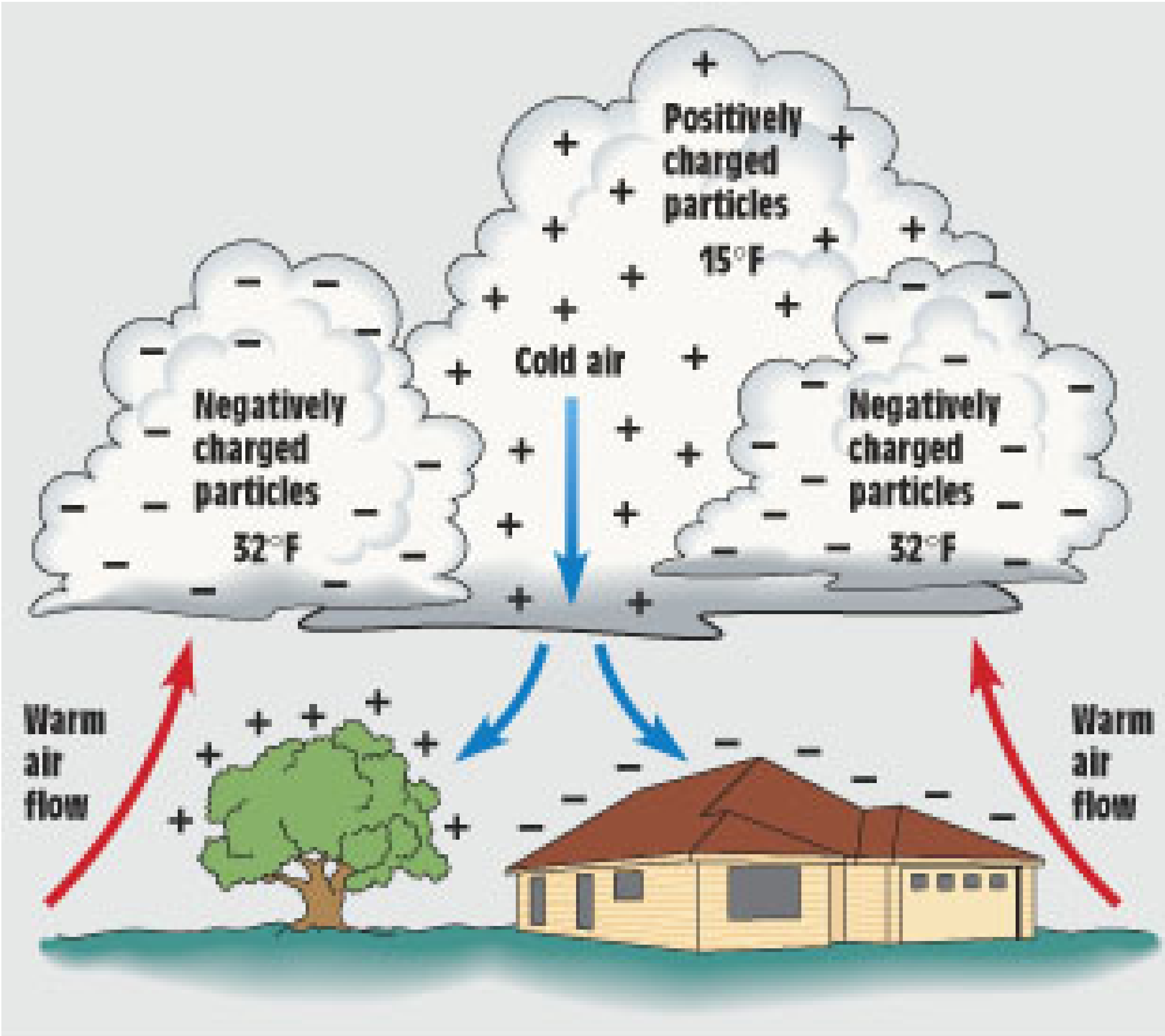
Basic Electricity

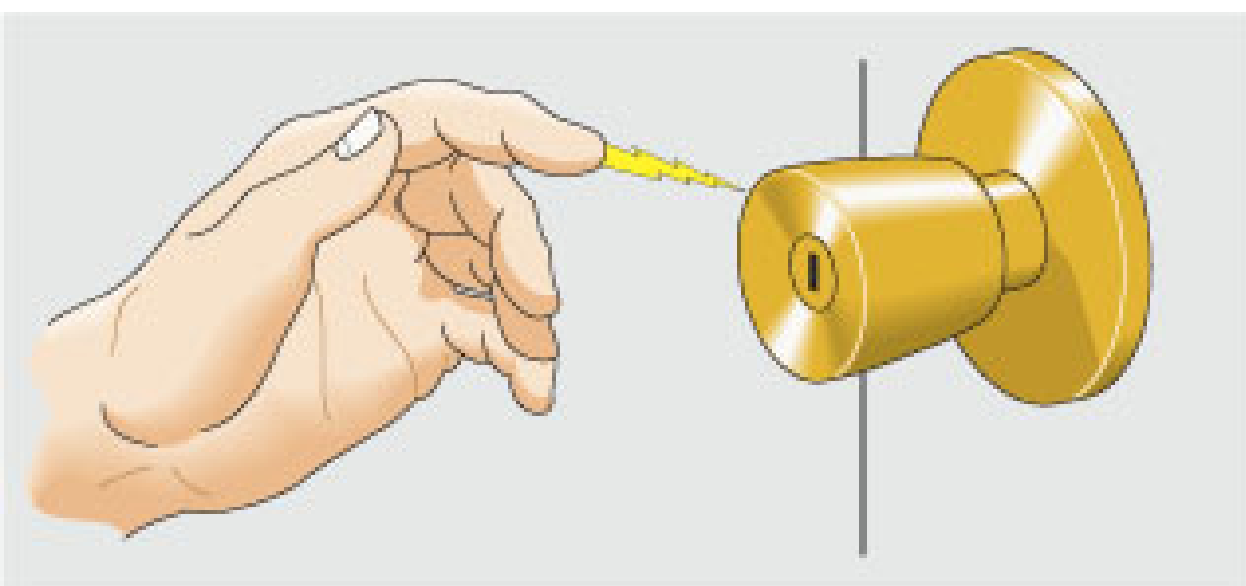
Electricity is an apparent force in nature that exists whenever there is a net electrical charge between any two objects.

Basics of Electrostatics:

- **Electrical charges are either negative (electrons) or positive (protons)**
- **The unit of charge, *q*, is called the coloumb.**
- **When there are equal numbers of positive and negative charges there is no electrical force as there is no net charge. This is the case for a neutral atom.**
- **Electrical force is created when electrons are transferred from one material to another (e.g. rubbing a wool cloth with a plastic comb).**
- **Electrical charge is conserved; charge is neither created nor destroyed**

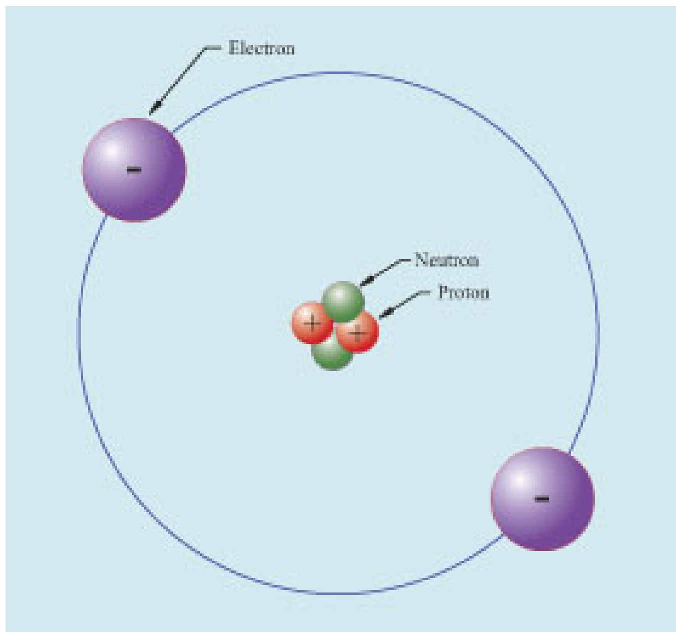
Examples of Electrostatics?

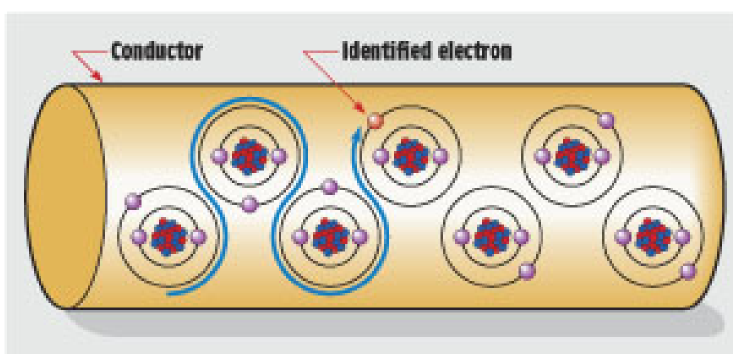

Positively charged particles
15°F
Cold air
Negatively charged particles
32°F
Negatively charged particles
32°F
Warm air flow
Warm air flow

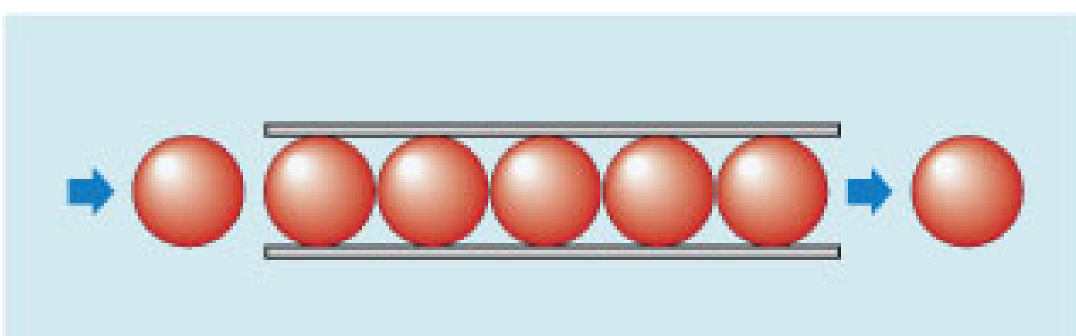


Properties of Electricity:

CURRENT: denoted by *I* and measured in amperes. Current flows from <u>negatively</u> charged material to <u>positively</u> charged material and is essentially the number of electrons per second that are carried through a conductor. Current is measured in units of amps. 1 amp = 1 coloumb/sec = 6.2×10^{18} electrons per second!







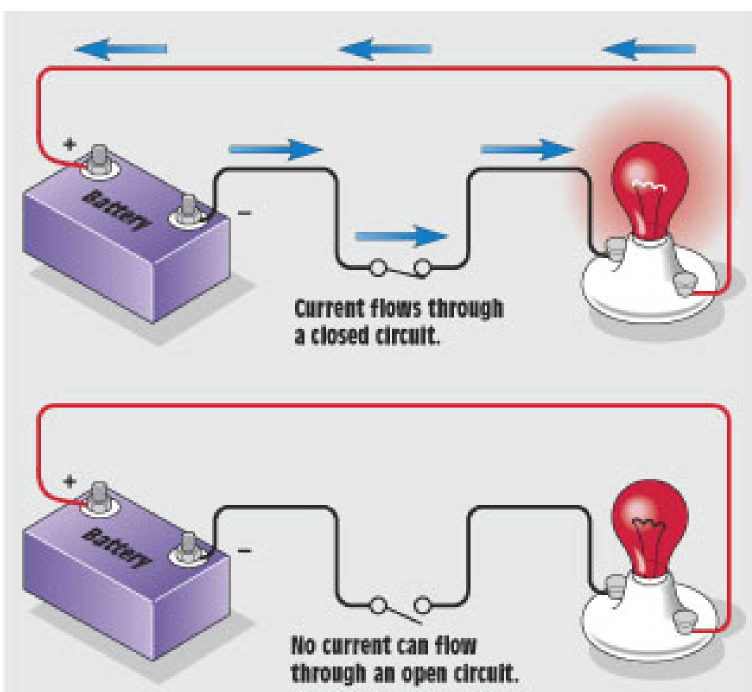
VOLTAGE: Potential difference between a negatively charged object and a positively charged one (like two terminals on a battery). Potential difference is measured in units of Volts (*V)* which represents the work done per unit charge to move electrons between the positive and negative terminals. If a potential difference exists, then energy can be extracted.

Imagine that you have two opposite charges that you want to separate. It takes work to separate the charge and thus the separated charges store energy. The amount of stored energy is given by:

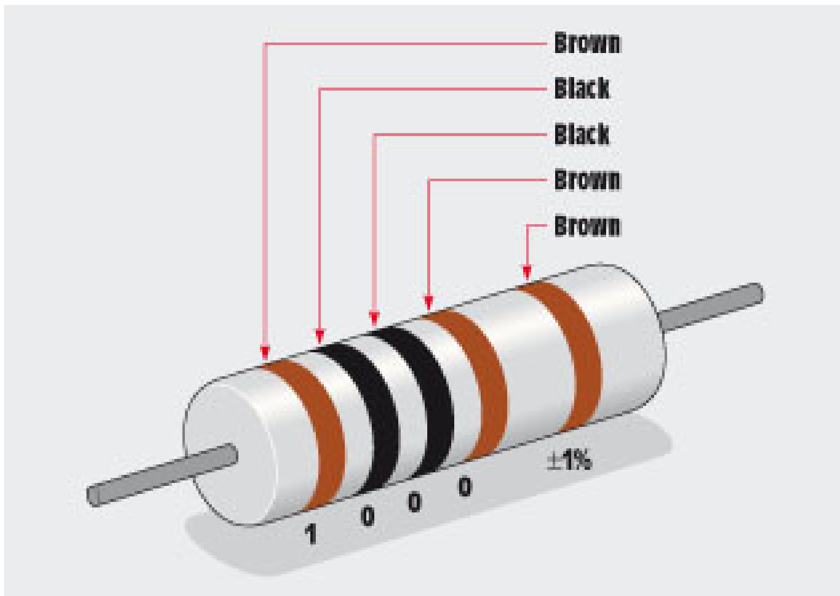
E = qV where V is the voltage or electric potential of some system.

The units of voltage or Volts: 1 Volt = 1 Joule/Coulomb

If the separated charges get back together, work/energy can be extracted from the system. If there is some pathway for the charges to flow then we get a current. Current is denoted by *I* and is in units of *amperes* or *amps* ☞ 1 Ampere = 1 coulomb/second



RESISTANCE: Property of material that helps prevent the flow of electrons in it. Metals are good conductors due to low resistance. Wood is a poor conductor due to high resistance. Resistance, *R*, is measured in ohms and depends upon both the type of material and its size. Long wires have more resistance than short wires; thin wires have more resistance than thick wires. *R* is also temperature dependent.



Something else you will need to know:

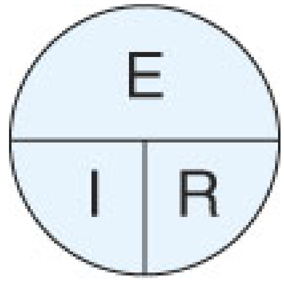
Resistance Total in a series circuit = R1 + R2 + R3 = Rt

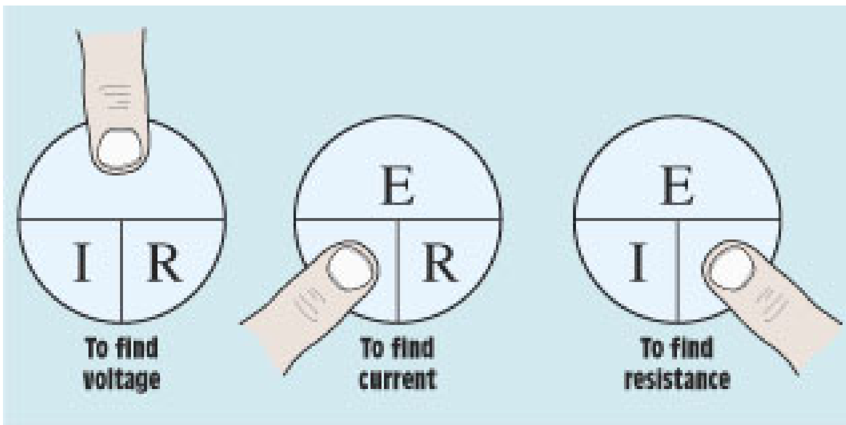
<u>1</u>

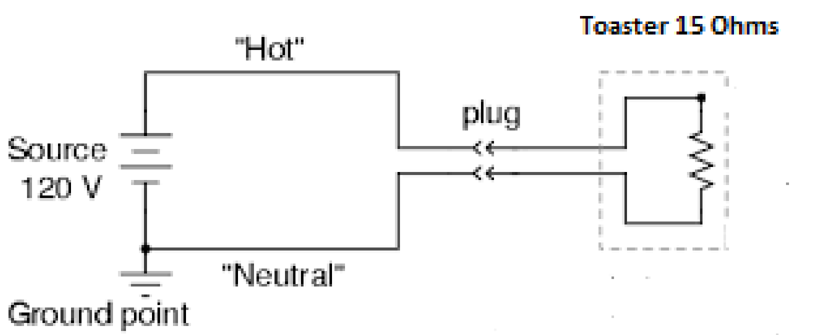
Resistance Total in an Parallel Circuit = Reciprocal Method or the Product over Sum method.

OHM's LAW

Is there a relation between *I*, *V*, and *R*.?







- **Standard US household voltage is 120 Volts.**
- **The heating element in your toaster has R = 15 ohms.**
- **What is the current flowing through your toaster?**

I = V/R = 120/15 = 8 amps

Your electricity bill essentially measures the amount of current that you use but you use this current as *Power*.

Power = V * I

So the toaster has a power of 120x8 = 960 Watts.

Energy = Power * Time (and its energy --> kilowatt hours that you pay for - a 100 watt light bulb left on 10 hours = 1 kilowatt hour.)

If you leave your toaster on for one hour, than that would also be approximately 1 KWH (960 watt-hours if you want to nit-pick).

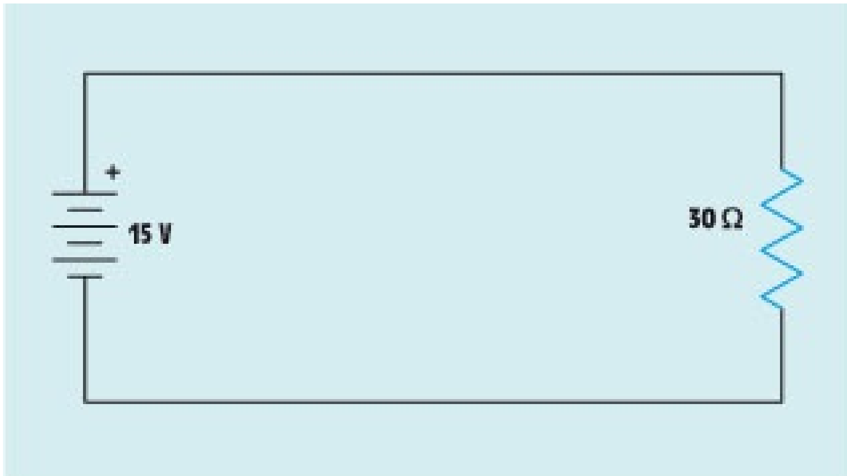
1000 Watt-hours = 1 Kilowatt hour (KWH); ☞A KWH will be our basic unit of energy in this class. You purchase KWHs from the electric utility whenever you use power in your home.

Kilo	1000
Hecto	100
Deka	10
Base unit	1
Deci	$\frac{1}{10}$ or 0.1
Centi	$\frac{1}{100}$ or 0.01
Milli	$\frac{1}{1000}$ or 0.001

Circuits

Types: Series, Parallel, and Combination circuits

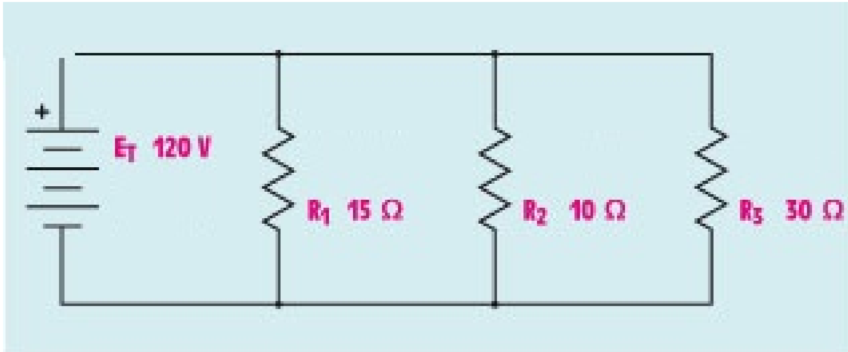
Series Circuit



Calculate Current Flow.

Calculate Power.

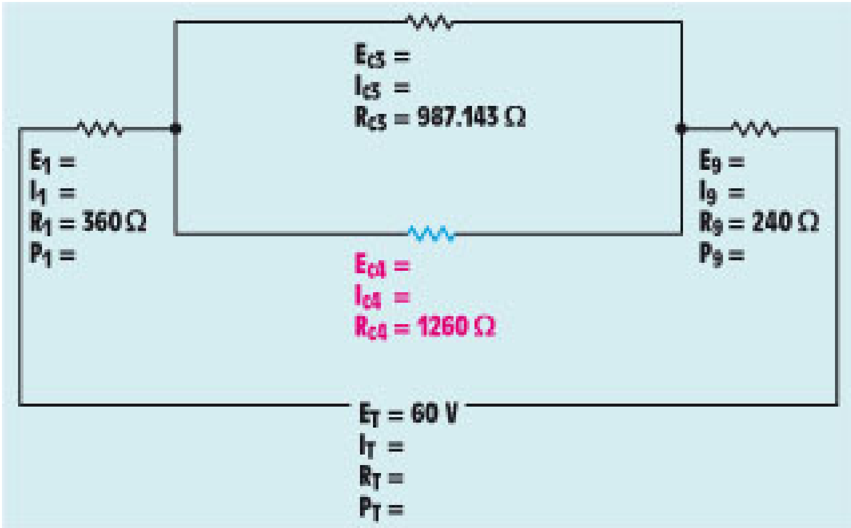
Parallel Circuit



Calculate Current Flow.

Calculate Power.

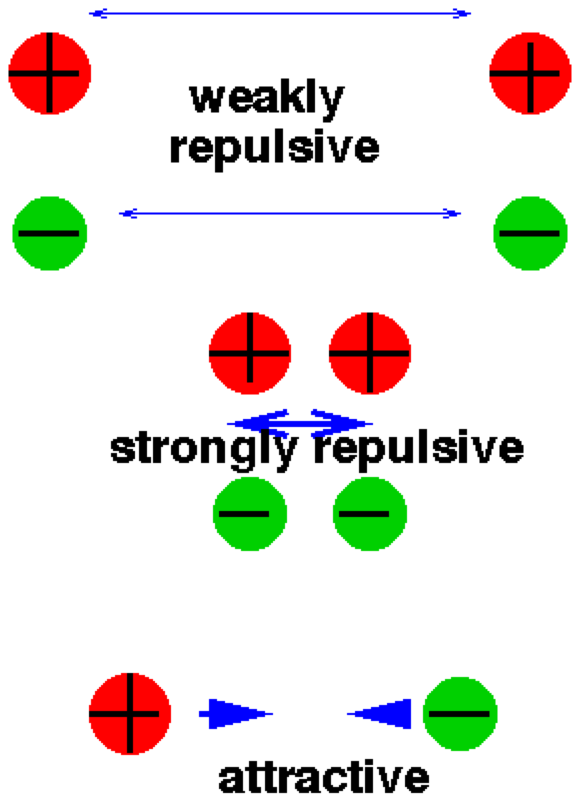
Combination Circuit



The Discovery of Electricity and Magnetism and the Generation of Electricity.

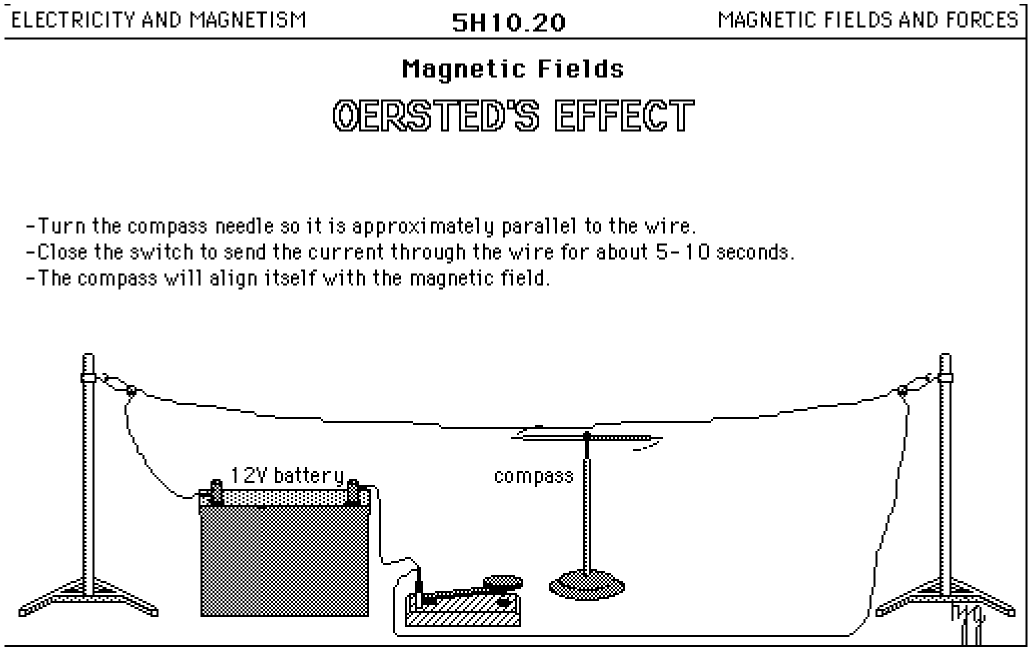
In the early 19th century the following similarity between two charged particles and two magnets was observed:

- **both created "forces" that could operate in a vacuum**
- **charge had a positive and negative component; magnets had a north and south pole force could then be either attractive or repulsive.**



- **both the magnetic force and the electrostatic force strength decreased as $1/R^2$**

In 1820 Oersted did this experiment:



he discovered that *an electric current creates a magnetic field*

Similarly, a coil of wire with a current passing through it generates a magnetic field. This is known as an electromagnet or solenoid.

So now we know that a current can create a magnetic field. If a magnetic field can create a current then we have a means of generating electricity. Experiments showed that a magnetic just sitting next to a wire produced no current flow through that wire. However, if the magnet is moving a current is induced in the wire. The faster the magnet moves, the greater the induced current.

This is the principal behind simple electric generators in which a wire loop is rotated between to stationary magnetics. This produces a continuously varying voltage which in turn produces an alternating current.

Diagram of a simple electric generator:

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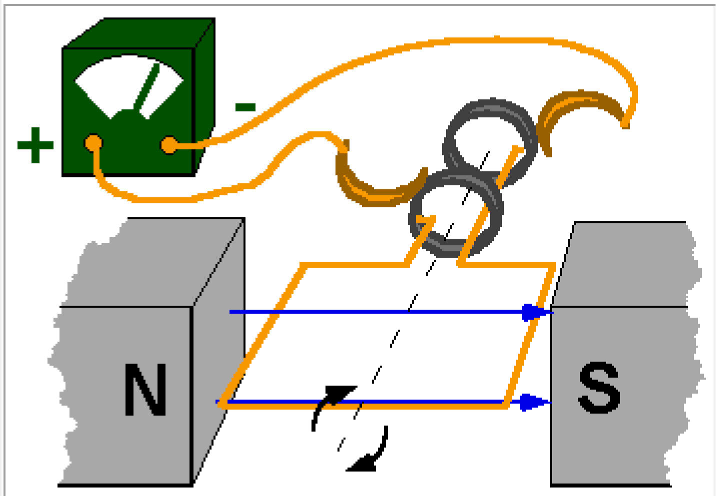
<td>
</td>
<td>In this position there is no current flow but there is a large potential difference (a large voltage)</td>
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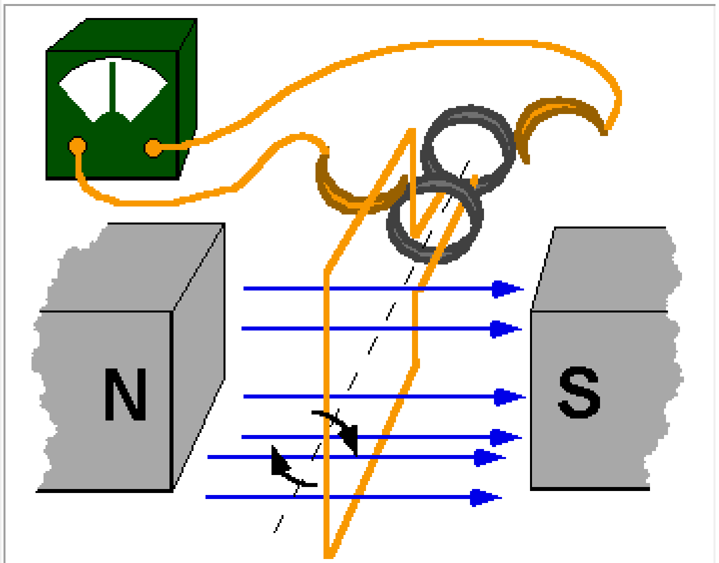
<td>
</td>
<td>In this position the Voltage is now zero and the current flow is at a maximum</td>
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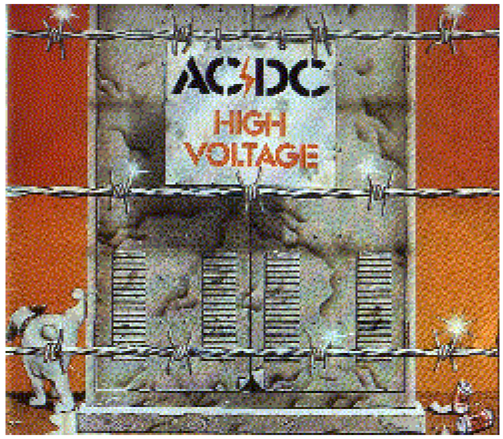
To generate electricity then, all we really want to do is have some (mechanical) mechanism turn a crank that rotates a loop of wire between stationary magnets. The faster we can get this crank turned, the more current we can generate.

Popular Methods of Turning the Crank:

- **Let water fall on it (Hydro Power)**
- **Direct a nozzle of steam at it (Coal or Nuclear Fired Steam Plant)**
- **Let the wind turn it (windmill)**



Why do transmission lines carry such high voltages?

Consider the following:

- **Electricity is generated at the generating plant at 120 Volts and then delivered to the households over conductors.**
- **There are 10 households and each needs 1000 Watts (for their toasters)**
- **The electric company must therefore supply 10x1000 = 10,000 Watts.**
- **Power = I x V ☞ I = P/V ☞ I = 10000/120 = 83 amps**
- **But, electrical power is dissipated as heat according to $P = I^2R$ (substitute V=RI from ohms law in above)**
- **Let's assume R= 1: We now have heat dissipation = (83.3)*(83.3)(1) = 6944 watts. ☞ Heat dissipation is energy lost by the system. This loss is unavoidable!**

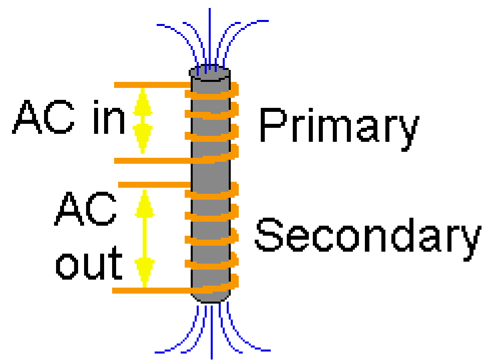
- **To deliver the 10,000 watts that the consumer needs requires that we generate 16,944 watts and hence have an overall efficiency of 10,000/16,944 = 59% ☞ which the consumer would pay for**

How to solve the loss problem:

Current = Power/Voltage; If we increase V by a factor of 10, then I lowers by a factor of 10 (at constant power) and the power dissipated as heat lowers by a factor of 10^2.

Hence if we increase 120 Volts to 1200 Volts we have only 69.4 watts of energy loss and a 99% energy efficient delivery system This is why high voltage (typically 760 thousand Volts or 760 kiloVolts) transmission lines are required to delivery electricity from central generating sources (e.g. a hydroelectric dam) to consumers/grids hundreds of miles away.

How to change the voltage: Use a Transformer



A transformer uses alternating current in one coil to induce alternating current in another. The induced voltage is given by: $V_{out} = V_{in} \times N_2/N_1$ where N_1 = Number of coils in the Primary and N_2= Number of coils in the secondary. When N_2 is less than N_1, we reduce V_{out}. This is why there are transformers on power lines to step the voltage down to 120 Volts by the time it reaches your house.

Energy conservation tells us that Power In = Power Out

so

$$V_{out} \times I_{out} = V_{in} \times I_{in}$$

Since V_{in} is very high, I_{in} is low and (to prevent transmission loss); when V_{in} is stepped down to produce V_{out} (what you get at your house), I_{out} increases so you can run your stuff.

And that's the way the world works.