

Electrostatics and electric fields

Electrostatics is the interactions between electric charges. It is often called **static electricity**. You are familiar with the terms positive and negative and should recall that atoms are composed of positively charged protons, negatively charged electrons, as well as neutral neutrons. While studying of atoms you learned that there were positively charged protons in the nucleus and negatively charged electrons which moved around the nucleus. You may not have learned that protons are about 2000 times more massive than electrons, however, the magnitude of electric charge is the same for each. The unit of electric charge is called a **coulomb (C)** and is equal to the amount of charge resulting from 6.25×10^{18} electrons. So, one electron and one proton result in no net electric charge: neutral. The basic rule of electrostatics is the familiar "like charges repel each other and opposite charges attract each other" rule. The forces that result from electric charges are on the order of 10^{20} times larger than the force of gravity. You have probably noticed the effect gravity more than the effect of electric force for the basic reason that gravity only attracts, while electric forces can attract and repel, thus they often cancel each other out. The amount of electric force experienced by electric charges increases as the amount of charge increases and decreases as the distance between the charges increases. The region of space around an electric charge has what is called an **electric field**. With electrical forces, as with gravity, no actual contact between the objects is required. Instead any electric charge in an electric field will feel a push or pull. **Coulomb's law** provides a mathematical relationship to determine the amount of push or pull experienced due to interaction of the electric fields of a pair of charges.

$$\vec{F}_e = k \frac{q_1 q_2}{d^2}$$

$$k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$$

Everyday objects can become charged in three basic ways: **friction, conduction, and induction**. All three methods involve the motion of electrons only. The protons are just too big and are held strongly in the atom's nucleus. **Charging by friction** is simply the scraping off of electrons from one object onto another by rubbing them together. The object losing the electrons becomes positively charged and the object scraping the electrons becomes negatively charged. **Conduction** simply involves contact between a charged and a charged or neutral object. When the two objects touch electrons are transferred away from a negatively charged object, or toward a positively charged object. If one of the objects is neutral it either gains or loses electrons based on the charge of the other object. Materials that allow conduction to occur easily are called conductors. **Charging by induction** involves a charged object coming near an object. If a negatively charged rod were brought near a neutral sphere the electrons on the surface of the sphere will be repelled to the far side of the sphere. This leaves the sphere near the charged rod positively charged. This part of induction is otherwise known as **polarizing**. The sphere's charges have been polarized, causing it to have a positive and negative side (or "poles"). This polarizing effect is only temporary while the charged rod is near. However, if the sphere is made of a good conducting material you can cause it to stay charged after you remove the charged rod. While the conductor is polarized you can provide a pathway for the electrons to flow onto or off of the sphere. This will cause the amount of positive and negative charge to be unequal, resulting in a charged object. This process is known as **grounding** since the pathway created is usually between the object and the ground. As it turns out, the earth itself is a virtually infinite reservoir of electrons and as such they will flow easily to and from the ground if provided a decent conducting pathway. You can ground a conductor by simply touching it with your finger, your body is then the pathway to the **ground**. Yes the human body is a fairly decent conductor as far the electrons are concerned, and remember that the electrical force is very strong. So in our current example the electrons on the far side of the sphere would be further repelled through your pathway all the way to the ground. Break the pathway by removing your finger and you have less electrons than protons and a positively charged sphere is the result. You say you want the sphere to be neutral again? Just touch it. You provide a path for electrons to be pulled onto the positively charged sphere. Since there is no other electric field present only the number of electrons needed to make the sphere neutral will move to the sphere. If more electrons were

q = electric charge

d = distance between center of each charge

to come on the sphere they would be repelled away back through your pathway. What happens when you reverse the induction example just discussed? Another example of charge induction is found in the production of lightning.

Clouds in a thunderstorm are often polarized; the top and bottom regions of the cloud have opposite charges. If the bottom of a certain cloud were negative it would induce a positive charge on the earth's surface below. This induced positive charge attracts more negative charge to the bottom of the cloud. If the electrostatic buildup of electrons becomes too great there is a discharge of the electrons from the cloud to the ground, which we know as lightning. Ground to cloud, cloud-to-cloud, and inter-cloud lightning are all results of the discharge of huge amounts of electrons. You may experience mini-lightning if you buildup charge on yourself and then touch another object, often a conductor like a doorknob or a car door, and get shocked. A lightning rod is an interesting device. Most people would tell you that the primary purpose of a lightning rod is to attract lightning, because that's probably the only visual they have of the lightning rod. The primary purpose is actually to prevent lightning. The small tip of the lightning rod is not able to hold a large amount of charge and it allows any charges building up on the structure to "leak off" into the atmosphere. This usually prevents the structure from becoming too charged and a lightning discharge does not occur. The second purpose is to safely guide the lightning around the structure to the ground. The lightning rod is metal and has a metal wire that runs from the rod into the ground, so the electrons move safely through the conductor and most damage is prevented. When electric charges gather on a conducting container such as a hollow metal sphere or a chainlink metal cage, a Faraday Cage, the charges will spread evenly over the surface. This charge distribution results in no net electric field inside the container, also known as electric shielding. If you were to be inside one of these Faraday cages which was struck by lightning, you would be safe as long as you were not in contact with any of the conducting material. A metal car body provides the electric shielding of a Faraday cage if you were to have a live power line fall on the car or it were to be struck by lightning.

In all charging and discharging of objects a change has taken place, which as we know requires energy. There is an **electric potential energy** (PE_e) much as there is a gravitational potential energy (PE_G). You must do work on a positively charged particle in order to move it closer to another positively charged particle. This work is equal to the PE_e gained by the particle. A change in the amount of charge also changes the PE_e , much like changing the mass of an object changes its PE_G . PE_e is not usually a useful quantity, but is incorporated in the idea of **electric potential**, which is the PE_e divided by the amount of charge present. The unit of electric potential is the **volt (V)** or 1 joule per coulomb. Consequently, electric potential is commonly called **voltage**. A lightning strike has on the order of 10^8 volts of electric potential. **Potential difference** specifically refers to the difference in electric potential between two points. In order for electric charges to move, as in lightning, there must be a potential difference. This is the voltage which causes electric current in an electric circuit. A **capacitor** is a device that can store electrical potential energy. This is simply two metal plates separated by an insulating material such as plastic. Opposite charges will build up on each plate when each of the plates is connected to the opposite ends of a battery. Basically the negative charges are forced onto one plate and the positive charge is left on the other. This requires work to move the charge, resulting in the plates having electrical potential energy. If the plates are then connected directly to each other the charge's energy will be released in a fraction of a second. An electric camera flash uses a capacitor. The charge is stored and then released in an instant through the bulb, causing the flash.