PHY 101 Lecture #6: Electrical Phenomena

Prof. Peter R. Saulson
saulson@physics.syr.edu

http://physics.syr.edu/courses/PHY101.01Fall/

Office Hours: Wed 12:30-2, or by appt.

Outline

1. Electrical charge
2. Electrical force and voltage
3. Electrical current
4. Electrical circuits

1. Electrical charge

Matter is made of atoms.

- Minority opinion from ancient world
- Gained adherents in 18th century, explained regularities of chemistry.
- Proven only in 20th century.

"Atom" means "uncuttable", i.e. smallest fundamental particle.

But atoms have internal parts.

Electrostatics

Electrostatic phenomena

- also known since ancient times
- 18th century started our systematic understanding

Electrostatic charge

- rubber rubbed with fur (negative charge)
- glass rubbed with silk (positive charge)

Electric force

- Like charges repel, unlike charges attract
- Force is stronger when charges are closer

Linking atoms and electrostatics

1. Electricity comes in small particles.
   electrical property is called *electric charge* (+ or -)
2. Atoms made out of those charged particles.
3. Those charged particles are “uncuttable”.
4. Ordinary matter (i.e. ordinary atoms) made up of equal amounts of positive and negative charge
   electrically neutral

Atomic structure

How atoms are built:

1. Outer region filled with electrons, particles with negative charge.
2. At core, a tiny nucleus made of protons (with positive charge) and neutrons (electrically neutral.)

Chemistry comes from counting:

Hydrogen: 1 electron, 1 proton

Helium: 2 electrons, 2 protons (and 2 neutrons)

etc.

Scale of atoms

- Atomic diameter:
  10^{-10} meters (= 0.1 nanometer = 0.1 nm)
- Nuclear diameter:
  10^{-15} meters (= 1 femtometer = 1 fm)

- Mass of electron: $m_e = 9.11*10^{-31}$ kg
- Mass of proton: $m_p = 1.67*10^{-27}$ kg
  mass of neutron 0.1% larger

Scale of electrical charge

SI unit of electrical charge is the *Coulomb*.

This is a huge amount of charge:

- Two 1 C charges separated by 1 meter exert a force on each other of $9*10^{9}$ Newtons!

Electron charge = $-1.602*10^{-19}$ C

Proton charge exactly equal and opposite

2. Electrical forces

Electrical phenomena recognized by electrical forces.

Force between two charges q_1 and q_2 given by Coulomb's Law:

$$F_{elec} = \frac{k_e q_1 q_2}{r^2},$$

where charges are in Coulombs, distance r in meters, and $k_e = 9*10^9$. Force comes out in Newtons.

Electrical forces II

Force between electron and proton in hydrogen atom = $4.6*10^{-18}$ Newton.

This sounds small, but is huge when the tiny mass of electron and proton is taken into account.

Electrical force compared to gravitational force

Gravitational force also has a similar force law:

$$F_{grav} = \frac{Gm_1m_2}{r^2},$$

where G = 6.67*10^{-11} SI units.

(F=mg is merely a good approximation near Earth's surface.)

Gravity is MUCH weaker than electric force:

Gravitational attraction between electron and proton in hydrogen only 2*10^{-57} Newtons. (!!)

Electrical potential energy

Electrical force means you have to do work to move an electric charge from one position to another.

If you have to do work to move the charge, then you store *electrical potential energy* in the system.

The units of EPE are Joules.

Voltage

Voltage at some location is defined as the electrical potential energy that would be stored in moving 1 C of charge from a reference point to that location.

SI unit of voltage is the Joule / Coulomb, also known as the Volt.

Voltage in real life

Voltage's definition may sound awkward, but it is easy to measure with a voltmeter.

Voltage between two points is easy to set, using a battery, which maintains a fixed voltage between its two terminals.

Many kinds of battery available, with voltages between 1 and 24 Volts.

Later, we will study the chemistry that makes them work.

3. Electrical current: conductors

Electrical charge can move from one place to another through empty space, of course.

Astonishing fact: electric charge can move freely through certain kinds of materials, called *conductors*.

Metals are the most common example of conductors.

Conductors *vs.* insulators

Materials called *insulators* do not allow the free movement of electrical charges.

Examples:

- rubber
- plastic
- glass
- ceramics

Appearance is often a good guide: conductors are usually shiny like metals.

Current: the motion of charge

When charges move, we call it an electrical current.

Current is measured in Coulombs/sec passing a given place.

SI name for a C/s is the Ampere, abbreviated A.

1 A is a pretty large current:

- Fuses in a building usually set to prevent currents exceeding 15 A.

4. Electrical circuits

To do useful things with electric currents, allow current to flow in a complete *circuit* from one terminal of a battery to another.

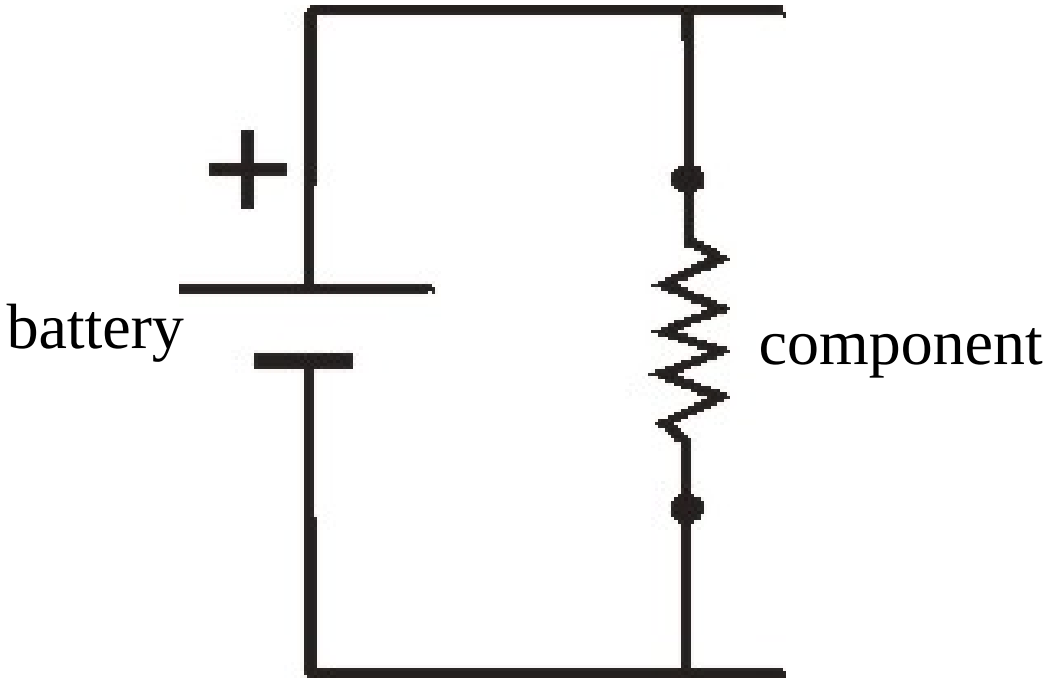
Circuit can be a simple component connecting battery terminals, or several components.

Components can be combined in two basic patterns:

- series connection
- parallel connection

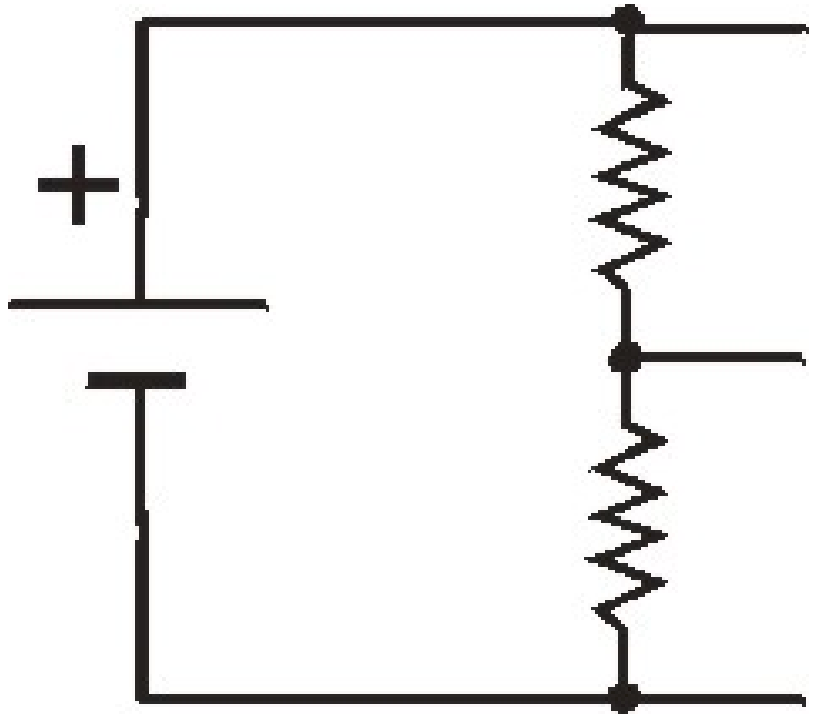
Simple circuit

A single component completes the circuit from one battery terminal to the other.



Series circuit

Two components complete the circuit, arranged so that the same current goes through both of them.



Parallel circuit

Two components complete the circuit, arranged so that the current is split between them.