

Electrostatic Phenomena

"It frequently happens that in the ordinary affairs and occupations of life, opportunities present themselves of contemplating some of the most curious operations of nature."

B. Thompson, Count Rumford (1753-1814)

OBJECTIVES

To gain a qualitative understanding of some electrical effects.

THEORY

The effects of "static electricity" were probably known to the ancients, but scientific understanding came slowly. Simple observation showed that electrified objects could exert forces on other objects, electrified or not. More detailed investigations demonstrated that when only one object was electrified the force was initially attractive. When both were charged, the force was repulsive if the objects had been charged the same way, but sometimes attractive if different methods had been used. A new property of materials was also discovered in the course of these electrical experiments. It was shown that some materials, now called insulators, could hold electricity, while other materials, called conductors, allowed it to move freely. With this insight it was easy to understand how electricity could be transferred between objects, or confined in one place for experiments.

By the end of the eighteenth century electricians generally agreed that the observed phenomena could be explained by assuming electricity was an odd sort of material substance. It could be contained or moved like a fluid, but no weight changes could be detected when an object was electrified. There also had to be two types of "fluid", which Ben Franklin called positive and negative, in order to account for the force observations. Although we might now consider this a rather quaint model, these simple ideas unified a large number of observations, as you will see.

EXPERIMENTAL PROCEDURE

This exercise calls for a number of qualitative observations, as well as some quantitative measurements. Concentrate on watching carefully and recording your observations clearly, so that you can write a coherent explanation of what you see.

Three kinds of plastic rods will provide electricity for our work today. When gently rubbed with dry paper they will become electrified. Except on the soggiest days, you should be

able to get enough charge on any of the rods to hear a soft crackling sound. The sound indicates that the electricity is leaking off through the air, so further rubbing will not increase the electrification.

Most plastics are insulators, which is why you can retain a charge on the rods. By contrast, all metals and many liquids are conductors. The situation can become a bit confused, however, when an insulating material has a thin conducting film of water on the surface. This is quite likely to happen if the humidity is high and the insulator has been handled. The problem can be minimized by carefully cleaning the surfaces that you want to be insulating with methyl alcohol. A gentle wipe with alcohol dampened paper will also transfer charge from the rod to you, so it is a good way to clean the electricity off the rods when necessary.

The first experiments will use a device called an electroscope, which can detect the presence of electricity. It consists of a thin metal leaf hanging near a flat metal vane. The vane and leaf are connected to a metal disk and supported on an insulator. The whole assembly is enclosed in a metal can to protect it from drafts. Connect the metal can to the “ground” prong of an electrical outlet to avoid accumulating charge on the can.

Uncharged electroscope

Electrify one of your rods and bring it near, but not touching, the metal disk on top of the electroscope. What happens? Explain what you see in terms of the "fluid" model. Hint: It is best not to charge the rod too much, nor to get it too close. Otherwise, the electroscope leaf may touch the can, confusing the results. What happens with the other two rods?

Electroscope charged by contact

Now transfer some charge to the electroscope by rubbing one of the lightly-charged rods against the electroscope plate. Since the rod is an insulator you will need to touch all the parts of the rod from which you want to remove charge. A drop of alcohol on the plate may help the transfer by connecting the two solid surfaces. How does the electroscope respond to being charged? What happens if you now bring a charged rod near the metal disk? Try this with each rod in turn, and explain what you see, perhaps with appropriate sketches.

Electroscope charged by induction

Discharge the electroscope by touching the plate. The leaf should return to the resting position. Now electrify one of the rods, bring it close to the disk, and then briefly touch the disk with your hand before taking the rod away. This is called "charging by induction". What happens? How does the electroscope react to the different charged rods now? Is the charge on the

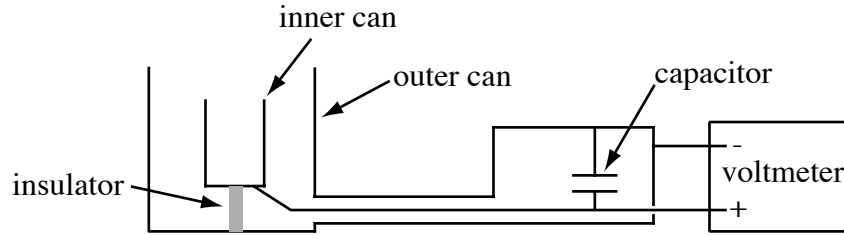


Fig. 1 Sketch of the coulombmeter. It consists of a can connected to a capacitor. When a charged object is surrounded by the inner can, a proportional charge is induced on the capacitor. A voltmeter measures the potential on the capacitor, which is proportional to the induced charge. The meter reading is therefore proportional to the charge on the object. The outer can, which is connected to the earth, shields the instrument from stray charges.

electroscope the same or different than that on the rod you used to charge it? Explain what you see.

Coulombmeter operation

We also have available a coulombmeter, explained in Fig. 1, which can quantitatively measure electrification. To use the device, set the voltmeter to measure DC voltage by turning the knob to the position labeled V with a solid and dashed line. The meter reading is then proportional to the charge on any object inserted into the inner can. If the meter does not read zero when the can is empty, push the "zero" button to remove the residual charge. You can choose the sensitivity by setting the toggle switch to 0.1 or 1.0 μF positions.

To become familiar with coulombmeter operation, use it to check the charge on each of the three rods. Are the relative signs consistent with what you found from the electroscope? Can you see the increase in charge as you rub the rod more?

Charged conductors

Charge one of the small metallic spheres by induction, holding it near whichever rod you can electrify most strongly. Are the relative charges on the rod and sphere consistent with your model? (Be careful when handling the spheres. The support rods break easily.)

We have tacitly assumed that we transfer something, rather than creating it, when we electrify the rods or spheres. This idea can be tested by seeing if the amount of electrification is constant when we do a transfer. Electrify one or both spheres and measure their charge. Then touch them and measure the charge again. Is the sum of the charges constant? Be sure to try both the same and opposite sign initial charges.

It might be objected that charge can only be transferred once it is on a metal, but that rubbing insulators is a different process. Check this possibility by removing the electricity from

the flat rod and one of the round ones, using the coulombeter to be sure you succeed. Now gently rub the rods together until you charge them both. Measure the charge on each rod. Is the result more consistent with rearrangement of a fixed amount of electricity, or with creation by rubbing? Try the same test with one of the rods and the paper you use to charge it. Do you get the same results? Why or why not?

Charge distribution on conductors

Our last project will be to examine the charge distribution on some objects. We can make a simple object by holding the two spheres together. Bring a charged rod close to the pair and then separate the spheres while the rod is nearby. Measure the charge on each sphere. Can you explain the sign and relative strength of the charges? Can you change the relative strength by changing the orientation of the pair with respect to the rod? Some sketches may help you clarify your argument.

The other test subject is a metal soda can which is mounted on an insulating post. Electrify the can as strongly as you are able. (Charging by induction from the flat strip usually works best.) Be sure that one of the metal spheres is free of charge. By touching the sphere to the can at various points, you can sample the charge at the contact point. Use the coulombeter on the most sensitive scale, 0.1 μF , to find out how much charge you pick up. Be sure to check the inside surfaces as well as outside. Can you explain your results in terms of the "fluid" model?