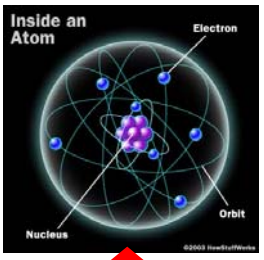
L 23 Electricity & Magnetism [1]

- Static electricity
  - Why do I get a shock when I walk across the rug and touch the door knob or another person?
  - Why do socks stick to my shirts in the dryer?
  - Why does my hair stick to my comb?
- What is lightning?
- What produces the aurora?
- What are volts, amps and ohms?
  - What are GFICs (special electrical outlets in the bathroom)
  - Are compact fluorescent lights or LEDs more efficient?

We will discuss the basic aspects of electricity that will hopefully remove some of the mystery and fear surrounding it.

1

It's the CHARGE!



Nitrogen Atom

- we know that matter has MASS but . . .
- it also has CHARGE!
- the mass is what gives the gravitational force
- the charge is what gives us Electrical forces
- We don't directly see the effects of charge because the charge is bound inside of atoms

2

What is in atoms?

- charge is just another property like mass
- Atoms have a nucleus at its center and a electrons that move around it
- The nucleus: two kinds of heavy particles
  - **neutrons** – have no charge
  - **protons** – have a positive charge
- Two kinds of charge: *positive* and *negative*
- Electrons and protons have the same *magnitude* of charge but electrons are – and protons are +
- The mass of the proton is about 2000 times the mass of the electron

3

Electric forces

- charges exert electric forces on other charges
  - two positive charges repel each other
  - two negative charges repel each other
  - a positive and negative charge attract each other

The repulsive electric force between 2 protons is 10^{39} *times stronger than the attractive gravitational force!*

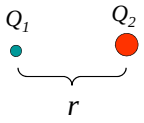
4

How Strong is the Electric Force between two charges?

- It depends on how big the charges are, and how close they are
  - The bigger the charges, the bigger the force
  - The closer the charges, the bigger the force
- This is known as **Coulomb's Law**
- The unit of charge is the **Coulomb (C)**

Coulomb's Law

$$F_e = k_e \frac{Q_1 Q_2}{r^2}$$



5

Conductors and Non- Conductors

- Metals (copper, aluminum, iron) are **conductors** of electricity → that means that charge can move through them
- Plastics, wood, ceramics, and glass are **non-conductors** (or insulators) → they do not let electricity flow through them
- You should **not** stick a metal knife into an electrical outlet!
- You could stick a plastic knife into an outlet without electrocuting yourself
- **Please do not do this!**

6

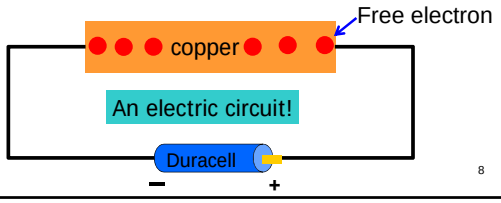
What makes conductors conduct?

- Atoms have equal numbers of positive and negative charges, so that a piece of material usually has **no net charge** → the plusses and minuses cancel each other.
- However, when you put many metal atoms (like copper) together an amazing thing happens → one electron from each atom forgets which atom it belongs to.
- The homeless electrons are free to wander about randomly inside the material.

7

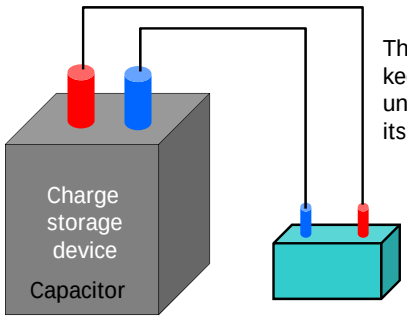
Current– charges moving around

If I connect a battery to the ends of the copper bar the electrons in the copper will be pulled toward the positive side of the battery and will flow around and around.
→ this is called **current** – flow of charge



8

Seeing and hearing electricity!

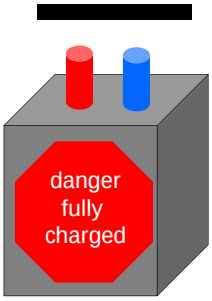


The capacitor keeps charging until it reaches its limit.

Many Batteries

9

Fully loaded and ready to go!

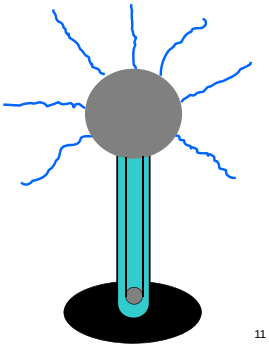


- The sudden discharging of the capacitor is accompanied with a big spark and a bang → man-made lightning!
- A spark occurs when there is enough energy released to cause the electrons in the air molecules to be ripped out of the molecules → **ionization**

10

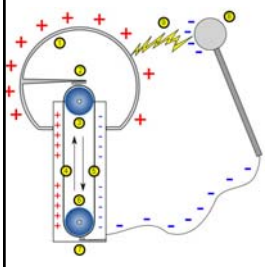
Danger High Voltage !

- The van de Graff can charge the sphere to more than 50,000 volts!
- This is enough to cause discharges to the surrounding air → *ionization or breakdown*
- The sparks excite air molecules which give off visible light



11

Making Sparks: The Van de Graff Generator



- The van de Graff generator is a device for building up a large electrical charge on a metal sphere
- The charge is generated by friction between a conveyor belt rubbing a charged comb
- The charged belt transfers the charge to the collecting comb attached to the metal sphere.

12

Both conductors *and* non-conductors can be charged!

- Even though non-conductors do not have free electrons wandering about, they can be charged by friction
- When you move your comb through your hair, the friction (rubbing) between the comb and hair can pull some of the electrons out of your hair and onto the comb
- as a result your comb ends up with a net negative charge and attracts your hair which is now positive.

13

Charging by friction - triboelectricity

- If you rub plastic with fur (e.g. cat or rabbit), electrons are rubbed onto the plastic making it negative
- if you rub glass with silk, electrons are rubbed off the glass making it positive
- the charge can be transferred to other objects.

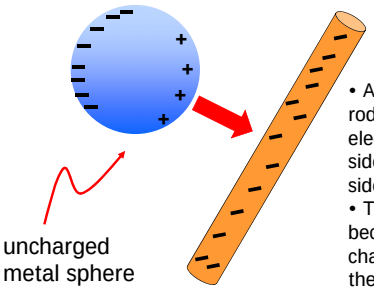
14

The charging process

- an object is charged positive (has a net positive charge) if electrons are removed from it
- an object is charged negative (has a net negative charge) if electrons are transferred to it
- charges can be transferred from conductors or non-conductors but they *can only move through conductors.*
- ***Charge is conserved in the transfer of charge ➔ the charge is merely passed from one object to another, no charge is lost in this process.***

15

Attracting uncharged objects



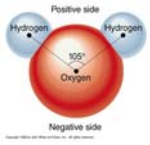
uncharged metal sphere

- A negatively charged rod will push the electrons to the far side leaving the near side positive.
- The force is attractive because the positive charges are closer to the rod than the negative charges

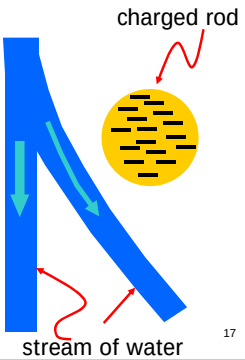
16

You can bend water with charge!

The water molecule has a positive end and a negative end.



When a negative rod is brought near the stream of water, all the positive ends of the water molecules turn to the right and are attracted to the negative rod.



17

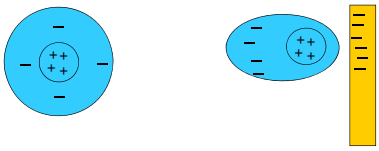
The Magic Wand

We can make the board move with electric forces

18

Can attract nonconductors also

Even though nonconductors do not have free electrons that can move around, the molecules can be polarized – the positive and negative charges can be separated slightly



19

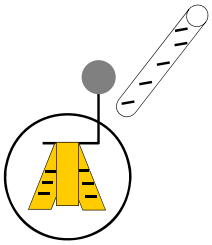
One Coulomb is a HUGE charge

- To get a charge of one Coulomb on an object we would have to remove roughly 6×10^{18} electrons from it!
- In the capacitor discharge demonstration, only 1/100 of a Coulomb was involved.

20

Seeing the effects of charge: the electroscope

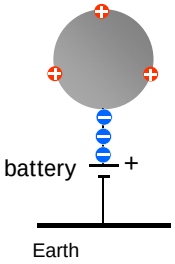
- the electroscope is a simple device for observing the presence of electric charge
- it consists of a small piece of metal foil (gold if possible) suspended from a rod with a metal ball at its top



- If a negatively charged rod is placed near the ball, the electrons move away because of the repulsion. The two sides of the metal foil then separate.

21

Electric Potential ➔ voltage



- The amount of charge on a charged sphere can be measured in terms of its electric potential or voltage
- The more charge that is on the sphere, the higher its voltage or electric potential measured in **VOLTS**
- If I connect a battery to the sphere, it pulls the negative electrons from the sphere and deposits them to the ground, thus leaving the sphere with a net positive charge.

22