CHAPTER 23

Electricity - Physical Science

Chapter Outline

23.1 Electric Charge

Lesson Objectives

- Define electric charge and electric force.
- Describe electric fields.
- Identify ways that electric charge is transferred.

Lesson Vocabulary

- electric charge
- electric field
- electric force
- law of conservation of charge
- static discharge
- static electricity

Electric Charge and Electric Force

Electric charge is a physical property of particles or objects that causes them to attract or repel each other without touching. All electric charge is based on the protons and electrons in atoms. A proton has a positive electric charge, and an electron has a negative electric charge (see **Figure** 23.2).

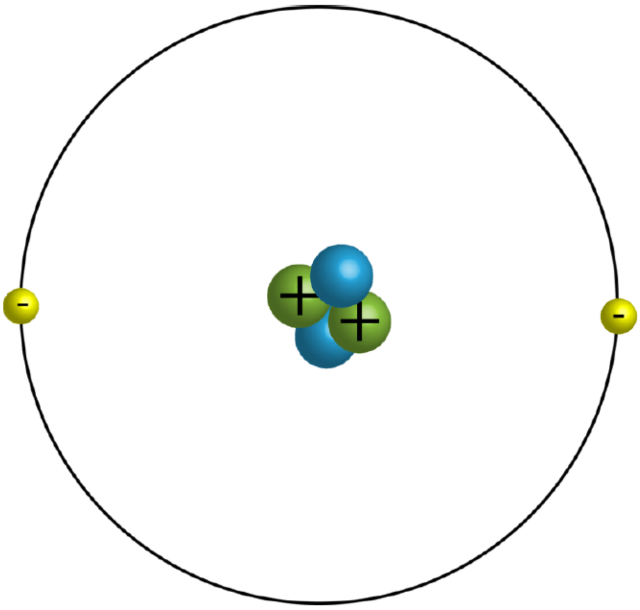


FIGURE 23.2
Positively charged protons (+) are located in the nucleus of an atom. Negatively charged electrons (-) move around the nucleus.

When it comes to electric charges, opposites attract. In other words, positive and negative particles are attracted to each other. Like charges, on the other hand, repel each other, so two positive or two negative charges push apart from each other. The force of attraction or repulsion between charged particles is called **electric force**. It is illustrated in **Figure** 23.3. The strength of electric force depends on the amount of electric charge and the distance between the charged particles. The larger the charge or the closer together the charges are, the greater is the electric force.

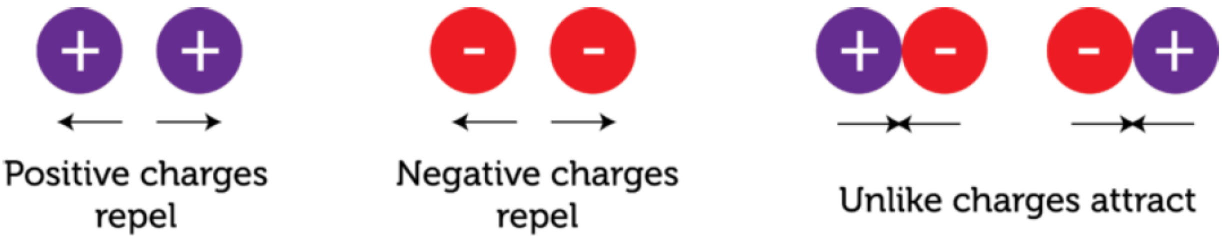


FIGURE 23.3
These diagrams illustrate the electric forces between charged particles.

Electric Fields

Electric force is exerted over a distance, so charged particles do not have to be in contact in order to exert force over each other. That's because each charged particle is surrounded by an electric field. An **electric field** is a space around a charged particle where the particle exerts electric force on other particles. Electric fields surrounding positively and negatively charged particles are illustrated in **Figure** 23.4 and at the URL below. When charged particles exert force on each other, their electric fields interact. This is also illustrated in **Figure** 23.4.

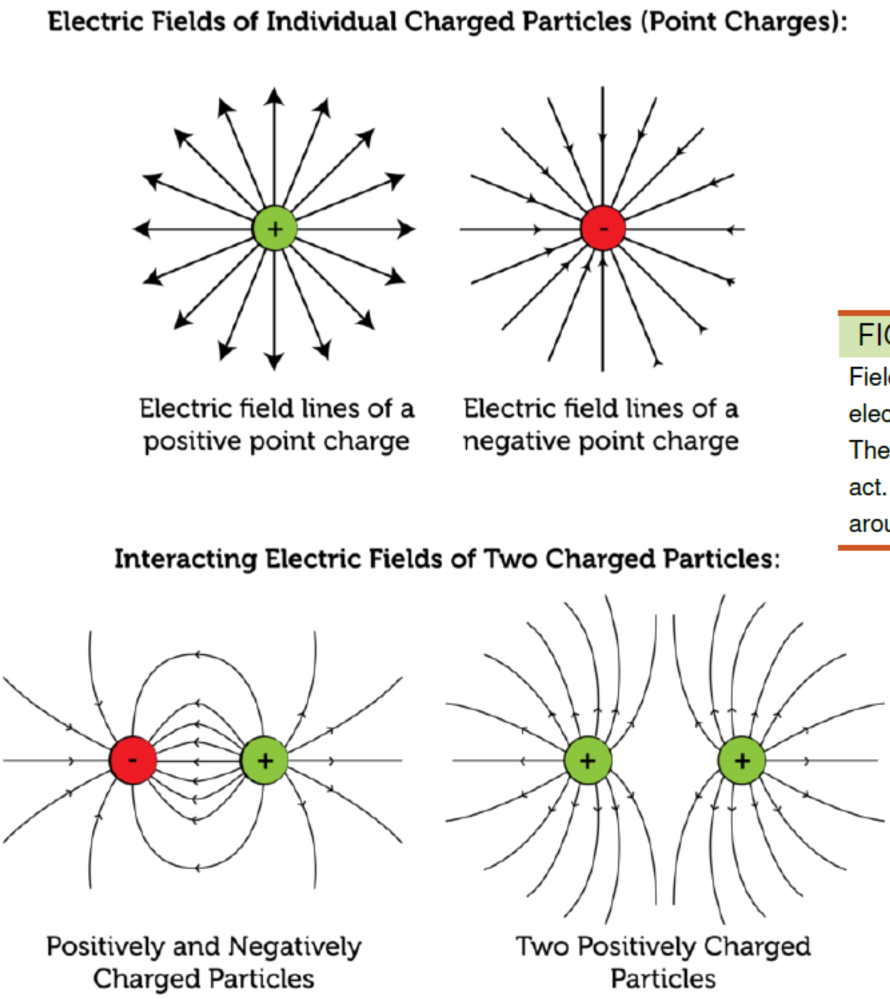


FIGURE 23.4

Field lines represent lines of force in the electric field around a charged particle. The lines bend when two particles interact. What would the lines of force look like around two negatively charged particles?

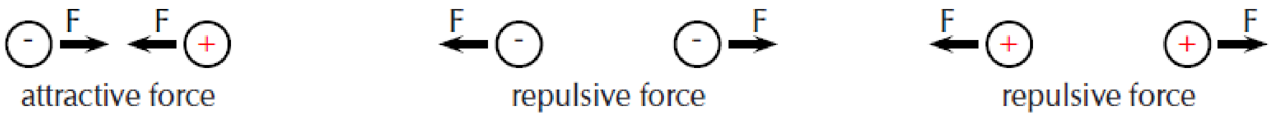
Phet: Charges & Fields

Phet: Electric Field Hockey

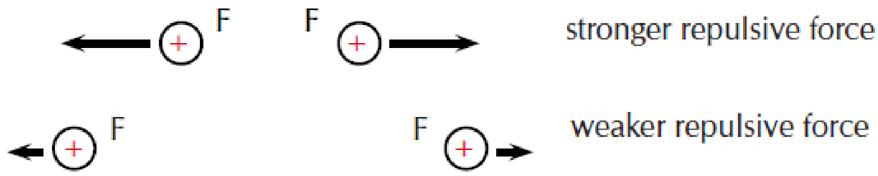
Static charges apply a force (a push or a pull) on each other:

- **like** charges is **repulsive**
- **opposite** (unlike) charges is **attractive.**

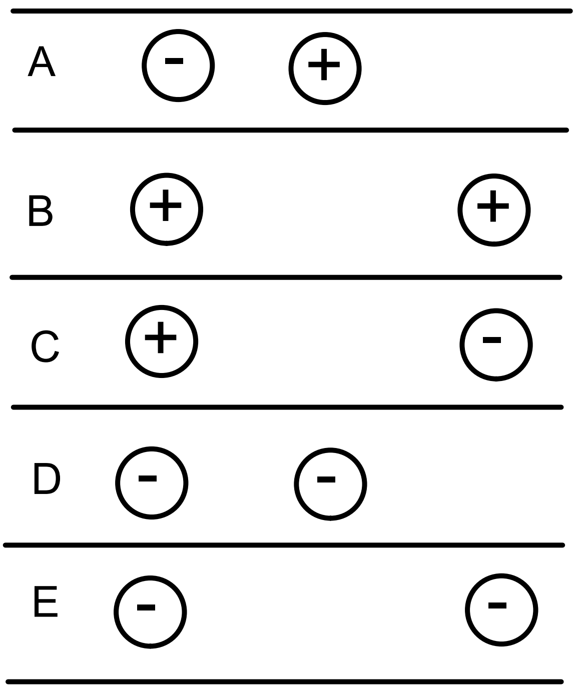
In other words, like charges repel each other while opposite charges attract each other.



The *closer* together the charges are, the *stronger* the electrostatic force between them.



Examples (assume each metal sphere has the same charge)



Weak repulsive force: _________

Strong repulsive force: _________

Strong attractive force: _________

Weak attractive force: _________

Conservation of Charge

The principle of conservation of charge states that the net charge of an isolate system remains constant during any physical process, e.g. two charge objects making contacting and separating.

The charge on a single electron is $q_e = 1.6 \times 10^{-19}$ C. All other charges in the universe consist of an integer multiple of this charge. This is known as charge quantisation.

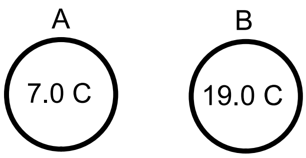
$$Q = nq_e$$

Charge is measured in units called coulombs (C). A coulomb of charge is a very large charge. In electrostatics we therefore often work with charge in micro-coulombs ($1\ \mu C = 1 \times 10^{-6}$ C) and nanocoulombs ($1\ nC = 1 \times 10^{-9}$ C).

Example Problems

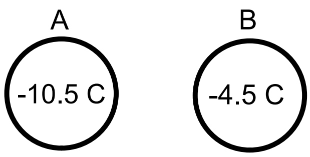
Determine the resulting net charge of each metal sphere.

1.)



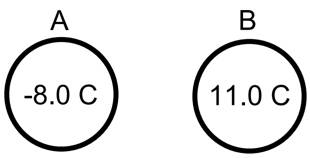
After A and B touch: A = __________ B= __________

2.)



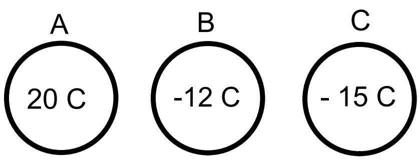
After A and B touch: A = __________ B= __________

3.)



After A and B touch: A = __________ B= __________

4.)



A and B touch: A = __________ B = __________ C = __________

B and C touch: A = __________ B = __________ C = __________

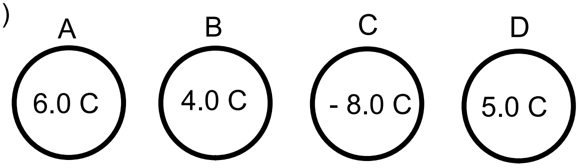
A and B touch: A = __________ B = __________ C = __________

Total Charge: _____

A, B, and C touch at the same time:

A = __________ B = __________ C = __________

5.)



Total of Charges: _______

C and D touch: A = __________ B = __________ C = __________ D = _________

A and C touch: A = __________ B = __________ C = __________ D = _________

B and C touch: A = __________ B = __________ C = __________ D = _________

B and D touch: A = __________ B = __________ C = __________ D = _________

All four spheres are touched together at the same time:

A = _______ B = _______ C = _______ D = ________

Transfer of Electric Charges

Atoms are neutral in electric charge because they have the same number of electrons as protons. However, atoms may transfer electrons and become charged ions, as illustrated in **Figure** 23.5. Positively charged ions, or cations, form when atoms give up electrons. Negatively charged ions, or anions, form when atoms gain electrons.

Like the formation of ions, the formation of charged matter in general depends on the transfer of electrons either between two materials or within a material. Three ways this can occur are friction, conduction, and polarization. In all cases, the total charge remains the same. Electrons move, but they aren't destroyed. This is the **law of conservation of charge**.

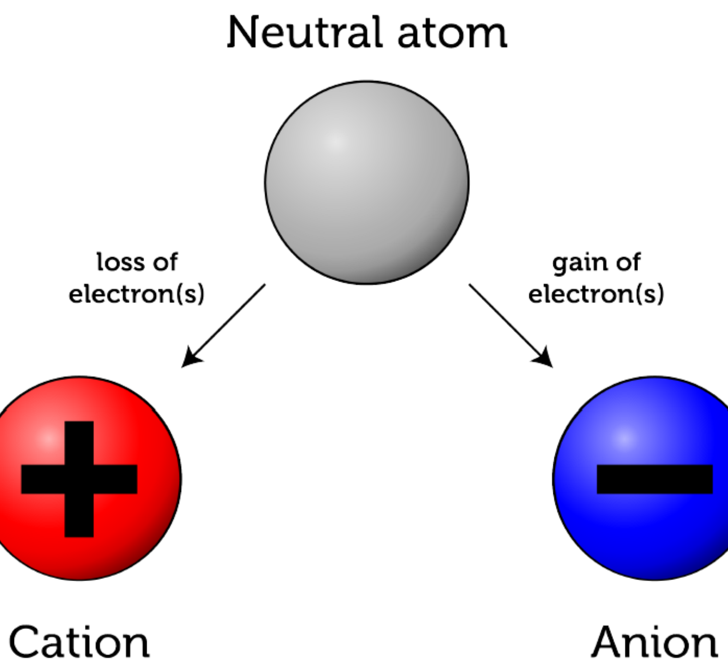


FIGURE 23.5

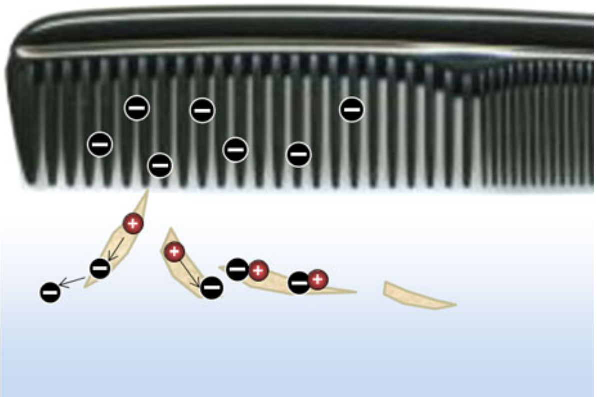
Atoms are electrically neutral, but if they lose or gain electrons they become charged particles called ions.

Friction

Did you ever rub an inflated balloon against your hair? You can see what happens in **Figure** 23.6. Friction between the rubber of the balloon and the baby's hair results in electrons from the hair "rubbing off" onto the balloon. That's because rubber attracts electrons more strongly than hair does. After the transfer of electrons, the balloon becomes negatively charged and the hair becomes positively charged. As a result, the individual hairs repel each other and the balloon and the hair attract each other. Electrons are transferred in this way whenever there is friction between materials that differ in their ability to give up or accept electrons.

Phet: Balloons & Static Electricity

"Rub the balloon in your hair and then it'll stick to the wall"



When a comb is rubbed against your hair, the comb becomes negatively charged and your hair becomes positively charged.

Conduction

Another way electrons may be transferred is through conduction. This occurs when there is direct contact between materials that differ in their ability to give up or accept electrons. For example, wool tends to give up electrons and rubber tends to accept them. Therefore, when you walk across a wool carpet in rubber-soled shoes, electrons transfer from the carpet to your shoes. You become negatively charged, while the carpet becomes positively charged.

Another example of conduction is pictured in **Figure** 23.7. The device this man is touching is called a van de Graaff generator. The dome on top is negatively charged. When the man places his hand on the dome, electrons are transferred to him, so he becomes negatively charged as well. Even the hairs on his head become negatively charged. As a result, individual hairs repel each other, causing them to stand on end. You can see a video demonstration of a van de Graff generator at this URL: http://www.youtube.com/watch?v=SREXQWAIDJk.

AGT: Arc Attack

AGT: Arc Attack - Iron Man

Polarization

Polarization is the movement of electrons within a neutral object due to the electric field of a nearby charged object. It occurs without direct contact between the two objects. You can see how it happens in **Figure** 23.8. When the negatively charged plastic rod in the figure is placed close to the neutral metal plate, electrons in the plate are repelled by the positive charges in the rod. The electrons move away from the rod, causing one side of the plate to become positively charged and the other side to become negatively charged.

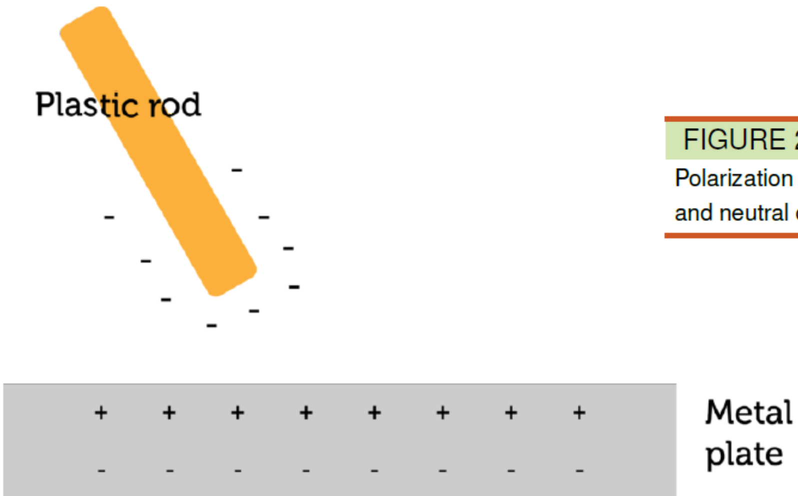
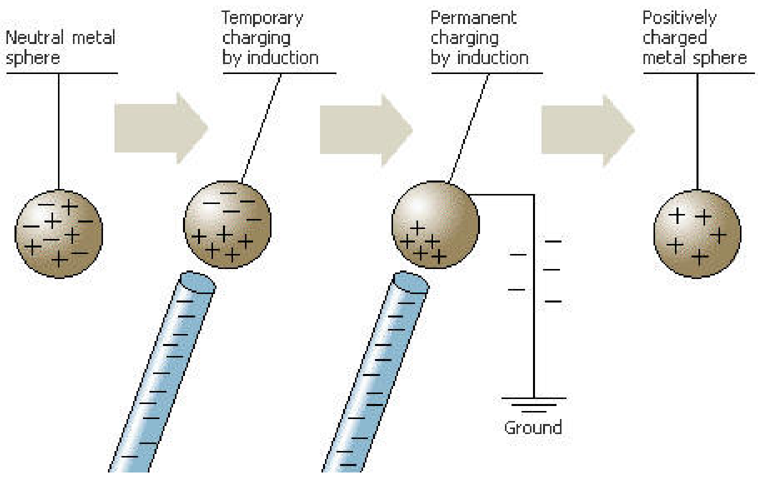


FIGURE 23.8
Polarization occurs between a charged and neutral object.

Induction

There is a third way in which objects can become charged, **charging by induction**. When the term induction is used in physics it means that something happens without direct contact.

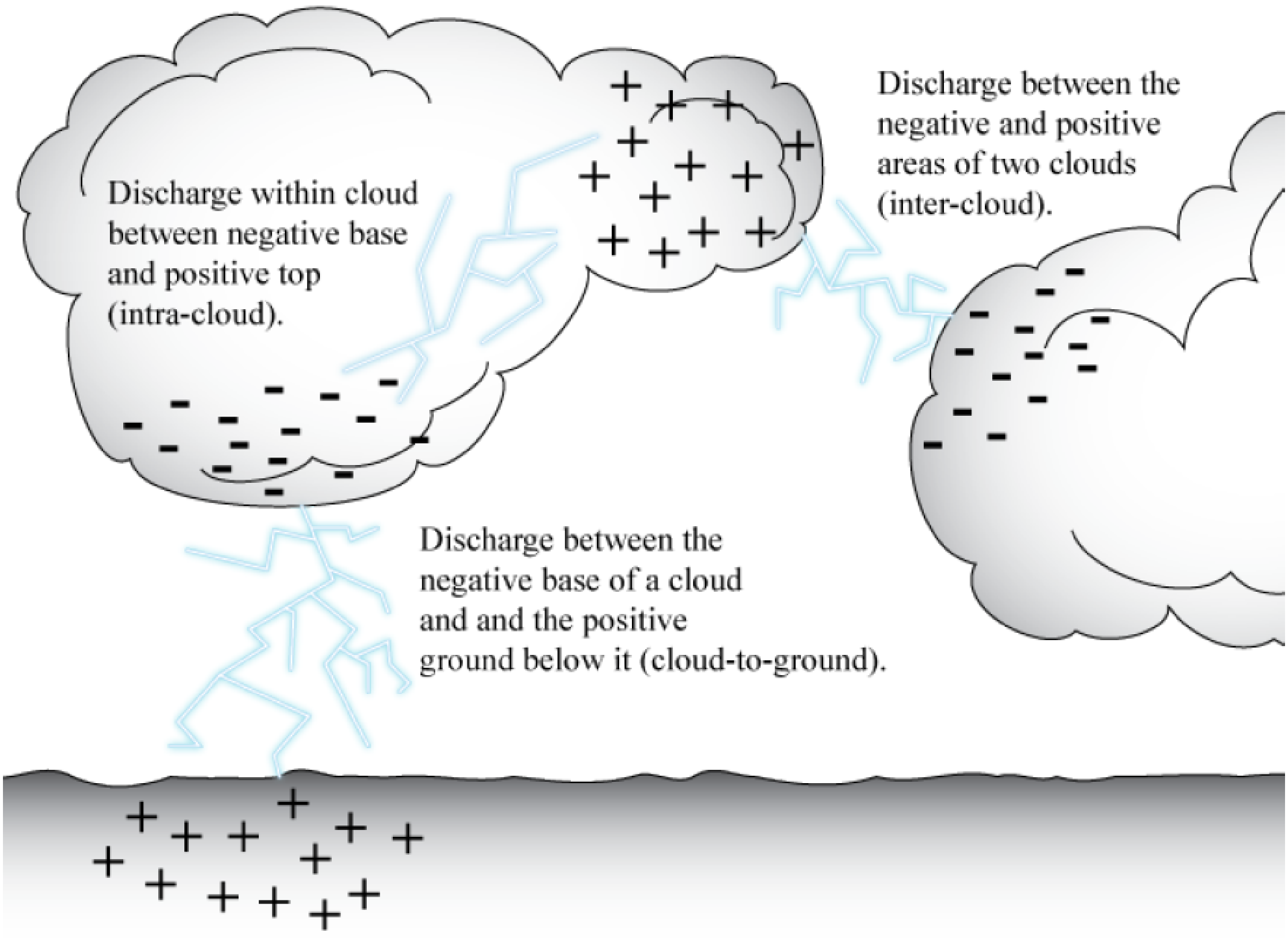


Static Electricity and Static Discharge

Polarization leads to the buildup of electric charges on objects. This buildup of charges is known as **static electricity**. Once an object becomes charged, it is likely to remain charged until another object touches it or at least comes very close to it. That's because electric charge cannot travel easily through air, especially if the air is dry.

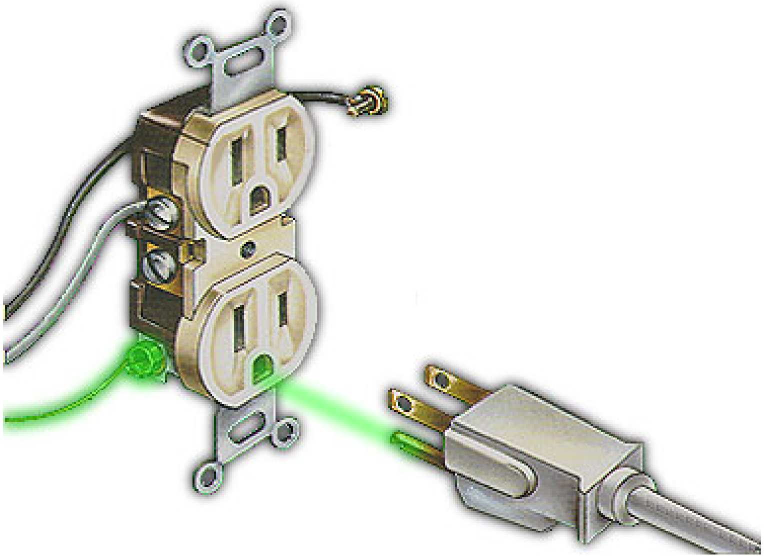
Consider again the example of your hand and the metal doorknob. When your negatively charged hand gets very close to the positively charged doorknob, the air between your hand and the knob may become electrically charged. If that happens, it allows electrons to suddenly flow from your hand to the knob. This is the electric shock you feel when you reach for the knob. You may even see a spark as the electrons jump from your hand to the metal. This sudden flow of electrons is called **static discharge**. Another example of static discharge, on a much larger scale, is lightning. You can see how it occurs in **Figure** 23.9. At the URL below, you can watch a slow-motion lightning strike. Be sure to wait for the real-time lightning strike at the very end of the video.

http://www.youtube.com/watch?v=Y8oN0YFAXWQ&feature=related



Grounding

When a charged object is connected to Earth, the charge is shared with the entire Earth, all excess charges are safely removed.

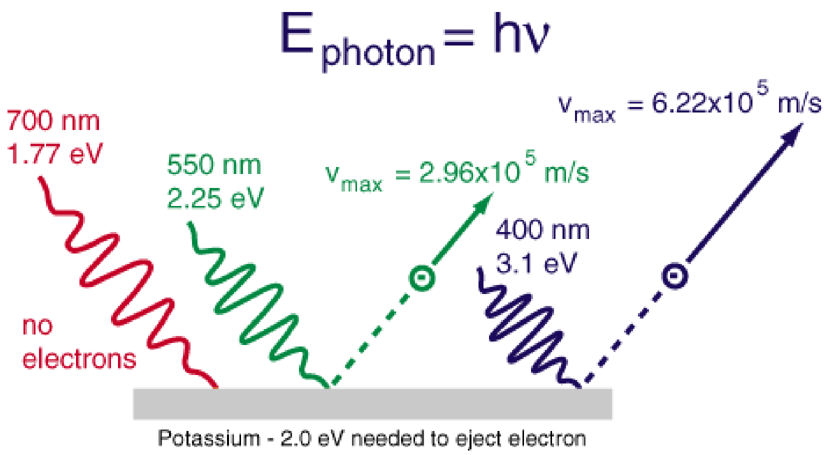


<u>Discharge at a Point</u>

Used on airplanes, car or other objects that cannot be grounded.

Electrons repel each other off of the tip of a sharply pointed rod in a continuous stream. These rods are called **static wicks.**

Other Ways to Discharge Objects: exposure to humid air, shine a light on it, or expose the object to radioactivity



Photoelectric effect

Metal in a Microwave

Don't try this at home!

Electrical Insulator: a substance in which electrons cannot move freely from one atom to another.
Some elements have a tight hold on their electrons. Therefore, electrons cannot flow freely through them. This property makes them good insulators.
These materials can protect us from electric shock. Ex. rubber, paint or wax.

Electrical Conductor: a substance in which electrons can move freely from one atom to another.
Some elements allow electrons to flow freely through them, making them good conductors. Ex. copper
For example, you can not charge metal taps because the charge is conducted away to the ground.

eTextbook Page 526 #1 - 7, Points to Consider.