# Anticipation Guide: Introduction to Electric Circuits

**Before Reading:** In the space to the left of each statement, place a check mark (✓) if you agree or think the statement is true or an (X) if you disagree or think the statement is false.

**During or After Reading:** Add new check marks or cross-through the X’s for which you have changed your mind. Keep in mind that this is not like the traditional “worksheet”. You may have to put on your thinking caps and “read between the lines.” Use the space under each statement to note the **page, column, and paragraph(s)** where you have found information to support your thinking (evidence).

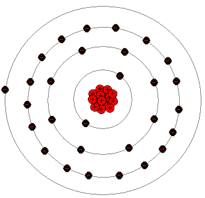
1. \_\_\_\_\_ Valence electrons are located in the outer shell of atoms.
2. \_\_\_\_\_ Without an outside forces free electrons randomly move through conductors.
3. \_\_\_\_\_ Electric current is a flow of electrons through a material.
4. \_\_\_\_\_ Materials that do not tend to share their electrons easily are called conductors.
5. \_\_\_\_\_ When electrons flow from atom to atom with a direction, we call is electricity.
6. \_\_\_\_\_ An ampere is the flow of electrons.
7. \_\_\_\_\_ 1 ampere or amp is 1 Coulomb of charge per hour.
8. \_\_\_\_\_ A ammeter is used to indicate how many amps of current are flowing.
9. \_\_\_\_\_ Electromotive Force (EMF) is electrical pressure.
10. \_\_\_\_\_ A battery is a source of EMF.
11. \_\_\_\_\_ If electrons flow too fast the conductor will become very how.
12. \_\_\_\_\_ When there is a balance of electrons at both ends of a battery the battery can do work.
13. \_\_\_\_\_ The difference in charge between two points is called voltage.
14. \_\_\_\_\_ Voltage is similar to water pressure.
15. \_\_\_\_\_ If we remove the voltage source then the current will continue to flow.
16. \_\_\_\_\_ Resistance is measured in volts.
17. \_\_\_\_\_ Forces which oppose the flow of electron current are called resistors.
18. \_\_\_\_\_ Some materials have not resistance.
19. \_\_\_\_\_ Materials with high resistance require more voltage.
20. \_\_\_\_\_ Resistance is bad.
21. \_\_\_\_\_ Resistance may cause heat.
22. \_\_\_\_\_ Resistance is higher is larger wires.
23. \_\_\_\_\_ Too much voltage pushed through a small wire may cause them to explode.
24. \_\_\_\_\_ Most metals are good insulators.
25. \_\_\_\_\_ Insulators let electrons flow easily.
26. \_\_\_\_\_ Insulators are used to protect us from dangers of electricity.
27. \_\_\_\_\_ If voltage is high enough current can be made to flow through insulators.
28. \_\_\_\_\_ Conductors have low resistance to electrical current.
29. \_\_\_\_\_ Voltage, current, and resistance are mathematically related.
30. \_\_\_\_\_ As resistance increases current also increases.
31. \_\_\_\_\_ Electrons must have a voltage source and a path for an electric circuit to be produced.
32. \_\_\_\_\_ Voltage may be created at a power plant.
33. \_\_\_\_\_ Without a voltage source there is not current flowing.
34. \_\_\_\_\_ All circuits require at least one resistor.
35. \_\_\_\_\_ In order to complete a circuit the switch must be opened.
36. \_\_\_\_\_ An ammeter indicates that current is flowing.
37. \_\_\_\_\_ Anything in a circuit which is using energy is considered a load.
38. \_\_\_\_\_ A hair dryer could be a load.
39. \_\_\_\_\_ Resistors are used to control amount of current flowing in a circuit.
40. \_\_\_\_\_ If there are not resistors the current will stop flowing.
41. \_\_\_\_\_ In a series circuit, all electrons flow through all components in order.
42. \_\_\_\_\_ In a parallel circuit the electrons flow through multiple loads at the same time.
43. \_\_\_\_\_ When current flows through a parallel circuit some of the current is lost.
44. \_\_\_\_\_ Resistance is lower in parallel circuits than in series circuits.
45. \_\_\_\_\_ A voltmeter measures difference in EMF from one area to another.

# Introduction to Electric Circuits

## The Valence Shell

**What is the valence shell?**

Notice that in the **copper atom** pictured below that the outside shell has only one electron. This represents that the copper atom has **one electron** that is near the outer portion of the atom. The outer shell of any atom is called the **valence shell**. When the valence electron in any atom gains sufficient energy from some outside force, it **can break away from the parent atom** and become what is called a **free electron**.

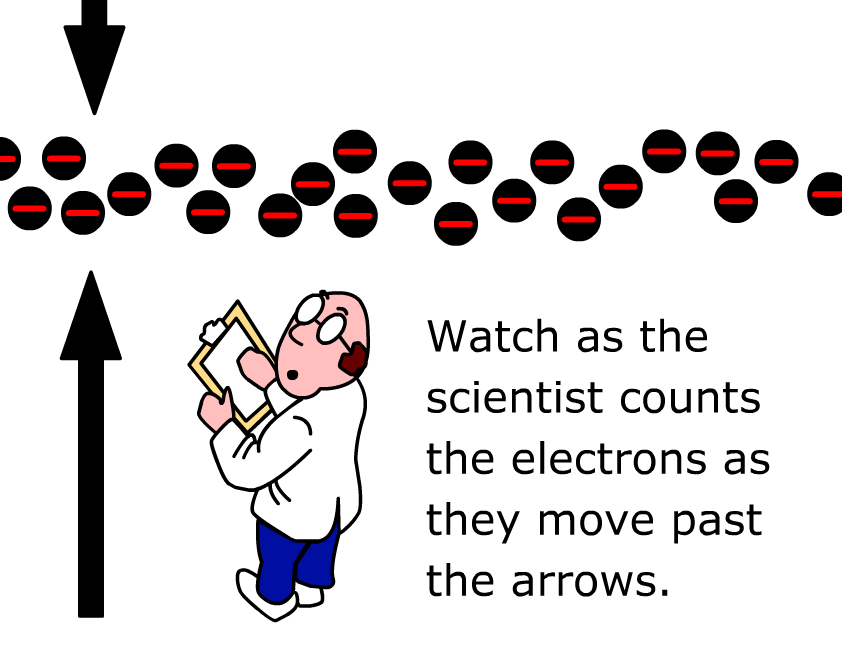


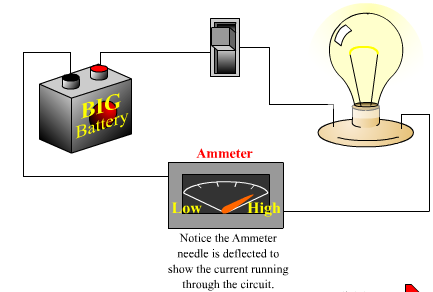
Atoms with few electrons in their valence shell tend to have more free electrons since these **valence electrons are more loosely bound** to the nucleus. In some materials like copper, the electrons are so loosely held by the atom and so close to the neighboring atoms that it is difficult to determine which electron belongs to which atom. Under these conditions, the valence or **free electrons tend to drift randomly from one atom to its neighboring atoms**. Under normal conditions the movement of the electrons is truly random, meaning they are moving in all directions by the same amount. However, if some **outside** **force acts upon the material**, this flow of electrons can be directed through materials and this flow is called **electrical current**. Materials that have free electrons and allow electrical current to flow easily are called **conductors**. Many materials do not have any free electrons. Because of this fact, they do not tend to share their electrons very easily and do not make good conductors of electrical currents. These materials are called **insulators**.

**Electricity**

**Electricity** is a term used to describe the energy produced (usually to perform work) when electrons are caused to directional (not randomly) flow from atom to atom. In fact, the day-to-day products that we all benefit from **rely on the movement of electrons**. This movement of electrons between atoms is called**electrical current**.

**Amperage**

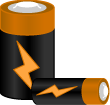
It is very important to have a way to **measure and quantify the flow of electrical current**. When current flow is controlled it can be used to do useful work. Electricity can be very dangerous and it is important to know something about it in order to work with it safely. The flow of electrons is measured in units called **amperes**. The term **amp**is often used for short. An amp is the **amount of electrical current** that exists when a **number of electrons**, having one Coulomb (ku`-lum) of charge, **move past a given point in one second**. A **coulomb** is the charge carried by **6.25 x 1018 electrons**. 6.25 x 1018 is scientific notation for 6,250,000,000,000,000,000. That is a lot of electrons moving past a given point in one second!

Since we **cannot count this fast and we cannot even see the electrons**, we need an instrument to measure the flow of electrons. An **ammeter** is this instrument and it is used to indicate **how many amps of current are flowing** in an electrical circuit.

**Voltage**

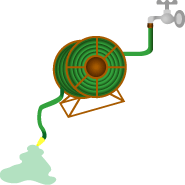
We also need to know something about the **force that causes the electrons to move** in an electrical circuit. This force is called **electromotive force**, or **EMF**. Sometimes it is convenient to think of EMF as **electrical pressure**. In other words, it is the force that makes electrons move in a certain direction within a conductor.

But how do we **create this “electrical pressure”** to generate electron flow? There are many **sources of EMF**. Some of the more common ones are: batteries, generators, and photovoltaic cells, just to name a few.

**Batteries** are constructed so there are **too many electrons in one material** and **not enough in another material**. The electrons want to balance the electrostatic charge by **moving from the material** with the excess electrons **to the material with the shortage** of electrons. However, they cannot because there is no conductive path for them to travel. However, if these two unbalanced materials within the battery are connected together with a conductor, electrical current will flow as the electron moves from the **negatively charged area to the positively charged area**. When you use a battery, you are allowing electrons to flow from one end of the battery through a conductor and something like a light bulb to the other end of the battery. The battery will work **until there is a balance of electrons at both ends** of the battery. Caution: you should never connect a conductor to the two ends of a battery without making the electrons pass through something like a light bulb which **slows the flow of currents**. If the electrons are allowed to flow too fast the **conductor will become very hot**, and it and the battery may be damaged.

A **volt**is the difference in the electrostatic charge that exists between two points. It is this imbalance in the electrostatic charge that causes electrons to flow from one point to the next.

 To understand how voltage and amperage are related, it is sometimes useful to make an analogy with water. Look at the picture here of water flowing in a garden hose. Think of electricity flowing in a wire in the same way as the water flowing in the hose. The **voltage** causing the electrical current to flow in the wire can be **considered the water pressure at the faucet**, which causes the water to flow. If we were to increase the pressure at the hydrant, more water would flow in the hose. Similarly, if we **increase electrical pressure** or voltage, **more electrons would flow** in the wire.

Does it also make sense that **if we were to remove the pressure** from the hydrant by turning it off, the **water would stop flowing**? The same is true with an electrical circuit. **If we remove the voltage source**, or EMF, **no current will flow** in the wires.

Another way of saying this is: **without EMF, there will be no current**. Also, we could say that the free electrons of the atoms move in random directions unless they are pushed or pulled in one direction by an outside force, which we call electromotive force, or EMF.

**Resistance**

There is another important property that can be measured in electrical systems. This is **resistance**, which is measured in units **called ohms**. Resistance is a term that describes the **forces that oppose the flow of electron current** in a conductor. **All materials** naturally **contain some resistance** to the flow of electron current. We have not found a way to make conductors that do not have some resistance.

If we use our water analogy to help picture resistance, think of a hose that is partially plugged with sand. The sand will slow the flow of water in the hose. We can say that the plugged hose has more resistance to water flow than does an unplugged hose. If we want to get more water out of the hose, we would need to turn up the water pressure at the hydrant. The same is true with electricity. **Materials with low resistance let electricity flow easily**. **Materials with higher resistance require more voltage** (EMF) to make the electricity flow.

The scientific definition of **one ohm** is the **amount of electrical resistance that exists** in an electrical circuit **when one amp of current is flowing** with **one volt** being applied to the circuit.

**Is resistance good or bad?**

Resistance can be both good and bad. If we are trying to transmit electricity from one place to another through a conductor, resistance is undesirable in the conductor. **Resistance causes some of the electrical energy to turn into heat** so some electrical energy is lost along the way. However, it is **resistance that allows us to use electricity for heat and light**. The **heat** that is generated from electric heaters or the light that we get from light bulbs **is due to resistance**. In a light bulb, the electricity flowing through the filament, or the tiny wires inside the bulb, cause them to glow white hot. If all the oxygen were not removed from inside the bulb, the wires would burn up.

An important point to mention here is that the **resistance is higher in smaller wires**. Therefore, **if the voltage or EMF is high**, too much **current will follow through small wires and make them hot**. In some cases hot enough to **cause a fire or even explode**. Therefore, it is sometimes useful to **add** components called **resistors** into an electrical circuit **to restrict the flow of electricity** and **protect the components** in the circuit.

Resistance is also good because it gives us a way to shield ourselves from the harmful energy of electricity.

**Conductors and Insulators**

**Conductors**

Do you remember the copper atom that we discussed? Do you remember how its **valence** shell had an **electron** that **could easily be shared** between other atoms? Copper is considered to be a conductor because it **“conducts”** the **electron** current or **flow** of electrons **fairly easily**. **Most metals** are **considered to be good conductors** of electrical current. Copper is just one of the more popular materials that are used for conductors.

**Insulators**

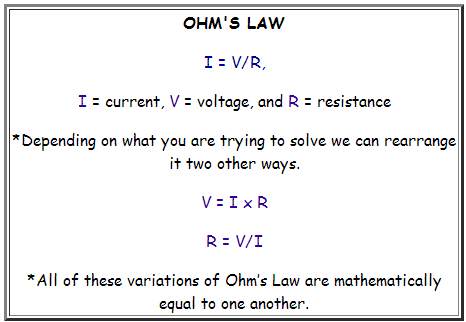
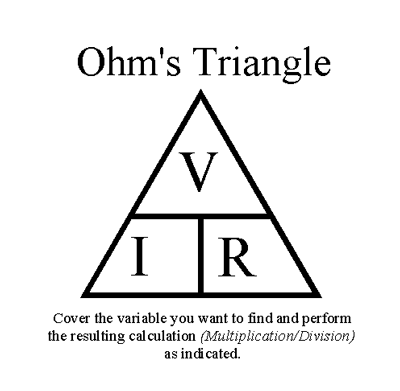
**Insulators** are materials that have **just the opposite effect** on the flow of electrons. They **do not let electrons flow** very easily from one atom to another. Insulators are materials whose **atoms have tightly bound electrons**. These **electrons are not free to roam** around and be shared by neighboring atoms.

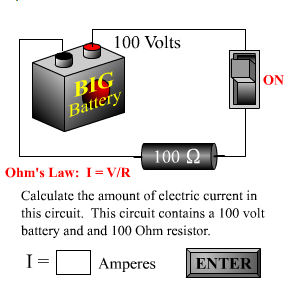
Insulators are used to **protect us** from the dangerous effects of electricity flowing through conductors. Sometimes the voltage in an electrical circuit can be quite high and dangerous. **If** the **voltage is high enough**, electric **current can** be made to **flow through** even **materials** that are generally **not considered to be good conductors**. **Our bodies will conduct electricity** and you may have experienced this when you received an electrical shock. Generally, electricity flowing through the body is not pleasant and can cause injuries. The function of our **heart can be disrupted by a strong electrical shock** and the **current can cause burns**. Therefore, we need to shield our bodies from the conductors that carry electricity. The rubbery coating on wires is an insulating material that shields us from the conductor inside. Look at any lamp cord and you will see the insulator. If you see the conductor, it is probably time to replace the cord.

Recall our earlier discussion about resistance. **Conductors have a very low resistance** to electrical current while **insulators have a very high resistance** to electrical current. These two factors become very important when we start to deal with actual electrical circuits.

**Ohm’s Law**

Probably the most important mathematical relationship between voltage, current and resistance in electricity is something called **“Ohm’s Law”.** A man named George Ohm published this formula in 1827 based on his experiments with electricity. This formula is used to calculate electrical values so that we can design circuits and use electricity in a useful manner. Ohm's Law is shown below.



As you can see, voltage, current, and resistance are mathematically, as well as, physically related to each other. We cannot deal with electricity without all three of these properties being considered.

**How many Amps of current are running through the circuit to the right? Use Ohm’s Law to calculate.**

1. **1**
2. **2**
3. **3**
4. **4**

**Series and Parallel Circuits**

When we **connect various components** together with wires, **we create an electric circuit**. The electrons **must have a voltage source** to create their movement and, of course, **they need a path** in which to travel. This **path must be complete** from the EMF source, through the other components and then back to the EMF source.

The **voltage for any electric circuit can come from many different sources**. Some common examples are: batteries, power plants, fuel cells.

When we plug an appliance into a wall outlet, voltage and current are available to us. That **voltage is actually created in a power plant** somewhere else and then delivered to your house by the power wires that are on poles or buried underground.

As a matter of fact, since no current can flow unless there is a voltage source, we also refer to these sources as current sources. In other words, **without the voltage source**, there will be **no current** flowing. This makes it a current source instead of a voltage source.

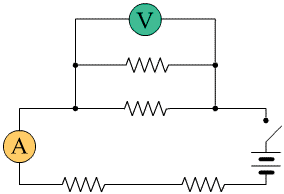
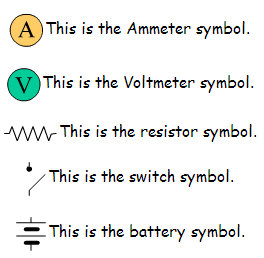
**Batteries create voltage** through a **chemical process**. **Power plants** generate electricity from numerous mechanical methods. Some burn coal or gas to create steam while others use water flowing through a dam on a lake. There are also nuclear-powered generating power plants. All of these power-generating systems turn **large turbines that turn the shaft on a generator**. All of these sources of electricity convert something called **potential energy to kinetic energy**. The **potential energy is stored in the fuel**, whether it is coal, gas, uranium, water in a dam, etc. When we utilize these fuels to generate electricity, they become kinetic energy.

We might say that potential energy is waiting to be used while kinetic energy is being used.

In addition to the voltage source, we **need to have wires** and other components **to build an electric circuit**. Remember that copper wires are conductors since they can easily conduct the flow of electrons. We may also use **resistors or other forms of loads** to form a complete circuit. If we did **not include resistors in our circuit**, there may be **too much current flowing** to and from our voltage source and we **could damage the voltage source**.

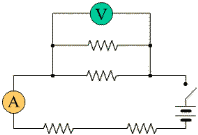
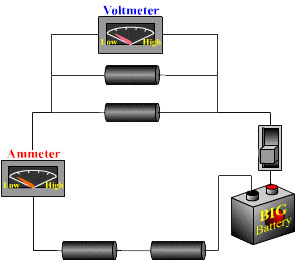
**Circuit Diagrams**

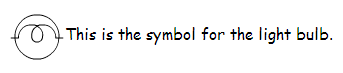
**Circuit diagrams** are a pictorial way of showing circuits. Electricians and engineers draw circuit diagrams to help them design the actual circuits. Here is an example circuit diagram.



The important thing to note on this diagram is **what** **everything stands for**. You see that there are **straight lines** that connect each of the symbols together. Those lines **represent a wire**.

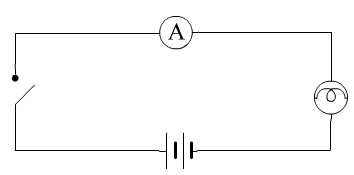
The important thing to remember about this symbol is that the **long bar on top represents** the **positive terminal** on a battery while the **short bar** on the bottom **represents** the **negative terminal**.

Below is the actual circuit made from the circuit diagram above. Pay close attention to see how similar the diagram and the real circuit looks.



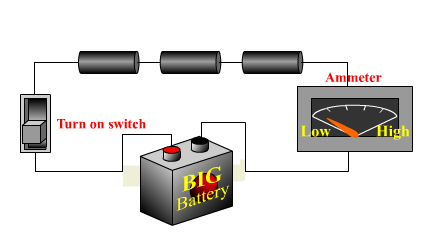
**The Series Circuit**

**Using your parts, try building this simple series circuit.**





Notice that when you **close the switch to complete the electrical circuit**, the **electrons start moving** and the **ammeter indicates** that there is **current flowing** in this circuit. Also notice that the **light bulb begins to glow**. This happens because the **electrons moving through** the tiny **wires** in the bulb (or filament) make them **become so hot that they glow**. If there is any air inside the light bulb, the filament wires will burn up.



What you have just created is something called a **series circuit**. This is called a **series circuit** because there is **only one path for the electrons to take** between any two points in this circuit. In other words, the components, which are the battery, the switch, the ammeter, and light, are all in “series” with each other.

**Load defined**

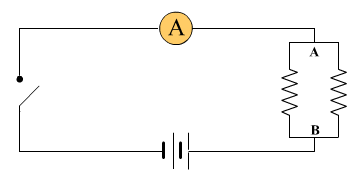
The light **bulb is** considered **a load** in this circuit. You might think of a load as **anything that is using the energy** that is being delivered by the electric current in a circuit. It could be anything from a light bulb to a computer to a washing machine and so on.

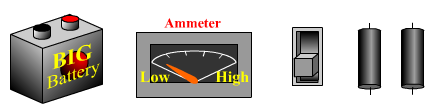
**Try building a series circuit with resistors**

Build another series circuit, but this time will **use some resistors** instead of a light bulb. **Resistors** are components that are **used to control that amount of current** flowing in a circuit. The light **bulb** in the first circuit **was actually acting like a resistor** because it only allowed a certain amount of current to flow through it. If there are **no resistors** or components that act like resistors to slow the flow of electrical current, **too much current may flow** through the circuit and damage its components or wires. **Too much current** flowing through a component **results in the generation of heat** that can melt the conductive path through which the electrons are flowing. This in **known as a short circuit** and is the **reason fuses or circuit breakers are often included** in a circuit.

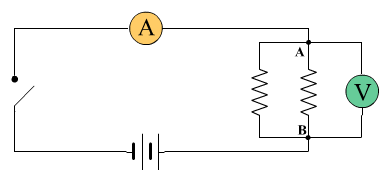
**The Parallel Circuit**

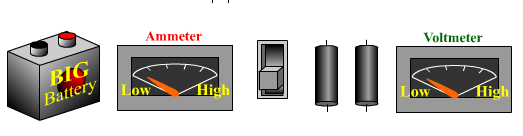
Like the series circuit, **parallel circuits also contain a voltage** (current) source as well as wires and other components. The **main difference** between a series circuit and a parallel circuit **is in the way the components are connected**. In a **parallel circuit** the electricity has **several paths** that it can travel.



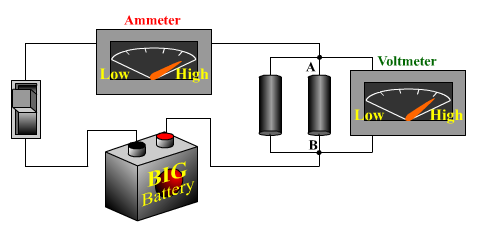


Notice that when you **closed the switch**, the **electrons flowed through both loads** at the same time. In our series circuit, all the electrons flowed through all the components in order. With the **parallel circuit**, **some electrons go through one load** and **some go through the other load**, **all at the same time**. At point A, the **total current splits up and takes different paths** before the circuit joins back together again at point B.





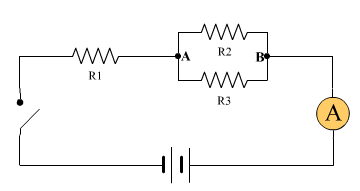
**Completed parallel circuit**



This parallel circuit contains 3 branches (two resistors and a voltmeter), which means the electron current goes through all three branches at the same time. We put a voltmeter on this second circuit to show an important fact. In the last 4 circuits you made, you included an **ammeter** into them. **Ammeters must always be placed in series in a circuit**, **otherwise they will not work**. The voltmeter we added in the last circuit has a different requirement in order to work.  **Voltmeters must be placed in parallel with the circuit in order to work**. This is because voltage meters measure the difference in electromotive force (EMF) from one area to another. They are used to measure the difference in EMF on one side of a component compared to the other side of the component. In our homes, most circuits contain 120 volts of EMF.

**The Series/Parallel Circuit**

When we have a circuit in which some of the components are in series and others are in parallel, we have a **series/parallel circuit**.



Notice in this series/parallel circuit that the **resistors R1, the switch, the battery, and the ammeter** are **in series** with each other while **resistors R2 and R3 are** in **parallel** with each other. We might also say that the R2/R3 combination is in series with the rest of the components in this circuit. This is a very common circuit configuration. **Many circuits have various combinations of series and parallel components**.

**Review**

1. The **valence shell** is the outer shell of the atom.
2. Some materials have a free electron in their valence shell and this electron can easily move from atom to atom.
3. The **free electrons** are responsible for electrical current.
4. Electricity is a word used to describe the directional flow of electrons between atoms.
5. The directional movement of electrons between atoms is called **electrical current**.
6. **Amperage** is a term used to describe the number of electrons moving past a fixed point in a conductor in one second.
7. **Current** is measured in units called amperes or **amps**.
8. **EMF** is electromotive force. EMF causes the **electrons to move** in a particular direction.
9. EMF is measured in units called **volts**.
10. **Resistance** is the opposition to electrical current.
11. Resistance is measured in units called **ohms**.
12. Resistance is sometimes desirable and sometimes undesirable.
13. **Conductors** conduct electrical current very easily because of their free electrons.
14. **Insulators** oppose electrical current and make poor conductors.
15. Some common conductors are copper, aluminum, gold, and silver.
16. Some common insulators are glass, air, plastic, rubber, and wood.
17. **Ohm's Law** is used to describe the mathematical relationship between voltage, current, and resistance.
18. Wires and various components connected together form a circuit.
19. Power plants and fuel cells are some examples of sources that the voltage for any electrical circuit can come from.
20. **Circuit diagrams** are used to show how all the components connect together to make a circuit.
21. When all the components are in line with each other and the wires, a **series circuit** is formed.
22. A **load** is any device in a circuit that is using the energy that the electron current is delivering to it.
23. When some of the components are connected parallel with each other, they form a **parallel circuit**.
24. A voltmeter must be wired in parallel in a circuit in order to measure the difference in EMF from one point to another.
25. Some circuits contain series and parallel components. These are called **series/parallel circuits**.