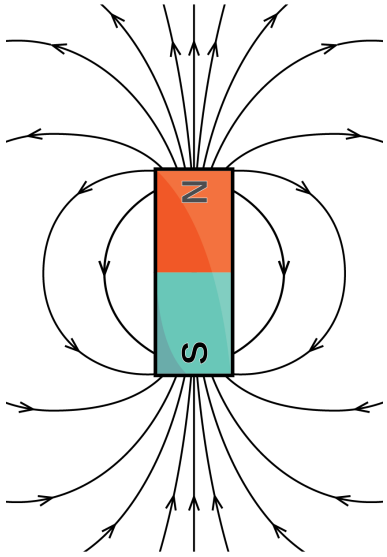



Notice:

1. More loops → stronger field
   Total field = sum from all loops
2. The field looks like a bar magnet:

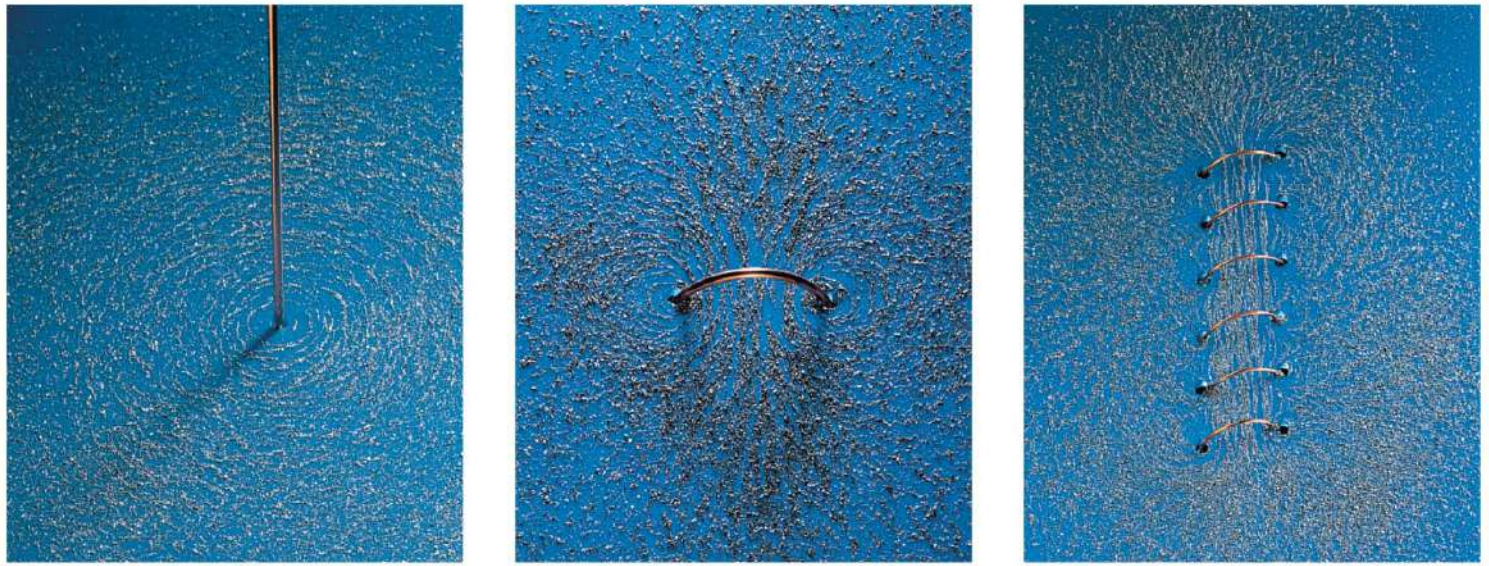
→ A current coil has poles!

3. Many loops = a coil, aka a ***solenoid***



# Electric Currents and Magnetic Fields, Continued-1

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



13. In Chapter 22, we learned that the direction of the electric field about a point charge is radial to the charge. What is the direction of the magnetic field surrounding a current-carrying wire?

14. What happens to the direction of the magnetic field about an electric current when the direction of the current is reversed?

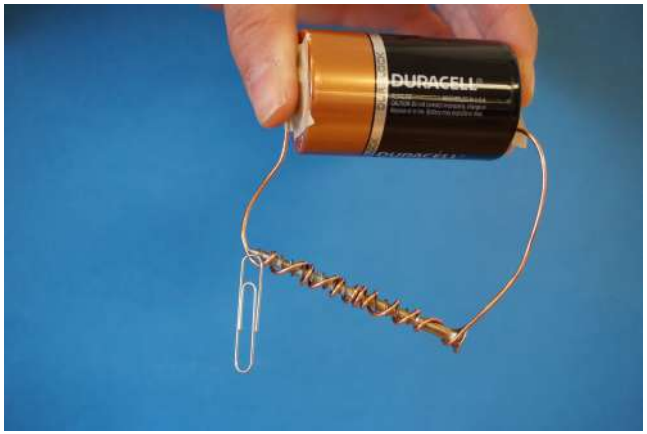
15. Why is the magnetic field strength greater inside a current-carrying loop of wire than about a straight section of wire?

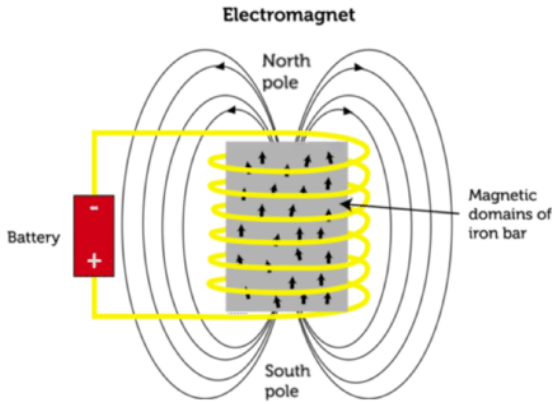
- **Electromagnet:** a current-carrying coil of wire

  To strengthen an electromagnet:

  1. increase current I;
  2. increase number of loops or coils; and,
  3. insert a **ferromagnetic** (Fe, Ni or Co) **core**.

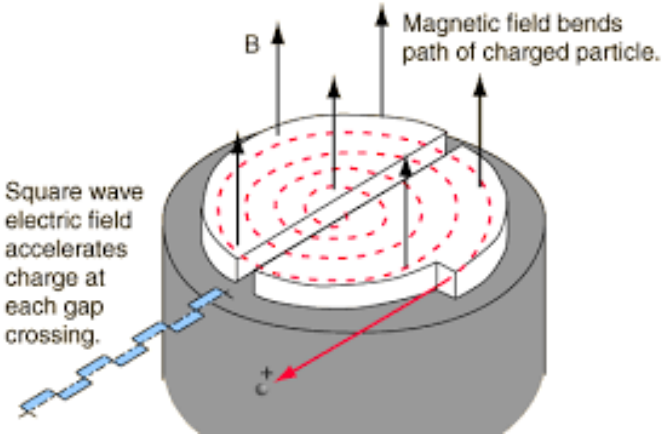
  Magnetic field from current aligns domains in iron. This makes the magnetic field even stronger.



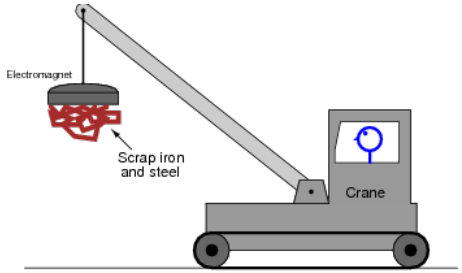



– Applications

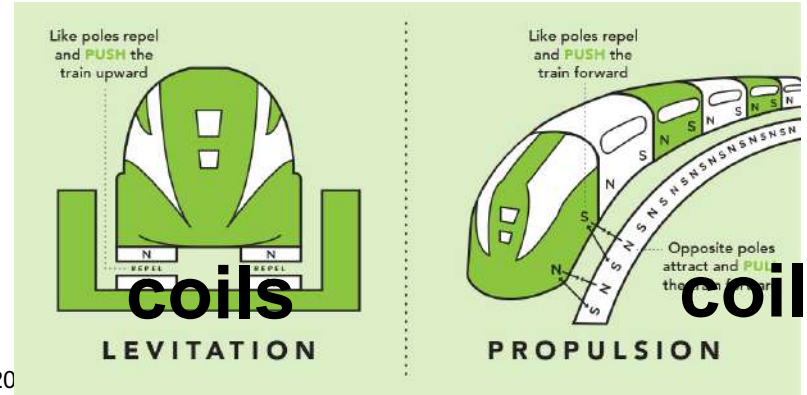
- control charged-particle beams in high-energy accelerators




- lift automobiles and other iron objects




- levitate and propel high-speed maglev trains




# Most powerful—employs superconducting coils that eliminate the core

- No heating → no wasted energy
- No electrical resistance → enormous currents
- Large currents → very strong fields
- *Uses:*

- **LHC:**
- fields guide particles

- **MRI machines:**
- fields create images

# 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.**

16. Why does a piece of iron in a current-carrying loop increase the magnetic field strength?

17. Why are the magnetic fields of superconducting magnets often stronger than those of conventional magnets?