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GSC inc.
GO Science Crazy

Mini Motor Model
#4-18470

Warning:

- Not a toy; use only in a laboratory or educational setting.
- California Proposition 65 Warning: This product can expose you to chemicals including styrene, cobalt, nickel, and lead, which are known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

This model of both an AC and DC electric motor is easy to assemble and disassemble. The model can also be used to demonstrate both permanent and electromagnetic motors. Everything comes packed in its own protective case that is later used as the base for the motor.

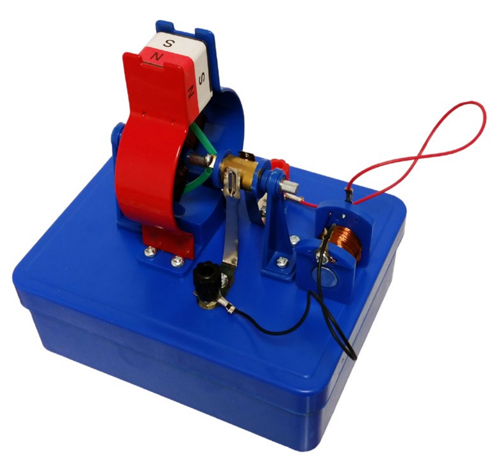
Introduction:

Understanding how a motor works will give you a good foundation for understanding many other electrical devices as well as generators. Motors and generators are just the inverse of each other. A motor is a device that converts electrical energy into mechanical energy, and a generator is a device that converts mechanical energy into electrical energy. If a permanent magnet is used as a magnetic energy supply, then a motor can become a generator or a generator can become a motor. Since a generator converts mechanical energy into electrical energy, and a motor converts electrical energy into mechanical energy, is it possible that a motor could be mechanically connected to the generator and the generator electrically connected to the motor in such a manner that once you started the system it could run continually with no outside influence? Hint: Think FRICTION!

Electromagnetism:

Electromagnetism was discovered in 1820 by Oersted. His discovery was as a result of observing that a magnetic field surrounds an electrical conductor, as an electric current traveled through it. He also discovered that the direction of flow of the current affected the direction of the magnetic field and that it was perpendicular to the wire.

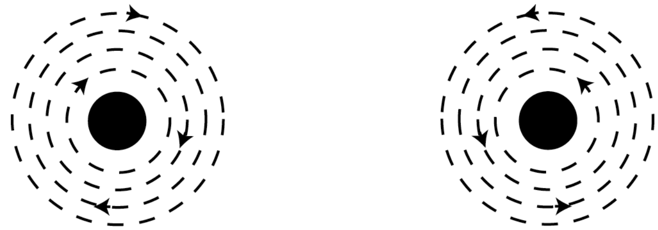
For example, take a look at the accompanying illustrations. The circles surrounding the wire in the illustration represent the magnetic field set up by the current. In the first drawing the electrical current is traveling toward you and the magnetic lines are traveling in a counter-clockwise direction. In the second drawing the electric current is traveling away from you and the magnetic lines of force are traveling in a clockwise rotation.



The strength of the magnetic field created due to an electric current flow can be calculated by Ampere using the formula $\triangle H = \frac{I \sin\theta \Delta s}{r^2}$

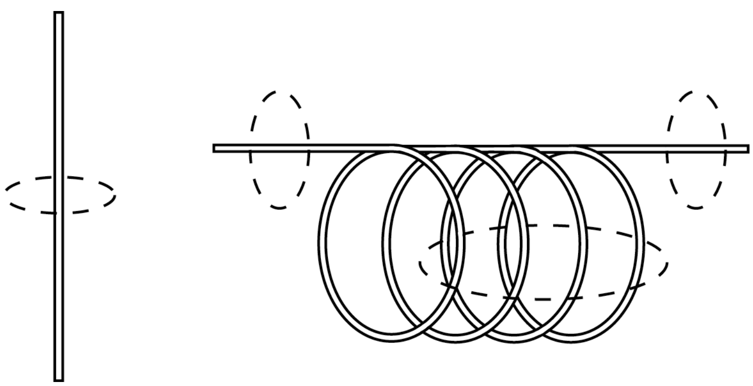
By using a mathematical formula, as well as through experiments it can be seen that the intensity of the magnetic field varies inversely to the square of the distance from a wire that is creating it. Also, by doubling the current, the strength of the magnetic field is doubled and by doubling the length of the element will also double the intensity of the field.

You will find that a conductor with current traveling through it will experience force acting on it when this conductor is located within a magnetic field. This principle is used in many practical applications such as voltmeters, ammeters, galvanometers and switches.

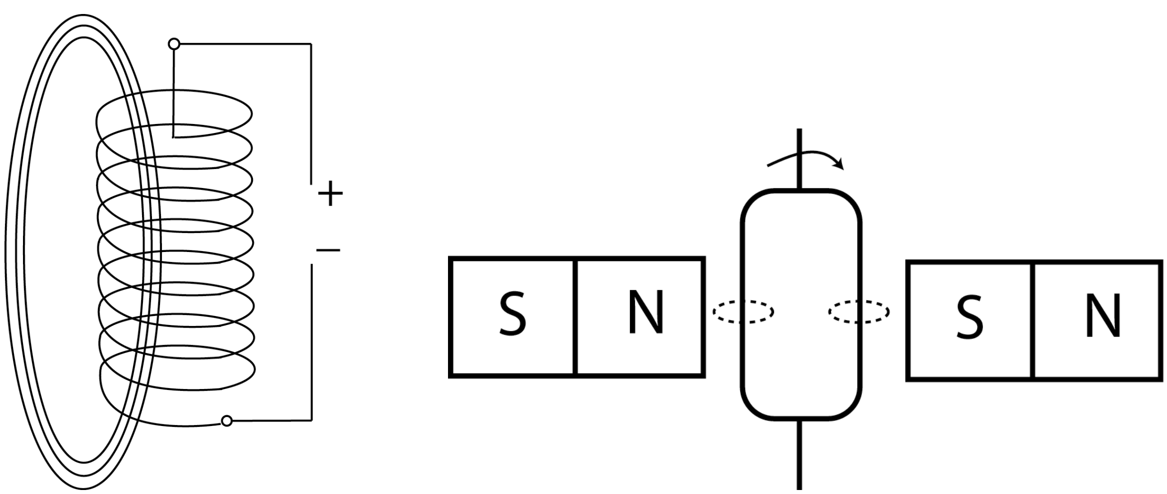


Current going away from you Current coming toward you

The direction of this force will be determined by the direction of the flow of both the current in the conductor as well as the current traveling through the coil.

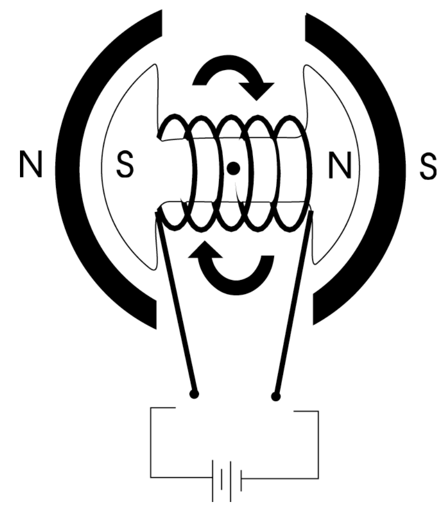


The following illustration depicts a simple form of galvanometer. The coil in the middle lies between two permanent magnets. As current flows through the coil, a magnetic field is set up that either is attracted to or repelled by the permanent magnet, depending on the direction of current flow. A needle attached to the coil will indicate the amount of movement of the coil and the strength of the magnetic field can be determined.



DC Motor:

In order to understand the workings of the DC motor take a look at the figure.



This view of the inside of the motor gives you an idea of the internal workings. There are two curved permanent magnets around the outside of the armature. These magnets have their poles arranged as in the drawing. The armature is wrapped with hundreds of turns of thin coated copper wire. When electricity passes through these coils they set up a magnetic field in the armature. The brushes on the armature direct which way the current will flow through the wire. As you can see sometimes the armature's magnetic field will be of the same polarity as the permanent magnet that it lies close to. Because opposite magnet poles attract and same poles repel, the armature is pushed away. When this occurs, the armature turns and the path of the current through the brushes will change. This change causes the new end of the armature to change polarity, to the same as the permanent magnet that it is now close to. This process continues, causing the armature to continue to be pushed away which in turn causes a continuous turning motion on the shaft of the motor.

The conversion of electrical energy into mechanical motion is caused by creating a current in a coil of wire that is encompassed by a magnetic field. When a current exists in the coil, a magnetic field is created. Just as two permanent magnets will either be attracted or repelled by each other, a magnetic field created by a permanent magnet interacts with a magnetic field created by a current, either attractive or repulsive. If the permanent magnet is fixed so that it cannot move and the coil is free to move, the result will be that the coil will rotate in the presence of a magnetic field if current exists in the coil. The direction of rotation is determined by the direction of the current in the conductor.

Generators:

The generation of electricity using a permanent magnet is accomplished in one of two ways: a stationary conductor and moving magnet or a moving conductor and stationary magnet. The net result is the same since the conductor is moving relative to the magnetic field in both cases. The process by which current is produced is called *electromagnetic induction*. Though either method will produce a current, the method most often used is to move a conductor through the magnetic field produced by a magnet (in this case a permanent magnet). Utility companies usually use magnetic fields generated by currents; such magnets are called *electro-magnets*.

If permanent magnets are used, it can be mechanically cumbersome to move the magnet and hold the conductor stationary. The more efficient way is to move a combination of conductors in the form of a coil through a magnetic field. The direction of the current is directly dependent on the direction of the motion of the conductor through the magnetic field.

Usually, the conductor is rotated about a fixed axis such that it moves in a circular path. Depending on how the coil is wound and how the current is taken from the coil, the resulting current can be either alternating current (AC) where the current changes direction or direct current (DC) where the direction of the current does not change. The motor-generator set that you is about to use is wired for DC.

When a metal coil is rotated in a magnetic field, current is produced. The amount of current is proportional to the area of the coil, the number of loops, the strength of the magnetic field, the speed with which the coil is rotated, and the angle of the coil to the magnetic field. The formula for the induced voltage is : ε **= NBAw sin** θ

Where:

ε is the induced voltage
N is the number of loops
B is the strength of the magnetic field
A is the cross sectional area of the loop
W is the angular velocity of the coil (2 f)
θ is the angle of the coil relative to the magnetic field.

It can be seen that for a particular generator, where the physical dimensions of the coil, the number of loops, and the strength of the magnetic field remain constant, the induced voltage is dependent upon two factors; the speed of rotation and the angle of the coil. However, for situations where the coil is moving rapidly enough to generate appreciable voltage, the only value of interest is the maximum voltage produced.

Since we are interested in a maximum, and are dealing with a sine function, it follows that the maximum voltage is produced when the sine is 1, and is 90^{o}. Therefore, when we are examining the voltage produced by a generator, the only factor which is of importance is the rotational speed. For the general formula rotational velocity is given in radians per second.

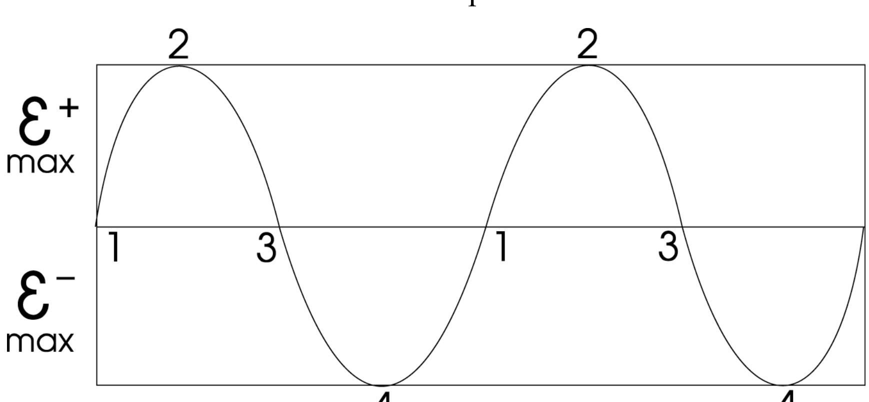
As an example, let us look at an extremely simple hypothetical generator. If the coil has one loop, with an area of one square meter, and it is moving through a magnetic field of one Tesla at a rotational velocity of one radian per second, the Maximum induced voltage would be:

1 loop x 1 Tesla x 1 square meter
x 1 radian/sec x 1 = 1 Volt

If the rotational velocity were increased to 2 radians/sec the resulting induced voltage would be 2 volts. In other words, the induced voltage is directly proportional to the speed of rotation.

When the coil is turning in the magnetic field, the first half of each rotation is in a direction relative to the magnetic field such that the resultant force is in one direction along the coil loop (in this case OUT of the plane of the paper).

The second half of the rotation produces a resultant force that is in the opposite direction (in this case INTO the plane of the paper). For convenience we label these two resultant forces positive and negative, and the corresponding voltages as positive or negative. If the voltage were plotted the result would be a sine wave, with O voltage occurring at the point where the voltage changes from positive to negative. It is important to remember that we are using the terms positive

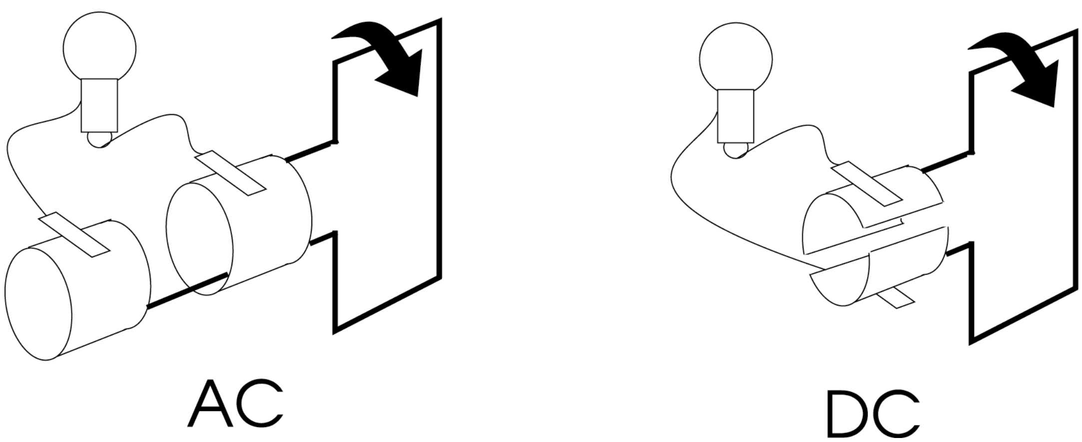


and negative to refer to the direction of movement of current. There is no negative voltage.

In an AC generator the ends of the wire loop are connected through brushes and slip rings so that the same end of the wire loop is always connected to the same place in the circuit. This means that as the direction of current changes in the coil it also changes in the resistor.

In a DC generator the ends of the wire loop are connected through a split-ring, so that as each end of the wire loop moves through the positive phase it is connected to a positive ring. The split in the ring is aligned so as to exchange ends at the point where voltage is 0.

In some cases the difference between AC and DC is unimportant. For instance, a light bulb works due to the resistance of the filament to a current. As the current increases the resistance causes the filament to heat up, producing light. It does not matter which direction the current flows. A light bulb will work on either AC or DC, as long as the voltage is in the proper range.



If we want more current (a higher voltage) what can we do? We can increase the rotational velocity, turn the crank faster, but there is a limit to the speed the coil can attain. We can increase the strength of the magnetic field, but are limited by the size of the magnet. We can increase the area of the coil, but again reach size limitations.

There are two ways to dramatically increase the output of a generator. The first is to increase the number of loops in the coil. Since voltage is directly proportional to the number of loops, doubling the number of loops will double the voltage.

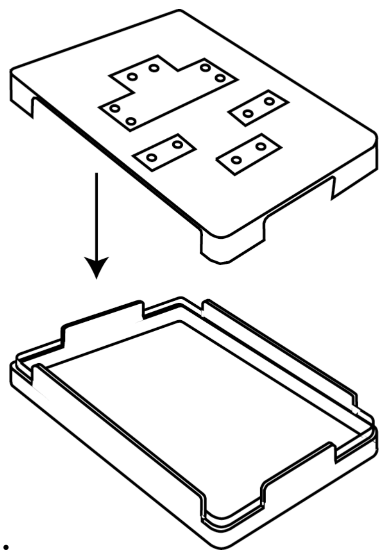
When even this is not enough we can increase the number of coils within the magnetic field. By placing a number of coils in the field, and arranging them so that they are evenly spaced around the circumference, we can increase the induced voltage tremendously. This arrangement has other advantages. Since the voltage is related to the angle of the coil to the magnetic field, with E max at 90o and Eo at 0o, by arranging two coils at 90o to each other we can have one coil producing E max when the other is producing Eo and have a relatively continuous voltage.

In most large scale generating plants, the coils are stationary and the magnets are revolved around them. This is a much simpler mechanical situation, and allows for easier construction of the slip rings.

In summary, the generation of induced current is the direct result of the laws relating to the movement of a charge in a magnetic field. While this discussion of induced voltage may be more advanced than required for some students, the basic forces and resultant effects are the same at all levels of instruction. A simple explanation of the observed results may be sufficient for a general science class, while an advanced physics class can explore the phenomena in greater depth.

Assembly of DC Motor:

1. Begin by emptying all of the contents from the plastic box base and place the top on the table with the flat base on top.
2. Mount the housing with the permanent magnet to the base by placing small screws down through the housing and attaching the nuts from underneath.
3. Mount the end bushings the same as above by placing the screws down from the top and putting the nuts on from underneath. Do not tighten the screws yet.
4. Insert the armature into the bushings and tighten the nuts on the bushing columns. Push the pulley onto the long end of the armature.
5. Mount the brushes by placing a small screw into the smaller hole of the brush and inserting this into the appropriate hole of the top. Next take the long screw and bring it into the second hole of the brush from underneath the base. Put the big nut onto this screw and tighten. Finally screw the cap nut onto this screw/post.
6. Apply power by attaching 3 to 6 volt DC to the binding post. You may have to give the armature a little spin to get it started.



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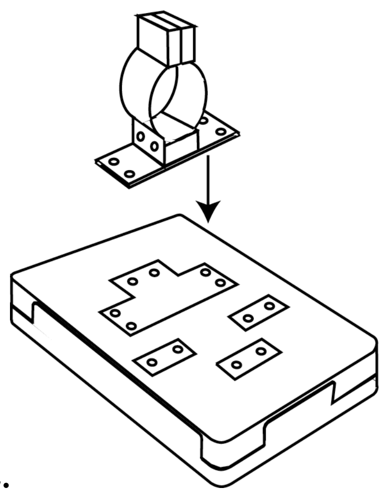

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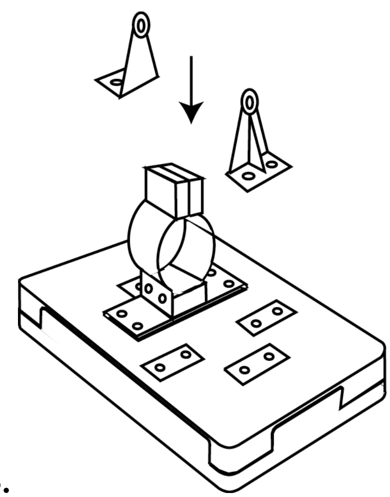

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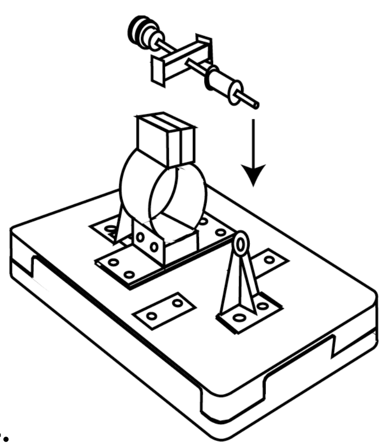

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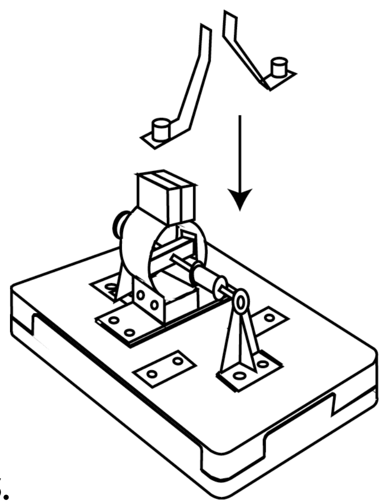

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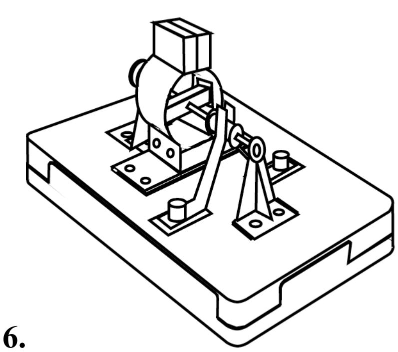

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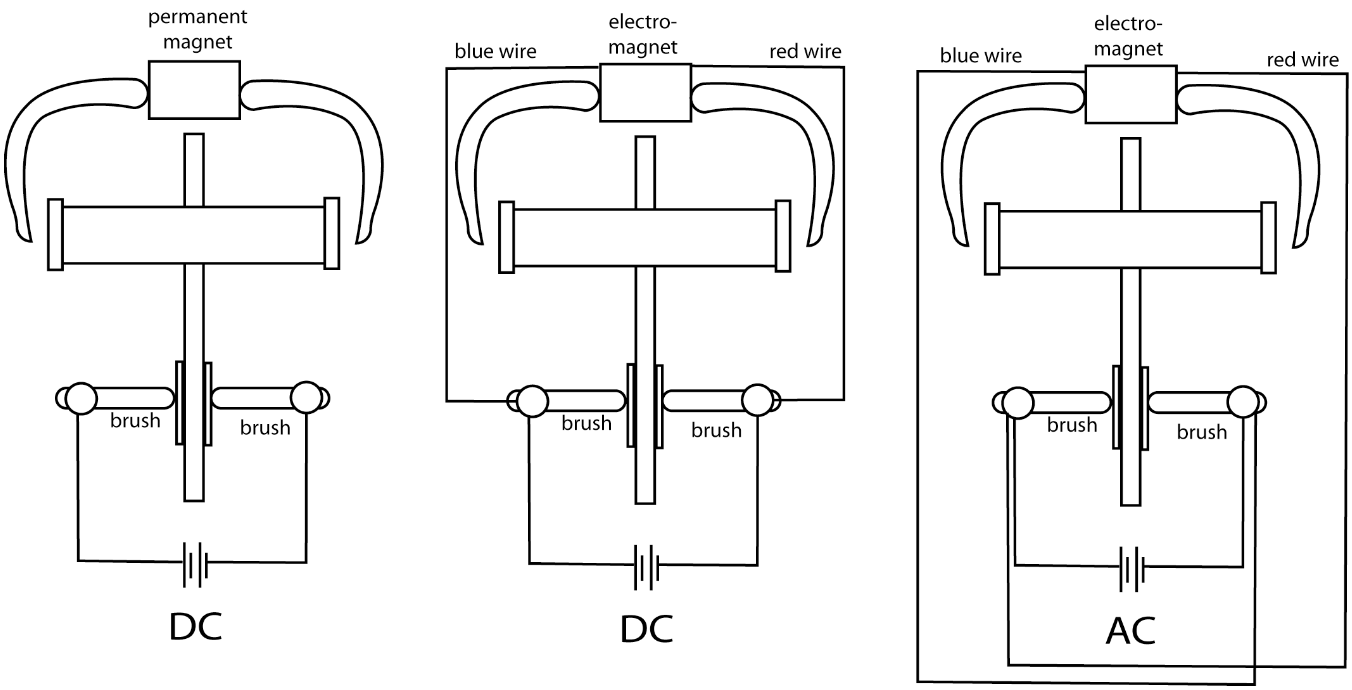
Assembly of AC Motor:

To operate the motor under AC power all you must do is to complete the motor as above except rather than using the permanent you will use the electromagnet. See the enclosed illustration for wiring direction.



A Few Facts About Electricity:

1. Electricity is a form of energy thus capable of doing work.

2. Electrical phenomena were apparently discovered as far back as 600 B.C.

3. The flow of electrons in a circuit is called current and is measured in amps.

4. The pressure pushing the electrons through a circuit is called voltage.

5. Direct current (D.C.) is current that flows in one direction.

6. Alternating current (A.C.) is current that alternates its direction, first one way then the other.

7. Electrons flow from the negative terminal of a battery to the positive terminal.

8. Batteries connected in series (one behind the other) increase the total voltage. Batteries connected parallel to one another increase the total current.