Interactions of Charges

Overview

Oftentimes called "ghost particles," neutrinos can travel through nearly everything (the sun, the earth, you!) undetected. Because they are nearly massless, gravitational fields do not affect neutrinos; Similarly, because they are chargeless, electric and magnetic fields do not con affect neutrinos. This lack of interaction is advantageous for IceCube researchers – when they detect a neutrino, it is a straight line back to its source. On the other hand, it becomes quite difficult to detect something that's nearly undetectable!

This lesson plan focuses on better understanding the effect of electric fields on charges. By focusing on more commonly understood electrons, protons, and neutrons, students will gain a fundamental understanding that can then be extended to other sub-atomic particles such as neutrinos.

Objectives

- Understand which charges move, which charges do not move, and why.
- Identify when an object is being charged through induction, conduction, or friction.
- Draw the movement of charges on an object that is being charged.
- Explain attraction and repulsion of charged objects.
- Make predictions for the effects of charges on a neutrino

Lesson Preparation

Details

- Lesson
- Antarctic
- About 1 period
- Download, Share, and Remix
- Middle School and Up

Materials

1 clear plastic cup with a hole (per student)
~10cm x ~30cm aluminum foil (per student)
~3g of clay (per student)
1 paperclip (per student)
permanent markers
scissors
rulers
ballooons

Standards

Gather and prepare materials:

- 1 clear plastic cup with a hole (one per student) – may want to punch a hole in the bottom of the cup before class
- ~10cm x ~30cm aluminum foil (one per student) – may want to pre-rip sheets before class
- ~ 3g of clay (one per student) – may want to tear into small balls before class
- 1 paperclip (one per student) – may want to open paperclip before class
- permanent marker (to write name on cup when finished)
- scissors
- ruler
- balloons (one per student)

NGSS: HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

NGSS: HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

NGSS: HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predictthe gravitational and electrostatic forces between objects.

Procedure

1. Lecture that covers charges of protons/electrons/neutrons, electrons can move because they're small/light/on the outside, net charge of an object, opposite charges attract/like charges repel, charging by friction/conduction/induction, and discharging & grounding. (see attached "Presentation_Electrostatics" slides 1-14)
2. Students complete the Pre-lab questions using their knowledge from the lecture (see attached "Electroscope Lab")
3. Students build their electroscope (see attached "Presentation_Electroscope Building")
   Cut a piece of foil ~2 cm x ~4 cm.
   Fold the foil in half (hot dog style) and fold one end over 0.5 cm.
   Cut a small triangle along the edge to create a diamond-shaped hole after unfolding it.
   Carefully unfold the foil and cut into two separate leaves. Unfold one end of paperclip and hang the leaves on the loop. Insert the paperclip into the cup and secure it with the clay.
   Ball up the remaining foil and place on the straight end of the paperclip.
   Write your name on the cup.
4. Students explore Part 1: Charging by Induction, by charging a balloon on their hair and bring it close to the aluminum foil ball of the electroscope. Students should observe the leaves of the electroscope repelling each other. Together, model the charges using the diagram in Question 4

– For the “initial,” draw equal number of positive and negative charges distributed equally on the electroscope. For the “final,” draw equal number of positive and negative charges with the positive charges distributed equally (protons do not move) and negative charges repelling the negative balloon, collecting on the bottom leaves of the electroscope. Thus, the net negative left leaf and net negative right leaf are repelling. Students should recognize that the total number of charges has not changed, but the distribution of negative charges has.

5. Students explore Part 2: Charging by Conduction, by charging a balloon on their hair and then touching it to the aluminum foil ball of the electroscope. Students should observe the leaves of the electroscope repelling each other. Together model the charges using the diagram in Question 3 – For the “initial,” draw equal number of positive and negative charges distributed equally on the electroscope. For the “final,” draw more negative charges, as they have transferred from the balloon onto the electroscope via conduction. Thus, the net negative left leaf and net negative right leaf are repelling. In contrast to the previous example of charging by induction, students should recognize that the total number of charges has increased.
6. Students explore Part 3: Discharging and Part 4: Charging by Friction.
7. Students extend their knowledge to make a prediction for a positively charged rod brought close to the electroscope. This is a great formative assessment for students’ understanding of induction, which is usually a difficult concept.
8. Class discussion about the interaction of positive and negative charges and the lack of interaction for neutral charges. Extend this discussion to predictions for neutrinos and why IceCube might be interested in neutrinos. (see attached “Presentation_Electrostatics” slide 17 for guiding questions).

Extension

Students research other types of subatomic particles and their charges and then make predictions as to how those particles might interact with one another.

Resources

- Presentation: Electrostatics (attached)
- Electroscope Lab (attached)
- Presentation: Electroscope Building (attached)

Assessment

See #7 in the above lesson plan for a formative assessment during the lesson.

Author/Credits

This lesson was modified by Kate Miller (contact: kate.miller@polartrec.com) from resources produced by the Washington-Lee High School General Physics Collaboration (including Mary Clendenning and Christine Scott)

Name:______________________________ Date;______________________ Pd._______

Electroscope Lab

Objectives:

- Understand which charges move, which charges do not move, and why.
- Identify when an object is being charges through induction, conduction, or friction.
- Draw the movement of charges on an object that is being charged.
- Apply the golden rule of electrostatics to explain attraction and repulsion of charged objects.

Pre-Lab:

1. Which type of charge can move? Why?

2. | Golden Rule of Electrostatics: |
   |---|
   | |

3. Polarization is ____
   ____

Make your own electroscope!

Materials:

- ~10 cm x ~30 cm piece of foil
- 1 paperclip
- 1 plastic cup with a hole
- ~3 g of clay

Procedure:

1. Cut a piece of foil ~2 cm x ~4 cm.
2. Fold the foil in half (hot dog style) and fold one end over 0.5 cm.
   Cut a small triangle along the edge to create a diamond-shaped hole after unfolding it.
3. Carefully unfold the foil and cut into two separate leaves.
4. Unfold one end of paperclip and hang the leaves on the loop.
5. Insert the paperclip into the cup and secure it with the clay.
6. Ball up the remaining foil and place on the straight end of the paperclip.
7. Write your name on the cup.

Thinking about electrostatic forces, what would cause the leaves to separate?

Part 1: Charging by Induction

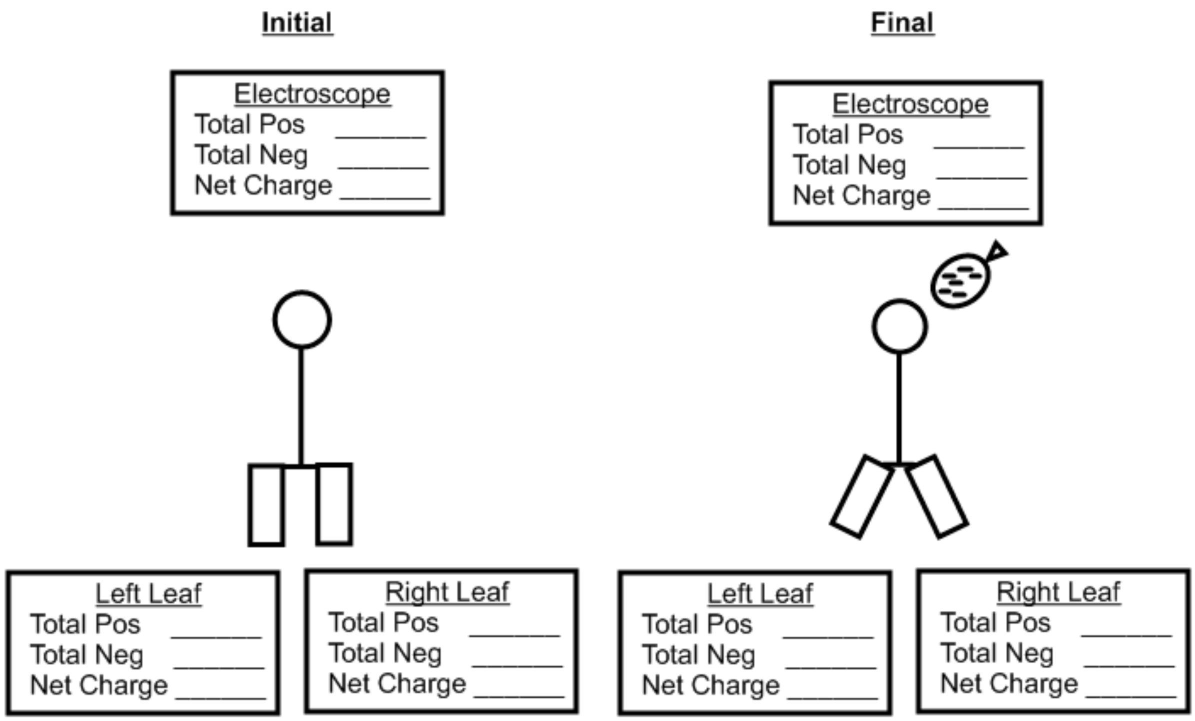
1. To charge an object by *induction* means____
____

2. Bring a charged balloon near (but don't touch!) the foil ball at the top of your electroscope.

Let's make sense of your observations:

3. What type of charges *can* move?________________________________
What type of charges can *not* move? _______________________________

4. Draw the charges on your electroscope.



5. a) What do you notice about the total number of positive charges on the *electroscope*?

b) What do you notice about the total number of negative charges on the *electroscope*?

c) What do you notice about the net charge on the *electroscope*?

6. a) What do you notice about the total number of positive charges on the *left and right leaves*?

b) What do you notice about the total number of negative charges on the *left and right leaves*?

c) What do you notice about the net charge on the *left and right leaves*?

7. Write 2-3 sentences explaining your observations.

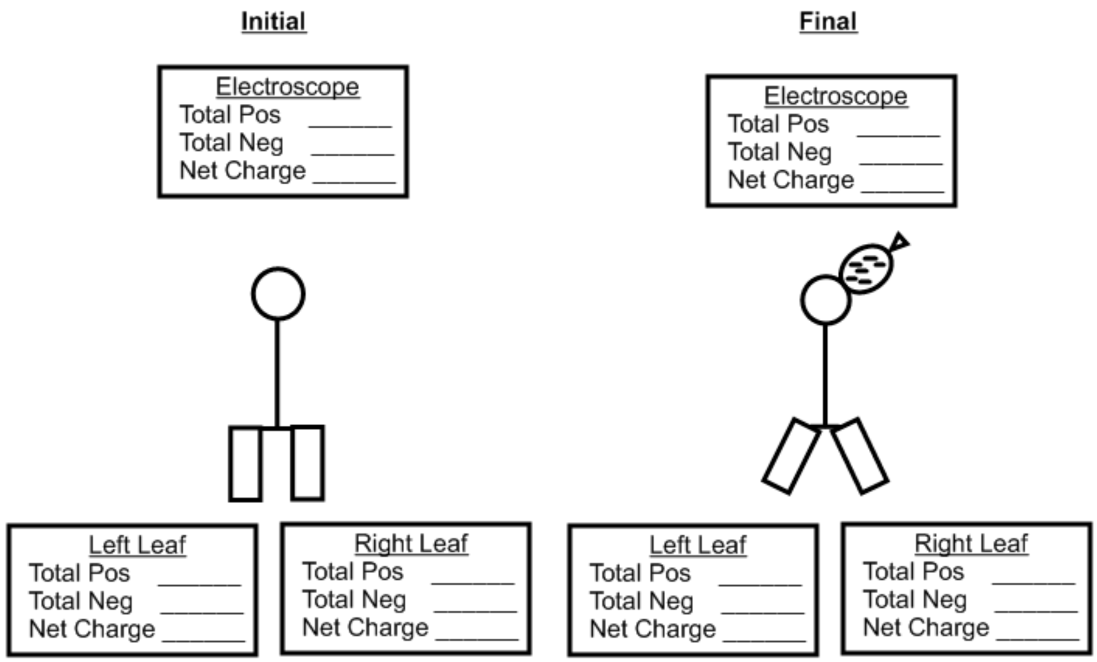
Part 2: Charging by Conduction

1. To charge an object by *conduction* means____
____

2. Recharge the balloon. Bring the balloon near again, and DO touch your electroscope with the balloon.

Let's make sense of your observations:

3. Draw the charges on your electroscope.



4. a) What do you notice about the total number of positive charges on the *electroscope*?

   b) What do you notice about the total number of negative charges on the *electroscope*?

   c) What do you notice about the net charge on the *electroscope*?

5. a) What do you notice about the total number of positive charges on the *left and right leaves*?

   b) What do you notice about the total number of negative charges on the *left and right leaves*?

   c) What do you notice about the net charge on the *left and right leaves*?

6. How are induction and conduction different?
   (Hint: What happens to the total number of negative charges on the *electroscope* for each?)

7. Write 2-3 sentences explaining your observations.

Part 3: Discharging

1. To discharge an object means ____
   ____

2. How can you discharge your electroscope? Why does this work?

Part 4: Charging by Friction

1. To charge an object by *friction* means ____
   ____

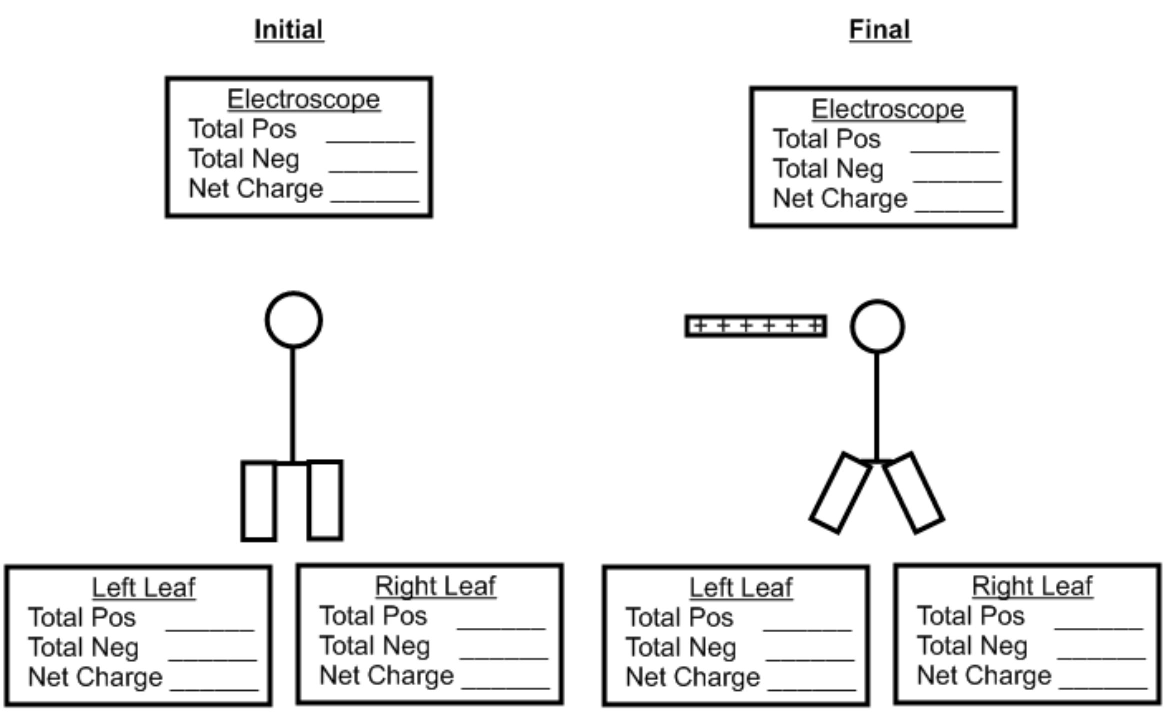
2. Write 2-3 sentences explaining how you've been giving the balloon a net negative charge.

Wrap Up:

What would happen if you brought a positively charges object near a neutral electroscope?

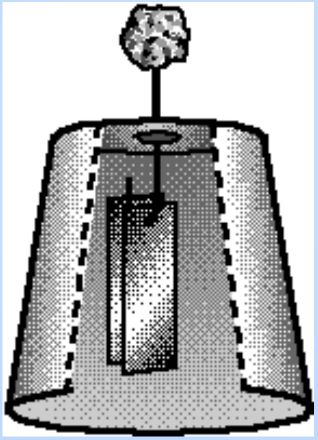
1. State your hypothesis.

2. To support your hypothesis, draw the charges on the electroscope.



3. Is this an example of charging by *induction* or *conduction*? How do you know?

Lab:
Making and Using an Electroscope



List your **materials**:

- ruler
- scissors
- 10 cm x 30 cm piece of foil
- 1 paperclip
- 1 plastic cup with a hole
- 3 g of clay

Write the procedure:

1. Cut a piece of foil 2 cm x 4 cm

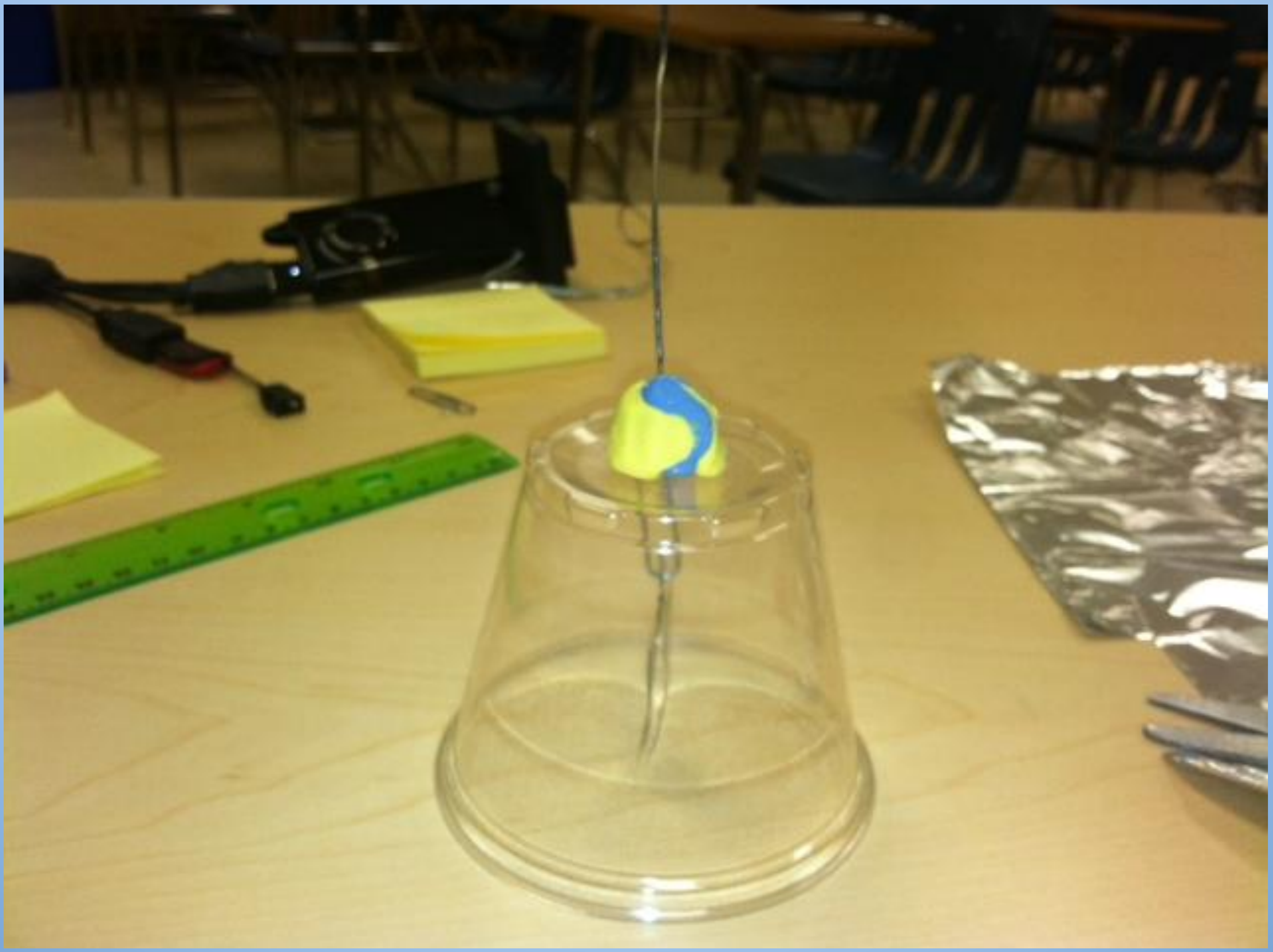
2. Fold foil in half (hot dog style) and fold one end over 0.5 cm

Cut a small triangle along the edge to create a diamond-shaped hole after unfolding it

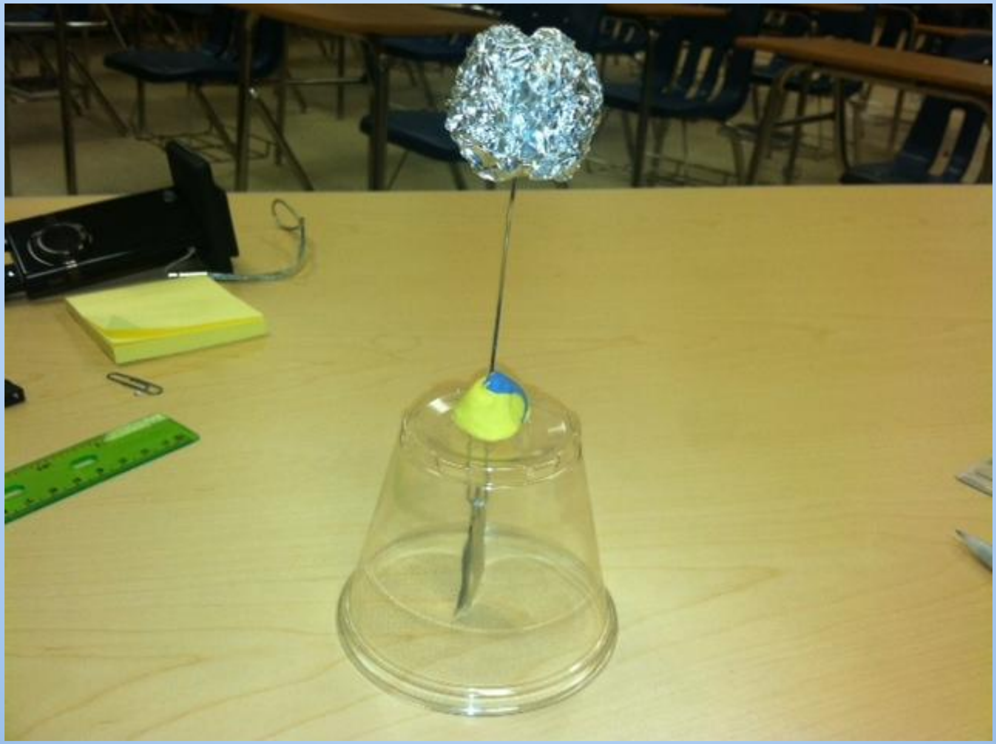
3. Carefully unfold the foil and cut into two separate leaves

4. Unfold one end of a paper clip and hang the leaves on the loop

5. Insert the paperclip into the cup and secure it with the clay.



6. Ball up the remaining foil and place on the straight end of the paper clip



7. Write your name on a Post-it and secure it to the electroscope

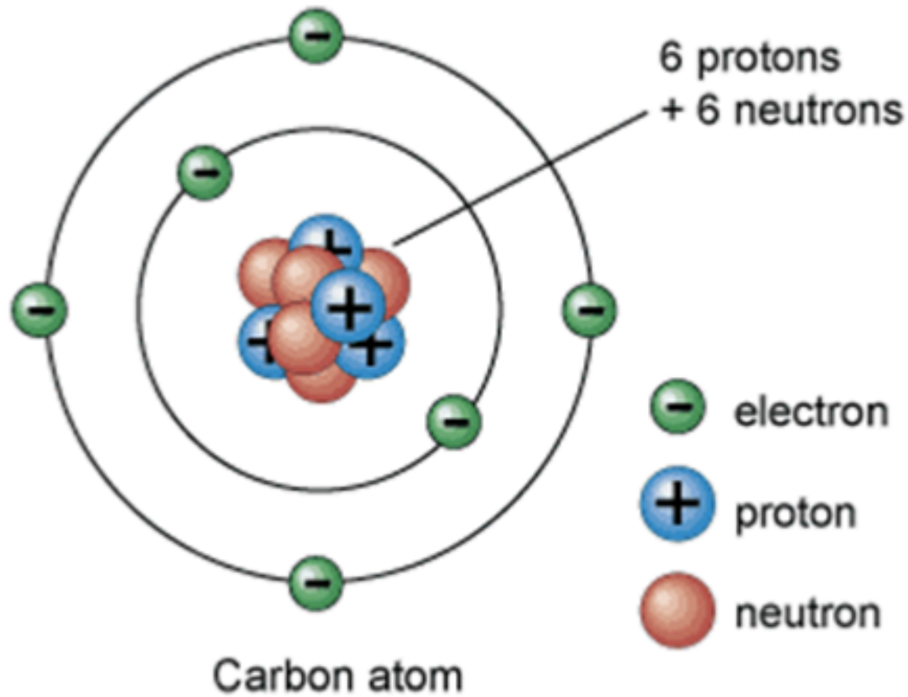
Charges:

- Protons and electrons have equal but opposite charges

particle	charge	
electron	-1.60×10^{-19} C	(-e)
proton	$+1.60 \times 10^{-19}$ C	(+e)
neutron	0	

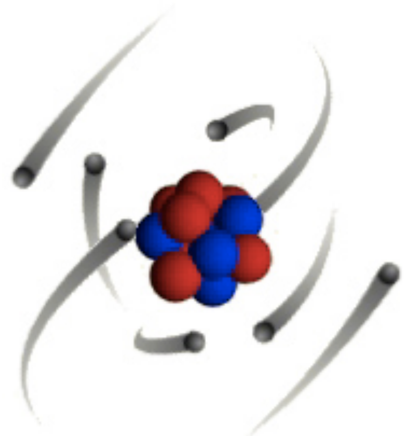
The Atom


Thanks Bohr!


6 protons
+ 6 neutrons
electron
proton
neutron
Carbon atom

Which particles can move and why?

- ELECTRONS!
    1. They’re light (mass = $9.10938356 \times 10^{-31}$ kilograms)
    2. They’re small (radius = ~2.8179×10^{-15} meters)
    3. They’re on the outside of the atom



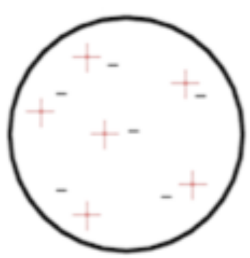
Net Charge:

- An object that gains electrons is "charged negative"
- An object that looses electrons is "charged positive"

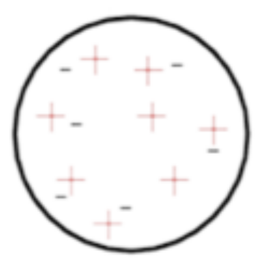
What is the NET charge on these objects?

There are:

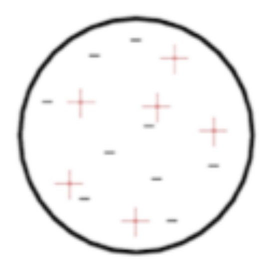
6 positive charges and
6 negative charges



8 positive charges and
6 negative charges



6 positive charges and
9 negative charges

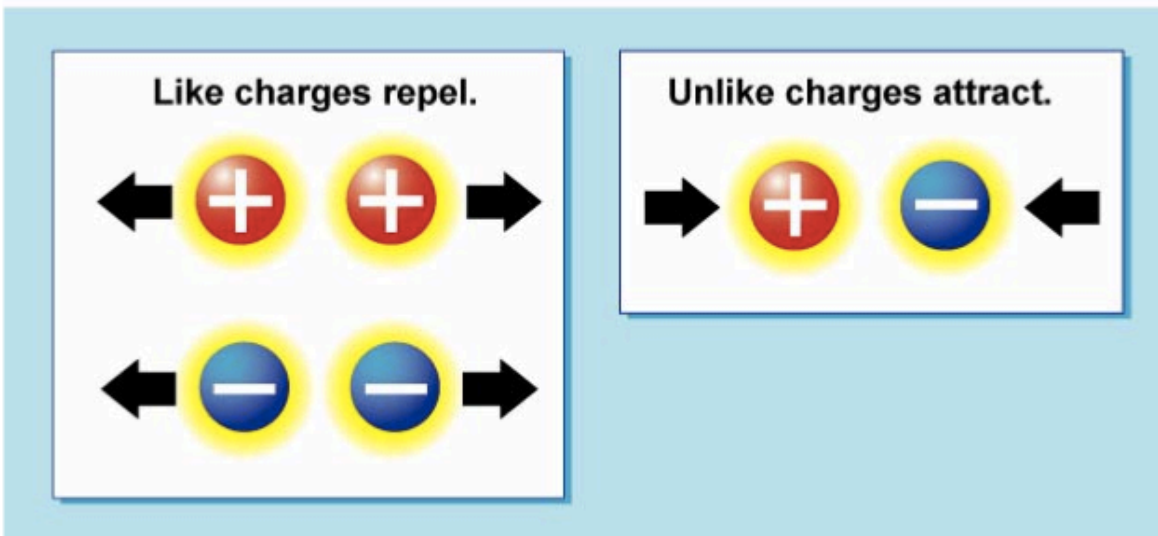


Golden Rule of Electrostatics:

Opposite charges attract; like charges repel

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

F = electrostatic force
q = electric charge
r = distance between charge centers
k = Coulomb constant
$9.0 \times 10^9\ N \cdot m^2/C^2$



How can we charge an object?

How can we charge an object?
Think: How can we get electrons to move?

- Friction - transferring electrons through *rubbing*
- Conduction - transferring electrons through *touch or contact*
- Induction - bringing a charged *close* to a neutral object and polarizing it

Friction: transferring electrons through *rubbing*

- Think: ripping electrons off one object and transferring them to another.
- Example: sock & shirt
- http://phet.colorado.edu/en/simulation/balloons

Conduction: transferring electrons through *touch*

- Think: electrons flowing from one object to another
- Example: Van de Graaff Generator and hair

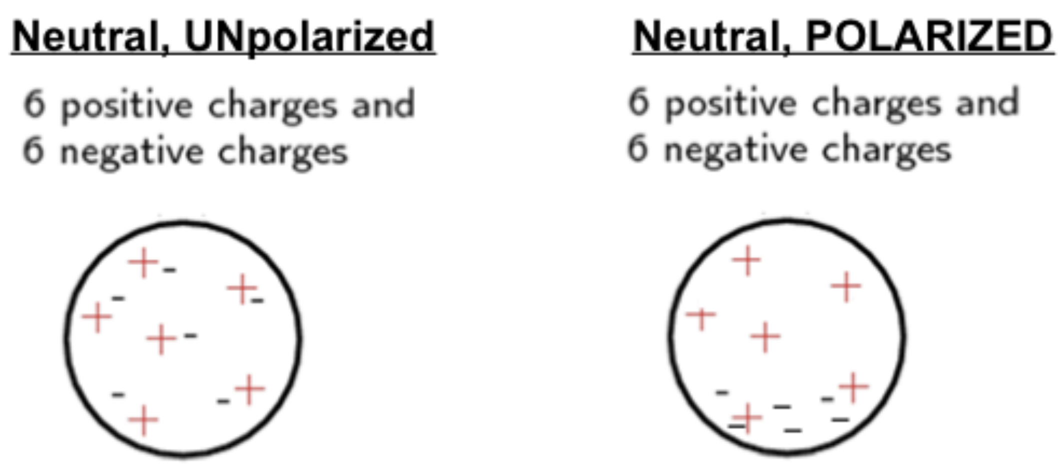
Induction: bringing a charged *close* to a neutral object and polarizing it

What's that?

Polarization:

- Even though your net charge might be neutral, the object can still be polarized!

- Polarization is when each side of the object develops a charge.



Induction: bringing a charged *close* to a neutral object and polarizing it

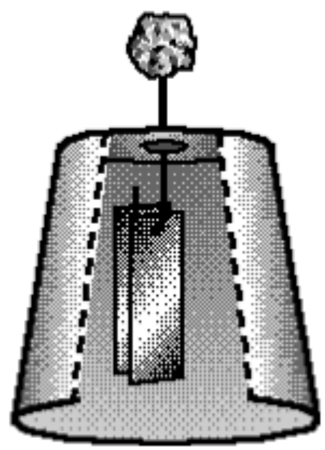
- Think: Think: *inducing* a charge at a distance
- Example: Pop can & rod

How can we get rid of a net charge?
Think: How can we restore a neutral charge?

- Discharging: getting rid of net charge

- Grounding: removing electrons through contact with the 'ground'
  - A ground is something that has seemingly infinite supply of electrons; it can give or take electrons from the object
  - Example: ground
  - Example: person

Electroscope Lab



Thinking about electrostatic forces, what would cause the leaves to separate?

Pre-Lab:

1. Which type of charge can move? Why?

2.

Golden Rule of Electrostatics:

3. Polarization is ____
____

Post-Lab Discussion:

1. Describe how positive and negative charges interact with one another.
2. Describe how neutral charges interact with other charges.
3. Knowing that a neutrino is chargeless, what types of interactions would you expect?
4. Knowing this, why might IceCube researchers be so interested in neutrinos? (Hint: Think about the path a neutrino would take from its source to you!)
5. Knowing this, why might neutrinos be difficult for IceCube researchers to detect?