Household Magnets

Introductory Question

- Suppose you have a long, thin bar magnet with a north pole at one end and a south pole at the other. If you break this bar in half, the two new ends–one on each half of the bar–will

A. attract
B. repel
C. neither attract nor repel

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

Introductory Question (revisited)

- Suppose you have a long, thin bar magnet with a north pole at one end and a south pole at the other. If you break this bar in half, the two new ends–one on each half of the bar–will

A. attract
B. repel
C. neither attract nor repel

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

Clicker Question

- If two bar magnets are oriented so that their opposite poles face one another and slowly moved together, they will

A. switch from repelling to attracting.
B. each rotate 90° so that they are aligned parallel.
C. increase their attraction gradually.
D. increase their attraction suddenly.

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.

Clicker Question

- When a bar- or button-shaped permanent magnet is first formed out of molten ingredients, it has

A. no magnetic poles on its ends.
B. north magnetic poles on both of its ends.
C. south magnetic poles on both of its ends.
D. a north pole and a south pole at opposite ends.

Question 4

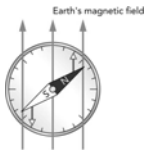
- Why does a magnetic compass point north?

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.



Clicker Question

- The earth acts like a giant bar magnet. Located near the earth's north geographic pole is the earth's

A. south magnetic pole.
B. north magnetic pole.

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