

Household Magnets

Observations about Household Magnets

- They attract or repel, depending on orientation
- Magnets stick only to certain metals
- Magnets affect compasses
- The earth seems to be magnetic
- Some magnets use electricity to operate

5 Questions about Household Magnets

- Why do any two magnets attract *and* repel?
- Why must magnets be close to attract or repel?
- Why do magnets stick only to some metals?
- Why does a magnetic compass point north?
- Why do some magnets use electricity?

Question 1

- Why do any two magnets attract *and* repel?
 - Why don't they attract *or* repel?
 - Why do their orientations affect their forces?

Magnetic Pole (Part 1)

- Objects that attract or repel magnetically carry portions of a physical quantity called magnetic pole or simply "pole"
- Pole comes in two types:
 - Poles of the same type repel
 - Poles of different types attract
 - The two types are named "north" and "south"

north pole = -south pole
 net pole = north pole - south pole

Magnetic Pole (Part 2)

- Magnetic pole
 - is a conserved quantity
 - is analogous to electric charge
- There is, however, one big difference:
 - no isolated magnetic pole has ever been found!
 - the net pole on any object is always exactly zero!

Magnetic Pole (Part 3)

- Every magnet has equal north *and* south poles
- They have magnetic polarizations, not net poles
 - A typical bar or button magnet is a magnetic dipole
 - A dipole has one north pole and one south pole
- A fragment of a magnet
 - has a net pole of zero
 - retains its original magnetic polarization
 - is typically a magnetic dipole

Question 2

- Why must magnets be close to attract or repel?

Magnetic Forces (Part 1)

- Two poles push or pull on one another
 - with forces that are exactly equal in magnitude
 - but exactly opposite in direction.
- These magnetostatic forces are
 - proportional to the amount of each charge
 - inversely proportional to (distance between charges)²
- The forces increase as the separation decreases

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

Magnetic Forces (Part 2)

- Since a magnet is a dipole (or more complicated)
 - it has both north and south poles
 - it simultaneously attracts and repels a second magnet
 - their net forces depend on distance and orientation
 - their net forces decrease precipitously with distance
 - they may also experience net torques

Question 3

- Why do magnets stick only to some metals?

Magnetism in Atoms

- Magnetism is due primarily to electrons
 - Electrons are intrinsically magnetic—they're dipoles
 - Atoms contain electrons, so atoms can be magnetic
- When electrons assemble into atoms,
 - their magnetic dipoles often cancel one another
 - but this cancellation is usually incomplete
 - so most atoms are magnetic.

Magnetism in Materials

- When atoms assemble into materials,
 - the electron magnetic dipoles can cancel still further
 - and that cancellation is complete in most materials.
 - Most materials are essentially non-magnetic
- Some materials don't experience full cancellation
- Ferromagnetic materials
 - have small domains that are magnetic dipoles
 - Those domains ordinarily cancel on another
 - An external magnet, however, can alter the domains

Refrigerators and Magnets

- A refrigerator's steel has magnetic domains,
 - but they normally cancel so it appears nonmagnetic.
- When a magnetic pole is brought near the steel
 - it causes some domains to grow and others to shrink
 - and the steel develops a net magnetic polarization
 - so that it attracts the magnetic pole.
- Magnets thus stick to steel refrigerators

Soft & Hard Magnetic Materials

- Soft magnetic materials
 - have domains the grow or shrink easily,
 - so they are easy to polarize or depolarize.
 - They quickly forget their previous magnetizations.
- Hard magnetic materials
 - have domains that don't grow or shrink easily,
 - so they are hard to polarize or depolarize.
 - They can be magnetized permanently.

Question 4

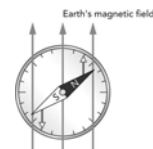
- Why does a magnetic compass point north?

Magnetic Fields

- A magnetic field
 - is a structure in space that pushes on magnetic pole
 - is vector in character: it has magnitude and direction
 - may depend on position and time
- The magnetic field at a given position and time
 - is proportional to the force on a north test pole
 - is often represented graphically by an arrow
 - but is actually located at just one point on that arrow

The Earth's Magnetic Field

- The earth is magnetic,
 - so it is surrounded by a magnetic field
 - and that field pushes north poles northward.
- A magnetic compass immersed in earth's field
 - experiences a magnetic torque
 - that aligns it so that its north pole points northward.



Question 5

- Why do some magnets use electricity?

Electromagnetism (Version 1)

- Magnetic fields are produced by
 - magnetic poles (but free poles don't seem to exist),
 - moving electric charges,
 - and changing electric fields [for later...].
- Electric fields are produced by
 - electric charges,
 - moving magnetic poles [for later...],
 - and changing magnetic fields [for later...].

Electromagnets

- Electric currents are magnetic
 - A current-carrying wire has a magnetic field
 - A coil of wire carrying current mimics a bar magnet.
- An electromagnet uses an electric current to produce its magnetic field, although that field is often enhanced by ferromagnetic materials.

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