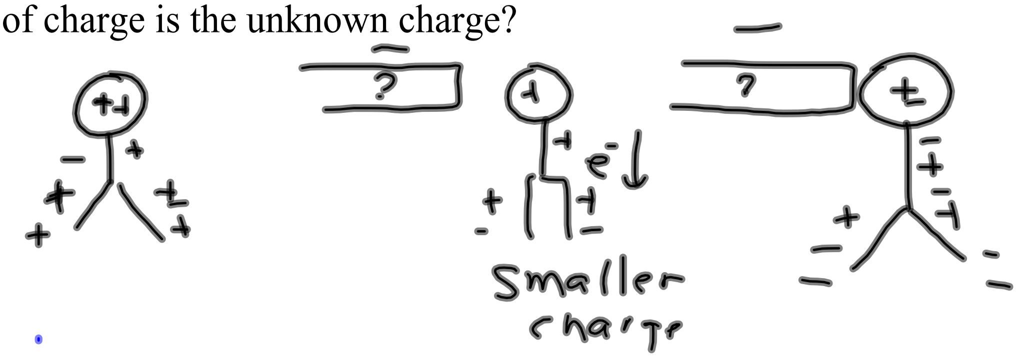
Section 9: Using a Charged Electroscope to Determine the Charge on Another Object

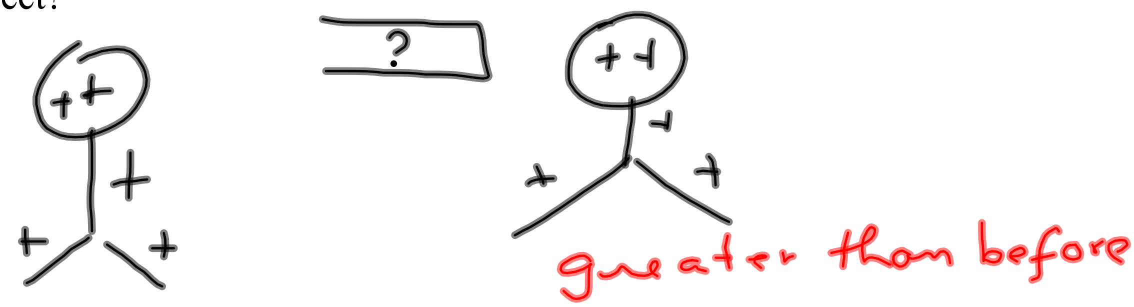
Examples:

1. When an unknown charge is brought near a positively charge electroscope, the electroscope's leaves first collapse and then diverge again. What type of charge is the unknown charge?



The electroscope has a positive charge and therefore has a deficiency of electrons. The leaves will only collapse if they have a smaller charge than before (or if they become neutral). This could only occur if electrons were forced down onto the leaves, which means the rod is negative. As the negative rod gets closer, the electric field created by the rod increases and even more electrons are force down to the leaves and the leaves diverge again due to an excess of electrons.

2. When an unknown charge is brought near a positively charge electroscope, the electroscope's leaves move further apart.What is the charge on the object?



The electroscope has a positive charge and therefore has a deficiency of electrons. The leaves will diverge further apart if they have a greater charge than before. This could only happen if more electrons are attracted up from the leaves. This can only happen if the unknown charge was positive.

Note: If the leaves collapse and then repel, the unknown charged object and the electroscope must be oppositely charged. If the leaves diverge further apart, the unknown charged object and the electroscope must be similarly charged.

Homework:

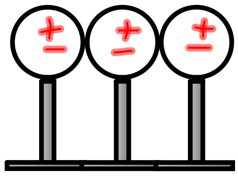
1. When an unknown charge is brought near a negatively charge electroscope, the electroscope's leaves first collapse and then diverge again. What is the charge on the object?

   A negatively charge electroscope has an excess of electrons. The leaves will only collapse if they have a smaller charge than before. This could only occur if electrons were attracted up to the knob of the electroscope by a positive charge. As the rod moves closed, even more electrons are attracted to the knob and the leaves diverge again.

2. When an unknown charge is brought near a negatively charge electroscope, the electroscope's leaves move further apart. What is the charge on the object?

   A negatively charge electroscope has an excess of electrons. The leaves will only diverge further apart if they have a larger charge than before. This could only occur if electrons were repelled down to the leaves of the electroscope by a negative charge.

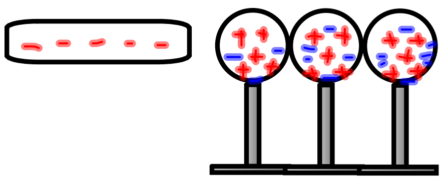
Example: The diagram below shows three identical metal spheres each on insulating stands and touching each other.

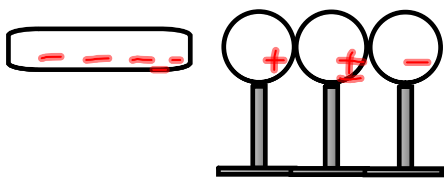


Redraw the 3 spheres with the appropriate placement of positive (+) signs and negative (-) signs for each of the following steps:

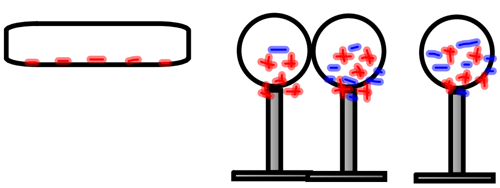
A) A negative rod is brought near
B) The far sphere is grasped by the insulating stand and is moved.
C) The middle sphere is grounded.
D) The ground is removed.
E) The remaining spheres are separated using the insulating stands.
F) The negative rod is removed.

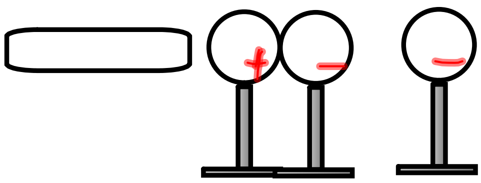
A) A negative rod is brought near. The negative rod causes a repelling force on the free electrons of the spheres. Free electrons migrate to the right. The resulting charge on each sphere is shown below.





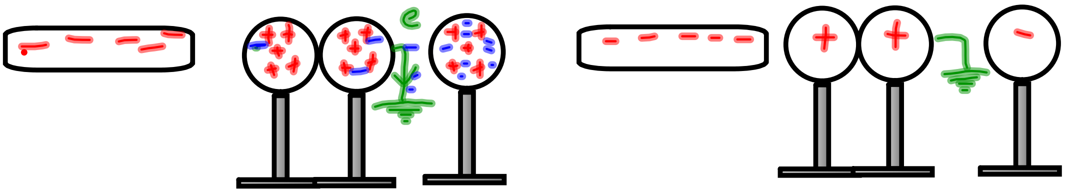
B) The far sphere is grasped by the insulating stand and is moved.





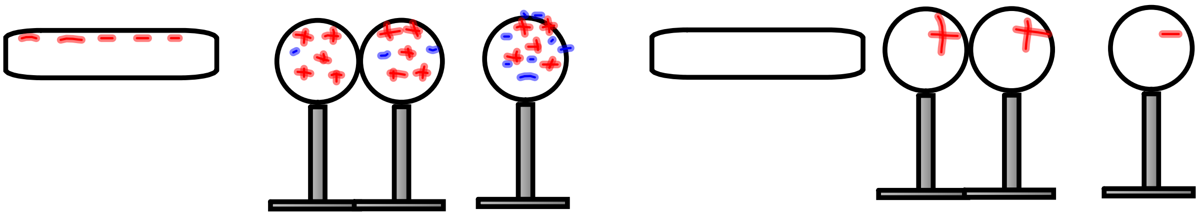
As soon as this happens, more free electrons will be forced from the left-hand sphere to the middle sphere. These extra electrons would not move while the right-hand sphere was touching the middle sphere because of the excess electrons already on the right-hand sphere. Before the right-hand sphere was moved, the electrons on it opposed the migration of more and more electrons. This opposition is diminished when the right-hand sphere is moved further to the right, so, more electrons will move to the middle sphere. The figure below shows the left-hand sphere with a deficiency of electrons (positively charged) and the other two spheres with an excess of electrons (negatively charged).

C) The middle sphere is grounded.

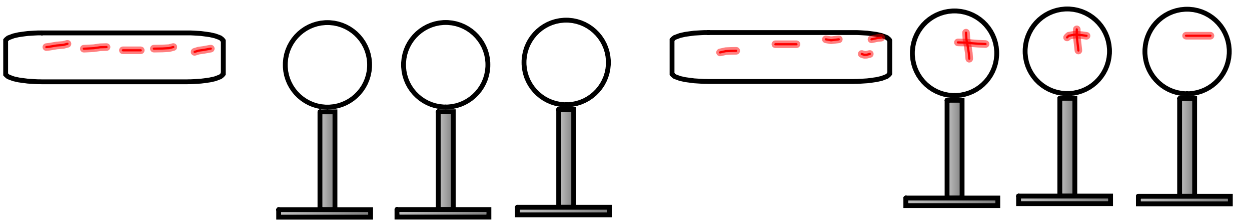


When this occurs, many, many, electrons will be repelled to the ground by the negative rod. The result is the left-hand sphere and the middle spheres both have a deficiency of electrons (a positive charge) while the charge on the right hand sphere is still negative.

D) The ground is removed. The picture for this situation is the same as for part C except the ground is removed.



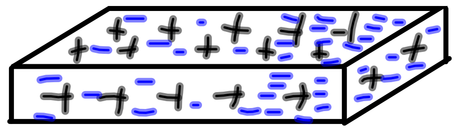
E) The two left-hand spheres are separated. This picture is the same as D. The only difference is the left-hand sphere and the middle sphere are no longer touching.



F) The negative rod is removed. The picture is identical to that in part E with the negative rod out of the picture. The final result of the procedure is the left-hand sphere and the middle sphere is positively charged and the right-hand sphere is negatively charged.

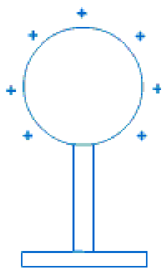
Section 10: The Shape of Objects and Charge Distribution

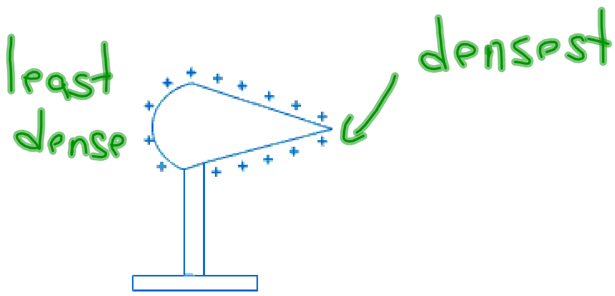
An insulator can be charged by friction. Consider a vinyl strip: If the left end of the strip was held and the right end was rubbed with wool, the charge distribution will look like this:



In an insulator, the electrons are not free to move from atom to atom. Thus, the charge will not distribute itself evenly over the surface of the strip. Rather, it stays in the region it was deposited.

When a conductor is charged (by conduction or induction) the charge will distribute itself evenly over the surface of the conductor. This is because electrons in these materials do not act as if they belong to one specific atom but to the object as a whole. The charge distribution on a hollow metal sphere is uniform and it will always be on the surface of the conductor. THERE IS NO EXCESS CHARGE IN THE INTERIOR. For other shapes, the charge tends to be concentrated near any sharply contoured features. The **greatest concentration** of charge occurs around **sharp pointed areas** on the conductor's surface. The charge on a conductor will be **densest in the areas** with the **greatest curvature**. Electrons are more likely to leap off the pointy end of the conductor.





Section 11: Electrical Discharge

You are more familiar with fast electrical discharge than slow electrical discharge. For example, the "prickle" that you feel when reach out to a door knob on a dry day, or the little "snaps" that you hear when removing clothes from an electric dryer are examples of fast discharge. Lightning is the Granddaddy of fast discharges.

Electric charge "jumps" or discharges due to repulsion forces when too many electrons build up in one place. The discharge is more likely to take place from pointy areas than from flat ones. This is why you are warned to stay away from trees in a thunderstorm.

When a charged object loses its charge and becomes neutralized, we call it an electrical discharge. There are different types of discharge as discussed below.

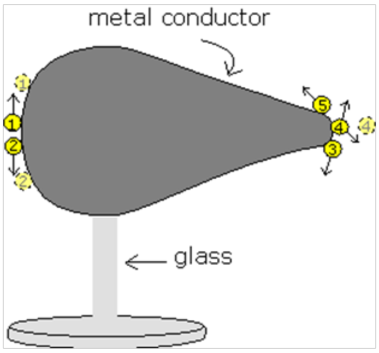
1. Grounding

The earth is a good conductor and because of its size it can give up electrons or accept electrons without becoming appreciably charged. We call the Earth a ground. If a negatively charged object is connected to the Earth, the excess electrons are drained into the Earth; or if a positively charged object is connected to the Earth, the electrons will come from the Earth to neutralize that object. These processes are called grounding.

2. Atmospheric Discharge for the Surface of a Conductor

Recall that electric charge "jumps" or discharges due to repulsion forces when too many electrons build up in one place. The discharge is more likely to take place from pointy areas than from flat ones. The picture suggests why electrical discharge is more likely to occur from places of high curvature (i.e., pointy places).

Notice that as electrons 1 and 2 repel each other, the forces are almost parallel to the surface of the conductor. These two electrons therefore spread further apart on the surface. In the case of electrons 3, 4, and 5, the repelling forces are no longer parallel to the surface of the conductor.



So, electrons on the pointy end will not be forced to spread out along the surface to the same extent as electrons 1 and 2. In fact, electron 4 is in a bit of trouble and will most likely leave the conductor altogether.

Don't forget that the electrons in the picture are just representatives of millions and billions of electrons. But no matter how many there are, those on the surface of low curvature (the big end) will spread out and be less dense that those on the surface of high curvature (the pointy end). Under these conditions, electron 4 is representative of the countless number of electrons that are discharged.

This phenomenon of discharge from surfaces of high curvature is the basis of the operation of lightning rods. Instead of charge increasing to large amounts and subsequently discharging rapidly and dangerously from buildings during thunderstorms, the lightning rod protruding from the roof permits a continuous but safe, slower discharge. Or, according to some writers, even if lightning does strike, it will be more likely to hit the lightning rod and be safely transferred to ground via a cable.

Question: Why are you more likely to receive a shock in the winter than in the summer?

In the summer, charged objects can discharge through the air. This is due to the fact that in the summer the air contains more moisture; the greater the moisture, the greater the number of ions present. Positive ions will neutralize to negatively charged objects and negative ions will neutralize positively charged objects. Electrons will jump from the negative ions to neutralize the positively charged object and electrons from the negative object will jump to the positive ions. During this process both the charged objects and the ions become neutralized.

3. Sparks and Arcing

When an object has an has an excess of electrons, the electrons exert strong force of repulsion on each other and move as far away from each other as possible. If a charged object approaches another conductor, some electrons may even jump across the gap of air between them. This type of discharge is called a **spark**. As electrons jump across the gap, a crack is heard and a small flash of light is seen. The electrons ionize the air and produce heat. This heat causes the air to expand rapidly and thereby produce a compression wave that spreads out at the speed of sound and hence a crack is heard. The heat also caused the air molecules to produce light and hence we see a flash. This is what occurs in lightning.

Sparks can be dangerous especially around flammable chemicals. This is why certain vehicles use chains dragged behind and carbon in the wheels to prevent charge from building up.

4. Lightning

The most spectacular display of electrical discharge is lightning. Lightning usually occurs as the result of:

A) Air masses moving against each other or
B) Precipitation

Each of these processes causes a charge build up in the atmosphere. A charged cloud induces a strong opposite charge on the surface of the Earth directly beneath it. If the charge on a cloud increases beyond a certain point, a gigantic spark discharge occurs. There are 2 scenarios: A) there is a positive charge on the cloud and an induced negative charge on the Earth or B) there is a negative charge on the cloud and an induced positive charge on the Earth. In either case, the discharge (lightning) goes from the negative to the positive side. Lightning may also travel between two oppositely charged clouds or between two oppositely charge centers in the same cloud. Remember that when lightning travels it travels the path of the least distance. This is why lightning usually strikes the tallest conductor in the vicinity.

Some properties of lightning:

Length	from 150 m to 3.0 km
Duration	from 0.002 s to 1.6 s
Width	from 1.0 cm to 30.0 cm
Temperature	up to 30 000°C
Electricity	up to 200°C, with power up to billions of kilowatts

Lightning, therefore, can be very dangerous to humans, building and nature. Therefore, people take certain precautions both before and during a lightning storm.

1. Lightning rods - These devices are located at the top of structures and have a point on its tip. This allows ions to be attracted to the rod while oppositely charged ions are attracted to the clouds in the air. This is sometimes sufficient enough to prevent lightning. Also, if there is an electrical storm, the lightning would strike the lightning rod (since it is closer) and the electrons would pass safely to the ground.

2. Stay away from tall structures during an electrical storm.

The following are just a few of the dozens of sites which have still pictures and videos of lightning strikes:

- http://www.chaseday.com/lightning.htm>
- http://www.srh.noaa.gov/meg/video/lightning.mpg
- http://www.srh.noaa.gov/meg/video/lightning.mpg>
- http://www.valightning.com/lightning.html>
- http://www.valightning.com/video.html>

Read pages 524-534. You should be able to answer questions 1 - 6, page 579, 33 - 40, page 582.