A Qualitative Study of Electrostatics

We all experience static electricity in everyday life. Amongst the many examples are: static cling, a bad hair day, getting zapped when you reach for a door knob, destroying a computer chip when replacing a board on your PC, the magic of Saran Wrap. This lab activity uses another piece of our everyday lives to explore static electricity. In your experimental “kit,” you will find a roll of scotch tape. This modest and unassuming piece of “equipment” will help you understand:

• the qualitative features of Coulomb’s Law;
• the existence of two types of charge;
• the conservation of charge;
• the behavior of insulators and conductors.

Note that inconsistent results will be obtained if you are not careful while handling the materials in the activity – so please follow the directions as faithfully as possible! The following experiments will need you to use strips of scotch tape that are about 10 cm long. Each time you are asked to use a strip of tape, fold over one end to form a non-sticky handle for easy handling.

A. Making a “T” Tape: Stick a 20 cm strip of tape on the lab table, sticky side down. This tape forms a standard base for making a “T” (for “top”) tape. Stick another strip of tape on top of this one, smoothing it down well with your thumb and fingers. Using a pen or marker, label the handle of this tape with a T. With a quick motion, peel off the T tape from the base tape. Test whether this T tape is attracted to your finger – if it is not, remake the tape. Once you know how to make a T tape, prepare two such tapes. Holding each one by the handle, bring the slick (non-sticky) sides of the two tapes towards each other. Observe what happens, noting how the behavior changes with the distance between the tapes.

What happens as the tapes are brought closer together?

What qualitative conclusions can you draw about the relationship between electric force and the distance between charges? How do your observations relate to Coulomb’s Law?

Can you tell from your experiment so far whether the tapes carry a positive charge or a negative charge? Briefly explain your answer.
**B. Making a “B” tape:** Place another base tape on the lab table as before. This time, use a marker to label the handle B (for "bottom"). Press another strip of tape on top of the B tape, sticky side down; label the handle T. Make sure the two tapes have stuck to each other smoothly. Now, **VERY SLOWLY** remove the pair of tapes from the table. Check whether the pair of tapes is attracted to your finger – if you do see an attraction, have one of your teammates rub the slick side of the tape with their fingers or thumb. Once you have made sure the pair of tapes is not charged, peel the pair apart to get a separate T tape and B tape. Let someone else in your team make another pair of B and T tapes. As before, your aim is to study the interaction between these different tapes by bringing the slick sides towards each other.

Describe the interaction between two T tapes, between two B tapes and between a T tape and a B tape.

**T-T interaction:**

**T-B interaction:**

**B-B interaction:**

Why did the two kinds of tapes acquire the types of charges that you observed? What **fundamental property of charge** is demonstrated by this experiment?

**C. Testing for charge with an electrometer:** An electrometer consists of a pair of extremely flexible thin metal foils attached to the bottom of a conducting rod as shown. The foils are fragile and usually protected, in this case by a glass flask. Bring a freshly charged T tape near the ball at the top of the electrometer, **but do not touch**. Observe what happens to the foils. Repeat with a freshly charged B tape.

Why do the foils respond the way they do?

Can the electrometer be used to detect the presence of electric charge? Can it be used to determine the **type** of charge present?
D. Identifying charge type: Using the additional equipment that has been supplied to you (a glass rod, a plastic rod, a piece of fur and a piece of silk), design and carry out an experiment that allows you to determine the sign of the charge on the tapes. Describe the experiment and its results, as well as any conventions that you may have followed for the sign of charge.

E. Superposition  Obtain a small pith ball attached to an insulating string. Charge a rod (A Van de Graph generator may be needed for this on humid days)  Touch the ball to the charged rod and observe the behavior of the ball after it touches the rod.

Is the ball changed? If so, does the ball have the same charge or opposite charge as the rod? Explain how you can tell.

Explore the region around the rod with the charged pith ball (this will be our “test charge”). Based upon your observations, sketch vectors to represent the net electric force on the ball at the points marked by an “x”.

Now take two rods (the second about 15 cm away from the original rod). Make sure both rods are charged and the test pith ball are charge. Based upon your observations, sketch vectors to represent the net electric force on the ball at the points marked by an “x”. 
What is meant by the principle of superposition?

Are your results consistent with the principle of superposition?

Does the left rod exert a force on the test charge when the test charge is directly to the right of the right rod? Explain.

Check your answer by observing the test charge at this point when the left rod is moved towards the right charge.

F. Electric Interactions Consider a small ball with zero net charge, with positive charge on one side and negative on the other. The ball is placed near a positive point charge as shown.

Would the ball be attracted toward, repelled from or unaffected by the positive point charge? Is your answer consistent with Coulomb's Law? Explain.

To see how charges interact with objects that do not have a net charge, another pair of T and B tapes. First, bring an insulator (e.g., a plastic pen) towards each tape and observe what happens. (Make sure that you do not allow the insulator to touch the tape.) Next, bring a conductor (e.g., a metallic object such as a key) towards each tape and observe what happens. (Make sure that you do not allow the conductor to touch the tape.) You should check if the tapes are still charged with the electrometer before each test.

Describe the interaction between the insulator and each tape.

**Insulator-T tape:**

**Insulator-B tape:**
Using a simple atomic picture of an insulator, explain your observations. A sketch may be useful.

Describe the interaction between the conductor and each of the tapes.

**Conductor-T tape:**

**Conductor-B tape:**

Using your knowledge of the nature of charge within electrical conductors, explain your observations. A sketch may be useful.

Was the interaction between the conductor and the two tapes stronger or weaker than that between the insulator and the two tapes
G A model of electric charge

Two students discuss what would happen if, instead of being uncharged, the conducting object had a small net charge. Assume the object and the tape both have positive charge.

Alexis: Since the object is a conductor, the excess charge will be evenly distributed on the surface. object the ball and the tape have like charge, they will repel.

Simon: The tape will still repel the positive charge on the object and attract the negative charge on the object. If the excess positive charge is not too much they may still attract each other.

Alexis: That can't be true. If the ball has a net positive charge then there is no negative charge on the ball.

So you agree with either student? Explain.

Two Identical Balls are mounted on stationary insulating stands. Initially, the balls have the same non-zero net charge.

Draw a separate free-body diagram for each ball. Identify any third law force pairs. Label each force to indicate
- the object exerting the force
- the object on which the force is exerted.
- the type of force (gravitational, normal etc)
- whether the force is a contact or a non-contact force

Are there any forces represented on your diagrams that are equal in magnitude?
Suppose the charge on the ball on the right is decreased so that it is less than that on the ball on the right. How do the free-body diagrams in this case compare to the free-body diagram of the previous case. Explain

Suppose the net charge on the ball on the right is reduced to zero. How do the free body diagrams compare with the previous two cases.

Are your answers here consistent with your observations of the interactions between the charged tape and the uncharged metal object? If not, modify your answers above so that they are consistent.