Electrostatics

For this lab, please pair up with someone. During the course of this semester, you will be working either in a group of 2 or 4 (or, occasionally, 3) depending on the specific lab activity. When you have finished the experiments, your group will turn in one lab report clearly describing your findings, results, and answers to lab questions. The lab format and policies should have been given to you already as handouts. If you do not have them, please ask your TA for copies.

Electrostatics is the study of the electric fields and forces created by static arrangements of electric charge in space. In doing experiments, charged particles will move around, but we are concerned primarily with what the situation is after everything has stopped moving. That is, although we will have to think about how charges get from one place to another, we will not try to analyze what is happening in detail while they are actually in motion. The reasons for the configuration of charges in a given experiment can ultimately be traced back to Coulomb's Law, which describes the force that one point charge exerts on another. Coulomb tells us that the effects of a charge can be canceled out by another charge with opposite sign at the same position (or extremely close by), so what we are really interested in is the net charge carried by a given object. Net charge is a property that we infer from observed interactions. It is not necessarily made up of electrons\(^1\).

Centuries ago, natural scientists found that conductors (materials in which charge moves freely) behave differently than insulators (in which charge cannot move). Most objects in daily life (whether conductors or insulators) carry '+' and '-' charges in equal numbers and therefore carry no net charge. We say that they are electrically neutral.

In this lab, you will learn several methods for transferring charge from one object to another in large enough quantities that you can see (or feel) the effects of net charge. To get the benefit of the lab exercises, you must think carefully about what is happening to the charges as you execute various maneuvers. Don’t settle for hazy notions of what is going on; and make sure your understanding explains all of the observed phenomena in a logically consistent way.

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\(^1\) Consider what happens if you remove electrons from an electrically neutral material, rather than add them!
Introduction: methods of giving a net charge to conductors and insulators

- **Conductors** may be charged by two methods:
  - **Charging by conduction**: Referring to the Illustration 1, say that conductor A already carries a net charge (that it acquired somewhere else). If we wish to charge conductor B, then we touch B to A. Since charges flow freely in conductors and like charges repel, the Coulomb forces cause some of the charges on A "flow" onto B. Charge is neither created nor destroyed, so this means A will lose some of its charge.

  ![Illustration 1. Charging by conduction](image)

  Illustration 1. Charging by conduction

  - **Charging by induction**: Referring to Illustration 2, say that we already have a charged object A. This may be a conductor or an insulator — all that matters in this case is that charges exert forces on each other. If we have a neutral conductor B that we wish to give a net charge, we first move B near to A (without touching). This causes the '+' and '-' charges within B to separate, since like charges are repelled to the far side and opposite charges are attracted to the near side. If we touch the far side of B with another conductor (a finger, for example), we provide a path that allows the charges to separate further. Some charge flows into the finger, leaving a net charge on the original conductor.

  ![Illustration 2. Charging by electrostatic induction](image)

  Illustration 2. Charging by electrostatic induction
• **Insulators** may be charged using frictional effects by rubbing them against another material having a different electrical affinity. Below is a list of electrical affinities for different materials. When two materials with different affinities are rubbed together and then separated, the one with a more negative affinity will end up with an excess of negative charge. The other (with a more positive affinity) will have an excess of positive charge. This will occur to some extent with any two materials, but may not be obvious unless both materials are good insulators. Why would this be more apparent for insulators than for conductors?

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**Hands-on activities**

**Goals**

• Experimentally determine whether a conductor is being charged by conduction or electrostatic induction.

• Use electrical affinities and Scotch Tape to deduce whether an object is negatively or positively charged.

• Use your observations to charge two spheres oppositely or identically (and prove it).

**Materials**

• 2 metal spheres on insulating stands
• Foam slab
• Piece of wool
• Scotch "Magic" tape
Experiment 1: Static charges and forces on conductors

In this activity you will be using pieces of scotch tape as detectors (and carriers) of electric charge.

CHARGING BY FRICTION

1. From the roll of tape, tear off two 15 cm pieces. On each piece, fold over one end about 1 cm to form a handle. This makes it easy hold each piece of tape. Label them "A" and "B".

2. Stick pieces A and B separately onto the table. Make certain they do not touch each other. Each piece is now in contact with the tabletop material. Press the tape with your fingers to maximize contact.

3. Peel off piece A (be careful only to touch the "handle") and hang this from the edge of your lab table. Write down your observations. What can you conclude about the charges on each piece of tape?
   - Peel off piece B and bring it close to piece A. What do you observe?
   - Hold the metal sphere by the plastic stand, and bring it near piece A. Also (to compare) bring it near piece B. What do you observe?
   - Based on your observations and what you know of different charging mechanisms, sketch (and describe) the charge configuration on the sphere when it is held near the tape in step b.

4. For this one, prepare new pieces of tape, since your previous pieces may have unknown charge that lingers on them. Now, try something different: Press piece A to the table, then adhere piece B exactly on top of piece A. Peel the combination off the table (as a single unit), then briskly peel them apart.
   - What happens when they are brought close to each other? What do your observations imply about their charges?
   - Repeat the second step from the previous question. What is different now (if anything)? Discuss your observations with your group members. Again sketch (and describe) what charges are "doing" on the sphere.
Experiment 2: Induced charges on conductors

You should have a foam slab at your lab station, together with a piece of wool. The foam slab is charged by friction (e.g. rubbing vigorously with wool). We can examine the behavior of objects brought near to or in contact with it.

5. Charge the foam. (You will have to re-charge the foam frequently if you perform this experiment on rainy days or during the summer!) Use the table of electrical affinities to write down the polarity (positive or negative) of charge which has been acquired by the foam:

6. Give pieces of tape A and B opposite charges, and determine whether each is positively or negatively charged. You will be able to use these pieces of tape as + and - charge sensors. Remember, if at some point you need to re-charge the pieces of tape, you should re-test which is positive and which is negative.

   Tape charges:   Piece A _______________   Piece B _______________

7. Predictions: Touch a metal sphere to neutralize it. Holding the plastic handle, bring the metal sphere in contact with the charged foam slab. Do not touch the sphere at any time. Take the sphere away from the foam. Has it acquired a charge? Will it shock you if touched? If it has acquired a charge, predict the polarity. Sketch and briefly explain your predictions, then check to see if you were right.

8. Try something different: When the sphere is neutral, bring it into contact with the foam, and touch the sphere while it is touching the foam. What happened? Now take the metal sphere away from the foam. Touch the sphere again.

9. Neutralize a metal sphere by having a lab partner touch it. Bring it close to but not touching the charged foam. Touch the sphere, then carry it several feet away. What happens when you touch it?

10. Devise an experiment to figure out precisely what is happening in questions 8 and 9. Remember that your scotch-tape charge sensors can be very useful. As you discuss what you will do, consider the following: (1) Is what you observe in 8 and 9 the same thing or two different things? How will you figure this out? (2) Your conclusions need to be consistent with each other and with the other observations you have made in the other activities in this lab. (3) Your results have to be repeatable, which means you will need to be careful when you do your experiments and think about whether your method is really achieving the aim you hope to achieve.
Describe your reasoning, methods, and results. Based on your conclusions, sketch and briefly explain what happens to charges on the sphere in question 8. In the table below, sketch "snapshots" of what happens to charges in question 8. Use tiny “+” and “-” symbols:

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<td></td>
<td>Rubbing the Foam</td>
<td>Setting the sphere on the Foam</td>
<td>Touching the sphere resting on the Foam</td>
<td>Lifting the sphere</td>
<td>Touching the sphere after it is lifted.</td>
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**Experiment 3: Charging two spheres**

11. Using knowledge you have acquired from your experiments, sketch and briefly describe a method to give the metal spheres a nearly identical + charge without touching the charged foam.
   
   • Verify that your method works, and demonstrate the proof to your TA.

**Level II Bonus point:**

12. Sketch and briefly describe a method to give the metal spheres identical opposite charges.
   
   • Verify your method works, and demonstrate the proof to your TA.

**Level III Bonus point:**

13. Sketch / briefly describe a method to give the metal spheres nearly identical negative charges.
   
   • Verify your method works, and demonstrate the proof to your TA.