16-1 Electric Charge

In previous chapters, we have been concerned with several properties of objects, such as mass, momentum, energy, and angular momentum. These last three properties are associated with the object's motion, but the first property, mass, we often view as being an inherent property of the object itself. We often think of charge in a similar way, particularly the charge of an electron. Larger objects, such as ourselves, generally acquire a charge when they either lose electrons or acquire some extra electrons (we do this when we scuff our feet across a carpet, for instance). Table 16.1 shows the masses and charges of three basic constituents of atoms.

Particle	Mass (kg)	Charge
Electron	9.11×10^{-31} kg	$-e=-1.602\times10^{-19}$ C
Proton	1.672×10^{-27} kg	$+e=+1.602\times10^{-19}$ C
Neutron	1.674×10^{-27} kg	0

Table 16.1: The masses and charges of the electron, proton, and neutron, the basic building blocks of the atom.

EXPLORATION 16.1 – Experimenting with charge
One way to charge an object is to rub it with a cloth made from a different material. In this Exploration, we will investigate what happens when we do this with various combinations of materials. Such investigations go back as far as the ancient Greeks.

Step 1 – ***For this experiment, we need a piece of silk, two glass rods, and one piece of string. Suspend one of the glass rods from a string tied around the middle of the rod so that the rod is balanced. Rub one end of the rod with the silk. Rub one end of a second glass rod with the silk, and then bring the rubbed end close to, but not touching, the rubbed end of the rod that is suspended from the string. What do you observe?***
What you should observe in this case is that the end of the suspended rod moves away from the other rod – the suspended rod is repelled by the second rod. By Newton's third law, we know that the rods must be repelling one another with equal-and-opposite forces.

Step 2 – ***For this experiment, we need a piece of fur, two rubber rods, and one piece of string. Suspend one of the rubber rods from a string tied around the middle of the rod so that the rod is balanced. Rub one end of the rod with the fur. Rub one end of a second rubber rod with the fur, and then bring the rubbed end close to, but not touching, the rubbed end of the rod that is suspended from the string. What do you observe?***
Again, what you should observe in this case is that the end of the suspended rod moves away from the other rod – the suspended rod is repelled by the second rod. By Newton's third law, we know that the rods must be repelling one another with equal-and-opposite forces.

Step 3 – ***Now, bring the rubbed end of a glass rod (rubbed with silk) close to, but not touching, the rubbed end of the rubber rod (rubbed with fur) that is suspended from the string. What do you observe?***
In this situation, what you should observe is that the rods attract one another.

Step 4 – ***Repeat the experiments with a number of other types of rod material rubbed with different materials. What do you observe?***
In general, you should observe that all rubbed rods tend to act either like a glass rod rubbed with silk, or like a rubber rod rubbed with fur.

Step 5 – ***Can you explain these observations using a simple model involving charge? If so, describe the features of the model.***

The model we use to explain the observations with the rods is to first say that rubbing one material with a different material generally causes a transfer of charge from one material to the other. All glass rods rubbed with silk, for instance, should acquire charge of the same sign. To account for the observation that identical charged rods repel one another, our model states that like charges repel. We also build into the model that unlike charges attract, explaining why a glass rod rubbed with silk will attract a rubber rod rubbed with fur – a rubber rod rubbed with fur must acquire charge of the opposite sign to a glass rod rubbed with silk. Our model also accounts for two types of charge, which we call positive and negative.

Key ideas about interacting rubbed rods: The observations we make with the charged rods enable us to construct a basic model of charge. In this model, there are two types of charge, positive and negative. However, both types of charge can be obtained from the transfer of electrons, which have a negative charge. Rubbing a glass rod with silk generally transfers electrons from the glass to the silk, leaving the glass with a positive charge. Rubbing a rubber rod with fur generally transfers electrons from the fur to the rubber, giving the rubber a negative charge.
Related End of Chapter Exercise: 40.

Acquiring Charge

Everyday objects contain large numbers of electrons (negative charges) and protons (positive charges). In many instances the number of electrons is the same as the number of protons, so the object has no net charge. It is quite easy to give an object a net charge, however.

As we have learned, one way to charge an object is to rub it with a different material. For instance, rubbing a glass rod with silk transfers electrons from the glass to the silk, leaving the glass rod with a positive charge and giving the silk a negative charge. How effective this process is, and which material ends up with the negative charge, depends on where the two materials fit in the triboelectric series, shown in Table 16.2. "Tribos" is a Greek word meaning "rubbing", so triboelectricity is all about giving objects net electric charges by rubbing. Many centuries ago, the Greeks themselves did experiments with charge, rubbing amber with wool. It is no coincidence that the Greek word for amber is "electron."

Rubbing promotes charge transfer, but all that is necessary is to bring the two materials into contact, causing chemical bonds (which involve electrons) to form between them. Upon separation the atoms in one material tend to keep some of the electrons while atoms in the other material tend to give them up. In general, the farther apart the materials in the triboelectric series, the more charge is transferred, with the material farther down the list acquiring electrons and ending up with a negative charge.

MOST POSITIVE
Leather
Rabbit's fur
Glass
Nylon
Wool
Silk
Paper
Cotton
NEUTRAL
Amber
Polystyrene
Rubber balloon
Hard rubber
Saran wrap
Polyethylene
Vinyl (PVC)
MOST NEGATIVE

Table 16.2: The triboelectric series. When one material is brought into contact with another and then separated, some electrons can be transferred from one to the other. The material further down the list generally becomes negative.

***Essential Question 16.1*:** 1 coulomb (1 C) represents a large amount of charge. If –1.0 C worth of electrons is transferred from a glass rod to a piece of silk, how many electrons are involved? By how much does the mass of each object change? *(The answer is at the top of the next page.)*