

Lab 25: Electric Fields

Concepts to explore:

- Electric fields
- Field lines
- Electric potential energy
- Voltage
- Electric energy storage

Take a look around, and you will most likely be able to name something nearby that uses electricity. Thanks to countless advances in scientific knowledge of the nature of electricity, the modern world is full of useful electronic devices. But what is electricity, really—and how does it work? This lab will familiarize you with the basic components of electricity and with how electric energy relates to other branches of physics.

The fundamental element behind electricity is **electric charge**. Charges are everywhere—you are no doubt familiar with the phenomenon of **static electricity**, which produces the “shock” you get when you rub your feet on some carpet and then touch a piece of metal (or someone else!). Static electricity can be thought of as the gathering of charge around an object or body.

The basic building-blocks of matter can help illustrate how charge gathers. As you know, atoms are composed of protons, neutrons and electrons. These subatomic particles are actually held together by electric forces that are thousands of times more powerful than that of gravity!

Unlike gravity, where all matter attracts, charge is split into two varieties: **positive** charge and **negative** charge. When you rub a plastic rod with a piece of cloth or fur, the rod will *attract* enough charge to lift small pieces of confetti from a desk. The same will happen if you rub a glass rod; but, if you bring the two rods together, they will actually *repel* one another. This leads us to the basic principle that *like charges repel and opposite charges attract*. If two objects appear to attract each other because of static electricity, it's because one is positively charged and the other is negatively charged.

It turns out that the reason this happens can be explained by the existence and movement of **free electrons**. If an object *loses* electrons (like when you rub a glass rod with some fur) it becomes positively charged—the charge due to protons outweighs that from electrons. When you do the same with the



Figure 25.1:

Roller-coasters certainly show the power gravity has to move objects at high speeds, but the tiny electric forces inside an atom are countless times more powerful. Gravity seems so strong because the earth is so large—it takes all the gravitational force of a huge planet to keep you on the ground so securely—but atoms stay together despite their tiny size. Static electricity can easily beat the force of gravity, lifting this child's hair straight into the air!

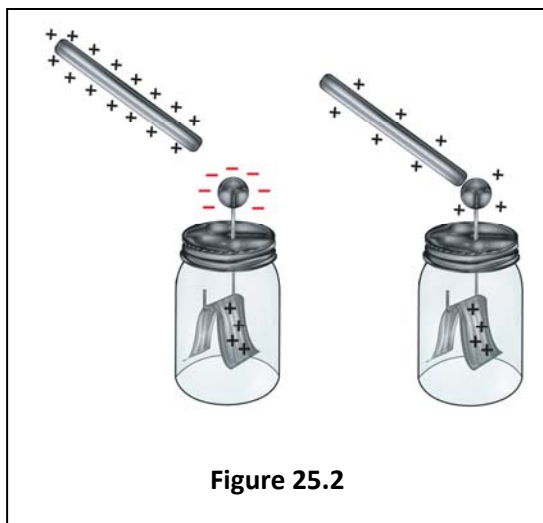


Figure 25.2

plastic rod, it *gains* electrons from the fur and becomes negatively charged. An important thing to remember is that in each case the total charge between the fur and the rod is conserved.

A useful device to demonstrate electric charge distribution is the electroscope, which consists of two very light conducting leaves connected to a conducting rod or ball (Figure 25.2). When the charged rod on the left is brought closer to the ball, it attracts the negative charges and repels the positive charges within the conductor. The previously neutral ball is now charged by **induction**. Induced charge does not require physical contact and does not create a total net charge in the original object; instead, it separates the positive and negative charges within the rod. As you can see, positive charges are distributed in the material farthest from the rod.

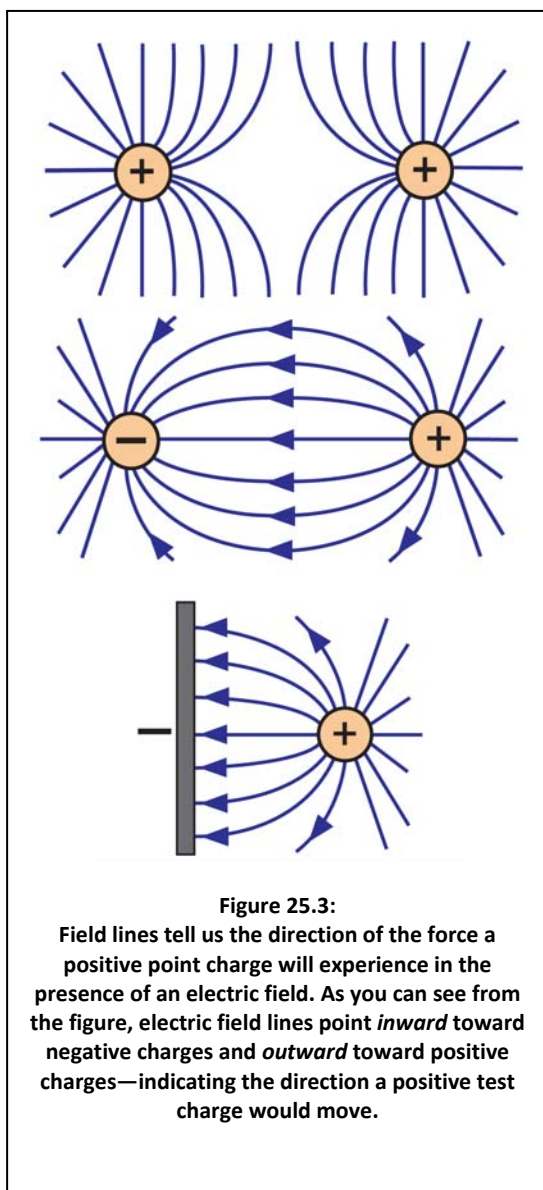


Figure 25.3:
Field lines tell us the direction of the force a positive point charge will experience in the presence of an electric field. As you can see from the figure, electric field lines point *inward* toward negative charges and *outward* toward positive charges—indicating the direction a positive test charge would move.

The next case, charge by **conduction**, happens when one charged object brings about a charge in another by *contact*. Here the positively charged rod contacts the metal ball, and the positive charge of the whole system is distributed evenly.

Particles feel attractive or repulsive forces due to the **electric field** that dictates the direction of the force between charges. By definition, the electric field *points in the direction of the force a positive charge would experience* in its presence. In the case of point charges, the electric field direction is straight outward, but the field for charged objects—such as cylinders, wires, and discs—can be more complicated. Drawing **electric field lines** can help you visualize the direction of the electric field emanating from charged objects and particles.

You have already learned about gravitational potential energy in mechanics. Similarly, charges have **electric potential energy** when they exist in electric fields. When a charge moves between regions with corresponding energies E_a and E_b , the potential difference is a measure of the change in potential energy between points *a* and

b. This can be expressed mathematically as:

$$V_{ba} = \frac{1}{q}(E_b - E_a) .$$

Another way to put it is that the change in potential energy of charge q moving through a potential difference of V_{ba} is the charge multiplied by the potential difference:

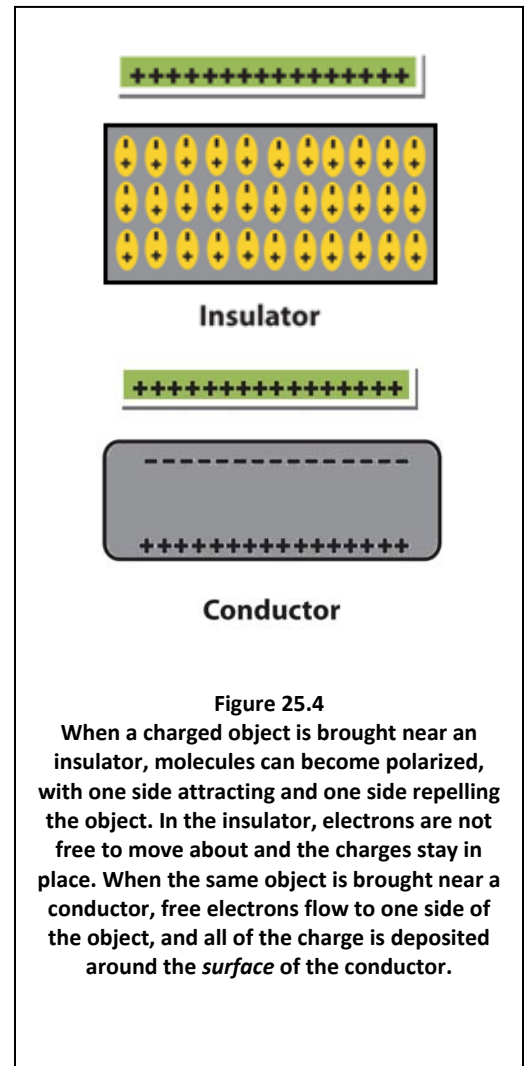
$$E_b - E_a = q V_{ba} .$$

In either case, V_{ba} is the electric potential measured in volts (1 volt = 1 Joule/Coulomb). Electric charge moves from areas with high **voltage** to areas with low voltage.

Electric energy can be stored in different materials; in a battery, electric energy can be gradually released by a slow chemical reaction that takes place inside. In a capacitor, charge that builds up on a pair of conduction plates can be kept isolated until this charge is released at a later time. Both of these methods of **electric energy storage** are very useful for electrical systems and are just two examples of ways to keep electricity stored for later use.



Figure 25.5:
If you look at a plain alkaline battery, you will see its rating given as a certain number of volts. This means that when the battery is plugged into a device, the potential difference between the positive and negative terminals on the battery is that many volts—the higher the voltage, the more energy it will give to a charge flowing in a circuit! Learn more about this in the electric current lab.



Lab 25.1: Static Materials

Materials

Static Kit materials

Paper

Procedure

1. Look for different kinds of fabrics in your closet to use as charging material. A cotton t-shirt, wool sweater, flannel pajamas or fur are some good examples.
2. Rub your fabric up and down on the glass rod, and then bring the glass rod near some small pieces of paper or confetti.
3. Try out different fabrics and note which works best to charge the rod. Use this fabric to charge the glass rod, and then take the rod into a bathroom with the lights dimmed. Bring the rod close to a metal faucet without touching it.

Questions

1. What happens when you bring the charged rod near the pieces? Why does this happen?

2. Do you know what type of charge is on the glass rod (positive or negative)? Why doesn't the type of charge matter for the rod to attract the paper?

3. What happened when you brought the charged rod near the metal surface? Explain what is happening in terms of free electrons.

3. Your hand is a neutral object. Why does this happen if your hand does not carry any net charge (*Hint: think about charge by induction*)?

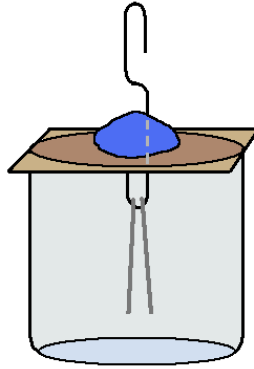
Lab 25.3: Simple Electroscope

Materials

1 small canning jar
Cardboard or a note card big enough to cover the top of the jar
1 metal paperclip
Aluminum foil
Scissors
Modeling clay
Balloon (optional)

Procedure

1. Remove the lid of the jar, and cut a piece of cardboard or note card paper big enough to sit on the top.
2. Bend the metal paperclip into an 'S' shape, and poke it through the cardboard so that the bottom of the 'S' hangs into the jar. You can use some modeling clay around the base of the paperclip to hold it all steady.
3. Cut a small strip of aluminum foil about 6 cm long and 0.75 cm wide. Fold the piece in half, and poke the folded end over the bottom of the paperclip.
4. Suspend this assembly in the jar so that you can see both strips of foil through the glass. Tape the cardboard to the sides of the jar so that the assembly stays put.
5. Rub the glass rod up and down with different types of fabric you can find in your closet, and then bring the rod close to the electrode where the paperclip protrudes out of the top. You could also charge a balloon by rubbing it on your shirt. Look at what happens to the aluminum strips!



Questions

1. What happens to the strips of aluminum when you bring a charged object near them?
2. What can you say about the charge in the strips—are they *like* or *unlike*?
3. Is your charged electrode *like* or *unlike* the charged rod? Why?
4. Does it matter which charge—positive or negative—is on the object you are testing?

5. Is this an example of charge by *induction* or *conduction*?