Household Magnets

Turn off all electronic devices

Observations about Household Magnets

They attract or repel, depending on orientation
Magnets stick only to certain metals
Magnets affect compasses
The earth is magnetic
Some magnets require electricity

5 Questions about Household Magnets

1. Why do any two magnets attract *and* repel?
2. Why must magnets be close to attract or repel?
3. Why do magnets stick only to some metals?
4. Why does a magnetic compass point north?
5. Why do some magnets require electricity?

Question 1

Q: Why do any two magnets attract *and* repel?
A: Each magnet has both north *and* south poles

Like magnetic poles repel, opposite poles attract
Magnetic pole is a conserved quantity
- North pole is a "positive" amount of pole.
- South pole is a "negative" amount of pole.

The net pole on any object is always exactly zero!

Magnets

Unlike charges, free poles are never observed
- A magnet always has equal north *and* south poles
- A magnet has magnetic *polarization*, but zero net pole

A typical bar or button magnet is a magnetic dipole
- A dipole has one north pole and one south pole
- Some household magnets have many poles, but still zero net pole

Even a broken fragment of a magnet has zero net pole
- It retains its original magnetic polarization
- It is typically a magnetic dipole

Question 2

Q: Why must magnets be close to attract or repel?
A: Forces are weakened by distance and cancellation

The magnetostatic forces between poles are
- proportional to the amount of each pole
- proportional to 1/distance^2

$$\text{force} = \frac{\text{permeability of free space} \cdot \text{pole}_1 \cdot \text{pole}_2}{4\pi \cdot (\text{distance between poles})^2}$$

Forces between Magnets

Each magnet has both north and south poles
- Any pair of magnets simultaneously attract and repel one another

The net forces and net torques on magnets
- depend on distance and orientation
- are typically dominated by the nearest poles
- increase precipitously with decreasing distance

Question 3

Q: Why do magnets stick only to some metals?

A: Only a few metals are intrinsically magnetic.

Electrons are magnetic dipoles—they are intrinsically magnetic

Electrons tend to form pairs; their magnetic dipoles tend to cancel
- Despite cancellations, most atoms retain some electron magnetism
- In most solids, however, cancellation eliminates all electron magnetism

In a few solids, the cancellation is incomplete
- Iron, most steels, and some stainless steels are ferromagnetic materials

Refrigerators and Magnets

Ferromagnetic materials have magnetic domains
- Those domains tend to cancel one another, hiding the magnetism
- Certain effects can alter those domains to produce magnetization

A nearby magnet can magnetize a steel refrigerator
- The magnet causes some domains to grow and others to shrink
- The refrigerator's steel develops a net magnetic polarization
- The magnetize steel always attracts the magnet that magnetized it

Magnets stick to steel refrigerators

Soft & Hard Magnetic Materials

Soft magnetic materials
- have domains the grow or shrink easily,
- so they are easy to magnetize or demagnetize.
- They quickly forget their previous magnetizations.

Hard magnetic materials
- have domains that don't grow or shrink easily,
- so they are hard to magnetize or demagnetize.
- They can be magnetized permanently.

Question 4

Q: Why does a magnetic compass point north?

A: Earth's magnetic field twists it northward.

The earth produces a magnetic field that
- pushes north poles northward, south poles southward
- exerts torques on magnetic dipoles, such as compasses

A magnetic field
- is a structure in space and time that pushes on pole
- a vector field: a vector at each point in space and time
- observed (in concept) using a (conceptual) north test pole at each point

A compass immersed in Earth's magnetic field
- aligns it so that its north pole points northward.

Question 5

Q: Why do some magnets require electricity?

A: Electric currents are magnetic!

A current-carrying wire produces a magnetic field
- A current-carrying coil mimics a bar magnet

An electromagnet typically uses an electric current
- to produce a magnetic field
- to magnetize a ferromagnetic material

Electromagnetism (Version 1)

Magnetic fields are produced by

- magnetic poles and subatomic particles,
- moving electric charges,
- and changing electric fields [for later…].

Electric fields are produced by

- electric charges and subatomic particles,
- moving magnetic poles [for later…],
- and changing magnetic fields [for later…].

Summary about Household Magnets

They all have equal north and south poles

They polarize soft magnetic materials and stick

They are surrounded by magnetic fields

Can be made magnetic by electric currents