2. Electrostatics

WEB, CPD, revised September 19, 2014

Objectives

1. To observe the interaction between a charged object and small neutral objects.
2. To verify the existence of two types of charge.
3. To experiment with separating charge from an object.
4. To verify that conductors have charge carriers that are free to move.
5. To demonstrate that charge can be stored after the source of the charge has been removed.
6. To demonstrate that objects can be charged by induction or by direct contact.
7. To observe the force between two charged spheres and the effect on the force of the distance between them.
8. To observe the force between a charged sphere and charged parallel plates.
9. To relate the change in potential energy of a system consisting of two charges to the movement of one charge relative to the second charge.

Equipment

1. One 18″ length of 1.5″ PVC pipe,
2. One square of wool cloth,
3. One insulating PVC rod and stand (white),
4. One capped copper rod and stand,
5. One Van de Graff generator,
6. One Leyden Jar,
7. One transparent PET sleeve with aluminum plate covers and conductive styrofoam ball,
8. Flakes of aluminum foil,
9. Six 5 in. aluminum pie plates,
10. One 1 in. diameter uncoated styrofoam ball with threads attached,
11. Four 1 in. diameter graphite coated (conductive) styrofoam balls with threads attached,
12. Two leads with alligator clips on at least one end,
13. Wooden support stand with adjustable cross dowel and mounted protractor,
14. Two chrome plated spheres and stands,
15. One pair of large conducting foil plates on wooden backing,
16. Tape, common nail.

Safety Risk

This lab uses Van de Graff generators. They are a source of very high voltage static discharge. They are completely safe for use by people with no electrical implants. People with implants such as pacemakers, insulin pumps, etc., should not participate in this lab unless cleared by their medical doctor. The discharge from the generator could damage the electronics. Keep laptop computers, cell phones, PDAs, or any other electronic equipment well out of the way.

The Leyden Jar is capable of holding enough energy to cause pain, or perhaps inflict injury. Do not discharge the Leyden Jar through your body.

Experiment

The Summary section beginning at page 9 will be completed and submitted for evaluation. Only one report per group should be submitted. Be sure that all group members in attendance are noted at the top of the summary sheet.

When using the Van de Graff generator, it need not run continuously. A few seconds is usually enough to charge it sufficiently. From time to time you will want to discharge the Van de Graff generator. You can do this by touching the ground lead to the globe of the generator. In many parts of the Experiment you must start with a neutral charge on a styrofoam ball or other object. You can ensure the charge on a conductor is initially neutral by touching it. You can ensure the charge on an insulator is neutral by grasping or touching the entire surface with your hands.

Electrostatics experiments are notoriously unpredictable, especially when the relative humidity is high. For this reason, you may have to repeat the procedures and re-charge objects several times depending on your *expected* outcomes and observations.

1. Interaction of Charged Objects with Neutral Objects

Using the wool cloth, rub the PVC pipe and observe what happens when you bring it into proximity of (i) small pieces of paper, (ii) small pieces of aluminum foil and (iii) a neutral (unpainted) styrofoam ball suspended by a thread. Record and explain your observations. ***Note:*** The paper and unpainted styrofoam ball are examples of insulators.

Turn the Van de Graff generator on for a few seconds to charge it. Do not touch the sphere otherwise you will discharge it. Hold a neutral conductive styrofoam ball suspended on a thread in close proximity, but don't touch the Van de Graff generator with the ball (if it touches, neutralize the styrofoam ball and start again). You may have to try this several times to see the effect. The styrofoam ball may be discharged by touching it with your hand. Now allow the ball to touch the Van de Graff generator. Record and explain the observations. (Note that the thread can also acquire a static charge.)

2. Existence of One Type of Charge

Rub the PVC pipe with the wool cloth to charge it. You have to rub it quite hard, so squeeze with a firm grip, or even press your hand between your knees. Bring the pipe close to a conductive styrofoam ball that is suspended on the wooden stand. Then make contact between the pipe and the ball. You may have to make contact at different points on the pipe to see the effect. Record and explain your observations.

3. Existence of Another Type of Charge

Charge the Van de Graff generator. Hold a conductive styrofoam ball by a thread and charge the ball by making contact with the Van de Graff. You should verify that the ball has the same type of charge as the Van de Graff. Charge another conductive ball suspended on the wooden stand by rubbing the PVC pipe and making contact with the ball as you did in Part 2 above. You should verify that this ball is charged and has the same type of charge as the pipe. Holding by the thread, carefully bring the ball charged by the Van de Graff into close proximity of the ball suspended on the wooden stand. What are your observations and conclusions?

4. Storing and Transferring Charge using a Leyden Jar

The Leyden Jar is a device that stores energy by means of separated charge. Be careful to hold the jar on its outside. Do not touch the inside of the jar or any piece of metal directly connected to the inside. The Leyden Jar holds a much larger store of separated charge than the Van de Graff and as a result delivers a shock that is more intense (it may be painful if you discharge the Leyden Jar through your body). Turn on the Van de Graff momentarily. Grasping the outside of the Leyden Jar, make contact between the ball of the Leyden Jar and the Van de Graff. Now transfer charge to a neutral conductive ball suspended on the wooden stand by making contact between the conductive ball and the (ball of the) Leyden Jar. How do you know the charge on the conductive ball is the same type (sign, not magnitude) as that of the Leyden Jar?

5. Conductors and Insulators

Place the copper rod in its plastic stand and position a neutral conductive styrofoam ball suspended from the wooden stand such that the ball hangs vertically and is approximately 5 mm from the centre of the end cap of the copper tube (see Figure 2.1 below). Charge the Leyden Jar using the Van de Graff. (*Note: It takes very little charge in the Leyden Jar to observe this effect. If you charge it too much it will arc into the copper rod every time you attempt this procedure.*) Bring the ball of the Leyden Jar within several millimetres of the other end of the copper tube without touching or arcing (you can both see and hear the arcing). You may have to repeat this process several times if you inadvertently contact the tube or there is arcing between the Leyden Jar and the tube. You must also ensure the conductive styro-

foam ball is neutral (by touching with your hand) each time you start this process. Record your observations and conclusions.

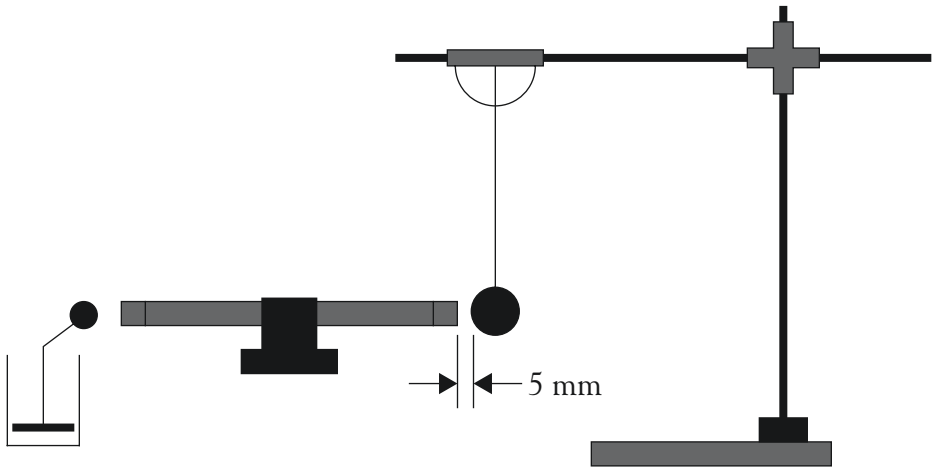

Figure 2.1 Conduction test apparatus

Repeat the process with the copper tube, but this time make contact between the Leyden Jar and the copper tube. Record your observations and conclusions. Replace the copper tube with a plastic tube and repeat the entire process. Record your observations and conclusions.

6. Charging by Induction

Place two of the chrome plated spheres (each supported on a plastic stand) side by side and in contact with each other. Charge the Leyden Jar with the Van de Graff and bring the ball of the Leyden Jar close to the far side of one of the spheres without contact and without arcing (see Figure 2.2 below). Now one of you will grasp the plastic support of the sphere in contact with the finger and separate the two spheres. Upon separation the two spheres are charged. Contrive and conduct a test to determine the type of charge on the sphere on the right. Is the type of charge the same as that of the Van de Graff? The plastic pipe?

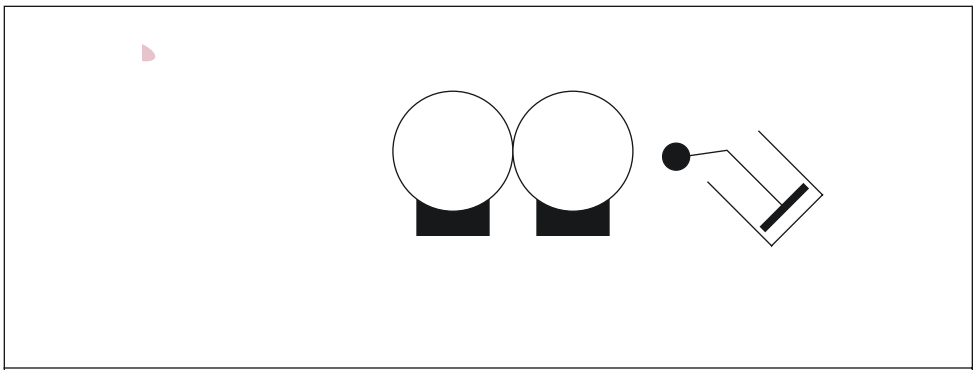

Figure 2.2 Charge by induction apparatus

7. Parallel Plate Capacitor

Position the two neutral rectangular aluminum plates about 25 cm apart such that they are parallel and a neutral conductive styrofoam ball (suspended from the wooden stand) is in contact near the midpoint of one of the parallel plates. Connect a wire from the ground pin of the Van de Graff to the parallel plate furthest from the conductive ball. Connect another wire between the globe on the Van de Graff and the parallel plate closest to the conductive ball (see Figure 2.3 below). Turn the Van de Graff on and leave it running. This should charge the conductive styrofoam ball because it is touching one of the capacitor plates.

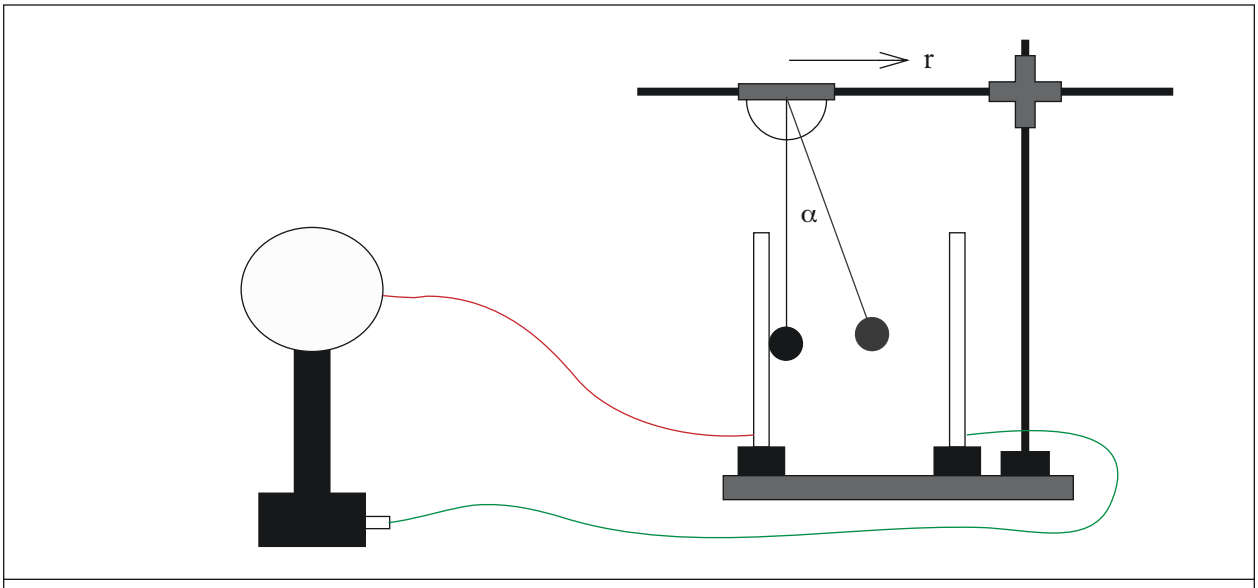

Figure 2.3 Charged parallel capacitor plates

Observe the effect on the angle of the thread when the ball is positioned at different points between the parallel plates. How does the potential energy of the system change (greater than zero, less than zero or equal to zero) as the ball is moved further away from the plate attached to the sphere of the Van de Graff? How does the potential energy of the system change (greater than zero, less than zero or equal to zero) as the ball is moved further away from the plate attached to the ground pin of the Van de Graff? *Note: Potential energy is energy contained in the system due to the relative position of the objects in the system.*

Now carefully slide one of the plates closer to the ball being sure that the ball doesn't touch the plate. What do you observe?

8. Static Equilibrium

Take four of the styrofoam balls, and hold them by the threads so that the balls are all the same distance from your hand. Place the Van de Graff generator on the stool and charge the Van de Graff generator. Swing the four balls in to make contact with the Van de Graff generator so they become charged. Turn the Van de Graff generator off. Now carefully lower the four balls from above the centre of the Van de Graff generator and observe the behaviour of the balls. Record and explain the observation.

9. Repulsion of Like-charged Objects

Discharge the Van de Graff generator. Stack 5 of the aluminum pie plates together. Turn them upside down on top of the Van de Graff generator. Turn the Van de Graff generator on. Record and explain your observation.

10. Mechanical Charge Transporter (the Van de Graff Rattle)

Discharge the Van de Graff generator. Tape one of the aluminum pie plates upside down on the Van de Graff generator globe. Now put the PET sleeve over it and tape it in place. Place one of the small conductive styrofoam balls in the sleeve (use a ball that does not have a thread attached). Now seat a second pie plate in the top of the sleeve and tape it lightly in place. Turn the Van de Graff generator on. Record and explain your observation.

11. Physical Detection of Discharge (Van de Graff Ionization)

Take the nail provided and stick it through a small square of duct tape with the head of the nail on the sticky side of the tape. Tape the nail head to the *side* of the globe of the Van de Graff generator. Turn the Van de Graff generator on and leave it running. Now lick your finger and move it to within a cm or two of the tip of the nail (this will ***not*** shock you). Alternately, you can place the center of the palm of your hand in front of the tip of the nail, about 1 cm away. What do you observe? Record and explain your observation.

Name(s):		ID(s):		Lab Group:	
				Lab Day:	
				Date:	

2. SUMMARY SHEETS : Electrostatics

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/58

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/10

1. Observation of the interaction between a charged PVC pipe and other objects:
   Describe the interaction of the charged PVC pipe with small pieces of paper:

   Describe the interaction of the charged PVC pipe with small pieces of aluminum foil:

   Describe the interaction of the charged PVC pipe with an unpainted styrofoam ball:

   Observation of the interaction between the Van de Graff generator and other objects:
   How does the Van de Graff generator interact with the neutral conductive styrofoam ball?

   How does the Van de Graff generator interact with the conductive styrofoam ball after it has made contact with the Van de Graff generator?

2. A charged PVC pipe or wool cloth is brought into proximity of a conductive (painted) styrofoam ball. Explain what happened in each of the following cases.
The PVC pipe is near the ball, but does not touch it:

The PVC pipe touches the ball:

The wool cloth is near the ball, but not touching it:

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/6

3. Observations and conclusions when a conductive ball that has been charged by the PVC pipe is brought into proximity of another ball charged by the Van de Graff generator:

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4. How do you know the charge on the conductive ball (put there by contacting the ball on the Leyden Jar) is the same as that on the ball of the Leyden Jar?

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5. Conductors and insulators – observations and conclusions.
The Leyden Jar is brought close to the copper rod without touching or arcing:

The Leyden Jar touches the copper rod:

The Leyden Jar is brought close to the plastic rod without touching or arcing:

The Leyden Jar touches the plastic rod:

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6. Charging by induction – describe the procedure used to determine the type of charge on the *other* sphere (the right hand sphere of Figure 2.2).

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7. Between the plates of the parallel plate capacitor how does the angle, α, vary as a function of displacement, r?

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How does the potential energy of the system change when the ball is moved away from the plate connected to the globe of the Van de Graff? (Hint: see if you can think of the analogous situation in the context of gravity.)

How does the potential energy of the system change when the ball is moved away from the plate connected to the ground pin of the Van de Graff?

What happens to the angle of the support thread as the plates are brought closer together?

8. Static equilibrium and 4-suspended charged styrofoam balls – explain your observations (what happens and why?):

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9. Explain what happens to the pie plates.

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10. Explain what happens to the conductive ball between the pie plates:

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11. Explain what happens when you place your finger near the tip of the nail attached to the Van de Graff generator (what do you feel and why).

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/4