

Static Electricity

(A Qualitative Study of Electrostatics using Sticky Tape)

Goals:

- To become familiar with basic electrostatic phenomena
- To learn the *charge model* and learn to apply it to conductors and insulators
- To understand polarization and the attraction between neutral and charged objects

Equipment:

- Sticky tape (*e.g.* Scotch™ brand)
- PVC pipe
- Glass rod
- Wool cloth
- Rabbit fur

Introduction:

Various civilizations have recorded observations of what we would typically call “static electricity” for thousands of years, dating back to the ancient Greeks and possibly even earlier. They noticed that when pieces of amber were rubbed or polished with animal fur, the amber could attract small bits of straw, even causing them to fly through the air to reach the amber. In the Elizabethan era, the English physician William Gilbert (1544–1603) first referred to this attraction as the “electric” attraction, deriving from the Greek word for amber, *elektron*. From these early beginnings, we have the modern words of *electric*, *electricity*, *electrical*, and so on.

Gilbert was able to determine two “kinds” of electricity. In his terminology, amber, when rubbed with fur, acquires “resinous electricity” and when rubbed with silk, acquires “vitreous electricity.” He noted that pieces of amber with the *same kind* of electricity *repelled* each other and pieces with the *opposite kind attracted* each other.

Years later, the American printer, author, philosopher, diplomat, inventor and scientist Benjamin Franklin (1706–1790) proposed that these two “kinds” of **electric charge** be named positive and negative, symbolized by (+) and (–), respectively, and this is the terminology that we still use today. Franklin claimed that all materials possess a single kind of electrical “fluid” and that the action of rubbing one material against another did not create an electrical charge, but merely transferred some of this “fluid” from one body to the other. He presumed that **neutral** bodies consisted of equal numbers of positive and negative charges, and that rubbing transferred some positive charges from one body to another, leaving the first body with a **net** negative charge and the other with a net positive charge. He again confirmed that the same type of charges were found to repel each other while opposite charges were found to attract each other.

Through a very careful set of experiments involving a torsion balance and equally charged pith balls, the French engineer Charles Coulomb (1736–1806) was able to *quantify* the electric

attraction and repulsion in the form we now call “Coulomb’s Law”. Coulomb’s law describes the force between two charged particles, labeled 1 and 2, and can be stated:

1. If two point particles, having charges q_1 and q_2 respectively, are a distance r apart, the charges exert forces on each other with a magnitude of:

$$|\vec{F}_{1on2}| = |\vec{F}_{2on1}| = k \frac{|q_1||q_2|}{r^2} \quad (\text{Eq. 1})$$

These forces are equal in magnitude, but opposite in direction.

2. The forces are directed along the straight line drawn between the two charges. The forces are mutually attractive if the charges are opposite, and mutually repulsive for like charges.

We will not repeat Coulomb’s experiments, but we can make some qualitative observations using everyday items such as sticky tape, plastic pens, and metal keys. With equipment as simple as this, we can repeat the same types of experiments that natural philosophers, inventors, and scientists have been performing for over 2400 years.

Today, the process of rubbing two materials together to transfer electric charge is known as **triboelectric charging**. Table 1 below indicates the relative ability of a material to gain or lose charges due to rubbing. More plusses (+) next to a material in the chart indicates a greater ability to obtain a net positive charge. More minuses (–) next to a material in the chart indicates a greater ability to obtain a net negative charge.

In general when two objects listed in the chart are rubbed together, the material listed higher in the chart becomes positively charged and the material listed lower in the chart becomes negatively charged. The greater the separation of the materials in the chart, the greater the magnitude of the charge transferred.

Material	Relative charging with rubbing
rabbit fur	+++++
glass	+++++
human hair	++++
nylon/wool	+++
silk	++
paper	+
cotton	–
wood	--
amber	----
rubber	-----
PVC	-----
Teflon	-----

Table 1 Triboelectric charging

With the table above, we can typically determine which type of net charge (positive or negative) will be acquired by two materials when we rub them together. But we also find it useful to classify materials by how easily charge can flow along or through them. Materials that easily allow charge to flow through them are known as **conductors**. We call those materials though

which charge cannot easily flow **insulators**. As we'll see below, it's the structure of the materials at an atomic scale that makes them different.

In Figure below, we show a crude atomic model of an insulating material. The material is assumed to be electrically neutral, which means that it must contain equal numbers of positive and negative charges. Today, we know that every atom consists of a positively charged nucleus and a negatively charged electron cloud, represented in the figure by plusses for the nuclei and minuses for the electrons in the cloud. The nuclei remain essentially fixed with respect to each other, but the electrons are continually in motion.

In an insulating material, all of these electrons are tightly bound to their nuclei and cannot move very far away from them. In our crude model, we use a minus sign to symbolize an electron (or many electrons) closely orbiting the plus sign representing the positively charged nucleus. These orbits might distort a bit due to external or internal influences, but would be quite difficult to cause an electron to leave its host atom.

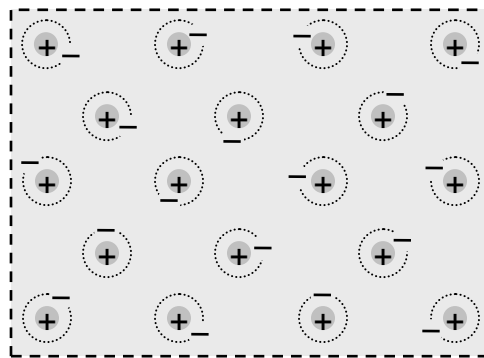


Figure 1 Cross section of an atomic model of an insulating material. The negatively charged electrons are tightly bound to their host nuclei, and thus cannot move around freely throughout the material. We say then that these materials do not *conduct* electricity well.

In contrast, an atomic model of a conducting material is shown in Figure 2. Again, if the material is neutral, there must be equal numbers of positive and negative charges. Here, though, not all of the negatively charged electrons are completely bound to their nuclei. The outermost electrons, typically called the **valence electrons**, are free to wander anywhere throughout the solid. They continually bounce about the solid randomly, and they can very easily and rapidly redistribute themselves if external (or internal) conditions change.

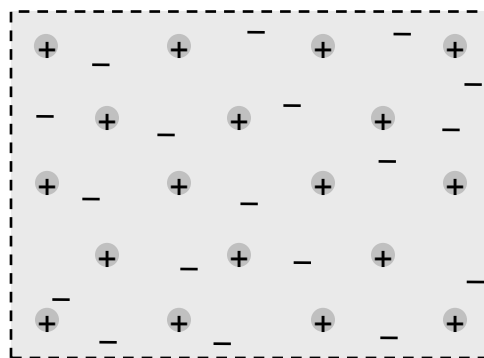


Figure 2 Cross section of an atomic model of a conducting metal. The electrons are not tightly bound to their nuclei and thus bounce randomly throughout the metal much like the atoms of a gas or liquid. We often refer to these electrons as a “sea of electrons” to remind us of how easily they can flow through the metal.

Name: _____

Sect.: _____

Name: _____

Name: _____

Directions:

Note: If you are not careful while handling the materials in the activity, you may obtain inconsistent results. Please follow the directions as faithfully as possible!

The following experiments will need you to use strips of tape that are about 20 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, as in Figure 3.

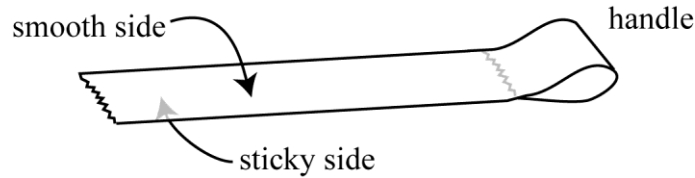


Figure 3 Preparing a strip of tape by making a non-stick handle

Activity 1: Examining a “T” strip

Stick a 15-cm strip of tape on the lab table, sticky side down. This tape forms a standard base for making a “T” (for “Top”) strip. 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 strip with a “T”. With a quick motion, peel off the T-strip from the base strip. Test whether this T-strip is attracted to your finger (but do not let it touch your finger). If the strip is not attracted to your finger, repeat the steps above.

Once you know how to make a T-strip, prepare two such strips. Holding each one by the handle, bring the slick (non-sticky) sides of the two strips toward each other. Observe what happens, noting how the behavior changes with the distance between the strips.

Q1. Describe and explain what happens as the two T-strips are brought closer together.

Q2. What **qualitative** conclusions can you draw about the relationship between electric force and the distance between charged objects? How do your observations relate to Coulomb’s Law?

fingers or thumb. This is important: by rubbing your finger along the pair, you **discharge** the pair, ensuring that the *pair* of tape strips is neutral.

Once you have made certain the pair of strips is neutral, peel the pair apart to get a separate T-strip and B-strip. Let someone else in your team make another pair of B and T strips in the same way. As before, your aim is to study the interaction between these different strips by bringing the slick sides towards each other.

Q5. Summarize the interactions between two T-strips, between two B-strips and between a T-strip and a B-strip.

T-T interaction:	(a) no interaction	(b) they attract	(c) they repel
B-B interaction:	(a) no interaction	(b) they attract	(c) they repel
T-B interaction:	(a) no interaction	(b) they attract	(c) they repel

Q6. In Q4, you determined the sign of charge on the T-strip. Based on that sign, and the interactions above, what is the sign of the B-strip? Describe how you could use the same method you described in Q4 to verify the sign of the B-strip, and do so.

Q7. Given that you made certain that the pair of tape strips was neutral before separating the strips, is it possible to create a T-strip and B-strip that repel each other (provided that you don't allow them to come into contact with anything else)? Explain why or why not.

Activity 3: Testing charged strips with conductors and insulators

Make another pair of T and B strips. Suspend them from the edge of the table as shown in Figure 4 below.

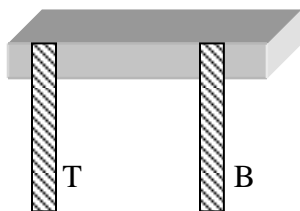


Figure 4 Hanging T-strip and B-strip from edge of table

Hold a neutral conductor (*e.g.* a metallic object such as a key) near each tape and observe what happens. Make sure that you do not allow the conductor to touch the tape.

Q8. Describe the interaction between the conductor and each strip.

Conductor/T-strip interaction:	(a) no interaction	(b) they attract	(c) they repel
Conductor/B-strip interaction:	(a) no interaction	(b) they attract	(c) they repel

Q9. Using a few sentences and a clear sketch, explain these observations. Your sketch should show how the different charges in the conductor (“plusses” and “minuses” for now) are distributed when the conductor is far away from a charged tape strip and when it is close to a charged tape strip.

Sketch:

Now, hold a neutral insulator (*e.g.* the end of a plastic pen or the glass rod, provided that it has been discharged) near each tape and observe what happens. Make sure that you do not allow the insulator to touch the tape.

Q10. Describe the interaction between the insulator and each strip.

Insulator/T-strip interaction:	(a) no interaction	(b) they attract	(c) they repel
Insulator/B-strip interaction:	(a) no interaction	(b) they attract	(c) they repel

Q11. Using a few sentences and a clear sketch, explain these observations. Your sketch should show how the different charges in the insulator (again, you can just indicate charges with “plusses” and “minuses”) are distributed when the insulator is far away from a charged tape strip and when it is close to a charged tape strip.

Sketch:

Q12. Based on your observations, which was stronger: the interaction between the conductor and the tape strips or the interaction between the insulator and the tape strips? Explain this observation.

Analysis

Q13. If you observe that two objects are electrostatically attracted to each other, are they necessarily oppositely charged?

Q14. Offer an explanation as to why the charged strips of tape are attracted to your finger when you bring it close to the strips.
