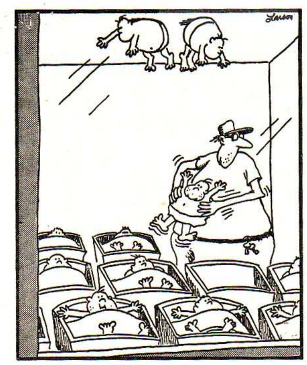
Name_____________________________________

Period________

Lesson 12 Electrostatics and Magnetism

12.1 Experiment: Evidence of a Property of Matter Called Charge

For this experiment, you will need a straw, napkin, and tiny scraps of paper.



Late at night and without permission, Reuben would often enter the nursery and conduct experiments in static electricity.

(a) Tear a few tiny scraps off of a corner of paper (no more than 1cm long) and lay them on the table. Bring a straw close to them without allowing them to touch. What happens to the scraps of paper?

(b) Holding it at one end, rub the straw with a tissue or napkin and repeat part (a). Describe your observations.

(c) What do you think gave the straw the ability to interact with the paper without touching it? Come up with your own theory and put it here.

*The ancient Greeks discovered the same thing over 2500 years ago (around 600BC), only they didn't use a plastic straw. They used amber. It's no coincidence that the Greek word for amber is "*elektron*".

The ability to interact with other matter in this way is evidence of a property of matter called "charge", which is measured in the unit called the Coulomb (C). We will explore this property of matter in this lesson.

12.2 Experiment: Types of Charge

For this experiment, you will be using plastic straws, string, and a napkin.

(a) Charge a plastic straw with a napkin as in 12.1. Hang a neutral (uncharged) straw from **the stand** and bring the charged straw close to it without letting them come in contact. What happens?

(b) Now bring the napkin close to the straw on **the stand** without letting them come in contact. What happens?

(c) Charge two straws. With one on the stand, now bring them close together without letting them come in contact.
What happens this time?

Why do you suppose this happens?

(d) **PREDICT:** What do you think will happen if you bring the charged napkin close to the charged straw?

(e) Test your prediction by bringing the charged napkin close to the straw without touching it. Describe your observations.

WE WERE GOING TO USE THE TIME MACHINE TO PREVENT THE ROBOT APOCALYPSE, BUT THE GUY WHO BUILT IT WAS AN ELECTRICAL ENGINEER.

(f) Circle the correct underlined word:

- LIKE CHARGES <u>ATTRACT / REPEL</u>
- OPPOSITE CHARGES <u>ATTRACT / REPEL</u>

*This ability to exert attractive and repulsive forces at a distance is evidence of two types of charge. In 1747, Benjamin Franklin named them “positive” and “negative”.

*Atoms are made of protons, neutrons, and electrons. Electrons have identical charge: -1.60×10^{-19} Coulombs. Protons have the same charge as electrons, except positive. Neutrons have no charge. Atoms have the same number of electrons and protons. Since they have the same amount of positive and negative charge, the effects of attraction and repulsion coming from the atom cancel, leaving them electrically neutral.

*The masses of the protons and electrons, however, are vastly different. The mass of a proton is almost 2000 times bigger than an electron. Specifically, $m_{proton} = 1.673 \times 10^{-27}$ kg and $m_{electron} = 9.11 \times 10^{-31}$ kg. It may come as no surprise that the electrons move through circuits instead of the protons. Since they are negative, *negative* charge actually flows opposite the direction assumed by “conventional flow theory.” Since the effects are the same whether positive charge flows out the positive side of the battery or negative flows out the negative side, we still use conventional flow theory in most applications.

12.3 <u>Experiment: Balloons and Charge</u>

For this experiment, you will need 2 balloons, string, and your hair!

(a) Inflate two balloons and tie them together using a length of string.
PREDICT: What will happen when you rub each on the hair on your head and let them hang next to each other?

(b) Now try it out: After rubbing them on your hair, dangle the two balloons against each other by pinching the string halfway between them and letting them drop. Describe your observations.

(c) Do the balloons have the same or opposite charge after rubbing on your hair?

How can you tell this is the case?

(d) PREDICT: What will happen when you bring the balloon close to the hair it was rubbed against?

(e) Now test your prediction by bringing the balloon close to the hair it was rubbed on and describe your observations.

(f) Do the hair and balloon have the same or opposite charge after rubbing?

How can you tell this is the case?

12.4 <u>Exercise: Coulomb's Law</u>

Any objects that have the property called charge will attract or repel other objects that have charge. The force is stronger if there's more charge and it's weaker if the charges are moved farther apart. The specific force of attraction or repulsion is described by this equation:

Coulomb's Law

$$F = k\frac{q_1 q_2}{r^2}$$

q=charge [the unit is the Coulomb (C)]
r=distance between charged objects' centers [the unit is the meter (m)]
k = 8.99×10^9 Nm^2/C^2 [a constant with units that make the answer into Newtons]

(a) If the calculation comes out positive (+F), are the two charges (q_1 and q_2) both +, both –, or opposite?

How can you tell?

(b) Does a +F mean that the charges are repelling or attracting?

(c) If the calculation comes out negative (– F), are the two charges (q_1 and q_2) both +, both –, or opposite?

How can you tell?

(d) Does a –F mean that the charges are repelling or attracting?

*The calculation performed in Coulomb's Law is unusual in that we can't interpret the + and – the same way we are used to. The calculation only gives us the magnitude, how hard the forces push or pull. In this case, +F doesn't mean "right" or "up", but instead it means that the two charged objects are repelling in whatever direction they have to push to repel each other (even if that means "left" or "down"). Similarly, –F means that they attract. The direction can be determined by examining a picture of the charges or a detailed description, but the calculation alone does not give us enough information to figure out the direction.

12.5 Experiment: Magnetic Poles

We have observed that charged objects can exert forces over distances without touching. Doesn't this remind you of magnets? In this section we will examine these objects that have a similar ability.

Magnets have North and South poles, labeled on the bar magnet with N and S.

(a) PREDICT: What will happen when like magnetic poles are brought together.

(b) Hang a bar magnet from **the stand** and bring the same pole of the other magnet close to it without letting them come in contact. What happens?

(c) Now bring the opposite pole close to the magnet on **the stand** without letting them come in contact. What happens?

(d) Circle the correct underlined word:

a. LIKE POLES <u>ATTRACT / REPEL</u>

b. OPPOSITE POLES <u>ATTRACT / REPEL</u>

12.6 <u>Experiment: Magnetic Field</u>

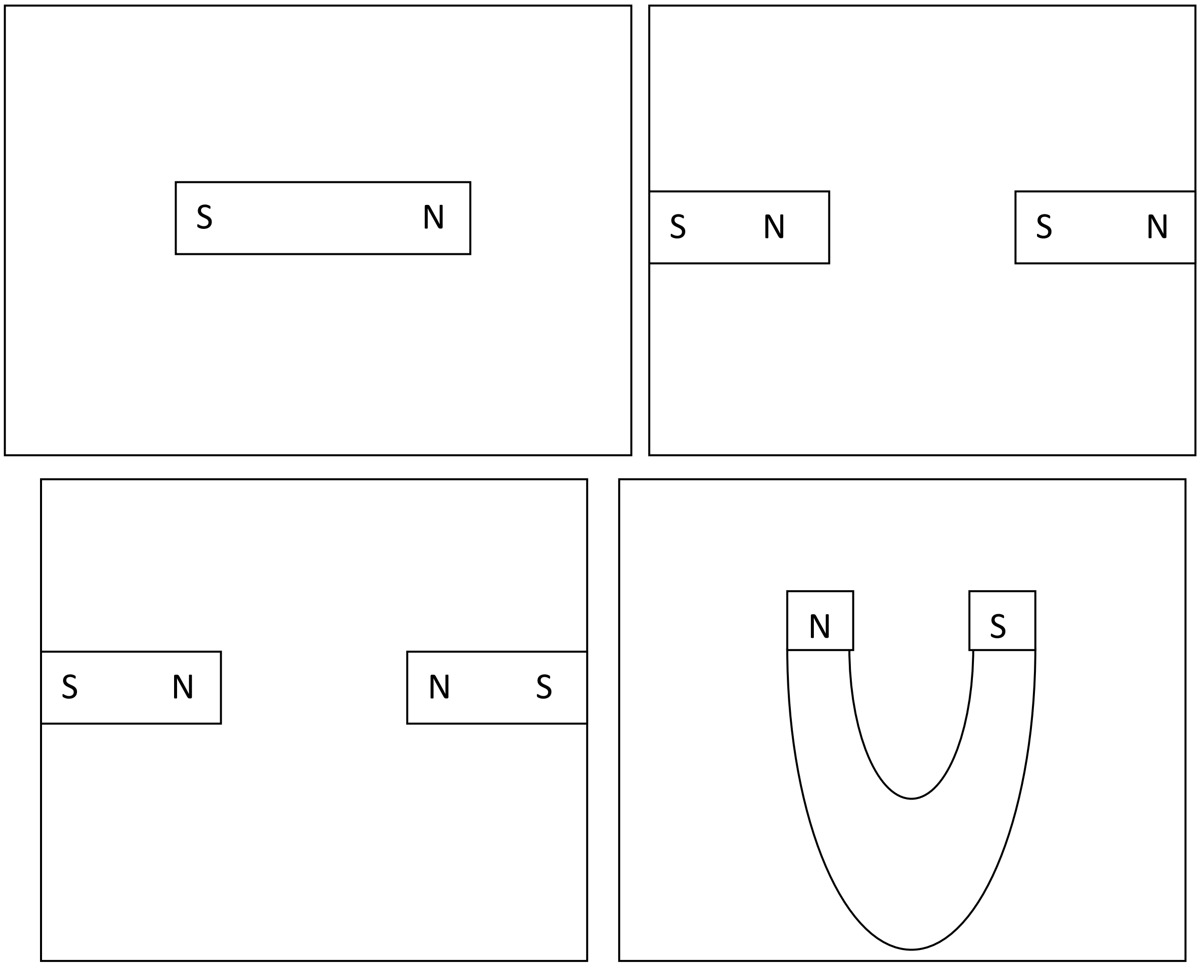
For this experiment, you will need a string tied to a needle and a bar magnet.

(a) Hold the string tied to a sewing needle above one magnet. Bring it close to the magnet, but don't allow the needle to touch it. Move the string around sideways to observe where the needle points at various positions on the magnet.
Describe your observations. Where does the needle point?

Does the needle point toward the middle?

(b) Drop the needle slowly onto the middle of the magnet to see what happens when it is placed horizontally between the north and south poles. Describe your observations.

(c) Observe as iron filings or paper clips are spread around arrangements of magnets. Draw the resulting patterns on the diagrams below:



(d) We have observed evidence that small pieces of metal pulled by a magnet will arrange themselves in a specific pattern around the magnet. The resulting pattern of forces is called the Magnetic Field (B). The unit of the magnetic field is the Tesla (T). The magnetic field points in a direction. By convention, it points out of the north pole and into the south pole and runs through the middle of the magnet to form loops.

Label your patterns above with arrows showing the direction of the B field (magnetic field).

12.7 Experiment: Magnetic Field and Charge

For this experiment, you will need a bar magnet, a solenoid (coil of wire), wire, and an ammeter (or a galvanometer).

(a) Attach the two ends of the solenoid to the ammeter using wires.
PREDICT: What will happen when a bar magnet is moved into the solenoid?

(b) Move the bar magnet into the solenoid and observe the ammeter. What happens?

(c) Now leave the magnet in the solenoid. What is the value on the ammeter while the magnet is at rest relative to the coils?

(d) Observe the ammeter once more as the magnet is removed. What happens?

(e) PREDICT: What will the ammeter show if you move the OPPOSITE pole into the magnet?

(f) Test your prediction by <u>reversing the magnet</u> and moving it into the solenoid. Describe your observations.

* When a magnetic field is moved relative to a wire, a current can result. The resulting current is called an "induced current". This is caused by an "induced voltage", also known as an "induced emf" that results from the relative motion. This only results when the charge in the wires moves through from one magnetic field line to another. It has to "cut through" the lines to work.

This is the principle responsible for generation of electric currents in generators and for the force that spins motors.

12.8 <u>Exercise: Right Hand Rules</u>

The relative motion of charge and magnetic field are related by right angle motion that can be described by using your right hand to help you visualize the 3 edges at the corner of an imaginary box as described in class. Draw and label the right hand rules below in the boxes.

(a) Right Hand Rule #1 ("FBI")

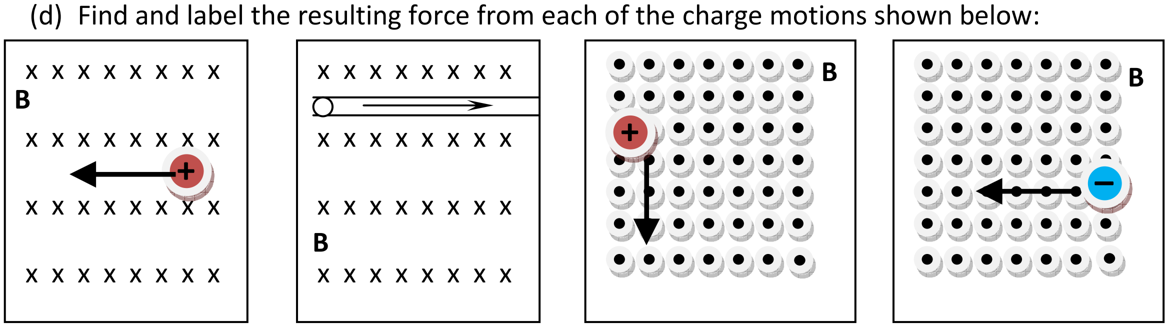
(b) Sketch what the arrow might look like if it's flying straight out of the page right at you:

What symbol do you use to show something coming out of the page at you?

(c) What if the arrow is moving into the page away from you? Sketch what that might look like:

What symbol do you use to show something going into of the page away from you?

(d) Find and label the resulting force from each of the charge motions shown below:



*The force from the right hand rule shown above can be calculated by using the equation:
F = qvB, where F = the size of the force the B field exerts perpendicularly on the moving charge, q = the amount of charge moving through the field, v = the speed of the charge, and B = the strength of the field.

*In the case of charge moving through a B field in the form of *current* in a wire, use this one:
$F = BIl$, where F = the size of the force the B field exerts perpendicularly on the wire, I= the current running in the wire, l = the length of wire in the B field, and B= the strength of the field.

(e) Right Hand Rule #2 (the grabbing one)

(f) This right hand rule describes a natural side-effect of running a current through a wire. Every time a current goes through a wire, a magnetic field is produced around the wire.
What evidence did we see in Lesson 11 (Electric Circuits) that showed a magnetic action-at-a-distance when charge flowed through a wire and stopped when the current dropped to zero?

*To calculate the strength of the magnetic field from a current-carrying wire, use this equation:

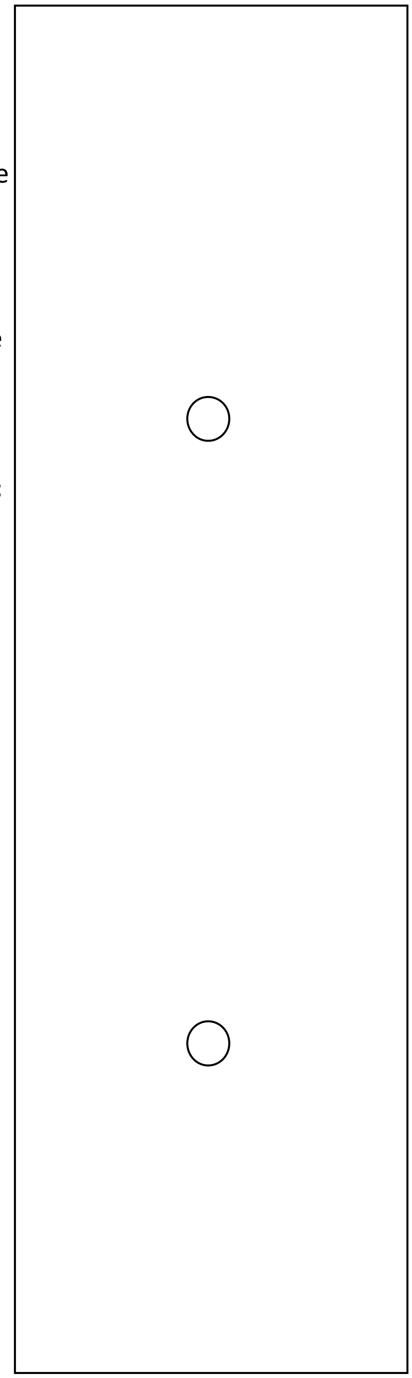
$$B = \mu_0 \frac{I}{2\pi r}$$

where B = magnetic field produced (in Teslas), I = strength of current (in Amps), r = the distance from the wire to the object in the B field, and μ_0 = $4\pi \times 10^{-7}$ Tm/A (a constant called "the permeability of free space").

(g) Have someone in your group take a wire and gently poke it *through* the page at one of the circles at the right. Next take one of the ends and poke it into the page just below, kind of like sewing, but with paper and a wire. Two ends of the wire will be sticking out of the same side. Use the alligator-clip ends to clip them together on that side. Now it's a loop going into your page on top and out of your page on bottom.

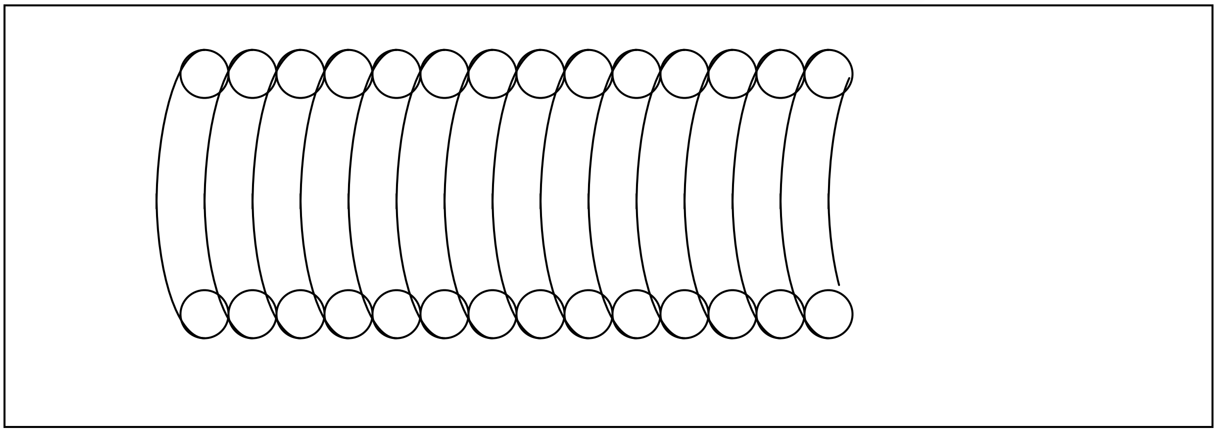
If we run a current in this loop, charge flows into the page at one place and out of the page at the other.

Draw and label the currents that would result and resulting magnetic fields at both places in the diagram at right:



(h) A “solenoid” is a coil of wire. For every “turn” of the coil (each time it winds around), it makes a loop of wire just like you made in this exercise. A bunch of the above loops right next to each other is just what a solenoid looks like: 

Draw a solenoid (a coil of wire) and show the current and field produced:



(i) Is there a magnetic field inside the solenoid?

(j) Is there a magnetic field outside the solenoid?

(k) Where do the field lines help out by running in the same direction? That’s where the field is strongest.

(l) Refer back to magnetic field section (12.6c) where you drew diagrams of magnetic fields. What does the pattern drawn in the solenoid resemble most closely?

(m) What does the solenoid become when a current runs through it?

(n) Recall that the magnetic field runs in the direction pointing out the North pole and into the South pole. **Label the north pole with an N and the south pole with an S in your solenoid diagram above.**

12.9 <u>Electric Field</u>

(a) <u>Electric Field (E) –</u>

Unit:

(b) There are two equations for the electric field. Write them here:

1.)

2.)

(c) Draw the electric field around the shapes below: