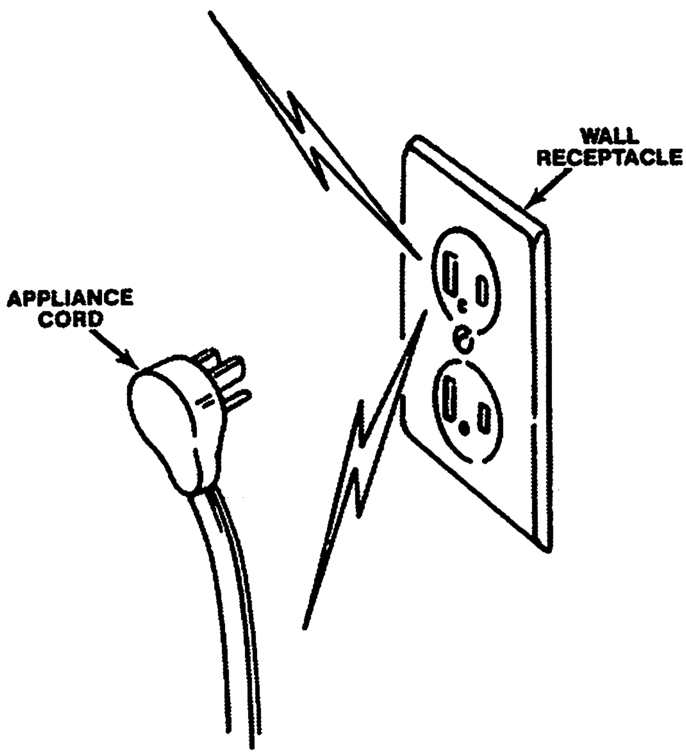
BASIC ELECTRICITY

STUDY COURSE
for Home Appliances

UNDERSTANDING:
- ELECTRICAL WIRING
- ALTERNATING CURRENT
- DIRECT CURRENT



MODULE 1

LIT787739 Rev. A

INTRODUCTION

The material presented in this module is intended to provide you with and understanding of the fundamentals of electricity as applied to major appliances.

Major appliances have become more sophisticated, taking them out of the screwdriver and pliers category. Their electrical circuits include several different types of automatic controls, switches, heaters, valves, etc.. Semiconductors, solid-state controls, and other components usually associated with radio and television electronic circuits are being engineered into automatic washers, dryers, dishwashers and refrigerators.

The appliance technician is emerging into a professional status of his own. He must prepare himself now to be able to perform his duties today as well as to retain his professionalism in the future.

No longer is on-the-job training sufficient to prepare technicians for the complicated procedures required for todays sophisticated appliances. This training can best be obtained through organized classroom study and application. However, much of the knowledge necessary to service todays appliances can be obtained through study courses. Completion of this and other courses will provide you with sufficient understanding of appliances and their operation to enable you to do minor service. It will also serve as a valuable stepping stone to more advanced study and on-the-job training to improve your servicing skills.

Information contained in this module is used on WHIRLPOOL® appliances.

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****NOTE:* We recommend taking the TEST for MODULE 1, right after studying it.**

CHAPTER 1

ELECTRICAL WIRING

Before we get started in this basic electricity course, let's simplify how electricity flows from your city's power source to inside your home.

Look at a road map and pick out a major highway from one location to another. This would be the same as electricity flowing from a power source to a step-up (increases voltage) transformer. Transformers are used to hold AC voltage over long distances.

Do you see small roads you can turn onto, off the major highway? This is like power lines going to different homes.

At the intersection of the small road and major highway, there is a step-down (decreases voltage) transformer. This transformer reduces the AC voltage to your home.

Now picture yourself going down the small road and into the city with all the city streets. These streets are like wiring inside your home.

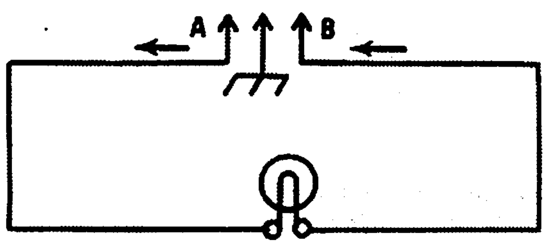
All the streets, roads and major highway are connected together. This is like having electricity flowing from the power source to all the outlets in your home.

But what if something doesn't work? It could be a break in the road (power line). In other words, say there is a drawbridge (like a switch) over water. As you drive down the road (like electricity flows), a sail boat decides to go under the drawbridge (switch). The drawbridge (switch) opens, stopping the flow of traffic (electricity). In order for the traffic (electricity) to start flowing again, the drawbridge (switch) has to be lowered.

WHAT IS A CIRCUIT?

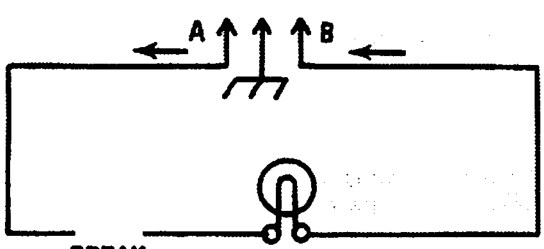
A circuit is a complete path for electricity to flow through.

This is an example of a *complete circuit*. It is called a complete or closed circuit because the electricity can flow all the way from point A to point B without interruption.



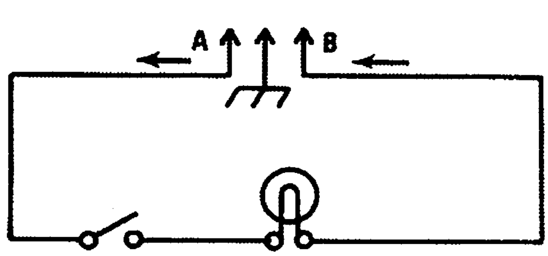
LIGHT BULB

This is NOT a complete circuit. There is a break in the path where the electricity (current) can flow.



BREAK

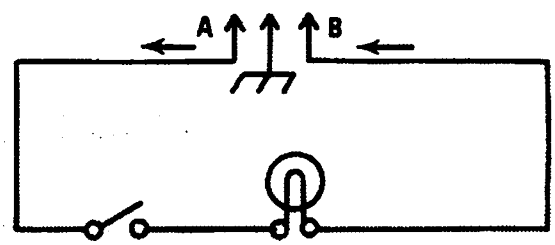
Sometimes a break in the circuit is caused by design. For example, when we turn a switch to its OFF position, we cause a break in the circuit. (It's like lifting a drawbridge.)



SWITCH

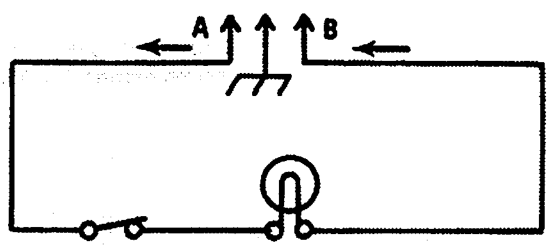
Sometimes a break is caused by accident, and then YOU have to find out where it is.

When there is a break in the circuit, we say that the circuit is OPEN. An OPEN circuit is one that cannot operate because there is a break in the path through which the current might flow.



OPEN CIRCUIT

A CLOSED circuit is one in which there is a complete path for the electricity to follow.



CLOSED CIRCUIT

CIRCUIT COMPONENTS

Circuits could have up to four kinds of components although there must be a power source and a conductor for any type of circuit.

1. **Power source.**
This might be a battery, or the electricity coming from the wall outlet.

2. **Conductors.**
A Conductor will usually be a wire, and sometimes the metal chassis (frame) on which the components are mounted.

3. **Loads.**
These are the components that do the work. For example, motors turn the agitator in washing machines, move the hands on clocks, and turn fan blades. Other examples of loads are resistors, solenoids, and light bulbs.

A load is anything that uses up some of the electricity flowing through the circuit.

4. **Controls.**
These are devices that control the flow of electricity to the loads (the things that do the work). A control is usually some sort of switch that is operated by the user of the appliance, or operated by the appliance itself.

SERIES CIRCUITS

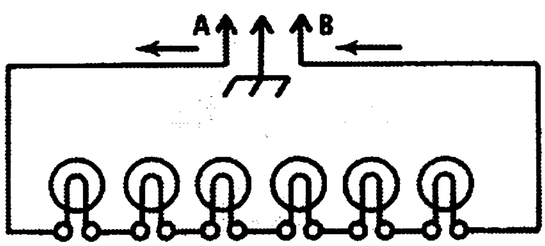
You will come across three kinds of circuits.

1. Series circuits
2. Parallel circuits
3. Series-parallel circuits (which are just combinations of the first two kinds).

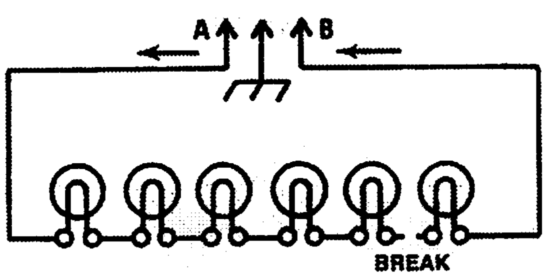
In a *series* circuit, components are joined together in a chain or series.

In a series circuit, there is only ONE path that electricity can follow. If there is a break anywhere in the circuit, current flow will be interrupted and the circuit will stop working.

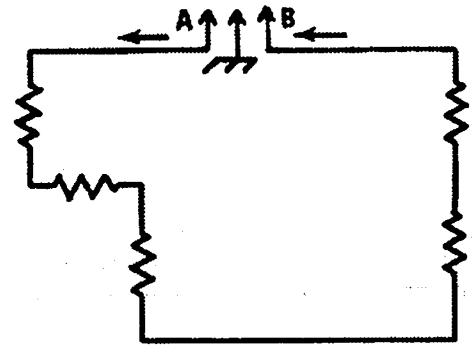
Example: The circuit below is a series circuit made up of a string of six light bulbs. This is how Christmas tree lights used to be wired.

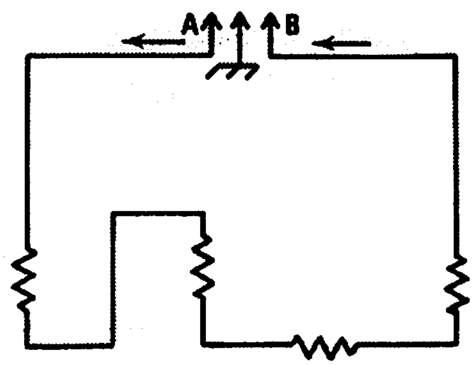


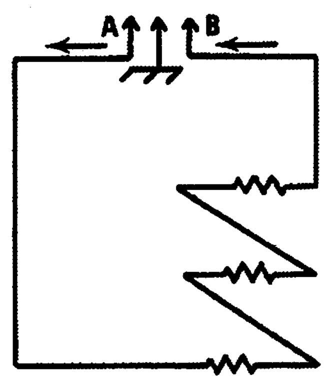
Here is the same circuit with a break (OPEN) in it. Notice that the current can no longer flow from point A to point B, and so the entire circuit will not work. (That was the trouble with wiring Christmas trees in series. If one bulb burned out, ALL the lights would go out because current no longer could flow through *any* part of the circuit.)

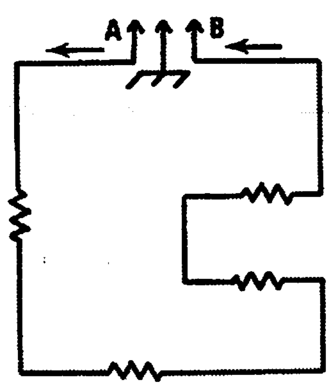


When you look at wiring diagrams you will find series circuits in all sorts of shapes. For example, on the circuits in the next column trace the path of current flow from point A to point B.







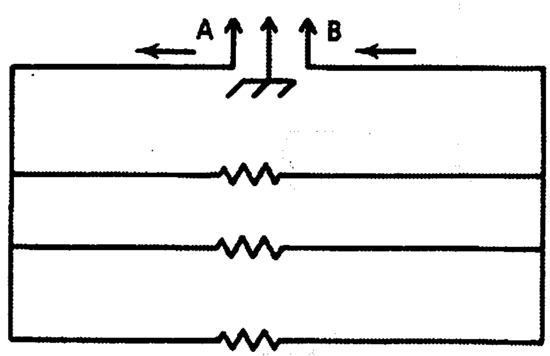


Notice that in each circuit there is only ONE path that the electricity can follow. There are no places where the current can branch into one path or another. Whenever you look at a circuit that has only one path to follow, you are looking at a SERIES circuit.

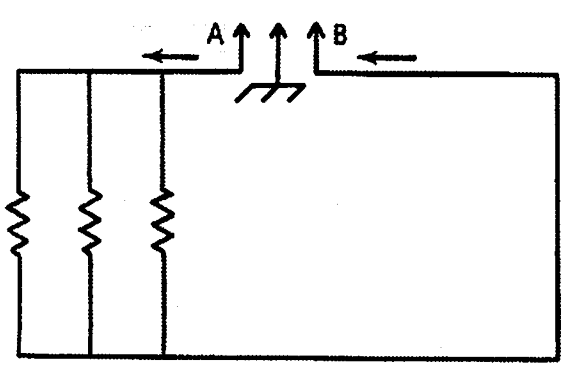
PARALLEL CIRCUITS

Often you will find circuits in which there is more than one path that the current can follow. As current flows from point A to point B it comes to a branch, like a fork in the road. When this happens, the current will flow through all the branches at the same time. The amount of current that will flow through each branch depends on the resistances (loads) in the branch. The parts of a circuit where current is flowing in two or more parts of the circuit at the same time is called a parallel circuit.

In this circuit, you will notice that there are three paths, or branches, through which current can flow at the same time. This is a parallel circuit.



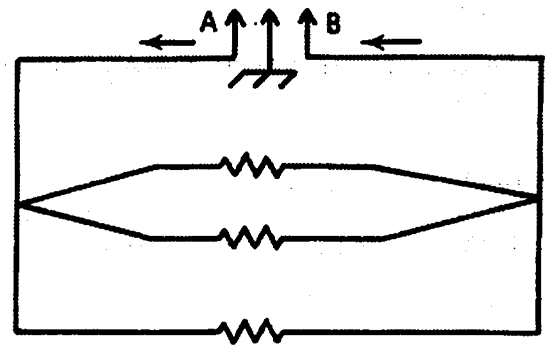
Look at the circuit below and count the number of paths that current can flow at the same time.

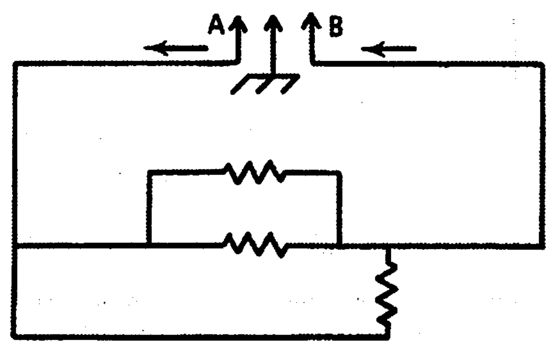


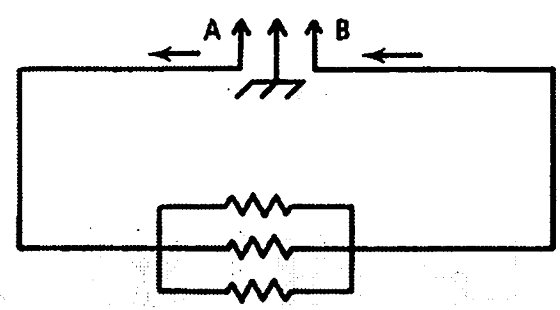
Three, right?

The voltage is the same across all branches in this parallel circuit. This has the same effect as wiring each branch directly to the voltage source.

Notice that like series circuits, *the same* parallel circuit can be drawn in many different ways.







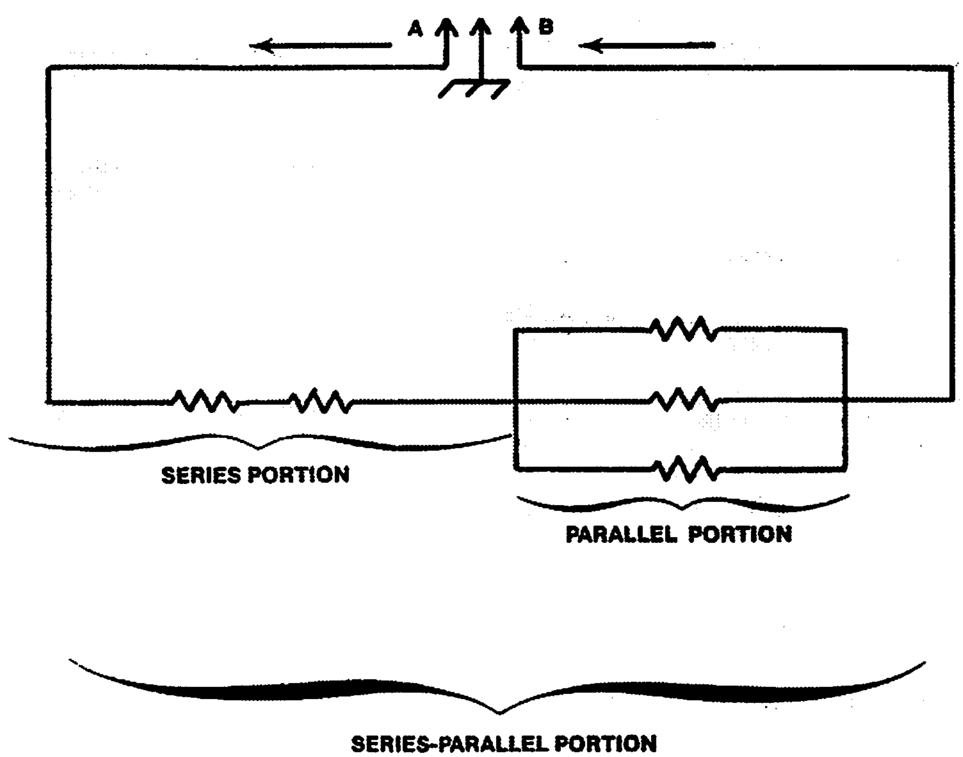
SERIES—PARALLEL CIRCUITS

The series-parallel circuit is a combination of series circuits and parallel circuits.

That part of a circuit within which there is only ONE path for current is a series circuit.

The part in which there is *more* than one path for current to follow is a parallel circuit.

The part where current flows through both one branch and then through two or more branches is a series-parallel circuit.



CHAPTER 2
ALTERNATING CURRENT

AC THEORY

An alternating current (ac) continually changes in potential—going from zero to maximum voltage and back to zero. In addition, ac periodically reverses its direction—from positive to negative. This is in contrast to a direct current (dc), which maintains a steady potential and flows in one direction only.

Fig. 1 shows how the voltage of an ac generator changes. At point A the voltage is zero. Immediately afterward it has a small, positive value. This value increases until it is maximum at B. A moment later the voltage, still positive, continues to drop steadily until it reaches zero again at C. Below C the voltage becomes negative. Therefore, the voltage is shown below the zero line from C to E.

Notice that the polarity does not reverse at B or D—these merely are the points of maximum positive or negative potential. The points of polarity reversal are at A, C and E.

The complete series of voltage values, represented by the curve from A to E, represents one complete *cycle.* When the curve is continued, the cycle is repeated. The time necessary to complete one full cycle is called a period.

The number of cycles generated in one second determines the frequency of the ac voltage. The electricity supplied to most homes is 60 hertz, which means the voltage goes through 60 complete cycles—from zero to positive to zero to negative to zero—in one second.

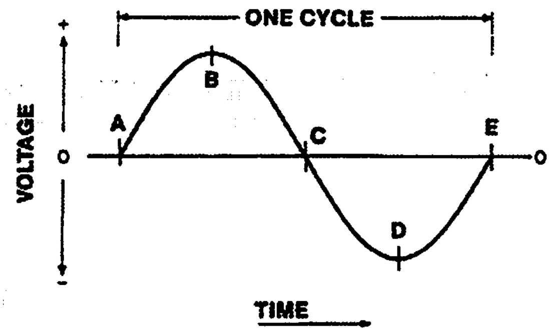


Fig. 1. Graph of changing voltage in an ac generator.

Although ac differs from dc in many ways, practically all the basic principles of electricity that apply to dc also apply to ac.

Advantages of AC

Alternating current can be transmitted more economically over long distances than dc. This is one of the great advantages of ac. It is easily transformed to higher or lower voltages. This is a very desirable characteristic for radio and television circuit applications. Many types of motors are designed for ac operation. Some ac motors operate without brushes, eliminating a common source of wear and motor maintenance problems.

CHAPTER 3
DIRECT CURRENT

An electric current is the motion of electrons. This motion is called a current flow. To enable these electrons to flow and to confine them in a particular path, an electrical *circuit* must be provided. (The word "circuit" means *to go around.*) A complete electrical circuit provides a continuous path for the passage of current (electron flow). See Fig. 2.

A practical electrical circuit has at least four parts: (1) a source of electromotive force (*emf*), (2) a set of conductors, (3) a load, and (4) a means of control.

Electromotive force (measured in volts) is defined as "the force that can move electrons." It can come from a cell or battery, a dc or ac generator, an electronic power supply, or any equipment that can provide a difference of electrical pressure.

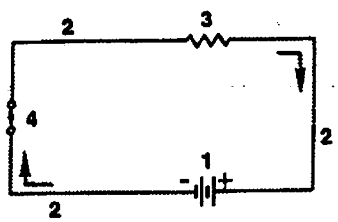


Fig. 2. A simple electrical circuit.

Although wires of many sizes can be used as *conductors*, the term "conductor" actually refers to any material which offers low resistance to current. Conductors may be good or poor; however, poor conductors are usually referred to as resistors or as *insulators* if the conductivity is very low. There are no sharp lines of distinction separating conductors, resistors and insulators; for instance, *semiconductors* fit into the areas between conductors and resistors and between resistors and insulators.

The *load* of an electrical circuit may be any device that uses electrical energy, such as a lamp, a bell or buzzer, a toaster, a radio, or a motor. The load is usually considered as being separate from the conductors that connect it to a current source.

The current flowing in an electrical circuit is stopped or started by means of *switches.* Further control is provided by variable resistances, such as *rheostats* and *potentiometers.* Fuses, circuit breakers, or relays can be used as controls.

Table 3 lists many common electrical abbreviations.

UNITS	SYMBOLS	DESCRIPTION
Coulomb	C	Unit of electrical quantity. The number of electrons which must pass a point in one second to produce a current of one ampere. The quantity which will deposit .0000116 ounce of copper from one plate to the other in a copper sulfate solution.
Ampere	A or amp	Unit of current. One coulomb flowing per second.
Milliampere	mA	.001 ampere. (The prefix "milli" means one-thousandth.)
Microampere	μA	.000001 ampere. (The prefix "micro" means one-millionth.)
Ohm	ohm or Ω	Unit of resistance (R). Measure of the opposition offered to the flow of current. The resistance offered by a column of mercury 106.3 centimeters in length and 1 square millimeter in cross-sectional area, at 32 degrees Fahrenheit or 0 degrees Celsius.
Megohm	M	1,000,000 ohms. (The prefix "meg" means million.)
Microhm		.000001 ohm. (The prefix "micro" means one-millionth.)
Mho	g	Unit of conductance (g). Measure of the ease with which a conductor will permit current to flow. A mho is the reciprocal of an ohm.
Volt	V	Unit of pressure difference (emf—electromotive force). Pressure required to force one ampere of current through a resistance of 1Ω.
Hertz	Hz	Frequency (one cycle per second.)
Millivolt	mV	.001 volt. (The prefix "milli" means one-thousandth.)
Microvolt	μV	.000001 volt. (The prefix "micro" means one-millionth.)
Kilovolt	kV	1000 volts. (The prefix "kilo" means one-thousand.)
Watt	W	Unit of power. One watt is equal to one ampere of current under the pressure of one volt. The formula for power is $P = A \times V$.
Milliwatt	mW	.001 watt. (The prefix "milli" means one-thousandth.)
Kilowatt	kW	1000 watts. (The prefix "kilo" means one-thousand.)
Watthour	Wh	Unit of work. (Power $\times$ time.)
Kilowatt hour	kWh	1000 watt-hours. (The prefix "kilo" means one-thousand.)
Horsepower	hp	746 watts. The power required to raise 550 lbs one foot in one sec.
Farad	F	Unit of capacitance. Capacity of capacitors (condensers).
Microfarad	mfd or μF	.000001 farad. (The prefix "micro" means one-millionth.)
Picofarad	pF	.000001 microfarad. (One-millionth of one-millionth of a farad.)
Henry	H	Unit of inductance (L).
Millihenry	mH	.001 henry. (The prefix "milli" means one-thousandth.)
Microhenry	μH	.000001 henry. (The prefix "micro" means one-millionth.)

Table 3. Electrical Abbreviations

Before we continue on with our study of basic electricity, let's set a new course toward easier understanding . . .

. . . To aid you down the path to easier understanding of the laws and formulas used in the study of "Basic Electricity," we will use the common name for the term and an appropriate initial. I know this isn't the way you would see these formulas in a physics class or an electrical engineering class, but in the real world a volt is a volt and should be indicated by a "V" in a formula not by an "E" for electromotive force. Think about this, when was the last time you heard someone say "my house is wired for 120 volts of electromotive force." Okay, if we are going to say "volts" let's use a "V" for volts in our formulas. Let's also use "R" for resistance and "A" for amps.

I hope this will help clear up some of the confusion caused by unfamiliar initials in the formulas. The cross reference chart (Fig. 4) shown below can be used as a reference to terms; however, the intent is to keep the formulas so understandable you won't have to refer back to the chart.

TERM	MEASURED IN	REFERRED TO IN FORMULAS AS	IDENTIFICATION USED IN THIS COURSE
Amperage	Amperes (Amps)	I	A for amps
Current	Amperes (Amps)	I	A for amps
Resistance	Ohms	Ω or R	R for resistance
Voltage	Volts	V or E	V for volts
Electromotive Force	Volts	V or E	V for volts

Fig. 4. Cross reference chart of formulas

Ohm's Law

The law which governs most simple and many complex electrical phenomena is known as Ohm's law. It is the most important law in electricity. In 1827, a German physicist, Dr. Georg Simon Ohm (1787-1854), introduced the law which bears his name. His many years of experimenting with electricity brought out the fact that the amount of current which flowed in a circuit was directly proportional to the applied voltage. In other words, when the voltage increases, the current increases; when the voltage decreases, the current decreases.

If the voltage is held constant, the current will change as the resistance changes, but in the opposite direction. The current will decrease as the resistance increases and will increase as the resistance decreases.

Ohm's law states: The current which flows in a circuit is directly proportional to the applied voltage and inversely proportional to the resistance.

There are three formulas concerning Ohm's law. See fig. 5.

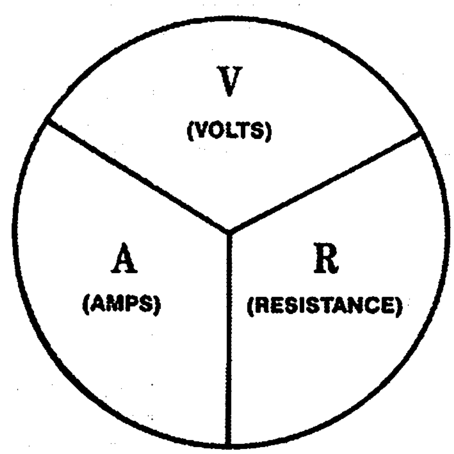


Fig. 5. Memory circle of formulas using Ohm's law.

Remember that a load is anything that uses up some of the electricity flowing through a circuit. A thing to remember also is, ELECTRICITY FOLLOWS THE PATH OF LEAST RESISTANCE. In other words, it is the potential difference from one side of the load to the other side that forces current to flow in a circuit.

Let's look at a problem from the perspective of Ohm's law. First we need to understand the three factors used in Ohm's law:

The first is voltage. Voltage is the difference in potential between two points or the difference in static changes between two points, voltage does not flow or do any work in a circuit, it is simply a potential. The fundamental law to find voltage is stated:

The pressure in volts is equal to the current in amperes multiplied by the resistance in ohms. The equation is:

$$V\text{ (volts)} = A\text{ (amps)} \times R\text{ (resistance)}$$

The second is current. Current is the flow of electrons from a negative to a positive potential. *Without a difference in potential, current will not flow.* Current is the factor that does the work in the circuit (light the light, ring the buzzer). The fundamental law to find current is stated:

The current in amperes is equal to the pressure in volts divided by the resistance in ohms. The equation is:

$$A\text{ (amps)} = \frac{V\text{ (volts)}}{R\text{ (resistance)}}$$

The third factor is resistance. Resistance is the opposition to current flow or the load. Current through the resistor causes work to be done. The fundamental law to find resistance is stated:

The resistance in ohms is equal to the pressure in volts divided by the current in amperes. The equation is:

$$R\text{ (resistance)} = \frac{V\text{ (volts)}}{A\text{ (amps)}}$$

Remember that current is what does the work and it only flows when there is a difference in potential.

In this series circuit (Fig. 6) there is a difference in potential between the positive and negative terminals of the battery of 20 volts DC.

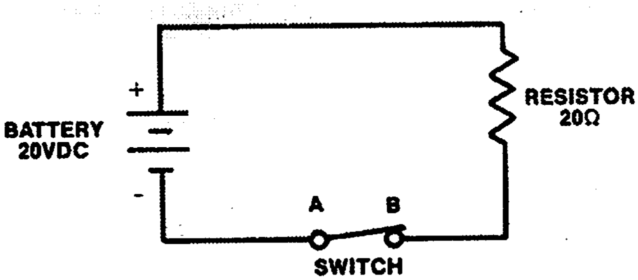


Fig. 6

Therefore, current will try to flow from the negative terminal to the positive terminal. There will be a difference of potential across the resistor. The current through the resistor will be:

Using Ohm's law:

$$A = \frac{V}{R} = \frac{20VDC}{20\Omega} = 1\text{ amp}$$

If we open the switch, the current in the circuit goes to zero because there is no path for current to flow. When we close the switch, current will again flow in the circuit. There will be no voltage drop across the switch because there is no resistance.

Now let's look at how current flows in a parallel circuit (Fig. 7).

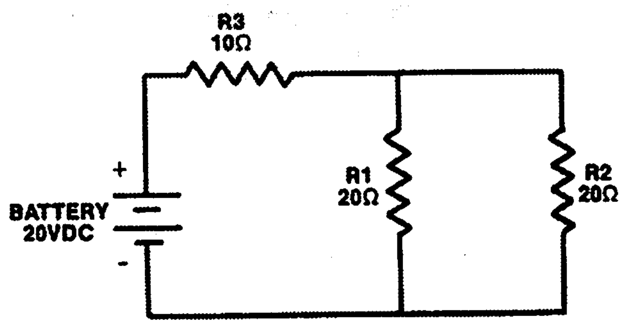


Fig. 7

In this case, the total resistance in the *parallel circuit* is figured using the formula:

$$\frac{R1 \times R2}{R1 + R2} = RT \text{ or } \frac{20\Omega \times 20\Omega}{20\Omega + 20\Omega} = \frac{400\Omega}{40\ \Omega} = 10\text{ ohms}$$

The parallel portion of the circuit is equal to 10 ohms. The total current in the circuit is equal to:

$$A = \frac{V}{R3 + RT} = \frac{20VDC}{10\Omega + 10\Omega} = 1\text{ amp}$$

The voltage drop across the parallel portion of the circuit will be:

$$V = A \times RT = 1\text{ amp} \times 10\text{ ohms} = 10\text{ volts}$$

But an interesting thing happens when current reaches the parallel portion of the network. It now has two different ways to go so it splits up. To find the current in each leg, use Ohm's law:

$$A = \frac{V}{R1} = \frac{10V}{20\Omega} = .5 \text{ amp (Leg 1 or R1)}$$

$$A = \frac{V}{R2} = \frac{10V}{20\Omega} = .5 \text{ amp (Leg 2 or R2)}$$

Now let's change the values of the resistors. See Fig. 8.

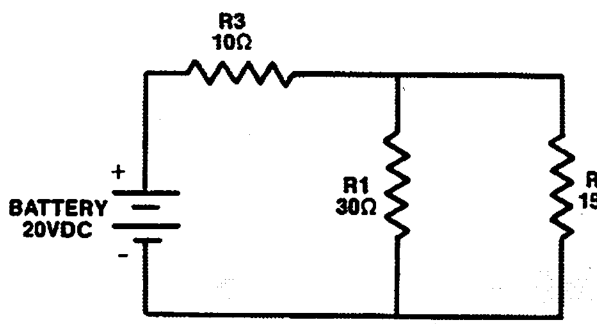


Fig. 8

In this case, the total resistance in the *parallel circuit* is figured using the formula:

$$\frac{R1 \times R2}{R1 + R2} = RT \text{ or } \frac{30\Omega \times 15\,\Omega}{30\Omega + 15\Omega} = \frac{450\Omega}{45\Omega} = 10 \text{ ohms}$$

The parallel portion of the circuit is equal to 10 ohms. The total current in the circuit is equal to:

$$A = \frac{V}{R3 + RT} = \frac{20VDC}{10\Omega + 10\Omega} = 1 \text{ amp}$$

The voltage drop across the parallel portion of the circuit will be:

$$V = A \times RT = 1 \text{ amp} \times 10 \text{ ohms} = 10 \text{ volts}$$

But an interesting thing happens when current reaches the parallel portion of the network. It now has two different ways to go so it splits up. Instead of the .5 amp in each leg as before, we now get:

$$A = \frac{V}{R1} = \frac{10V}{30\Omega} = .33 \text{ amp (Leg 1 or R1)}$$

$$A = \frac{V}{R2} = \frac{10V}{15\Omega} = .66 \text{ amp (Leg 2 or R2)}$$

This shows that more current flows in the leg with the least resistance. Therefore, it seems that current takes the path of least resistance.

Let's look at what happens when the resistance of one of the parallel legs is zero (Fig. 9).

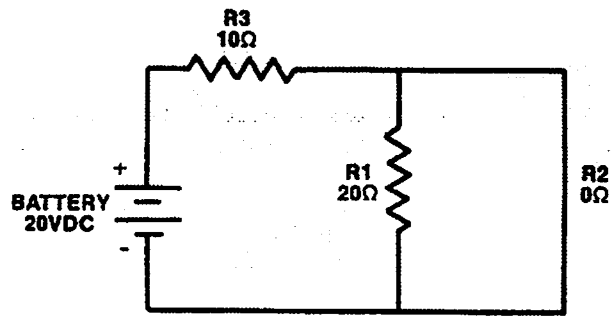


Fig. 9

In this case, the total resistance in the *parallel circuit* is figured using the formula:

$$\frac{R1 \times R2}{R1 + R2} = RT \text{ or } \frac{20\Omega \times 0\Omega}{20\Omega + 0\Omega} = \frac{0\,\Omega}{20\Omega} = 0 \text{ ohms}$$

The total current in the circuit is equal to:

$$A = \frac{V}{R3 + RT} = \frac{20VDC}{10\Omega + 0\Omega} = 2 \text{ amps}$$

The voltage drop across the parallel leg 1 or R1 will be:

$$V = A \times RT = 2 \text{ amps} \times 0 \text{ ohms} = 0 \text{ volts}$$

Therefore, the current flow through leg 1 or R1 will be:

$$A = \frac{V}{R1} = \frac{0V}{20\Omega} = 0 \text{ amps}$$

With no current flow through this leg, no work will be done. That is, the light won't light or the buzzer won't ring.

Amperes, Volts, Ohms

AMPERES

Current is measured in amperes. The term "ampere" refers to the number of electrons passing a given point in one second. This number is unbelievably large. If one could count the individual electrons, he would see approximately 6,280 quadrillion electrons go by during the one second that one ampere was flowing.

This number of electrons, 6,280 quadrillion, is a *coulomb*. This is a measurement of quantity (like saying there are eight pints in a gallon of water). When the electrons are moving, there is current. Current can be measured in amperes, which is a measurement of quantity multiplied by time. this would be similar to saying that we could fill so many gallon buckets with water at the rate of so many pints per minute.

One ampere is equal to one coulomb per second. An instrument called an ammeter will measure electron flow in coulombs per second. The ammeter is calibrated in amperes, which we always use instead of coulombs per second when speaking of the amount of current. Fig. 10 is a schematic showing an ammeter connected in a circuit to measure the current in amperes.

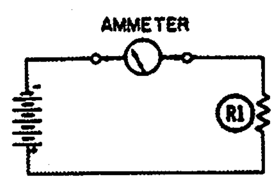


Fig. 10. An ammeter connected in a simple circuit.

VOLTS

Electromotive force is measured in *volts*. This is the amount of pressure difference between points in a circuit. It is this pressure or difference of potential that forces current to flow in a circuit. For example, suppose we have two automobile tires, one inflated to a pressure of 30 pounds per square inch, the other to a pressure of 10 pounds per square inch. If we connect a hose to the valves of the tires, the difference in pressure will send air from the 30-psi tire to the 10-psi tire. Air will continue to flow until the pressure is the same in both tires.

One volt (potential difference) is required to force one ampere of current through one ohm of resistance. This is similar to a water pump that forces water to flow through a pipe. The water pump can be compared to the potential difference. The number of pounds of pressure produced by the water pump corresponds to the number of volts produced by a current source. The action of the pump pushing a number of gallons of water per second past a certain point in a water system could be compared to the action of a current source sending a number of amperes of current. A valve in the pipe offers a resistance to the flow of water; the amount of resistance offered is comparable to the ohm. Keep this water-pump analogy and the road map analogy in mind as you study electricity. It will help you to better understand the action of the "Big Three"—voltage, amperage, and resistance—in an electrical circuit.

An instrument that will measure voltage is known as a *voltmeter*. Fig. 11 is a schematic showing a voltmeter connected in the circuit to measure the voltage. Voltmeter No. 1 is connected to read the applied or source voltage. Voltmeter No. 2 is connected to measure the voltage drop, or potential difference, across R2.

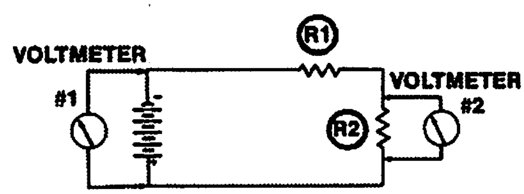


Fig. 11. A voltmeter connected in a simple circuit.

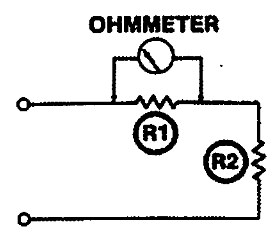


Fig. 12. An ohmmeter connected to read resistance.

OHMS

Resistance is measured in *ohms*. Resistance opposes the flow of electrons (current). The amount of opposition to the flow is stated in ohms.

If a glass tube 106.3 centimeters (approximately 41 inches) in length and one square millimeter in a cross-sectional area is filled with mercury and maintained at zero degrees Celsius (32 degrees Fahrenheit), the tube will offer a resistance of one ohm. This is the standard by which the ohm is determined.

An instrument that will measure ohms is known as an *ohmmeter*. Fig. 12 is a schematic showing an ohmmeter connected to read the resistance of R1. The resistance of any material depends on the type, size, and temperature of the material. Even the best conductor offers some opposition to the flow of electrons.

NOTES