From ancient times it was known that when certain materials are rubbed together, they can form an attraction to one another. This is the same discovery that is made every time you take clothes out of the dryer and they cling together. (As you pull them apart you might even see sparks fly, like small lightning bolts.) One famous example of this was documented in ancient Greece. It was seen that when thread was spun, by passing it over a spindle made of amber, the thread - and the hair of the spinstress for that matter - was attracted to the spindle. The Greek word for amber was elektron, hence this force came to be called “electric”.

Over the course of time, it was determined that dissimilar materials attract one another and similar materials repel each other. For example, if a piece of glass was rubbed by two different pieces of silk; either piece of silk would be attracted to the glass, but the two pieces of silk would repel each other; as would two pieces of glass that had each been rubbed by a piece of silk. The electric force could be either attractive or repulsive, with likes repelling and unlikes attracting.

Before being rubbed, the materials experience no force of attraction or repulsion towards one another. Also, after being rubbed, if the materials that attracted one another were brought into direct contact, the force between them would disappear. It was almost as if in the process of rubbing the glass with the silk, something had been taken from the glass and deposited upon the silk. Whatever that was, it seemed to “want” to get back to the glass, whence it came, thus creating an attraction between the silk and the glass. The only way this “substance” could get back to the glass was to bring the silk with it, creating an electric force of attraction between the silk and the glass.

This substance was later named “charge”. Since it seemed to come in two types, that when brought together in equal amounts added to zero, it was determined that charge must come in two forms; forms that were to be named “positive” and “negative”. A “neutral” object was one that contained an equal balance of positive and negative charge, so its total net charge would be zero.

A positively charged object contains more positive charge than negative charge and the reverse is true for a negatively charged object. (It’s important to note that neutral objects contain charge, just equal amounts of negative and positive charge.)
It was a great mystery as to which charge moved from one object to another when they were rubbed together. For example, when glass was rubbed by silk did a charge move from the glass to the silk or from the silk to the glass?

We now know that, in solid objects, only the negative charge can move. The positive charge is fixed into relatively permanent positions within the solid. To understand this better, we need to give you a brief overview of the atom.
The Atom

The word atom also comes from ancient Greece where the verb “tomi” meant “to divide” and the prefix “a” meant “not”. So the word atom means “not divisible”. Atoms are supposed to represent the indivisible pieces that make up all matter. But as we’re about to see, what we call “atoms” are in fact divisible; atoms have parts.

Atoms are made up of mostly empty space with a very small solid center called the nucleus and even smaller particles called electrons buzzing about in the empty space. If an atom were somehow “blown up” to be the size of a gymnasium the nucleus would be about the size of a baseball and would be located in the center. The electrons would be smaller than gnats and would be flying around in random directions at high speeds. It’s hard to picture an atom as mostly empty space; when we picture an “empty” gymnasium it’s still filled with air; but there’s nothing to fill the space inside an atom. The space not occupied by the nucleus or the electrons in an atom is truly empty, or as empty as anything that we can picture can be. Since all matter is made of atoms, including you and me, that means that everything, including you and me, is mostly empty space.

One reason that protons and neutrons don’t fly around like electrons is that they are a lot more massive than electrons – about 2000 times more massive. So while the lightweight electrons are flying around through all that empty space, the protons and neutrons are stuck together in the center of the atom.

But getting back to electricity; electrons are the carriers of negative charge; the positive charge resides inside the nucleus. The nucleus is comprised of two types of particles, the neutron and the proton. While neutrons and protons have very similar masses, the proton has a positive charge and the neutron has no charge. So all the negative charge that we’ll be talking about is carried by electrons and all the positive charge is carried by the protons, inside the nucleus of the atom.

The magnitude of the charge of a single electron or a single proton is the same and is given the symbol “e”. So, an electron has a charge of “-e” and a proton has a charge of “+e”. In their “normal” state, atoms have neutral charge; that is they have an equal amount of negative and positive charge. That also means that they have an equal number of protons and electrons.

Atoms can sometimes become charged; by gaining an extra electron or losing one of their electrons; these charged atoms are called ions. A positive ion has fewer electrons than it normally would, while a negative ion has more electrons than it normally would. While the number of electrons can change in this manner – by adding or losing electrons – atoms don’t gain or lose protons.

You’ll learn more about that when you learn about nuclear physics, but in terms of electricity; the only change that we’ll discuss with respect to atoms is when they gain or lose electrons: ionization. In fact, the names we give to atoms are based on the number of protons that they have; hydrogen atoms have one proton; helium has two protons; carbon has six; oxygen has eight; etc. Only nuclear reactions can change the number of protons; to learn more about that you’ll have to wait for the chapter on nuclear physics.

An important principle of physics is Conservation of Charge. It is always the case that charge is conserved; charge is never created or destroyed. In any closed system, the total net charge never
changes. So, whenever we speak of “charging a conductor” or giving something a charge, we mean that we are moving charge from one place to another, we are never creating it. To the extent that one object gains charge, another object must be losing an identical amount. Similarly, when we speak of “discharging” a conductor, we mean that we are moving charge to or from the conductor; we are not destroying charge in this process.

**Solids**

When solid matter is formed, the protons of the atoms that comprise the solid form a crystal with their positions very well defined with respect to each other. The only way to move the relative locations of the nuclei in a solid is through taking an outside action on it, like melting it; bending it; scraping it; etc. The reason that solids are “solid” is that they maintain their shape because the nuclei that comprise them are rigidly locked in position.

On the other hand, the electrons in a solid are very light and are not so tightly bound to one location. They are held in place by their attraction to the positive nucleus: Since they have an opposite charge to that of the nucleus, and opposites attract, most electrons stay with their nuclei. However, that is not always the case with all electrons. How tightly attached electrons are to their nuclei can vary; this leads to the two general types of materials we’ll be discussing: insulators (sometimes called dielectrics) and conductors (the third type of solid, semiconductors, requires its own discussion that is beyond the scope of this chapter).

The electrons in insulators are very attached to their nuclei. Since the nuclei aren’t moving, that means that the electrons in insulators also don’t move around. On the other hand, some of the electrons in a conductor, called conduction electrons, easily move around inside of a solid. You can picture them like a fluid that can flow throughout the conductor, but can’t leave it. Metals are great examples of conductors; they have conduction electrons that can move around the metal freely. (That’s why wires that carry electricity are made of metal; the conduction electrons in the metal are free to move and can carry electricity from the wall to your television, radio, etc.)

**Conductors**

Let’s now imagine a solid metal object. There are an equal number of immoveable positive nuclei scattered uniformly throughout it. Most of the electrons also can’t move; but the conduction electrons can go wherever they want. If the sphere is neutral, there’s not much more to talk about; the electrons will move about in it but it will have no net charge. The electrons will also be uniformly spread throughout the conductor as they are attracted to the nuclei as much as they are repelled by other electrons.

Now let’s charge the conductor by adding some extra electrons to it; electrons that are free to move anywhere they want. Since the conductor was previously neutral, there is no overall attraction for the electrons towards the center. On the other hand, since all the added electrons have the same negative charge, they spread out so they can be as far from each other as possible (like charges repel). The best way to achieve this is for all the excess electrons to move to the surface of the sphere and spread out uniformly over that surface. More generally, all excess electrons on a conductor are uniformly distributed over its surface.
The Atom

The atom is made of ______ basic subatomic particles.
Proton – has a _____ charge. It is in the _________ of the atom.
Neutron – has a _____ charge. It is in the _________ of the atom.
Electron – has a _____ charge. It _________ around the outside of the _____________.

Charge of Protons and Electrons

The unit of charge is the _______________. Charles Augustin de Coulomb (1736-1806)
A French physicist who performed the first accurate measurements of the force between charges.

A single proton has a charge of:

An electron has a charge of an electron:

Charge of an Object

The charge of an atom is _______________. There are equal number of _________ & ____________ which provides a perfect cancellation between positive and negative in matter leaving a ________________ of zero. It is then ________________.

Charged Object

An object is ___________________ when its net charge is not zero.
An object with more __________ than positive charge has a net __________ charge overall and more __________ than negative charge, the object has a positive net charge.
TRIBOELECTRICITY: GETTING RUBBED THE RIGHT WAY

When certain objects are rubbed against each other, charge is separated. One object becomes positive, the other becomes negative. Charge separation by rubbing is called **triboelectricity** (*tribo* means friction). Charge is separated in this way due to differences in electron affinity. Some materials are “electron grabbers,” others are “electron donors.” The atoms or molecules in electron grabbers hold on to electrons tightly and can even hold excess electrons effectively. The atoms or molecules in electron donors hold on to electrons loosely and can give away some of the electrons they own. But the distinction between electron grabbers and electron donors is a relative one. Material A may be able to grab electrons from material B but may also find itself donating electrons to material C. Materials can be arranged in a spectrum called the triboelectric sequence.

<table>
<thead>
<tr>
<th>ELECTRON GRABBERS</th>
<th>ELECTRON DONORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>rubber</td>
<td>cat fur</td>
</tr>
<tr>
<td>amber</td>
<td>wool</td>
</tr>
<tr>
<td>cotton</td>
<td>glass</td>
</tr>
<tr>
<td>skin</td>
<td>rabbit fur</td>
</tr>
<tr>
<td>silk</td>
<td></td>
</tr>
</tbody>
</table>

This is a partial listing of the triboelectric sequence. When rubbed together, a material from the left will gain electrons from a material on the right. The farther apart the two materials are, the greater the difference in electron affinity. In typical electrostatics experiments, rubber is rubbed with wool or rabbit fur to produce a negative charge on the rubber; glass is rubbed with silk to produce a positive charge on the glass.
Family Guy Think-Pair-Share
“the results may shock you”

**Directions**
You will be divided into different groups, A – E, and your group will be responsible for answering one of the following questions and presenting your answer to the class. Watch the following video, then answer the questions below:

**Questions**

A. How does Peter become electrically charged? What evidence suggests he is picking up charge? Sketch the charges on Peter’s picture below.

B. How does Peter get rid of the charge he picks up? What evidence illustrates that excess charge leaves his body? Sketch the charge leaving his body below.

C. Why does Peter rub his feet against the carpet? Would he produce the same results if instead he rubbed his feet against a wood floor? Why or why not?

D. Does Peter actually have to touch another person or object to get “rid” of the charge on his body? Why or why not? Sketch below.

E. What do you think would happen if Peter were to rub his feet against the carpet for a longer amount of time? Develop a relationship between “rubbing” and “amount of time.”
FRICITION: GETTING RUBBED THE RIGHT WAY

Charging by rubbing
As you’ll recall the first known discovery of electric force goes back thousands of years ago. The very name electric comes from the Greek name for amber, elektron, and was due to the charge generated in amber when it was rubbed with cloth.

You experience the same thing when you rub your feet on carpeting. Electrons move between you and the carpeting, giving you a net charge; when you touch something that is grounded, like a doorknob, the electrons flow through your fingers, bringing you back to being electrically neutral. That’s the shock you sometimes get when you touch a doorknob after walking on carpeting; it’s due to the flow of electrons between you and the earth.

An easy way to charge some materials is to rub them against another one. Here are two famous examples: rubbing a plastic rod with animal fur gives the rod a negative charge and the fur a positive charge; rubbing a glass rod with silk gives the glass a positive charge and the silk a negative charge. Each is charged by the movement of electrons between the materials. So in the first case, the charge of the plastic rod is exactly equal and opposite to that of the fur and in the second case the charge of the glass rod is equal and opposite to that of the silk. Charge is not created or destroyed, it only moves from place to place.

The frictional charging process results in a transfer of electrons between the two objects that are rubbed together. Rubber has a much greater attraction for electrons than animal fur. As a result, the atoms of rubber pull electrons from the atoms of animal fur, leaving both objects with an imbalance of charge. The rubber rod has an excess of electrons and the animal fur has a shortage of electrons. Having an excess of electrons, the rubber rod is charged negatively. Similarly, the shortage of electrons on the animal fur leaves it with a positive charge. The two objects have become charged with opposite types of charges as a result of the transfer of electrons from the least electron-loving material to the most electron-loving material.

Two balloons rubbed on human hair will become negatively-charged and have an attractive interaction with the hair. If the hair is removed, the balloons repel.
CHARGING by Conduction

Now let’s see what happens if we have two identical metal spheres, one negatively charged (it has excess electrons) and one neutral (it has an equal number of electrons and protons) and we touch them together. Once we touch them together, the excess electrons are free to move anywhere on the two spheres. Once again, they’ll spread out over the surfaces of the spheres. The best way to spread out is to cover both spheres with an equal amount of electrons, so the total charge will be divided in two, half on one sphere and half on the other. If we now separate the two spheres, so they are no longer touching, there’s no way for the charge on the second sphere to get back to where it started; the second sphere remains charged.

Giving something a charge by touching it with a second charged object and then separating them is called, charging it by conduction. The object that is being charged doesn’t have to be identical to the second object; it’s just that if they are identical the charge becomes equally divided. If they are not identical, more charge may end up on one conductor than the other.

How about if one sphere is neutral and the other one has a positive charge (it’s missing some electrons). In this case, there are more nuclei missing electrons on one sphere than on the other. When they are touched together electrons will flow from the neutral sphere to the positively charged sphere. If they are separated, the electrons can’t flow back to the neutral sphere, so both spheres are missing the same number of electrons; they both have an equal positive charge.

Note that in the second case, the neutral sphere acquired a positive charge by touching a positively charged sphere. It looks like positive charges moved from the positive sphere to the neutral sphere, but that is not the case. The positive charges, the protons, didn’t move. It’s just that some of shortage of electrons is now spread between both spheres making them both positive.

Before

![Diagram of two spheres before touching]

After

![Diagram of two spheres after touching]

Net charge (VDG):

Net charge (fur):
The Electroscope

The electroscope

Neutral

Metal rod and ball

Insulator

Leaves

Separating charges

The negative rod repels free electrons into the leaves so they repel each other. The ball is positive because it lost electrons.

Leaves

Charging by contact

Electrons

Electrons move from the rod to electroscope. The ball becomes neutral, but there is now a negative net charge on the electroscope.
INDUCTION: SAFE CHARGING

Charging by Induction

It is possible to charge a neutral conductor without touching it with a charged conductor; but, in this case, you need to touch it with another conductor; you need a total of three conductors.

Here’s how it work.
Take the negatively charged sphere and move it close to the neutral sphere. The conduction electrons on the neutral sphere will be repelled by the excess electrons on the charged sphere. They can’t leave the first neutral sphere since it’s not touching anything, but they can move to the side opposite the charged sphere. They’ll keep moving away from the charged sphere until the attraction of the abandoned nuclei near the charged sphere, which are now missing electrons because they moved to the other side, is equal to the repulsion from the excess electrons on the charged sphere. At that point, one side of the neutral sphere is positively charged and the other side is negatively charged; its total net charge is still zero. If, at this point, we moved the charged sphere away, the electrons would just flow back to where they started and that would be that.

But, what would happen if we touched the neutral sphere with another neutral sphere? The electrons, instead of just moving to the other side of the first neutral sphere will now move to the second neutral sphere; anything to get further from the charged sphere and spread out from one another. If we then take the second neutral sphere away, it will retain those extra electrons, giving it a negative charge. The first neutral sphere can’t get those electrons back, and it was initially neutral, so now it has a positive charge. No change occurs to the initially charged sphere, since it never touched anything; it retains all of its extra electrons. We’ve charged two neutral spheres by using a third charged sphere which never touches the other two. Is it clear from this explanation that the induced positive charge on the second sphere is equal in magnitude to the induced negative charge on the third sphere?

This same process can work in reverse, with a nearby positively charged sphere attracting electrons which then are also drawn from a second neutral sphere. The effect is the same since one of the two neutral spheres ends up with a positive charge and the other ends up with an equal negative charge.

Before

Net charge (VDG):

Net charge (ball):

Consider the following sequence:

After

Net charge (VDG):

Net charge (ball):
Diagram I:  
Two metal spheres are supported by insulating stands so that any charge acquired by the spheres cannot travel to the ground. The spheres are placed side by side (see diagram i. below) so as to form a two-sphere system.

Diagram II:  
Being made of metal (a conductor), electrons are free to move between the spheres - from sphere A to sphere B and vice versa. If a rubber balloon is charged negatively (perhaps by rubbing it with animal fur) and brought near the spheres, electrons within the two-sphere system will be induced to move away from the balloon. This is simply the principle that like charges repel. Being charged negatively, the electrons are repelled by the negatively charged balloon. And being present in a conductor, they are free to move about the surface of the conductor. Subsequently, there is a mass migration of electrons from sphere A to sphere B. This electron migration causes the two-sphere system to be polarized (see diagram ii. below).

Diagram III:  
Overall, the two-sphere system is electrically neutral. Yet the movement of electrons out of sphere A and into sphere B separates the negative charge from the positive charge. Looking at the spheres individually, it would be accurate to say that sphere A has an overall positive charge and sphere B has an overall negative charge. Once the two-sphere system is polarized, sphere B is physically separated from sphere A using the insulating stand. Having been pulled further from the balloon, the negative charge likely redistributes itself uniformly about sphere B (see diagram iii. below).

Diagram IV:  
Meanwhile, the excess positive charge on sphere A remains located near the negatively charged balloon, consistent with the principle that opposite charges attract. As the balloon is pulled away, there is a uniform distribution of charge about the surface of both spheres (see diagram iv. below).

Charging by Induction

Diagram i.
Two metal spheres are mounted on insulating stands.

Diagram ii.
The presence of a -charge induces e- to move from sphere A to B. The two-sphere system is polarized.

Diagram iii.
Sphere B is separated from sphere A using the insulating stand. The two spheres have opposite charges.

Diagram iv.
The excess charge distributes itself uniformly over the surface of the spheres.
Practice

1. In the examples below, electric charge is transferred by which method?
   a)
   ![Image]
   b)
   ![Image]

2. Consider the diagrams below. (a) A pair of insulated metal spheres, A and B, touch each other, so in effect they form a single uncharged conductor. (b) A positively charged rod is brought near A, but not touching, and electrons in the metal sphere are attracted toward the rod. Charges in the spheres have redistributed, and the negative charge is labeled. Draw the appropriate + signs that are repelled to the far side of B. (c) Draw the signs of charge in (c), when the spheres are separated while the rod is still present, and in (d) after the rod has been removed. The spheres have been charged by induction.

3. A negatively charged rod is brought near the left-hand side of two insulated, neutral metal spheres that are touching one another. The spheres are then separated with charges as shown below. Which pair of spheres shows the correct charges?
   a. ![Image]
   b. ![Image]
   c. ![Image]
   d. ![Image]

4. Charged rubber rods are placed near a neutral conducting sphere, causing a redistribution of charge on the spheres. Which of the diagrams below depict the proper distribution of charge on the spheres? List all that apply.

<table>
<thead>
<tr>
<th>Diagram A</th>
<th>Diagram B</th>
<th>Diagram C</th>
<th>Diagram D</th>
<th>Diagram E</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>
5. If you observe that the charge on balloon B is negative, what can you conclude about the charge on balloon A? What can you conclude about the charge on balloon C?
   a. It has a positive charge.
   b. It has a negative charge.
   c. It has no charge.
   d. It has a negative or neutral charge.

   ![Diagram of Case #1 with balloons A, B, C, and B showing charges.]

6. Which of the diagrams below represents the effect of bringing a positively charged rod near (but not touching) an electroscope.

   ![Diagrams of four options labeled 1, 2, 3, and 4 showing electroscope effects with positive and negative charges.]

Notes – Coulomb’s Law

It had been known for a number of years that objects that have a positive charge attract negatively charged objects and repel other positively charged objects; like charges repel and opposites attract. Benjamin Franklin and Joseph Priestly were the first to reason, in the 1760’s, that the electric force between two charged objects must decrease as the inverse square of the distance between two charged objects. Franklin had made the observation that excess electrons move to the surface of a conductor. Priestly then proved, mathematically, that that could only occur if the repulsion between electrons decreases as the inverse square of their separation. They thus showed that the electric force is proportional to \(1/r^2\): \(\text{FE} \propto 1/r^2\). That means that if the distance between the centers of two charged objects is doubled, the electric force is one-fourth as great; triple the distance, you get one-ninth the force; halving the distance yields four times the force.

In the 1780’s Charles Coulomb conducted a series of experiments that confirmed that result and also showed that the force is proportional to the charge of each object. He did this by using identical metal spheres and halving the charge on each one by touching them together with neutral spheres. This allowed him to vary the charge on each sphere. He then used a torsion balance to measure the force.

The symbol for charge is “q” so this yields the formula for the electric force:

\[
P = \frac{k \cdot q_1 \cdot q_2}{d^2}
\]

In this formula:
- \(k\) is a constant and equals \(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\)
- \(q_1\) is the net charge on one of the objects
- \(q_2\) is the net charge on one of the other object
- \(r\) is the distance between the objects, if they are point charges, or between the centers of the objects, if they are spherical

If the value of the electric force is:
1. (−) then the value for force signifies a repulsive force.
2. (+) then the value for force signifies an attractive force.
Example 1: Two point charges are located 10 cm apart. One has a charge of +20 \(\mu\)C and the other has a charge of -30 \(\mu\)C. What is the force on each due to the other?

\[
F_E = \frac{k \cdot Q_1 \cdot Q_2}{d^2}
\]

\[
F_E = (9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) (20 \times 10^{-6} \text{C}) (-30 \times 10^{-6} \text{ C}) / (0.10 \text{ m})^2
\]

\[
F_E = -540 \text{ N}
\]

The negative sign tells us that this is an attractive force so the answer should be given as \(F_E = 540 \text{ N} \) directly towards each other.

Example 2: Two electrons are located 2.0m apart. What is the force on each electron due to the other?

\[
F_E = \frac{k \cdot Q_1 \cdot Q_2}{d^2}
\]

\[
F_E = (9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) (-1.6 \times 10^{-19} \text{C}) (-1.6 \times 10^{-19} \text{C}) / (2.0 \text{ m})^2
\]

\[
F_E = 5.76 \times 10^{-29} \text{ N}
\]

The positive sign tells us that this is a repulsive force so the answer should be given as \(F_E = 5.8 \times 10^{-29} \text{ N} \) directly away from one another.

Coulomb’s Law

Classwork

1. Two positive charges of 1 \(\mu\)C and 10 \(\mu\)C are separated by a distance of 10 m. Find the direction and the magnitude of electrostatic force between the charges.

2. A particle with a charge of +7.4 \(\mu\)C is separated from another charged particle with a charge of –3.6 \(\mu\)C by a distance of 1.4 m. Find the direction and the magnitude of electrostatic force between the particles.

3. A +1.4 \(\mu\)C charge exerts a repulsive force of 20 \(\mu\)N on a second charge which is located a distance of 2.2 m away from it. What is the charge (magnitude and sign) of the second charge?

4. Two spherical objects, whose centers are 8 cm apart, have equal negative charges and repel each other with a force of 9 \(\mu\)N. What is the charge on each of them? How many extra electrons are on each of them?

5. Two conducting spheres have net charges of +9 \(\mu\)C and -7 \(\mu\)C and attract each other with a force of 4 \(\mu\)N. The spheres are brought in a contact and then moved apart to the initial distance. What is the new force between the spheres? Is this force attractive or repulsive?
Homework

6. Two negative charges of 2.5 μC and 9 μC are separated by a distance of 25 cm. Find the direction and the magnitude of electrostatic force between the charges.

7. Two charges of +2.6 μC and −5.4 μC experience an attractive force of 6.5 μN. What is separation between the charges?

8. What is the distance between two charges +7.8 μC and +9.2 μC if they exert a force of 4.5 μN on each other?

9. A −4.2 μC charge exerts an attractive force of 1.8 μN on a second charge which is a distance of 2.4 m away. What is the magnitude and sign of the second charge?

10. Two equal negative point charges repel each other with a force of 18 μN. What is the charge on each object if the distance between them is 9 cm? How many extra electrons are on each object?
Balloons and Static Electricity

Research Question
After reading the lab, create your own research question below then formulate a hypothesis to your research question:
______________________________________________________________________________
______________________________________________________________________________

Pre-Lab Discussion
As you are most likely aware, charge can be described as either positive or negative. When + or – charges are present in equal amounts, the object is considered electrically neutral. Large numbers of negative particles (electrons) can be transferred in certain circumstances from one neutral surface to another. This generates an excess of + charges on one object and – charges on the other. The following simulation illustrates the movement of both + and – charges and the resulting attractive and repulsive forces.

Procedure
Using the Site
• Access the site by either clicking on the link:
  http://phet.colorado.edu/en/simulation/balloons or by following:
• Once your application has started, click “Reset All”. Make sure that only the “Show all charges” and “Wall” buttons are selected.

Part 1 – One Balloon and Sweater
1. Look at the balloon. What can you say about its overall charge? (Hint: count both types of charges)

2. Click and drag the balloon and rub it against the sweater. Describe and sketch what happens to the balloon?

3. How did the balloon get charged, with what type of charge? What process gave the balloon this charge?

5. Bring the balloon in the middle, between the sweater and the wall. What happens to the balloon when you let it go? Explain why. Sketch the sweater, balloon and wall (sketch the charges on each and the direction the balloon moves)

**Part 2 – One Balloon and Wall**

6. What is the overall charge of the wall?

7. Predict what you think will happen when the balloon is brought close to the wall?

8. Bring the balloon in contact with the wall. What happens to the charges in the wall? Explain and sketch this process.


**Part 3 – Two Balloons**

10. Click the “Reset All” button. Select “Show all charges”, “Wall” and “Two balloons”. What can you tell about the overall charge of all the objects in your simulation window?

11. Select “Show charge differences”. Rub each balloon against the sweater. What happens to each one of them? Sketch this.

12. Why are the two balloons stuck on the sweater?

13. Try to get one balloon off the sweater by using the other balloon. Can you do it? If yes, explain why this is possible.

**Questions**

Based on your observations, attempt to explain why you sometimes see flashes of light when removing a fleece jacket in a dark room.
<table>
<thead>
<tr>
<th>Rubric – Balloons &amp; Static Electricity</th>
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</thead>
<tbody>
<tr>
<td><strong>Honors Physics</strong></td>
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</table>

<table>
<thead>
<tr>
<th><strong>Heading (1 pt.)</strong></th>
<th>Student labels the date in the upper left hand corner and title of lab in all CAPS in lab notebook.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research Question (2 pts.)</strong></td>
<td>Student generates a research question after reading the pre-lab discussion.</td>
</tr>
<tr>
<td><strong>Hypothesis (5 points)</strong></td>
<td>Student states hypothesis and explains their prediction.</td>
</tr>
<tr>
<td><strong>Sketch &amp; Description (2 pts.)</strong></td>
<td>Student sketches materials used in lab and a description of what they did.</td>
</tr>
<tr>
<td><strong>Procedure Question (15 pts.)</strong></td>
<td>Student answers all questions accurately and in complete sentences making sketches where necessary.</td>
</tr>
</tbody>
</table>

| **Total =** /25 points |                                                                                     |
Electric Field Hockey

**Purpose:**
To understand the effects of charges on the electric field and how a test charge will move through an electric field.

**Hypothesis:**
What variables will affect how a charge will move through an electric field?

**Procedure:**
Visit: [http://phet.colorado.edu/simulations/sims.php?sim=Electric_Field_Hockey](http://phet.colorado.edu/simulations/sims.php?sim=Electric_Field_Hockey), and click on **RUN NOW**. Familiarize yourself with the applet.

1. Set the game to match the difficulty, puck charge, and puck mass in the table.
2. Score a goal without going over the maximum number of charges.
3. Call Mr. Menzella over to initial.
4. Move on to the next game.
5. The more games you finish the better your lab grade. You must turn this sheet in to receive credit for the lab.

<table>
<thead>
<tr>
<th>Diff.</th>
<th>Puck</th>
<th>Mass</th>
<th>Max # of charges</th>
<th>Grade</th>
<th>Mr. Menzella’s Initials</th>
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