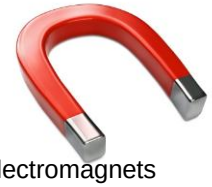
Note on Posted Slides

- These are the slides that I intended to show in class on Wed. Mar. 20, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

PHY205H1S
Physics of Everyday Life
Class 18: **Magnetism**



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

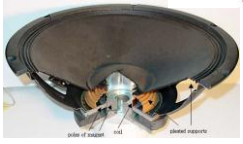
Magnetism

- Magnets exist in nature.
- We play with them, and use them to hold things on the refrigerator.

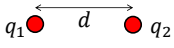
[Image from http://www.crystalvibrations.org/crystalfrh20healing%20photo%20gallery18.html]

Magnetism

Magnets are essential components of many devices used in everyday life.

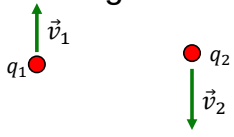


The Electric Force



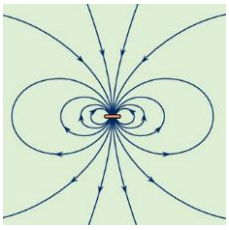
- Any two charged particles exert an electric force upon each other, as determined by Coulomb's Law.
- This is true whether or not they are stationary or moving.

The Magnetic Force



- If two charged particles are moving, they can exert a magnetic force on each other, in addition to the electric force.
- A Magnetic field is created by a *moving* charged particle.

The Magnetic Force



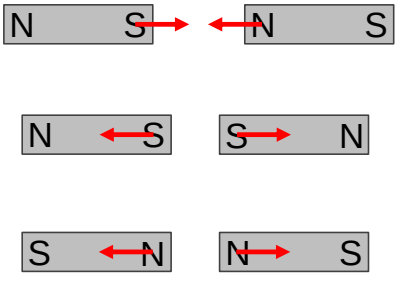
- This is the magnetic field surrounding a current loop.
- Electric charge is moving in a tiny circular path, perpendicular to the screen.

Permanent Magnets

- Every permanent magnet contains billions of tiny current loops which gives rise to the magnetic force.
- We call one end of a permanent magnet "N" or North, and the other end of a permanent magnet "S" or South
- The N and S are called **magnetic poles** – every magnet has both

The Magnetic Force

- Opposite poles attract, like poles repel.



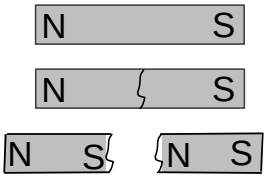
Magnetic Poles
CHECK YOUR NEIGHBOR

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

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

Magnetic Poles

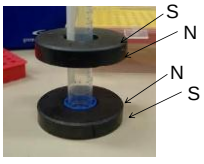
- If you break one magnet in half, you get two magnets, each with two poles again.

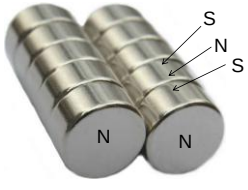


- No single isolated magnetic monopole has been found to exist in nature.
- Poles always come in N+S pairs like this.

Permanent Magnets

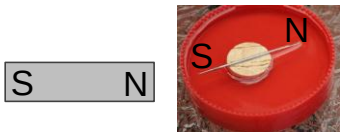
Magnets can come in many shapes; each one always has an N side and an S side.

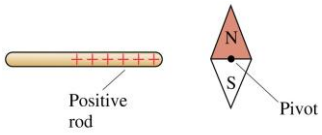




Compass

- A compass is a small bar magnet that is free to rotate about a vertical axis
- It aligns itself with the magnetic field
- The needle shown floating on a cork below is a compass
- It's N side is the "arrow", showing which way the compass points.





Does the compass needle rotate clockwise (cw), counterclockwise (ccw) or not at all?

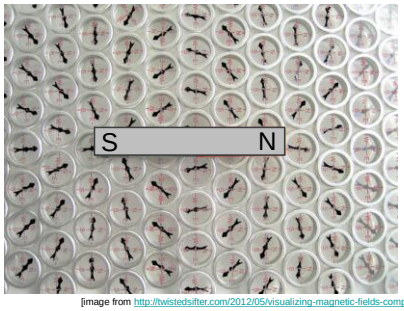
A. Clockwise
B. Counterclockwise
C. Not at all

Does the compass needle rotate clockwise (cw), counterclockwise (ccw) or not at all?

A. Clockwise
B. Counterclockwise
C. Not at all

Compass

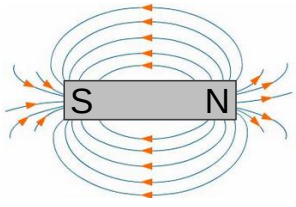
Compasses point in the direction of the magnetic field.



[image from http://twistedsifter.com/2012/05/visualizing-magnetic-fields-compasses-iron-filings/]

Magnetic Fields

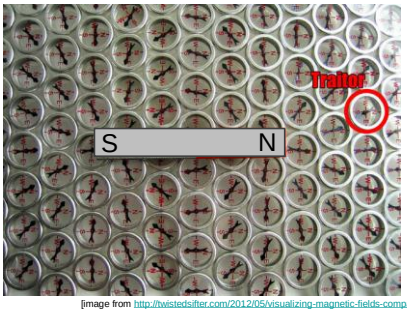
The direction of the magnetic field surrounding a bar magnet is from the north pole to the south pole.



[image from http://www.tutorvista.com/content/science/science-ii/magnetic-effects-electric-current/mapping-magnetic-lines.php]

Compass

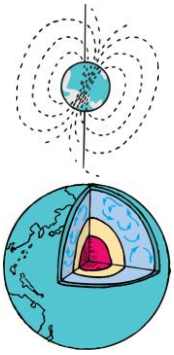
- A mis-labeled compass can point in the direction opposite to the magnetic field.



[image from http://twistedsifter.com/2012/05/visualizing-magnetic-fields-compasses-iron-filings/]

Earth's Magnetic Field

- Earth is itself a huge magnet.
- The magnetic poles of Earth are widely separated from the geographic poles.
- The magnetic field of Earth is due to electric currents in the molten interior.
- Earth's magnetic field reverses direction every several hundred thousand years

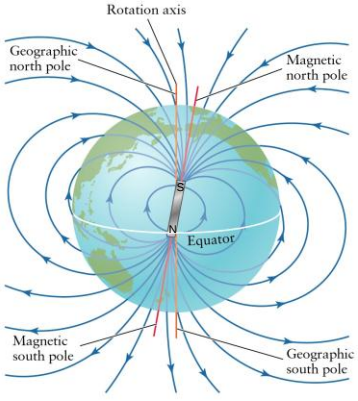


Magnetic Poles
CHECK YOUR NEIGHBOR

We know that the magnetic field of the earth is produced by electric currents in the molten core. The magnetic field of the earth can be modeled as if the earth contains a big bar-magnet.
Knowing the direction compasses point, which way is this internal bar-magnet oriented?

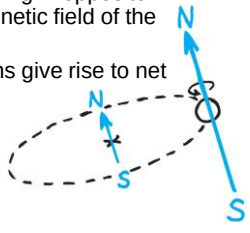
A 

B 



Magnetic Fields

- Produced by two kinds of electron motion
  - Electron orbits
  - Electron spin
    - main contributor to magnetism
    - pair of electrons spinning in opposite direction cancels magnetic field of the other
    - unpaired electron spins give rise to net magnetic field of iron



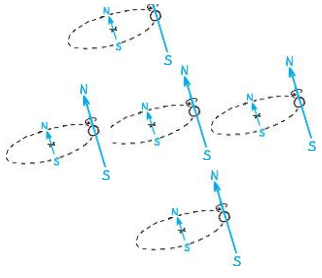
Magnetic Fields
CHECK YOUR NEIGHBOR

A source of magnetism is

A. electrons orbiting around an atomic nucleus.
B. electrons spinning around internal axes.
C. both A and B.
D. None of the above

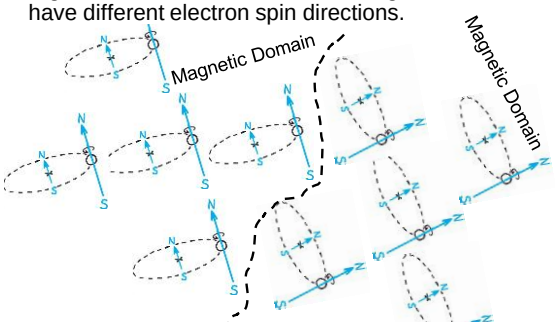
Ferromagnetism (Iron)

Neighbouring Iron atoms like to have their electrons spinning in the same direction.



Ferromagnetism (Iron)

Sometimes a border develops between two regions within the iron where the neighbours all have different electron spin directions.

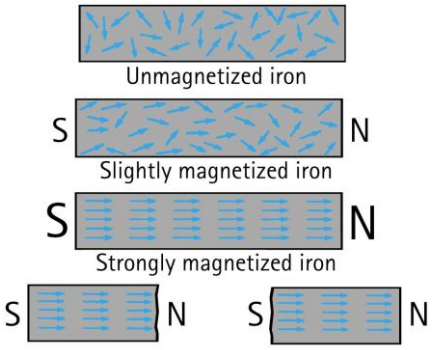


Magnetic Domains

Clusters of aligned magnetic atoms are called **magnetic domains**

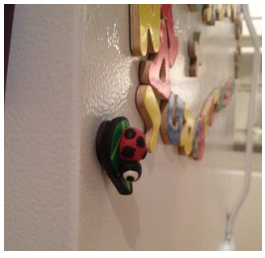
Hitting a piece of iron with a hammer in a magnetic field can magnetize the iron by aligning the magnetic domains.

Permanent Magnets



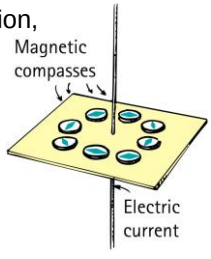
Magnetic Domains

- In a **Permanent Magnet**, the alignment of domains remains once external magnetic field is removed
- In a **Temporary Magnet**, the alignment of domains returns to random arrangement once external magnetic field is removed

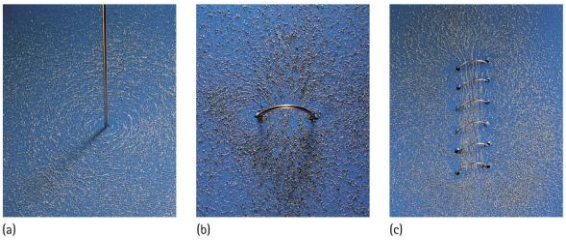


Connection between electricity and magnetism

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



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

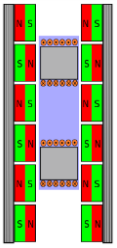


Electromagnets

- A current-carrying coil of wire is an **electromagnet.**
- The strength of an electromagnet is increased by
  - increasing the current through the coil
  - increasing the number of turns in the coil
  - having a piece of iron within the coil.
- Magnetic domains in the iron core are induced into alignment, adding to the field.

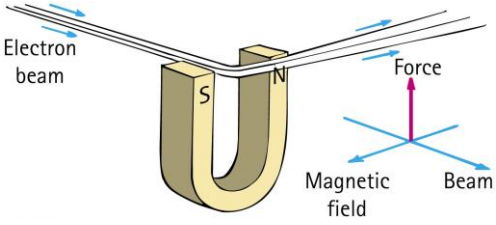
Electromagnets

The Scarborough LRT trains have freely rolling wheels, and use electromagnets of alternating polarity to pull themselves along.

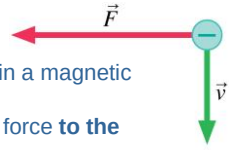


Magnetic Forces on Moving Charges

The magnetic force on a charged particle is perpendicular to the magnetic field and the particle's velocity.



Magnetic Force on Moving Charges
CHECK YOUR NEIGHBOR



An electron moves **down** in a magnetic field.
It experiences a magnetic force **to the left**, as shown.
What is the direction of the magnetic field?

A. Left or right
B. Into the page or out of the page
C. Up or down

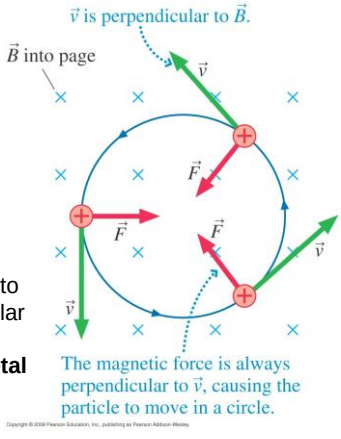
Magnetic Force on Moving Charges
CHECK YOUR NEIGHBOR

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

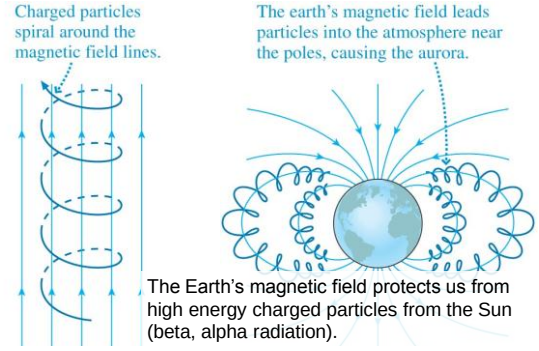
A. speed.
B. direction.
C. Both A and B.
D. Neither A nor B.

Magnetic Force is important for fast moving electrons or positive ions in a vacuum.

Since F tends to be perpendicular to v, it forms a good **centripetal** force.



Cyclotron Motion: in 3D the motion of charged particles is not a circle but a spiral.



The Earth's magnetic field protects us from high energy charged particles from the Sun (beta, alpha radiation).

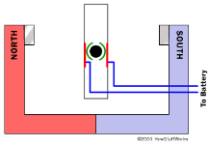
Earth's Magnetic Field

- Space is filled with fast-moving charged particles called cosmic radiation.
- This kind of radiation is harmful to plants and animals.
- Cosmic radiation is deflected away from Earth by Earth's magnetic field.
- Some of the charged particles are trapped in the outer reaches of Earth's magnetic field and make up the Van Allen radiation belts

Aurora Borealis is natural light caused by charged particles accelerating in the Earth's magnetic field.

Before class on Monday

- Please read Chapter 25, or at least watch the 10-minute pre-class video for class 19.



- Something to think about:
- Electric current can create a magnetic field.
- Can a moving magnet create an electric field?

Image from http://www.energyquest.ca.gov/story/chapter04.html