L 25 Electricity & Magnetism [2]

- static electricity
  - – the charging process
  - – the van de Graff generator
  - – electrostatic shielding
- liquid and gaseous conductors
- lightning
- batteries and frogs legs
- voltage , current, and resistance

review – electric charge

- Matter has two basic properties
  - mass → gravitational force
  - charge → electric and magnetic forces
    - – positive charge
    - – negative charge
- electric forces
  - like charges repel +/+ or - / -
  - unlike charges attract + / -
- charge is measured in **Coulombs [C]**
- all charge is a multiple of the basic unit of charge – we call this e = $1.60217646 \times 10^{-19}$ C
- charges cannot be divided into smaller units than this

Where is the charge?

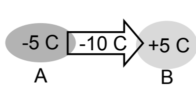
- the charge is bound in atoms
  - – positive → protons
  - – negative → electrons
- matter is electrically neutral → it has the same amount of positive and negative charge
- Only the electrons can be transferred from one object to another by rubbing (friction)
  - – to make an object (–) we move electrons to it
  - – to make an object (+) we remove electrons from it

Charging by friction

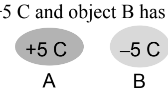
- If you rub plastic with fur, electrons are rubbed onto the plastic making it negative
- if you rub glass or plastic with silk, electrons are rubbed off the glass making it positive
- charge can be transferred to other objects
  - – charge can be transferred to or from conductors or non-conductors
  - – charge (electrons) can only move through conductors.
  - – only the electrons can be transferred and move through conductors

Example - charge transfer and conservation

- Initially, object A has a charge of –5 C and object B has a charge of +5 C. If –10 Coulombs of negative charge are transferred *from object A to object B*. What is the final charge on each object?



- ***ANSWER*:** Removing –5 C from A leaves it with no net charge. Removing -5 more leaves it with a net +5C. So, object A has a net charge of +5 C and object B has a net charge of –5 C.



- Note that the net charge (= 0) is the same before and after.

Lightning- big outdoor spark

- National Weather Service: about 25 million lightning flashes each year in the US
- NWS reports that over the last 30 years, on average, 58 people were killed each year
- causes 100 million dollars in damage each year in the US
- lasts only a thousandth of a second, with up to 200,000 A (typical hairdryer uses 10 A)
- causes the thunder!

development of a lightning bolt

[redacted]

separation leader streamer streamer bolt

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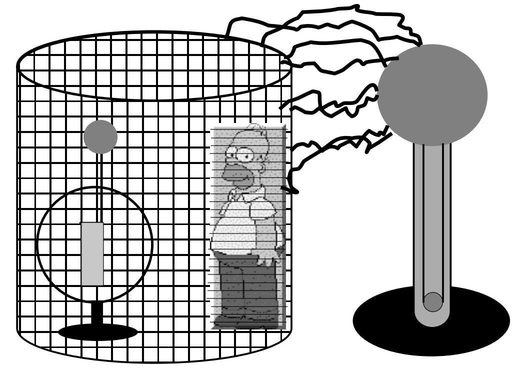
Electrostatic shielding



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Electrostatic shielding

- The effect of the high voltage on the van de Graff generator stops on the outside of the metal cage ➔ Homer is SAFE!
- Being inside your car during a lightning storm offers you some protection
- radio signals cannot penetrate through a metal enclosure
- the metal bars (rebar) that reinforce the concrete in walls can also interfere

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Conductors and Non-Conductors

Metals (copper, aluminum, iron) are **conductors** of electricity → they allow current (*moving free electrons*) to pass through them

Plastics, wood, ceramics, and glass are **non-conductors** (or insulators) → they do not let electricity flow through them → *they have no free electrons to move around*

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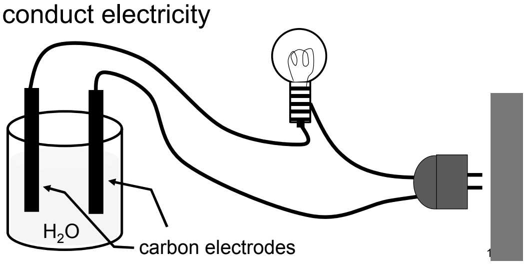
Pure water is non-conducting

- clean water will not conduct electricity
- if salt or acid is added, however, it will conduct electricity



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A salt water solution is a conductor

- When salt NaCl (sodium chloride) is added to water H_2O, the NaCl molecule dissociates into a positive ion Na^+, and a negative ion Cl^- .
- Thus the solutions contains both positive and negative ions, both of which can conduct electricity.
- Electric current can pass through dirty bath water and through you also!
- we are conductors – water + Na^+ + $Cl^–$

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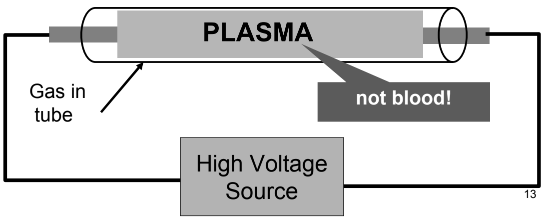
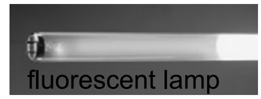
Gas discharges

When a high voltage is applied to a gas-filled tube, the gas can become ionized, one or more electrons are separated from each atom. Since positive and negative charges are present the ionized gas conducts electricity. The gas atoms are excited and emit light of a color characteristic of the gas.



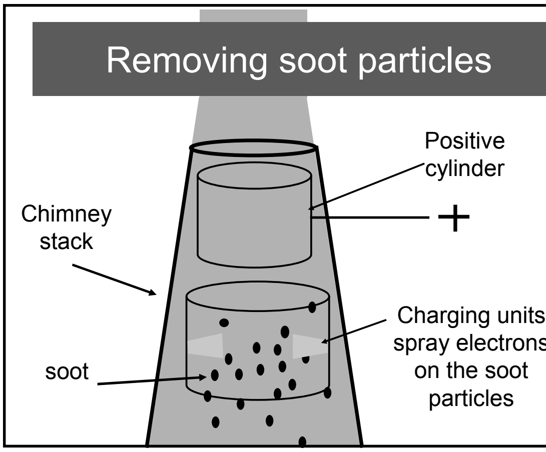
examples of electrical discharges



applications of electrostatics

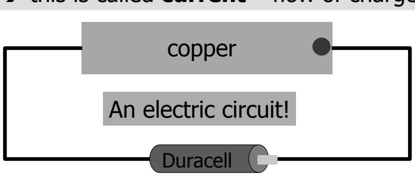
- Xerox copiers use electrostatic attraction to put the ink droplets on the paper
- electrostatic precipitators use the attraction of charged dust to remove dust particles from smoke.
- can be used to hold balloons on your head

Removing soot particles



Current– flow of electric charge

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



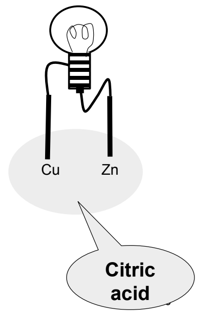
But, how does a battery work?

Frog's leg Batteries

- in 18th century Luigi Galvani a professor of anatomy at the University of Bologna found that a freshly dissected frog leg hung on a copper hook twitched when touched by an iron scalpel.
- The two metals had to be different.
- Galvani thought that he had discovered *the secret life force.*

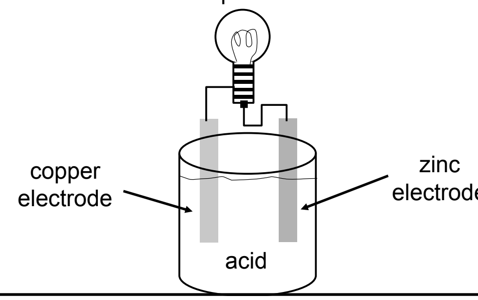
Alessandro Volta

- Professor of Physics at the University of Pavia realized that the electricity was not in the frog's leg but the twitching was the result of touching it with two different metals
- Volta had discovered the first battery.
- Lemon battery



Batteries

- use chemical energy to produce electricity
- two dissimilar metals immersed in a conducting fluid (like an acid for example) cause a chemical reaction which can produce electric current.



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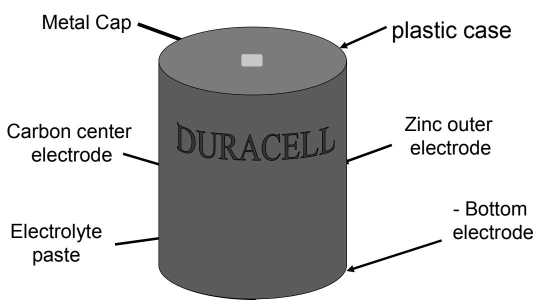
Inside a Duracell 1.5 Volt battery



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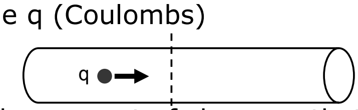
Electric current (symbol I)

- Electric current is the flow of electric charge q (Coulombs)



- It is the amount of charge q that passes a given point in a wire in a time t, $I = q / t$
- Current is measured in amperes
- 1 ampere (A) = 1 C / 1 s

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Potential difference or Voltage (V)

- Voltage is what causes charges to move in a conductor→ it produces an electrical force on the electrons which causes them to move
- Voltage plays a role similar to pressure in a pipe → to get water to flow there must be a pressure difference between the ends, this pressure difference is produced by a pump
- A battery is like a pump for charge → it provides the energy for pushing the charges around a circuit

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Electrical resistance (R)

- Galileo told us that no force is required to keep something moving with constant velocity
- So, why is it necessary to keep pushing the charges to keep them moving in a wire?
- As they move through the wire, the electrons collide with the atoms, so there is a type of friction involved; in this case a force is required to keep the electrons moving
- This continuous obstruction to the motion of the electrons is called electrical resistance → **R**
- The unit of electrical resistance is the ohm symbol (Ω)

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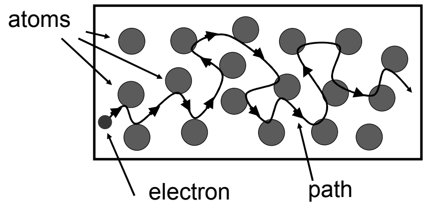
Electrons pass through an obstacle course in a conductor



- The **resistance (R)** is a measure of the degree to which the conductor impedes the flow of current
- We use the symbol

to represent the electrical resistance in a circuit