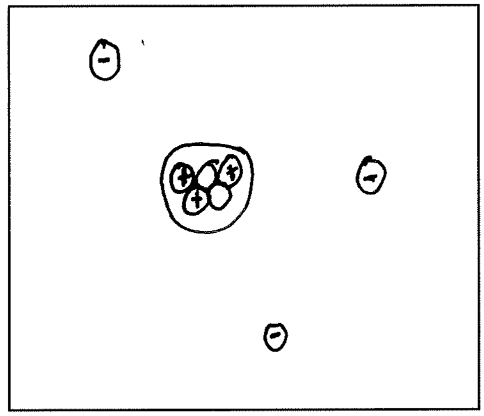
Note Booklet #~~4~~ 5:

~~Energy~~ - Electricity

All matter is made of atoms, which have a nucleus consisting of positively charged protons and neutral neutrons. Surrounding the nucleus are negatively changed electrons.



Like magnets positively charges particles are attracted to negative charges and repelled by positive charges. Similarly, negatively charged particles are attracted to positive charges and repelled by negative charges.

QUESTION: There is a negatively charged area connected by a wire to a positively charged area.

a) Are there more electrons or protons in the negatively charged area?

Electrons

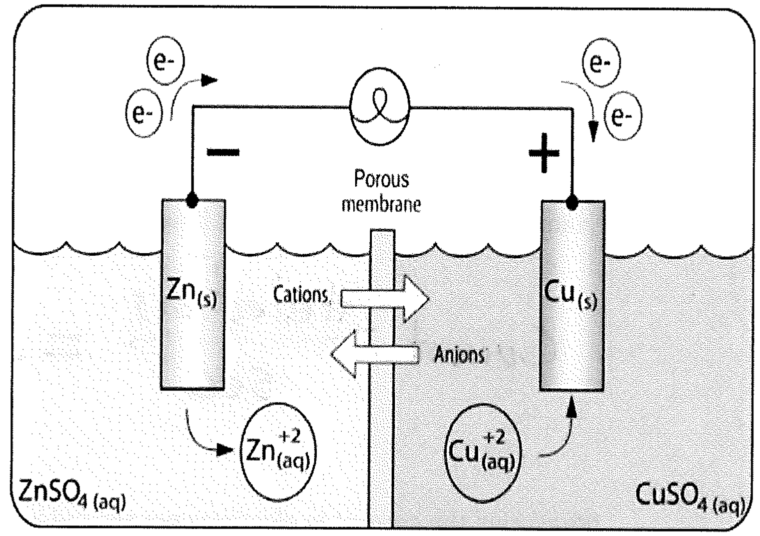
b) Are there more electrons or protons in the positively charged area?

Protons

c) What will happen?

Electrons will move from negative to positive until it is balanced

A battery contains a pair of chemical reactions, one which uses up electrons and one which produces electrons.

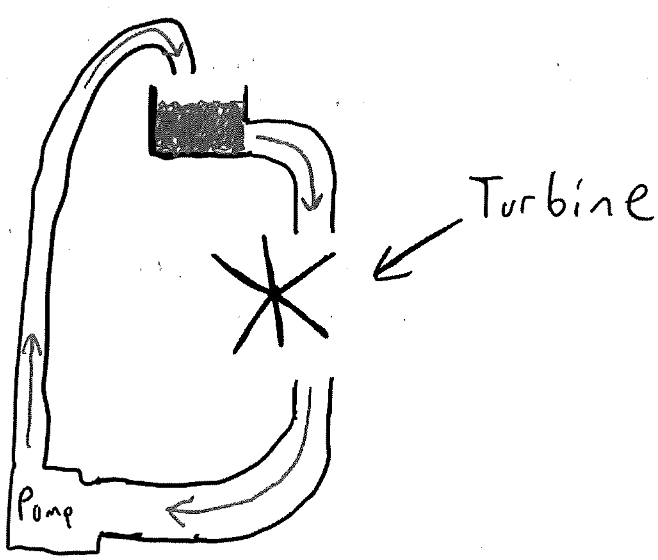


The place where the electrons are being used up will have fewer electrons than protons, so it will be positive, this is called a cathode.

The place where the electrons are being produced will have more electrons than protons, so it will be negative, this is called an anode.

If the anode is connected to the cathode with a wire, electrons from the anode will flow towards the cathode. The electrons at the anode have electric potential energy, this is analogous to gravitational potential energy.

We can think of the flow of electricity as the flow of water from a height. In that model consider water starting in a tank high above the ground, it flows downwards and as it flows it turns a turbine, doing work. When the water reaches the bottom, a pump lifts it back to the tank.



The pump represents the Battery

The water represents the electrons

The height difference between start and end represents the potential difference, called voltage.

In the water analogy the flow rate of the water is how much water passes a point each second and it could be measured in liters per second. In an electric circuit this is called __Current__ and can be measured in electrons per second.

Example: A 2.5×10^{19} electrons flow through a circuit in 5.0 seconds. What is the current?

$$\text{Current} = \frac{\#\text{electrons}}{\text{sec}} = \frac{2.5\times10^{19}\ \text{electrons}}{5.0\ \text{secs}} = \frac{5.0\times10^{18}\ \text{electrons}}{\text{sec}}$$

Measuring the current in electrons per second has the disadvantage of using massive number, so we normally use the alternative measure of coulombs per second, one coulomb of charge is the same as 6.24×10^{18} electrons.

Example: What is the current of the previous example in coulombs per second?

$$\frac{5.0\times10^{18}\ \text{electrons}}{\text{sec}} \times \frac{1\ \text{C}}{6.24\times10^{18}\ \text{electrons}} = 0.80\ \text{C}/\text{sec}$$

Example: How many electrons flow past a point in a circuit in 5.0 seconds if the current is 0.56 coulombs per second?

$$0.56 \times 6.24\times10^{18} = 3.4944\times10^{18}\ \frac{\text{elec}}{\text{sec}} \times 5\ \text{sec}$$

$$= 1.7\times10^{19}\ \text{electrons}$$

The unit for current is the ampere

$$1 \text{ amp} = \frac{1 \text{ coulomb}}{\text{sec}}$$

$$I = \frac{Q}{t}$$

current → I, charge → Q, time → t

EXAMPLE: 50.0 coulombs of charge flow through a wire in 25 seconds. What is the current?

$$I = \frac{50.0\ C}{25\ sec} = 2.0A$$

$1A = 1000mA$

EXAMPLE: How many electrons pass through a wire in 5.0 seconds if there is a 0.35mA current?

$$\frac{0.35mA}{1} \times \frac{1A}{1000mA} = 0.00035A$$

$$Q = It$$

$$= 0.00035A \times 5.0\ sec$$

$$= 0.00175\ C \times \frac{6.24 \times 10^{18}\ electrons}{1\ C} = 1.1 \times 10^{16}\ electrons$$

If you connect the positive and negative terminals of a battery with a wire

electrons flow from − to +

If you connect the positive and negative terminals of a battery with a piece of plastic

nothing happens

This is because a wire is a conductor and a piece of plastic is an insolator.
More generally we can say the wire has low resistance and the plastic has high resistance.

All standard materials have some resistance, an electrical appliance uses resistance to convert electrical energy into other forms of energy. Wires and resistors convert the electrical energy to heat.

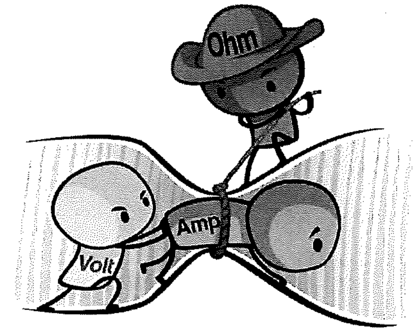
The units for resistance are ohms (Ω)

Ohm's Law:

$$R = \frac{V}{I}$$

$$V = IR$$

$$I = \frac{V}{R}$$



Example: A 50.0 Ω lightbulb is connected to a battery with a 9.0 volt potential difference between the terminals. What will the current be?

$$I = \frac{V}{R} = \frac{9.0V}{50.0\Omega} = 0.18A$$

Example: A circuit consisting of a 9.0 volt battery connected to a light has a current of 840 mA. What is the resistance of the light?

$0.84A$

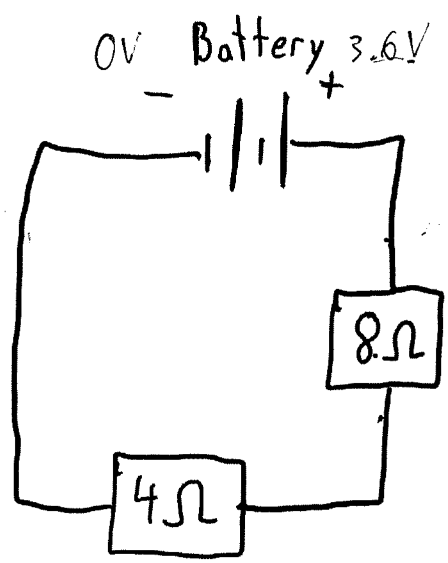
$$R = \frac{V}{I} = \frac{9.0V}{0.84A} = 10.71\Omega \approx 11\Omega$$

Example: What is the potential difference across a 250 Ω load that has 1.2 A of current flowing through it.

(voltage)

$$V = IR = 1.2A \times 250\Omega = 300V \approx 3.0 \times 10^2 V$$

Example: A battery with voltage of 3.6 V is connected to an 8.0 ohm and a 4.0 ohm load in series. The current through the circuit is 0.30 amps.



What is the potential difference across the 8 ohm load?

$$V = IR = 0.3A \times 8\Omega = 2.4V$$

What is the potential difference across the 4 ohm load?

$$V = IR = 0.3A \times 4\Omega = 1.2V$$

Electric Power: Recall Power is defined as work over time, and work is change in energy

$$P = \frac{W}{t} = \frac{\Delta E}{t} = VI$$

Power is measured in watts

Since $P \times t = \Delta E$

(P: watts, t: sec)

An alternative measure of energy is watt · sec

Kilowatt · hour

Example: A 1600 W hairdryer is connected to 120 V power source. What is the current flowing through the hairdryer?

$$I = \frac{P}{V} = \frac{1600\,W}{120\,V} = 13\,A$$

Example: A 20.0 V power source is connected to a 40.0 ohm resistor for 15 seconds. How much heat is generated?

$$I = \frac{V}{R}$$

$$P = VI = V\left(\frac{V}{R}\right) = \frac{V^2}{R}$$

$$P = \frac{20.0^2}{40\,\Omega} = 10 \text{ watts}$$

$$W = Pt = 10\,W \times 15\,sec = 150\,J$$