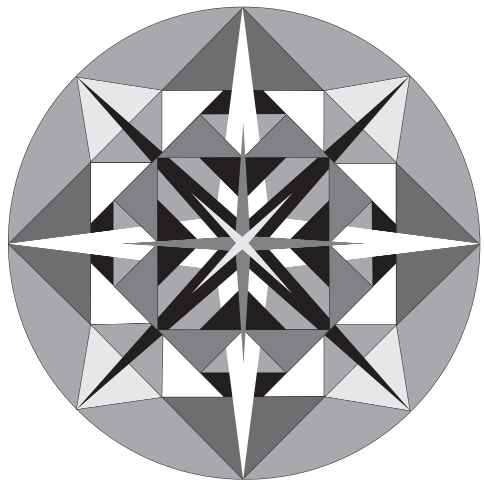

# Investigation E4: Electric Charge

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**Goals:** *Observe the behavior of charged objects and the charging of those objects.*

This investigation is intended to be carried out as a combination of Home Activities, Seat Activities, and Demonstrations. It is *not* intended to be as extensive, nor in-depth, as our study of circuits. In the large-class setting where full-class meetings are separated from lab session, this investigation is not intended to occupy any laboratory time. We recommend that only about one class period be taken up; treat this investigation as minimally as possible. You should choose from the available activities those that you think make sense for your situation and to accomplish the goal for this investigation.

The major goal is for the students to have direct kinesthetic experience with the repulsion and attraction effects associated with charged objects. The function of the experience is to provide a possible mechanism to be used in making sense of the motion of the "train cars" or carriers in the models the students are developing.

Keep in mind that this unit on electricity is intended for 20 hours of instruction time. Diversions into features of static electricity, which do not directly impact on current electricity, detract from the central goal of this unit. Our work developing this unit leads us to believe that a unit on static electricity would be worthwhile in its own right for at least two reasons. The first is that electrostatic phenomena are worthy of study in their own right. The second is that electrostatics was one of the avenues of investigation which contributed to modern ideas about the nature of atoms.

The conceptual goals of the previous investigations are extremely important. If they have not been realized, then this investigation can and should be postponed in favor of continuing discussion. Some changes in wording in Investigation E5 might be appropriate, if you decide to postpone Investigation E4 until later.

This Investigation E4 could just as easily be treated at some point after Investigation E5. Since this investigation, even for the large-class "lecture separate from lab" setting, is intended to be done at home and in class, this postponement should be seriously considered. A case could be made for not even including Investigation E4 at all for reasons we give below. We have found that many students decide that the carriers or "toy-train cars" pushing each other along makes sense to them. This conclusion is far better than having them merely be able to repeat back the physicists' "story" that electrons move around in the metal of the wires without reasons that explain why such a story makes sense.

The students' notions about the atomic nature of matter and the constituents of atoms are generally not sufficiently similar to those of the scientist for the students in general to make the kind of connections between electrostatic phenomena and circuit electrical phenomena that we see normally attempted in curricula. While most students can repeat things that they have been told about atoms and subatomic particles, they can do little more with this information because it is not connected to notions they actually use about the nature of matter. For many of the students, atoms seem to be little spherical particles which have the same properties as the material that they macroscopically compose. Hence, copper atoms are little metal spheres that are "copper colored" and conduct electricity. Their ideas seem to include the notion that space is essentially filled by these atoms so the notion of something moving through this filled space is not one that makes sense to them.

The clues that the students do not understand the electrostatics activities that are written by curriculum developers are found in the observations where they routinely misinterpret instructions and succumb to pitfalls that we naturally avoid. They seem not to know why they are performing the acts we request. The natural response from the instructor is to provide greater detail in the instructions and to emphasize what not to do. This tendency usually results in the triggering of the well-reinforced student response who then see what they are supposed to see. The sense-making, explanation-generating process turns off in the students and the whole exercise becomes a waste of time. It would be better for the students to remain with a fluid-like model of electricity than for them to avoid the explanation- generation mode and back into being shown and told what they are supposed to see.

The essential features of the classical view of the electric nature of matter are that there are two types of charge and that these two types exist in approximately equal numbers in "uncharged" matter. We see manifestations of these charges when we manage to separate the charges and congregate an excess of one or the other in a location, which causes a corresponding congregation of its opposite in another location.

The notion of charge separation is not the students' working model for what is happening. In everyday language one would simply say that an object (a rubbed balloon or a piece of adhesive tape recently peeled from a roll) is charged, which is consistent with a notion of charge as an entity which can be given to an object. Franklin seemed to believe that rubbing or friction endowed an object with "excess electrical fire." It is not unreasonable that students would produce a similar notion. As a result, the students do not spontaneously "know" to be careful about various things. For example, if there is no rubbing then there would be no charge separation, hence they do not allow for situations where charge might be transferred by contact or for the dissipation of excess charge via interaction with the air. For this reason we find the introduction of electrostatics has the strong potential to become a complication rather than a natural addition to a unit on electric circuits.

From our experience of carefully listening to and watching students as we worked on developing this unit, we believe that there are two circumstances under which one might justify the introduction of electrostatics in connection with a unit on electric circuits. The first and optimal approach is to consider electrostatics as a unit in and of itself. If anything, it appears that the students have an undifferentiated, pre-Franklin-esque or "single-fluid" notion of electric charge. The idea is to get them to consider electrostatic phenomena and allow time to make modifications in their initial notions of electric charge. This would require at least treating the topic as a whole and separate unit. The second, which we think might be possible, is to merely generate an experience with repulsion and attraction of charged objects. This way the students have a recent experience with a mechanism in which objects act on each which provides an approach to thinking about how things might "be caused to move around the circuit." We leave the generation of a whole unit on electrostatics to a future effort.

An appropriate accomplishment for the students is to realize a model of electricity that *differentiates the need for something that gets all the way around a circuit from something else which gets used up, includes the notion that the "stuff" which gets all the way around is not "sourced" in the batteries, but must be everywhere already, hence the battery is a "voltage or oomph" producer and not the source of current, and includes the notion of bulbs as resisters as well as consumers, as well as the other characteristics which we will mention in our materials.* This can be done in a sensible way, *even in the context of a single-fluid model*. After all, in most elements of electric circuits one only needs one type of charge moving to explain what is going on. The major exception among simple circuit elements might be the battery, but we along with more traditional physics approaches do not treat the mechanisms within the battery explicitly. We believe that moving to a two-fluid model of charge is an important future goal, but that this takes a subordinate role given where our students are starting, the time we have to work with, and what a well-developed single-fluid model can do for students. It is far superior to an attempt at a two-fluid model which does not accomplish the ideas listed above.

To implement the second approach, we recommend that you use only Activities 4.1 and 4.2 with 4.7 and that you leave out the rest of the activities in this unit. A next cut would be to include 4.3 and 4.4, but this runs the serious risk of falling into the trap of becoming frustrated that the students do not make the same use of the two-charge model as you do when you see the observations as so obviously supporting it. Either way you may want to provide the students with the letters from Benjamin Franklin for interest. Activities 4.5 and 4.6 are left over from our attempts to include electrostatics more thoroughly in this unit. We do not at this point recommend using them except in a separate electrostatics unit.

**Notes**

# Activity E4.1: Generating Charged Tape

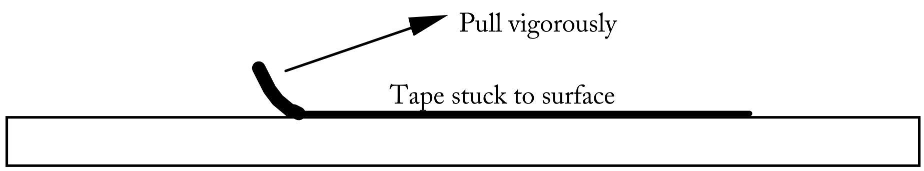
(Home Activity)

*Equipment:* Scotch™ Removable Magic™ Tape, table edge or stand, piece of wood (~1 meter long) to hold tape strips, and moistened sponge.

*Equipment Note:* Any transparent tape can be used, although some work better than others. We have used Scotch™ Removable Magic™ Tape because some of the other tapes stripped the finish off our tables when the tape was pulled up. The brand of tape and the surface that it is adhered to both affect the sign of the charge which the tape develops. To do specific comparisons of the students' observations, you must control for these two variables.

Many students have had some informal experiences with static electricity. In this activity they have what is often their first experience specifically noting the behavior of charged objects. This activity could just as easily be a seat activity.

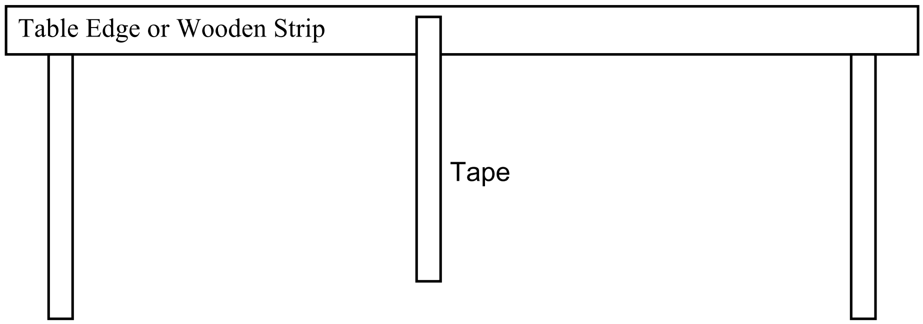
**TRY THIS: Measuring with your meterstick, pull off a 40- to 60- cm piece of transparent tape (*e.g.*, Scotch™ Removable Magic™ Tape) and fold a short section of it (~1 cm) to make a nonsticky "handle" at that end of the tape. Lay the tape adhesive side down and slide your finger along the tape to firmly attach it to the smooth, dry surface of a table or counter top. Peel the tape from the surface vigorously pulling up on the handle you have made on one end. Try not to let the tape curl up around itself or your fingers.**




It is important that the tape be adhered over its whole length to the surface by taking a finger and rubbing the tape down on the surface. It seems that a vigorous pull of the tape off the surface generates more charge. We started using only 20- cm lengths of tape to conserve tape, but such short lengths are frequently less flexible and less responsive to pulls or pushes from other charged and uncharged objects. We now urge students to use much longer pieces of about 40 - 60 cm.

It is the separation of the tape from a surface to which it is attached that results in a charge separation. Since the constituents of the tape are essentially non-conductors, then it is the sticky side of the tape which becomes charged when the tape is pulled up. It is important not to let that side come in contact with other objects, so as not to lose or disturb the charge that has been generated. It is also important that it be recognized that the excess charge on the tape dissipates into the air in time. The rate of dissipation depends on humidity and other factors. Generally the drier and clearer the air, the lower the rate, but it happens nonetheless. Tapes must be frequently checked and recharged if found to be low on charge.

**While holding the tape up by the handle and away from other objects, attach the tape to the horizontal wooden piece or the edge of your table.**




**Bring your finger or have someone else bring their finger near, but not touching, the nonsticky side of the tape.**

*Is there any sign of interaction between the tape and the finger?* **Record your observations in the space below.**

If the tape is charged, it will be strongly attracted to the finger.

**Try this with one or two other objects, ONLY one or two at this time.** ***Is there any sign of interaction between the tape and these other objects?*** **Record your observations in the space below.**

Generally, attraction is the response between a charged object and an uncharged one, due to the phenomenon of electrostatic dipolarization causing a dipolar attraction between the two objects. We urge students not to spend lots of time testing objects, because they will spend some time later doing this. At this point testing objects does not introduce any significant experiences which we want them to consider.

**You may already realize that this interaction that you see is evidence that the tape has gained a new property called "charge." When we cause this to happen to the tape, we say we are "charging" the tape.**

**You can remove the tape's ability to behave as you have observed above by lightly running your finger along the nonsticky side of the tape. If this does not work adequately, you may get a better result by dragging the nonsticky side of the tape across a moistened sponge. Be careful not to let the tape get too wet. Some types of tape have water soluble adhesive, so do not carry out this process on the sticky side.**

**E4.1(2)**

- **It is important that you find a way to reliably and completely discharge the tape, so keep trying things until you find a method that works. Even when you have found a reliable method, you should still check the results of your effort.**
- **It is also important that you find a way of telling whether or not something is charged.**

**Record the technique for telling that something is discharged, *i.e.* , is not charged, in the space below.**

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**How to determine that something is discharged:**

We find this last part to the investigation necessary for the reasons stated in the introduction to the unit. In order to observe the phenomenon as we intend, certain conditions have to be obtained. Neither these conditions nor how they are obtained are obvious to the students, yet the students will often miss the basics that we desire them to see. It is important that they know how to completely discharge a piece of tape and how to check to see that it is, in fact, discharged. We frequently see evidence that the students do not understand what is going on here and that they feel if they have gone through the motions of discharging then that should be enough. They believe checking to see that this is accomplished is not necessary. If they shared with us a notion of the nature of and role played by two types of charges in the atomic nature of matter, then the need to discharge and check what's accomplished would be more obvious to them. Explaining is not the answer.

The last instruction and request for a written response we intend as a reinforcement for the students to see that a tape is still charged before drawing conclusions from the way that it acts. This can get into a "chicken and egg" problem, but what we are looking for here is: The tape should be considered to be uncharged if it is not attracted to your finger as you run your finger down the tape, near it but not touching it.

# **Notes**