L 24 Electricity & Magnetism [2]

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

1

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
  → $e = 1.60217646 \times 10^{-19}$ C
- charges cannot be divided into smaller units

2

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 (–) put electrons on it
  - to make an object (**+**) remove electrons from it

3

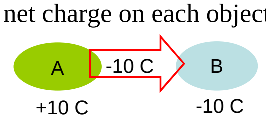
Charging by friction

- 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

4

Charge is *Conserved:* Example-1

- 10 Coulombs of negative charge are transferred from object A to object B. What, then is the net charge on each object?
- Answer:

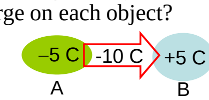


→ object A has a net charge of +10 C
→ object B has a net charge of –10 C.

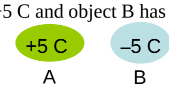
5

Charge is *Conserved:* Example-2

- 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.

6

Lightning-atmospheric electrostatics

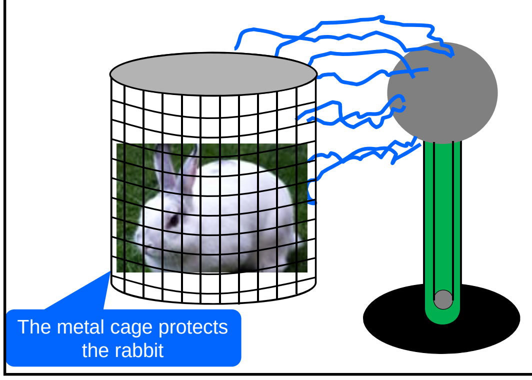
- **N**ational **W**eather **S**ervice: about 25 million lightning strikes each year in the US
- 400 people struck, 51 killed; odds 1/10,000 in lifetime
- causes 100 million dollars in damage each year in the US
- lasts only a thousandth of a second, with up to 200,000 A (typical hairdryer uses 10 A)
- produces the thunder!

7

development of a lightning bolt

charge separation | stepped leader | leader & streamer | leader meets streamer | lightning bolt

Electrostatic shielding



9

Electrostatic shielding

- The effect of the high voltage on the van de Graff generator stops on the outside of the metal cage ➔ The rabbit is unharmed!
- 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 walls affects radio transmissions

10

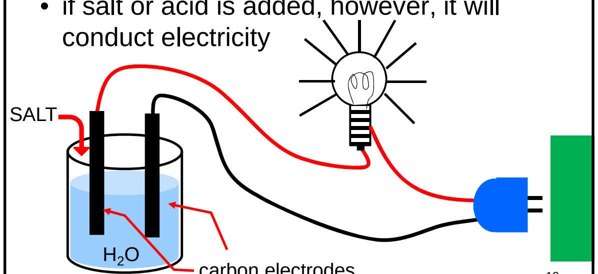
Liquid and gaseous conductors

- Except for mercury, which is a conducting liquid at room temperatures, the metallic conductors are solids
- Non-conducting liquids can be made conducting by adding ionic substances such as salt or acids
- Gases are non-conducting unless they are ionized (electrons removed from the atoms), then they become good conductors

11

Pure water is non-conducting

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



12

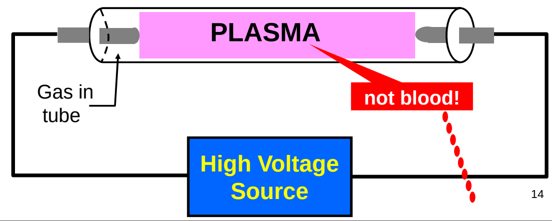
A salt water solution is a conductor

- 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^-

13

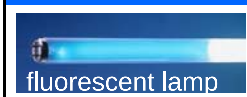
Gas discharges

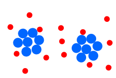
- When a high voltage is applied to a gas-filled tube, the gas becomes ionized → one or more electrons are removed from each atom.
- The ionized gas is a conductor → current can flow.
- The excited gas atoms emit light of a characteristic color



14

examples of electrical discharges





Ionization:

$$N_2 \rightarrow N_2^+ + e^-$$

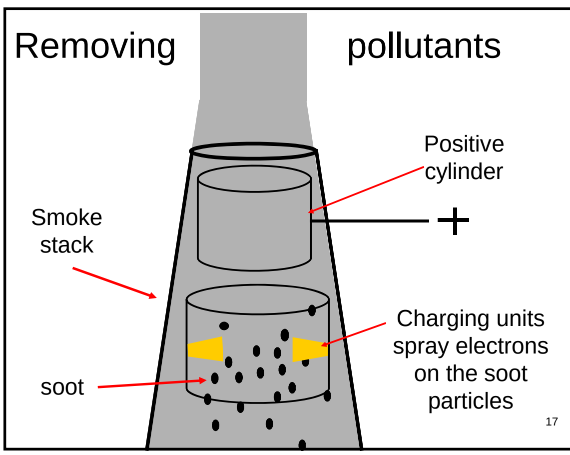
15

applications of electrostatics

- electrostatic attraction to put ink droplets on paper
  - Xerox machines
  - Inkjet printers
  - Paint sprayers
- Sorting particles by charge and weight
- electrostatic precipitators use the attraction of charged dust to remove dust particles from smoke.

16

Removing pollutants

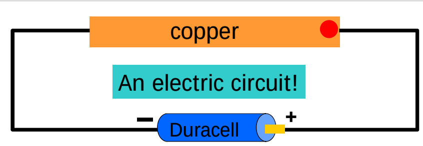


17

Current– flow of electric charge

Ordinarily, the free electrons in a piece of copper roam about *randomly* within the conductor – *no current!*

However, if I connect a battery to the copper bar the electrons are attracted to the positive side of the battery and will flow through the bar and connecting wires ➔ this is called **current** – *the flow of charge*

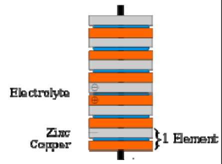


But, how does a battery work?

18

Batteries and frog's legs

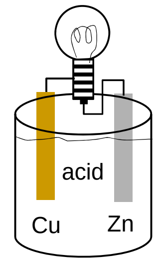
- Galvani found that a frog leg hung on a copper hook twitched when touched by an iron scalpel.
- Volta realized that the frog's leg was just acting as a conductor, and the two metals produced the current --- the first battery
- Volta replaced the frog's leg with brine soaked paper placed between strips of Cu and Zn

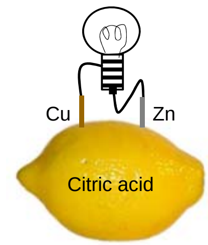


19

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 produces electric current.



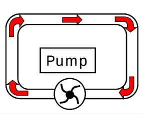


20

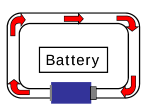
Potential difference or Voltage (V)

- 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

water

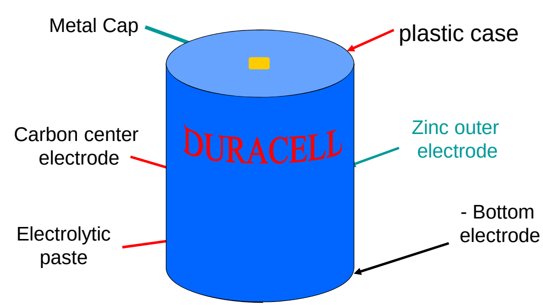


charge



21

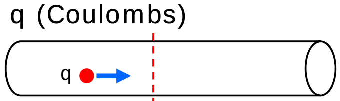
Inside a Duracell 1.5 Volt battery



22

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**, $I = \frac{q}{t}$
- Current is measured in **amperes**
- 1 ampere (A) = 1 C / 1 s

23