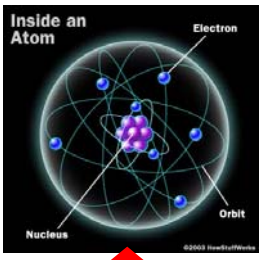
L 23 Electricity & Magnetism [1]

- Static electricity
  - Why do I get a shock when I walk across the rug and touch the door knob?
  - 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 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

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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

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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!*

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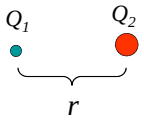
How Strong is the Electric Force between two charges?

- 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

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



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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 fork into an electrical outlet!
- You could stick a plastic fork into an outlet without electrocuting yourself
- **Please do not do this!**

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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.
- All the homeless electrons are free to wander about inside the material.

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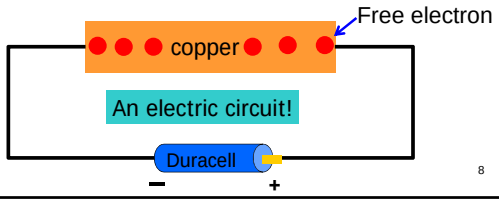
Current– charges moving around

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



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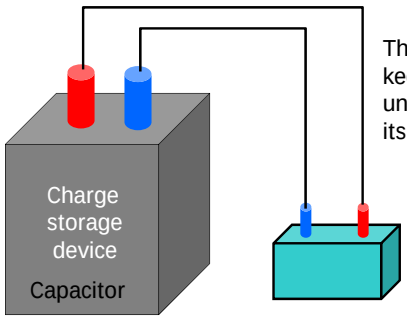
Seeing and hearing electricity!



The capacitor keeps charging until it reaches its limit.

Many Batteries

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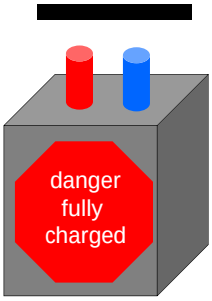
Fully loaded and ready to go!



- 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**

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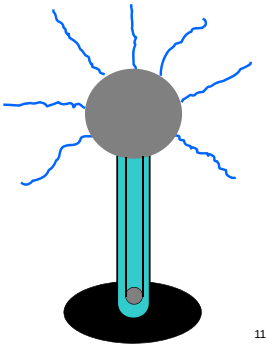
Danger High Voltage !

- 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



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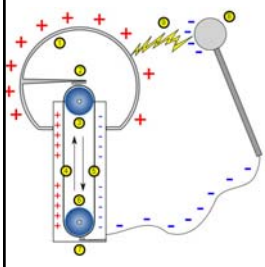
Making Sparks: The Van de Graff Generator



- 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.

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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.

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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.

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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.***

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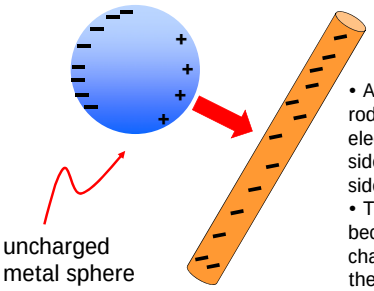
Attracting uncharged objects



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

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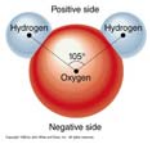
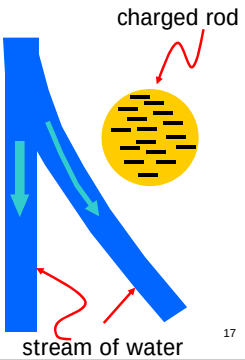
You can bend water with charge!

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.



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The Magic Wand

We can make the board move with electric forces

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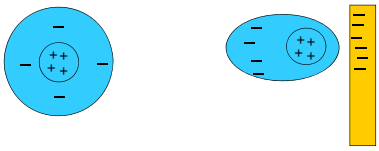
Can attract nonconductors also

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



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One Coulomb is a HUGE charge

- To get a charge of one Coulomb on an object we would have to remove 6.250×10^{18} electrons from it!
- In the capacitor discharge demonstration, only 1/100 of a Coulomb was involved.

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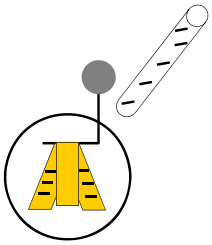
Seeing the effects of charge: the electroscope

- 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.

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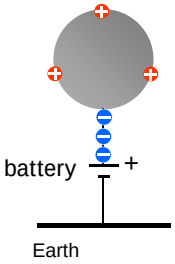
Electric Potential ➔ voltage



- 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.

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