Section 4 Magnetism and Magnetic Induction Hands on*

http://arts-sciences.und.edu/physics-astrophysics/mschwalm/mschwalm.cfm/

Activities

I. Magnetic force and magnetic field
   1. North and South magnetic poles
   2. Magnetic compass and magnetic field
   3. Action at a distance

II. What causes magnetism?
   4. Moving charges or a current carrying wire produce a magnetic field
   5. Electromagnet
   6. Magnetic force on moving charges—Levitation of aluminum foil

III. Electromagnetic induction
   7. Moving magnet toward/away from a coil produce induce current
   8. Lenz’s Law—magnetic breakdown

*Contributed by Mizuho Schwalm
I. Magnetic force and magnetic field

1. North and South Poles

(a) Use one magnet to push or pull another

(b) Place a fridge magnet on a melamine or plastic sheet. Move a cow magnet underneath and watch what the magnets do on the sheet.

Can you pile up all fridge magnets without touching them?

2. Magnetic compass and magnetic filed

The north pole of a compass needle is attracted by the earth’s magnetic south pole.
Connecting the needles of the compasses with imagining curved lines we can see the magnetic field created by the magnet (red end points North) placed at the center. The field lines, which continue inside the magnet, are similar to the curves shown in the drawing at the left.

3. Action at a distance

Is the magnet pulling the paper clip? Is the earth pulling the paper clip downward? The force this cow magnet is pulling the paper clip is stronger than the gravitational force of the Earth and the whole universe pulling the paper clip downward. At least up to the end of 19 century scientists took this view.

Magnets can attract other magnet or material such as this paper clip without touching it. This is called **action at a distance**. Gravity is another example of action at a distance.

Notice that there is nothing (except air) between the magnet and the paper clip.

Can you cut through the field using CD disk, aluminum sheet etc.? Even there were no air still the cow magnet and paper clip would interact. The modern way to view this is that the paper clip is responding to the magnetic field created by the cow magnet.
II What causes magnetism?

4. Moving charges or a current carrying wire produce a magnetic field

Hewitt: Conceptual Physics: Oersted's Discovery

Current through a platform of compasses. Before you press the tap switch, predict which way the needles of compass should point when the switch is pressed.

Using a bar magnet, make sure the needles are all pointing north. Press the switch and observe. Swap the wires connecting to the battery’s positive and negative terminals. You should see that the magnetic field sort of circulates around the wire.
5. Electromagnet

(a) When electric current flows in loops of wires (coil) it will act like a magnet. This is called electromagnet.

Press the switch and see it for yourself. Can the coil pick up the paper clips?

High current. Best not touch metal parts when turning the current on or off, so as not to be shocked. This is for demonstration only.

(b) Press the switch and observe what happens. Remove the black and red wires from the coil and swap the connection. Observe what happens again.

A current (moving charges) in a wire coil produces a magnetic field. Press the switch again and observe which way the magnet moved. Now swap the wires again and press the switch. Which way did the magnet turn?
6. Magnetic force on moving charge

**Levitation of aluminum foil:** Place the aluminum strip between the poles of magnets and close the switch. Observe what happens. Open the switch swap the red and black connections and try again.

When moving charges (or a current carrying wire) enter a magnetic field magnetic force acts on the moving charges. The magnets in the photo provides strong magnetic field between the magnet’s poles. When switch is closed the moving electrons passing the magnetic field feel upward or downward force depending on the direction of the motion of electrons. Because zillions(!) of electrons inside the aluminum foil are pushed down or up the net force is strong enough to push the entire aluminum foil up or down.

Using the right-hand-rule model below, predict which way the magnetic force should point. Do your predictions agree with what you actually see?

**Right-hand-rule** for magnetic force. If the green arrow is indicating the direction of electric current, blue arrow for magnetic field then the direction of magnetic force on the moving positive charges is perpendicular to the plane defined by the motion of the positive charge and magnetic field (pointing from N to S).
III Electromagnetic induction

Moving charges create a magnetic field. Then, would magnetic field create electricity? Yes! A changing magnetic field creates a voltage. This is called **electromagnetic induction**. Induction happens only when the strength of the magnetic field (more precisely magnetic flux: magnetic field per cross sectional area) is changing through a wire loop or circuit.

7. Moving magnet toward/ away from a coil produce induced current

A coil (wound wires) is connected to a galvanometer. No electric source is attached.

When a magnet is inserted to the coil, the needle of the galvanometer moves. When the magnet is pulled out from the coil, lo! again momentarily the needle moves, but this time the opposite way.

Now try pushing in/pulling out again but this time much more quickly. Is there any difference?

Why can this happen? Can we get free electricity this way? The G1 position (far right) is less sensitive. So as not to fry the meter, try G1 key first, then flip to G0.

As the magnet approaches a wire loop, an induced current flows in the wire such that induced electromagnet opposes the incoming magnet.
8. Lenz’s Law: Magnetic breaking

If you drop a strong magnet into a copper pipe, the induced magnetic force slows it down like friction. The effect of the induction is always to try to resist change. A magnet falling through a copper pipe induces a current in the pipe. The induced current creates a magnetic field that slows the fall of the magnet.

You can see the magnet falling inside the copper pipe.

The top induced magnet attracts the falling magnet and the bottom induced magnet repels.

Okay, well that’s it on magnets and magnetic induction. There is really great deal more to learn, and probably some amazing things still to be discovered by future engineers or physicists such as yourselves. I hope you found some of this interesting.