GENERATORS AND MOTORS

A device that converts mechanical energy (energy of motion – windmills, turbines, nuclear power, falling water, or tides) into electrical energy is called an **electric generator**. The operation of a generator depends on the relationship between electricity and magnetism.

Electricity to Magnetism
Deflection of a compass needle using electrical current showed that there is a relationship between electricity and magnetism. Hans Christian Oersted found that the current created a magnetic field around the wire. The amount of needle deflection depended on how much electric current was flowing in the wire. When the current was reversed, the needle moved in the opposite direction.

Electromagnets
When a soft iron core is inserted into a coil of wire and a current is passed through the wire, a very strong temporary magnet is produced, called an electromagnet.

The strength of an electromagnet is affected by the …
- type and size of core
- strength of current
- number of coils

Magnetism to Electricity
Electric effects can also be created using a magnet. Michael Faraday (and Joseph Henry) discovered electromagnetic induction in 1831. They demonstrated that moving a conducting wire through a magnetic field by moving it back and forth through the field, Faraday created the first electricity-producing generator, which could generate electrical current. They also found that moving the magnet worked as well.

Faraday introduced terms such as 'ion', 'electrode', 'cathode', and 'anode' to science and invented the lines of magnetic force. The farad, a unit for measuring stored electric charge, was named after him.
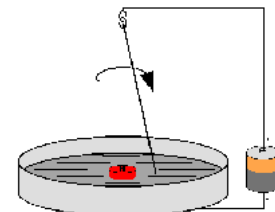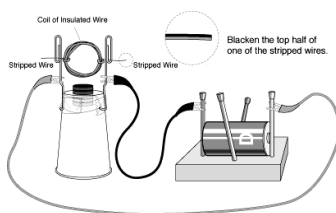
Generators
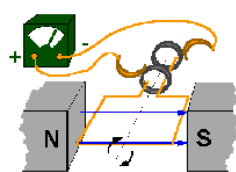
An **AC generator** – the most common type – has a coil of wire rotating inside a stationary field magnet. The central axle of an AC generator has a loop of wire attached to two slip rings. The current is switched as the loops move up and down alternatively through the magnetic field. The slip rings conduct the alternating current to the circuit through the brushes (the brush and ring assembly allows the whole loop to spin freely).

The electricity produced by this type of generator is called alternating current because it changes direction (in North America it changes direction 120 times per second – giving 60 Hertz or complete waves each second. In large AC generators many loops of wire are wrapped around an large iron core. Massive coils of wire rotating in huge generators can produce enough electricity to power an entire city.

A **DC generator** is much the same as a DC motor, and is often called a dynamo. The spinning armature produces the electricity (if electricity is passed through a DC generator, it will spin like a motor). The armature is connected to a split ring commutator which enables this type of generator to send current through a circuit in only one direction. The DC generator's pulsating electricity is produced in one direction - referred to as direct current - and coincides with the spinning of the generator.

Electric Motors: Electric to Mechanical Energy

An electric motor is constructed in exactly the same way as a generator. Instead of producing electricity, it uses electrical energy to make a wire coil spins between the poles of a magnet. Current flowing through the coils makes it an electromagnet, which is then affected by the laws of magnetic forces when it is in proximity to the field magnet. Opposite poles attract and like poles repel. All electric motors operate on this principle.
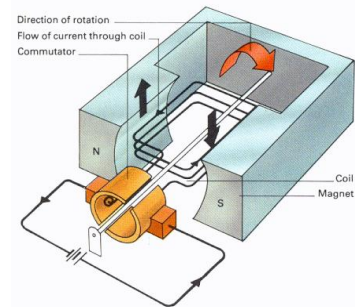

Some motors run on direct current (DC). It is 'direct', because the electricity flows in only one direction. Alternating current (AC) flows back and forth 60 times per second

DC Motors

Faraday constructed the first motor. By coiling (copper) wire around a (iron) metal core a strong electromagnet can be made. When attached to an electrical source it will produce a strong magnetic field. To keep this electromagnet spinning in a magnetic field, the direction that the current is traveling through the coil must be switched. This is accomplished by with a gap, which allows the polarity of the electromagnet change just before it aligns with the permanent magnet.

DC motors use a commutator (a split ring that breaks the flow of electricity for a moment and then reverses the flow in the coil, when the contact is broken, so is the magnetic field) and brushes (contact points with the commutator) to reverse the flow of electricity through the magnetic field. The armature (the rotating shaft with the coil wrapped around it) continues to spin because of momentum, allowing the brushes to come into contact once again with the commutator. The **St. Louis Motor** was designed to teach how a DC motor works

Parts of the ST. LOUIS MOTOR
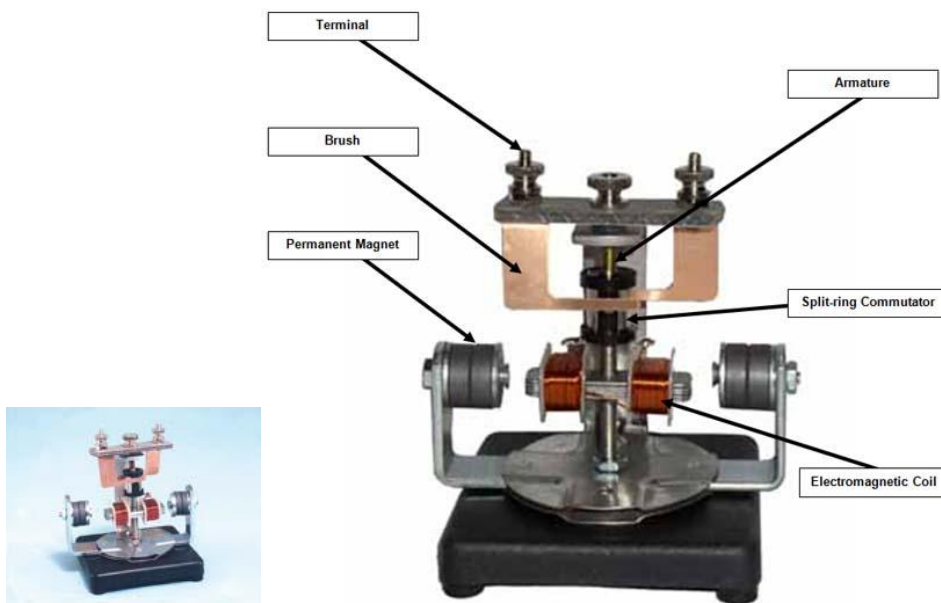
AC Motors

AC motors have a rotating core, or rotor, made up of a ring of non-magnetic conducting wires connected at the ends and held in a laminated steel cylinder. Surrounding the rotor is a stationary component called a stator. The stator is a two-pole electromagnet. When the motor is turned on, the attraction and repulsion between the poles of the stator and the rotor cause the rotor to spin.

TRANSFORMERS AND POWER

Transmission of Electricity through the Power Grid

Transformers are used to change the amount of voltage with hardly any energy loss. Voltage change is necessary because the most efficient way to transmit current over long distances is at high voltage and then reduced when it reaches its destination, where it will be used.

Electrical Power Grid
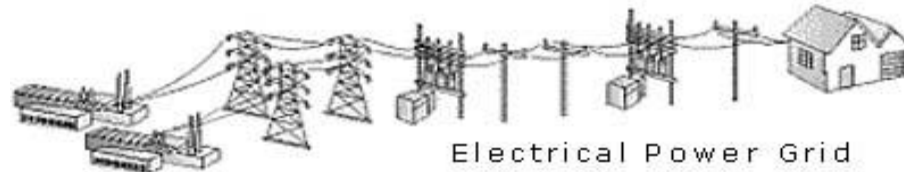
A *step-up transformer* increases voltage at the generating plant prior to distribution to the power grid over high voltage transmission lines, whereas, a *step-down transformer* reduces voltage just before entering your home.

From the Grid into Your Home

Coming in contact with a power transmission line can prove to be deadly.   By touching it, a short circuit can occur, because the electricity is trying to find a path to the ground - you can complete the circuit, and it may be fatal. Power needs to enter your home safely.

Electrical power enters a meter
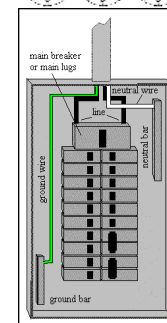on the side of your house where electrical usage is recorded   on little dials

Power is then routed into the service panel
(usually in the basement).

 The main circuit breaker
shuts off all the power in the house at once, in case of an overload.
The individual circuit breakers in the service panel
control the branch circuits, located throughout the entire house.

Each branch circuit is connected in parallel to wall plugs, lights and wall switches within a particular area of the house.

Each branch circuit is a series of 14 gauge electrical cables that contain:

2 *'live'* insulated wires (white – neutral; and black – hot);
And, a *'ground'* wire (bare copper wire, or insulated green).

Home Wiring

To install or change electrical wiring in your home a *permit* is necessary and all work done must meet a set of standards called the **electrical code**.

Typical 120V - 20A Parallel Circuit with 4 wallplugs - one of which is switched.
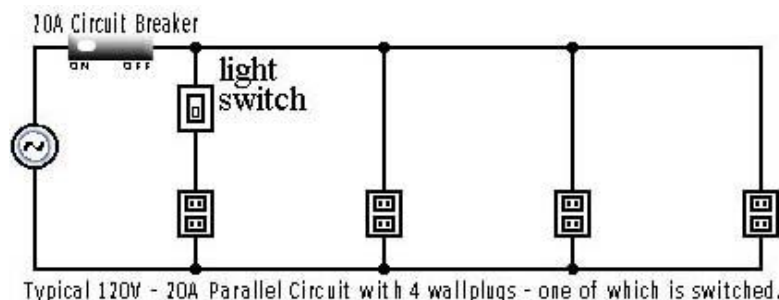
Digital Devices

The four basic elements of a circuit are present in a microcircuit, as well as a normal electrical circuit, although they may be in different forms. Conductors are thin traces of copper, instead of wires. Resistors and lamps are similar, but the **switches** are very different.

To process the digital information switches in microcircuits use 'binary code' – 0 and 1 - for on and off.

These *electronic digital switches are transistors* – solid state components that are controlled by electronic signals.

The transistors can then control other signals.
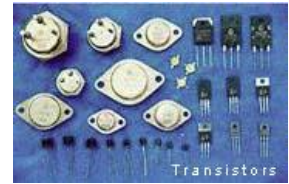
Measuring Electric Power

Power is defined as energy per unit time. Electric power describes the amount of electric energy that is converted into other forms of energy (heat, light, sound, or motion) every second. The formula that is used is:

Electrical power measures *voltage* and *current* and the formula is as follows:

Power (watts) = Energy (joules) / Time (seconds)

A *kilowatt* is 1000 watts.
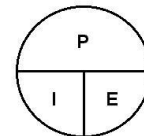
P = Watts
I = Amps
E = Volts

POWER = CURRENT X VOLTAGE

$$CURRENT = \frac{POWER}{VOLTAGE}$$

$$VOLTAGE = \frac{POWER}{CURRENT}$$

The electrical power formula can be manipulated as follows to determine Power, Current or Voltage use:

Model Problem

http://www.cix.co.uk/~hdh/power/power.htm
Do your own model problems online and get immediate results. (Good for homework questions as well.)

Paying For Electrical Energy

The power rating of a device can be used to determine the amount of energy the device uses. Multiply the power rating by the time the device is operating.
(E) Energy in joules (P) Power in watts (J/s) (t) time in seconds
$E = P \times t$ $P = E / t$ $t = E / P$

Kilowatt Hours is used as a unit for energy. The energy calculation is the same, except that hours are substituted for seconds and kilowatts (kW) are substituted for watts.
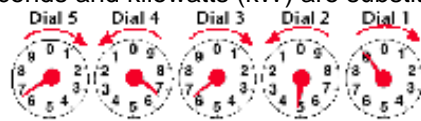
Electricity meters measure the energy used in kilowatt hours and then bills you for every kilowatt hour used.

Power Rating

The power rating on an energy using device tells you how many joules of energy (1 W = 1J/s) the device uses every second it is on. **ENERGUIDE** labels help consumers make comparisons of energy use, when purchasing large appliances.

Measuring energy inputs and energy outputs allows you to calculate the efficiency of devices and systems.
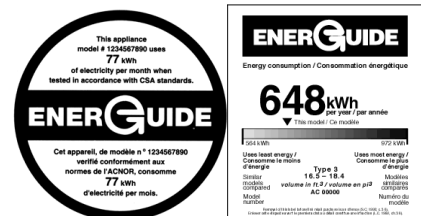
The large number indicates the approximate amount of energy the appliance uses in 1 year.

EFFICIENCY

Electric Devices and Efficiency

Energy is neither created nor destroyed. It doesn't appear and then disappear, but is transformed from one form to another. Known as the **Law of Conservation of Energy,** *no device is able to be 100% efficient in transforming energy*. Most of the energy transformed in a light bulb is wasted as heat. Most often, the energy is lost, or dissipated as heat. Mechanical systems also dissipate energy to their surroundings, but not as obvious as the heat loss. Much of the dissipated energy is sound.

The efficiency of a device is the ratio of the useful energy that comes out of a device to the total energy that went in. The more input energy converted to output energy, the more efficient the device is.

$$\textbf{Efficiency (\%) = } \frac{\textbf{\textit{useful energy output (J)}}}{\textbf{\textit{total input energy (J)}}} \textbf{\textit{ x 100\%}}$$

Comparing efficiencies of devices by their energy cost and their environmental impact can be an important decision that can affect sustainability of our resources, by helping us to make better consumer choices.

Incandescent light bulbs (5% is light energy, while 95% is heat)

Halogen lights (filled with high-pressure gas, with traces of iodine) (15%).

Florescent lights (20%) are even more efficient

Hybrid gasoline-electric vehicles are more efficient than gas-powered vehicles.

Model Problem

Calculate the efficiency of an 1000W kettle that takes 4 min to boil water. To heat the water to boiling point, it takes 196,000 J of energy. What is the **efficiency** of the kettle?

Given: P = 1000 W   Efficiency
        t = 4.00 min
Useful energy output (E_{output})= 1.96 X 10^5 J   Solution: Efficiency = $\dfrac{1.96 \ X \ 10^5 \ J}{2.40 \ X \ 10^5 \ J}$ **X** 100%

t = 4.00 X 60s/min = 240s

E_{input} = Pt   1000W x 240s = 2.40 X 10^5 J   Efficiency = **81.7%**

Formula: efficiency = $\dfrac{\text{Useful energy output}}{\text{Total energy input}}$ X 100%   The kettle is about 81.7% efficient.