2/7/13

Magnetism

- Upon initial glance, magnetism appears to be very different from anything we've dealt with so far

→ consider some simple experiments we can do with a **bar magnet**

1) Float it on a piece of cork in water and it lines itself w/ earth's magnetic field (this is essentially a **compass**!)

2) Two magnets can be arranged such that either their ends attract or repel (kind of like charge!)

3) It can be used to deflect a compass needle

4) Cut the bar magnet in half and we get two magnets (!) (albeit weaker ones)

5) Can use it to pick up paperclips, but no pennies (no one likes pennies!). In fact, the paperclips can leap off the table to the magnet! (force at a distance!)

6) When placed statically next to a charged rod, there is no effect on the mag

What do these simple expts. tell us?

- Magnetism is not electricity. There are common behaviors, but they are not the same.

- Magnetism can work over long distances (i.e. things need not be touching directly)

- Magnets have **two poles** (north and south) → this duality is called a magnetic **dipole**

2/7/13

- The poles of a magnet can be identified by a compass (e.g. the north pole of a compass attracts the south pole of a magnet). Similarly, a magnet can be used as a compass. (i.e. we can think of the earth as a large magnet!)

- Things attracted to magnets are said to be made up of **magnetic materials**. they are attracted to both ends of a magnet.

Some lingering questions (to ask up front)

- How does one 'make' a magnet?

- What is the difference between magnetic materials and non-magnetic ones in terms of why there is or is not an effect? (e.g. a penny and a paperclip are both metal, so why isn't copper magnetic while iron is?)

- How do animals 'sense' the earth's magnetic field to help w/ orientation?

- How/why does the earth act as a large magnet?

- What precisely is the relationship between magnetism and electricity?
  [this is a surprisingly profound question, one whose answer will tell us a lot about the world around us!]

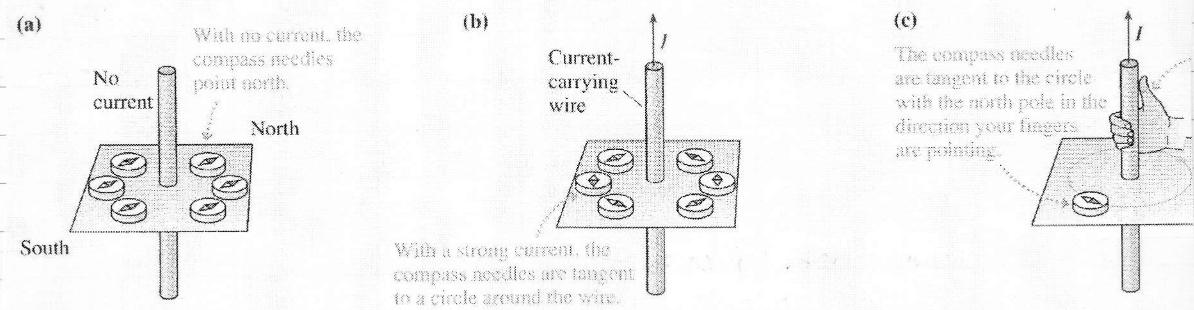
2/7/13

☐ Discovery of the Magnetic Field

→ classroom lecture demonstration in 1819 by Hans Christian **Oersted** (he noticed that when a strong current was placed through a wire, a compass that happened to be sitting nearby turned)

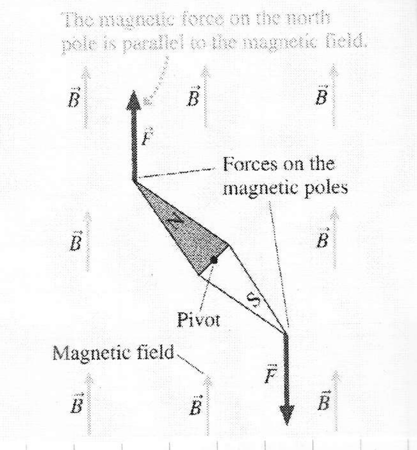
→ Oersted noticed that there was a very specific **directionality** associated w/ how the current affected the compasses

FIGURE 32.2 Response of compass needles to a current in a straight wire.



⇒ the current through the wire creates a force! Or put another way, it creates a ($\bar{B}$) field which can in turn affect the magnetized object (i.e. the compass needle). Much like an electric dipole in a $\bar{E}$-field, this behavior is essentially a **magnetic dipole** in a $\bar{B}$-field

FIGURE 32.5 The magnetic field exerts forces on the poles of a compass, causing the needle to align with the field.



2/7/13

NOTE: there is a three-dimensionality to magnetism that makes it a bit trickier relative to electric forces. So we need to clarify the directionality of things and set up an appropriate **reference**

- Directionality Oersted observed

FIGURE 32.4 The orientation of the compasses around a current is given by the right-hand rule.

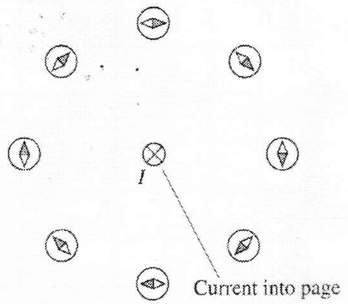
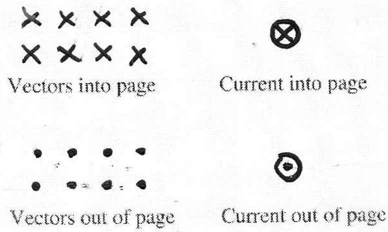


FIGURE 32.3 The notation for vectors and currents perpendicular to the page.



← Our way of visualizing the 3-D nature of things onto a 2-D surface

→ we will use the **right-hand rule** to determine directionality (NOTE: this is Giordano's RHR #1)

TACTICS BOX 32.1 **Right-hand rule for fields**

1. Point your *right* thumb in the direction of the current.
2. Curl your fingers around the wire to indicate a circle.
3. Your fingers point in the direction of the magnetic field lines around the wire.

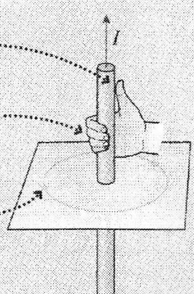
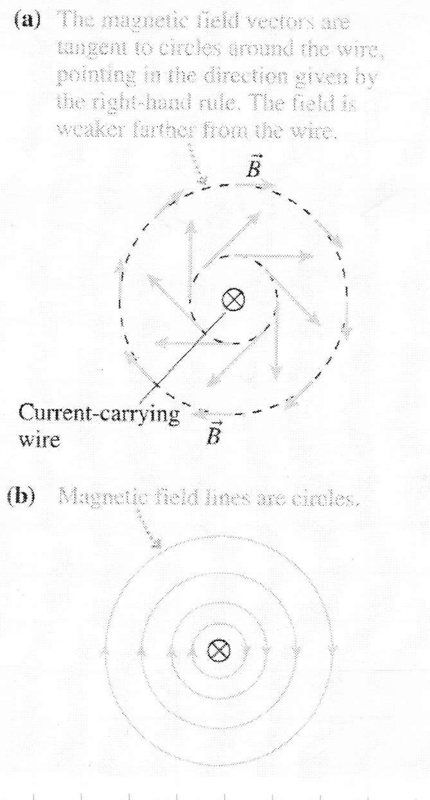


FIGURE 32.6 The magnetic field around a current-carrying wire.



- So as shown to the right, magnetic field lines are **circles** (put another way, magnetic lines always form **loops**)

2/7/13

Some (further) lingering questions

- ☐ How does a magnetic field ($\bar{B}$) produce a force?

- ☐ So if we need moving charge (i.e. a current) to produce $\bar{B}$, what then is a permanant magnet doing to create a $\bar{B}$? (looking ahead, so Giordano Fig. 20.51)

  → are there two kinds of magnetism?

- ☐ Electricity has a **monopole** (i.e. a point charge). Does magnetism also have a monopole?

- ☐ Why must field lines for $\bar{B}$ form closed loops? (look carefully at Giordano Fig. 20.2!!)

⇒ we'll see that the answers to all the questions are ultimately closely related and tell a very interesting story...