Koinonia School of Practical Trades
A Short Course In Electrical Technology

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Home Wiring

Electricity is the rapid flow of energy transmitted by electrons. A public, or sometimes private, utility generates the electricity and sends it to your home through overhead or underground wires called service conductors. The flow must make a complete circuit from the utility's generating station, along the lines to your home, through your household circuits and back to the utility.

How Electricity Works

A household electrical system can be compared with a home's plumbing system. Electrical current flows in wires in much the same way that water flows inside pipes. Both electricity and water enter the home, are distributed throughout the house, do their "work," and then exit.

In plumbing, water first flows through the pressurized water supply system. In electricity, current first flows along hot wires. Current flowing along hot wires also is pressurized. The pressure of electrical current is called **voltage.**

Large supply pipes can carry a greater volume of water than small pipes. Likewise, large electrical wires carry more current than small wires. This current-carrying capacity of wires is called **amperage.**

Water is made available for use through the faucets, spigots, and shower heads in a home. Electricity is made available through receptacles, switches, and fixtures.

Water finally leaves the home through a drain system, which is not pressurized. Similarly, electrical current flows back through neutral wires. The current in neutral wires is not pressurized, and is said to be at zero voltage.

The electricity goes through a meter, usually attached to the outside of the house into the main, entrance panel. The meter measures how much electricity your home uses during a certain period and is charged accordingly. At the service entrance panel, which contains a fuse or circuit breaker or fuse/breaker system, the electricity is divided into branch circuits. The fuses or breakers protect these individual circuits.

The branch circuits supply safe electrical power to the various rooms in your home: kitchen, bathrooms, living areas, bedrooms and so on. Each circuit is protected by its own fuse or circuit breaker and is independent of the others. That is why, when something causes one circuit to fail with a blown fuse or tripped breaker, the remaining circuits are unaffected and continue to supply power to the other rooms.

The force that moves the energy is called voltage. The flow itself is called current. The direction of flow changes 60 times a second. Thus, we speak of 120- or 240-volt, 60-cycle alternating current (AC).

Electricity - Conductors and Insulators

When you study high-school chemistry, you'll learn that some types of molecules feel more strongly about their electrons than do other types of molecules. This is a very useful characteristic for electricity and electronics.

Conductors Some materials are willing to let a few electrons move from molecule to molecule. Materials that let electrons move through them are called "conductors".

Although some are better than others, most metals are good conductors of electricity. Silver, Gold, and Platinum are very good conductors but are expensive, so they are not often used. Copper and Aluminum are reasonably good conductors and are fairly inexpensive. Thus the wiring in our houses is copper, and the high voltage electric lines that we see crossing the country use aluminum cables.

Insulators Other substances keep their electrons under very tight control. Materials that do not let electrons move through them are called "insulators".

Glass is an example of a type of material that keeps its electrons tightly controlled. Glass is made of silicon molecules, organized very tightly in to crystaline structures. Glass is an extremely good insulator. Many plastics are good insulators too. Plastics are cheap, flexible, and durable. That is why the wiring in our houses is covered with a layer of plastic.

Electricity - Conductors and Insulators: conductus, conducere - Latin words for leading, guiding. An electrical conductor does exactly that. It guides the electron flow from place to place.
- insula, insulae -
Latin words for separate or divided. An electrical insulator is a separation between conductors. Electrons do not flow across the division or separation formed by an insulator.

How Good is a Conductor or Insulator? Some materials conduct electrical current very well, others conduct poorly, and others not at all. Obviously this characteristic is really a gray scale, from very good to very poor. If the material conducts electrical current well enough to not affect the operation of the circuit, then it is considered a good conductor. If a material insulates well enough that any leakage through it is negligible (does not affect circuit operation), then that material is considered a good insulator.

A perfect vacuum (perhaps never achieved in the real world) would be a perfect insulator. Interestingly, pure water (again never seen in the real world) would also be an excellent insulator. (Water with any impurities is a fairly good conductor).

There are lots of materials in the world that are poor conductors or poor insulators. Sometimes we use these materials in electricity and electronics because we need poor conductivity. (Lamp filaments, and heating elements are examples of poor conductors we use in everyday life.)

Questions:

Q: Is air a conductor or an insulator?

A: A conductor (not correct). Let's perform a thought experiment about batteries to see if we can reason this out. The battery terminals are not covered with plastic... they are exposed directly to the air. If air was a conductor, then current would flow between the battery terminals all of the time. The battery would soon be dead! In fact all batteries would have a very short life (they would all die within hours of when they were made). Since that doesn't happen, air must not be a conductor. Air must be an insulator!

A: An insulator (correct).

Why is that question so important? Think about how hard it would be to make circuits that work correctly if air was a conductor. Everything would have to be carefully insulated. Most types of switches and relays we use now would not work (they use air as the insulator between poles when they are in the open position). We wouldn't want to use electricity for lighting and heat if the air was a conductor... our houses would be dangerous places!

<u>Ohm's Law</u>

Electricity follows certain rules that do not change. The most useful rule is called Ohm's Law, usually stated as a simple equation

E = I ´ R

Where

E = Voltage
I = Current
R = Resistance

Before proceeding, we need to understand some electrical terminology. E stands for Voltage, the electrical pressure causing electrons to flow in a circuit. The higher the voltage the greater the pressure that causes electrons to flow. An electron is the smallest known particle present in every atom. A circuit is the path for an electrical current. The most familiar circuits are the wires in our houses and cars which connect bulbs, motors, and appliances to a power source. These power sources can be a battery or the power company's electrical lines and generators. The I in the Ohm's Law equation stands for Current, the flow of the electrons in a circuit. Current is measured in amperes or amps, for short. Finally, the R stands for Resistance, the opposition to the flow of electrons or current in a circuit; it is measured in ohms.

So with this information, we can apply the mathematical relationships in electricity known as Ohm's Law. If you know two of the items in the equation you can solve for the third.

How much current is used in a car if a light bulb with 50 ohm's resistance has a voltage of 12 volts in the circuit ?

E = I ´ R Solving for I or current, we can change the equation to:
I = E / R
I = 12 volts / 50 ohms
I = 0.24 amps or 240 milliamps

If a current of 2 amps flows through a heater having a 50 ohm resistance, what is the voltage across the heater ?

Estimate the answer:

Less than 60 volts
Between 60 and 120 volts
Over 120 volts

MORE...

Terms used to describe the electrical effort are important to understand.

Common terms and their definitions are:

Voltage: potential difference, electrical pressure (volts).

Symbol "E".

Amperage: current flow, intensity of flow of current. Common term (amps).

Symbol "I".

Resistance: restricting the flow of current, measured in (ohms).

Symbol "R".

Power: the amount of current used. Measured in (Watts).

Symbol "P".

Ohm's Law is very helpful to determine unknowns when diagnosing electrical problems.

OHM's Law

Voltage divided by amps is equal to resistance

(E/I=R)

Voltage divided by resistance is equal to amps

(E/R=I)

Amperage multiplied by resistance is equal to voltage

(I*R=E)

Voltage multiplied by amps is equal to watts

(E*I=P)

Example:

If 12 volts is applied to 12 ohms of resistance, 1 amp of current will flow.

The amount of power used will be 12 watts.

Note: these formulas work for "resistive" circuits only. Other, more complicated formulas, are available through Ohm's law for "inductive reactive" circuits.

Inductive reactive circuits use magnetic fields to perform work. The resistance to the flow of current changes from their static values after current begins to flow.

Two- & Three-Wire Systems

Most homes built before 1941, had two-conductor (two-wire) electric service. If you live in a home built during this time and the electrical service has not been remodeled, your home may have two-conductor service. In effect, one conductor carries 120-volt current and the other provides a return path. Actually, the current flow alternates in direction, along both conductors.

Two-conductor service may limit the number and type of electrical appliances you can use. Even if the utility ran a third line to increase your service, your existing circuits might not let you use many of today's electrical conveniences. However, it may well be possible to add new circuits capable of handling the current demands of new appliances. Consult your power company and a qualified electrician to determine whether your present service can handle an increased demand.

Most homes have three-conductor service. Two of the wires are always "hot", meaning power is always present. The third wire, often inaccurately called "neutral", is hot only when current is flowing. In a modern home, where appliances are running all day and night, the neutral wire is always hot. There are 120 volts between each hot wire and the "neutral" conductor, and 240 volts between the two hot conductors. Thus, there is power for lights and small appliances that require 120 volts, and for large appliances that require 240 volts.

Wattage Ratings

To calculate the wattage (power) available in a circuit, first determine its amperage (amp rating). It will be marked on the circuit breaker or fuse for that circuit in the service entrance panel – 15 or 20 amps for most room circuits, 30 or 50 amps for most heavy duty circuits. Then, Watts = Volts x Amps. Thus, a 15-amp circuit with 120 volts carries (15 x 120 =) 1,800 watts; a 20-amp circuit carries 2,400 watts.

The wattage of any one appliance (see chart) should not be more than 80 percent of circuit's total wattage capacity. Appliances with large motors, such as air conditioners or refrigerators, should not exceed 50 percent of circuit capacity. To operate properly and safely, each such appliance must have a circuit to itself.

Typical Wattage Ratings

Appliance	Rating	Appliance	Rating
Air conditioner unit	800-1500	Garbage disposer	500-1000
Central air conditioner	5000	Hair dryer	400
Electric blanket	150-500	Heater (portable)	1000-1500
Blender	200-400	Heating pad	50-75
Broiler (rotisserie)	1400-1500	Hot plate	600-1000
Can opener	150	Hot water heater	500-5000
Clock	13	Microwave oven	650
Clothes dryer (240-v.)	4000-5000	Radio	10
Clothes iron (hand)	700-1000	Range (per burner)	5000
Coffee maker	600-750	Range oven	4500
Crock pot (2 quart)	100	Refrigerator	150-300
Dehumidifier	500	Roaster	1200-1600
Dishwasher	1100	Sewing machine	60-90
Drill (hand)	200-400	Stereo	250-500
Fan (attic)	400	Sun lamp	200-400
Fan (exhaust)	75	TV (color)	200-1500
Floor polisher	300	Toaster	250-1000
Food freezer	300-600	Toaster oven	1500
Food mixer	150-250	Trash compactor	500-1000
Fryer (deep fat)	1200-1600	Vacuum cleaner	300-600
Frying pan	1000-1200	Waffle iron	700-1100
Furnace (gas)	800	Washing machine	600-900
Furnace (oil)	600-1200		

The Working Tools

Electrical projects require several specialized tools. They also require several standard hand and power tools, such as hammers, chisels, squares and portable electric drills. You may already have many of these tools. However, if you do not, they may be purchased or rented on a project-to-project basis.

In order to save time, money and frustration, we recommend that you buy quality tools and equipment at the outset. Taken care of properly, they should provide many years of service.

The tools and equipment needs have been organized into two categories: basic tools needed for most repairs and simple projects, and additional tools for more ambitious projects, especially those involving carpentry skills.

You will find a selection of electrical tools and equipment at many home center stores and hardware outlets.

The Basic Tools

- Continuity tester or voltage tester.
- Multipurpose wire stripper. Removes insulation without damaging wire. Some strippers also cut and bend wire.
- Needlenose pliers. Excellent for bending tight loops in wire to go around terminals.
- Lineman's pliers. These 7- and 8- inch pliers have flat jaws used to bend, pull, twist and grip wires. Some have wire and cable cutters.
- Set of standard screwdrivers.
- Set of Phillips screwdrivers.

- Set of nut drivers.
- Pocket knife or utility knife.
- Adjustable wrench. (Buy either an 8- or 9- inch wrench for tightening nuts and connectors).
- Cable insulation ripper. Removes cable insulation.
- Electric solder gun.
- Volt-ohmmeter for circuit tests.
- Tape measure.

Additional Tools

- Many electrical projects require carpentry tools. The tools frequently needed are listed below.
- Locking pliers. Used to grip and hold wires, tighten bolts and pull cable through conduit and holes.
- Diagonal, cable or side cutters. Used to cut wires in cramped quarters, such as outlet boxes.
- Adjustable pliers. Used to handle locknuts and cable connectors.
- Pipe wrench. A 10-inch wrench is used for working with conduit.
- Variable-speed portable electric drill with several hole-saw, masonry and wood bits.
- Wood chisel set; cold chisel.
- Portable electric saber saw.
- Carpenter's level.
- Hammer.
- Hacksaw.
- Compass (keyhole) saw.
- Fish tape. Used to pull wires through finished walls and ceilings.

Mapping Circuits

The starting point for all electrical repair and improvement projects is the main electrical service panel, usually called the fuse box or the circuit's or the circuit breaker panel. This is where all circuits start and end. When there is trouble on a circuit, such as an overload or short, the fuses or breakers shut off the power at this point. When you do any work on a circuit, you must first remove a fuse or trip the breaker to turn off the power at this stopping and starting location.

The following two circuit protectors may not be found in the main service panel:

- A separate fuse box or circuit breaker added to the main electrical system to power a major circuit or appliance. For example, some older homes have a separate circuit to power a central air-conditioning system. You will find the location of this fuse box when you map the circuits.

Some appliances have a built-in protective system with a fuse or circuit breaker. An example is a garbage disposer that has a power overload device. When an overload occurs, the built-in system shuts down only the appliance. You push a reset button on the appliance to restore power to it. Appliances and devices with similar protection include ranges, clothes dryers, ground fault circuit interrupter (GFCI) outlets and heavy-duty motors.

The built-in system protects only the appliance; the circuit to which it is connected is protected by its own fuse or circuit breaker in the main service panel – one does not substitute for the other. In general, the built-in protector is designed to trip and shut down the appliance at a lower overload level than the fuse or breaker that protects the entire circuit. This helps prevent an appliance problem from affecting the overall circuit wiring.

Different Designs of Circuit Protection

Some circuit systems use only fuses, while others use only toggle-type circuit breakers. There also are systems that combine fuses and breakers. Fuses and toggles come in somewhat different shapes and sizes.

Circuit Protection

Fuses and circuit breakers interrupt the current flow in the situations where circuit overloading or line-to-line or line-to-ground faults have occurred.

Before you replace a fuse or reset a circuit breaker, find out what caused the power shutoff and correct this condition. Although installing a new fuse or resetting the breaker may restore power to the circuit, it will be temporary; the circuit will shut down again fairly quickly unless you correct the trouble. The problem may be an overloaded circuit, a short circuit in a damaged wire or a broken circuit in an appliance.

Sometimes, but very, very infrequently, a problem may exist in the main service panel. If, after making a thorough check, you cannot find trouble on the circuit, suspect the service panel. However, do not try to repair any damage yourself, unless you have the know-how. Hire a licensed electrician to do the job.

Safety at the Panel

When replacing a fuse or resetting the toggle on a circuit breaker, work safely by standing on a completely dry piece of plywood or a short length of 2x6 or 2x8 lumber. Here is a way to be sure the piece of lumber is there when you need it; Cut a piece of wood and drive a nail into the edge or end of it; then bend the nail over into a hook shape and hang the wood on a pipe or similar object near the main service panel.

Wear safety goggles and always use fuse pullers to remove or replace cartridge fuses. Use just one hand to remove or replace plug fuses or reset circuit breakers. This will avoid creating a circuit between you and the panel.

<u>Overloads & Shorts</u>

Plug Fuses

An overload occurs when too many appliances and lights in a circuit demand more current than the circuit can deliver safely. In this case, the small wire in the fuse will break without heating excessively. The window will be clean, and you should be able to see the broken wire.

A short circuit occurs when a bare wire carrying electricity touches another bare wire carrying electricity or touches the grounded metal case of an appliance. The rate of the current flow quickly becomes excessive. This in turn produces heat, which destroys the fuse wire. The fuse wire vaporizes and sprays the fuse window with discolored material.

Circuit Breaker Basics

Circuit breakers are protective switches that automatically flip off when there is an overload or short circuit. You reset a circuit breaker by pushing the switch or toggle to the full OFF position, and then to the full ON or RESET position.

Since you do not have a window in a circuit breaker to help determine the cause of a short circuit or overload, make a list of the lights and appliances that were operating on the circuit when the breaker tripped. Then add up the total wattage you were pulling at the time of the power failure and divide the wattage by the voltage. If the resulting amperage figure is more than the capacity marked on the failed fuse, there was an overload.

Cartridge Fuses

Two types of cartridge fuses are used in homes. The round-ended type, with a capacity of 10 to 60 amps, is used to protect circuits that supply a major appliance.

The other type of cartridge fuse is usually used in residential installations to protect the main power circuit. This fuse has knife-blade end contacts and is rated at 70 to 600 amps. The two types cannot be interchanged.

Changing Cartridge Fuses
1. **Shutting Off Power**. Some service panels with cartridge fuses are controlled by a lever along the outside edge of the panel. Move the lever to OFF position. Then open the box.
2. **Removing the Fuse**. Using a fuse puller, grasp the middle of the fuse and pull it out from the spring clips. If the fuse has knife-blade ends, do not bend them.
3. **Compartment Fuse**. Some cartridge fuses are mounted in a compartment-type housing. To remove the fuses, grasp the wire-loop handle and pull the compartment straight out of the panel.
4. **Testing the Fuse**. Touch one probe of continuity tester to one end of the fuse and the other probe to the other end. If the tester lights, the fuse is okay. If the tester does not light, replace the fuse. To install a new cartridge fuse, push it into the spring clips by hand.
Caution: Always remove a fuse from the service panel before testing it.

Working With Wire

Technically, the metal through which electricity flows is called a conductor. In the real world, it is called wire, cord and cable.

Wire Basics
For practical purposes, a wire is a single strand of conductive material enclosed in protective insulation. Single-strand wire can be purchased off of a roll at any length you need. Sometimes it can be bought precut and packaged in standard lengths. A cable has two or more wires grouped together within a protective sheathing of plastic or metal. Cable is normally sold boxed in precut lengths of 25,50 or 100 feet. Cord usually is a series of stranded wires encased in insulation. Cord is sometimes precut and packaged, but is usually sold off the roll. All conductors are priced by the lineal foot. There are three types of wires: copper, copper-clad aluminum and aluminum. For any project, you always should use the same type of wire that is installed in your home. You can determine this by opening a switch or outlet box, pulling out the wires and noting the information printed on the insulation. The markings tell you the voltage, the type of wire or cable, the manufacturer and the AWG wire size.

Wire Size
You will probably be concerned mostly with No. 14 and No. 12 wire sizes. The term wire refers to a single conductor. In a cable containing two wires, both wires will be the same size. Wire numbers are based on the American Wire Gauge (AWG) system, which expresses the wire diameter as a whole number. For example, No. 14 AWG wire is 0.064 inches in diameter, and No. 12 AWG is 0.081inches. The smaller the AWG number, the greater the diameter and the greater the current-carrying capacity. The National Electric Code requires a minimum of No. 14 AWG wire for house wiring. Exceptions to this are the wiring used in lighting fixtures, furnace controls, doorbells and other low-energy circuits.

Wire Ampacity
You also must consider the wire's ampacity, or the current in amperes that a wire can carry continuously under conditions of use without exceeding its temperature rating. If a wire is too small for the job, it will present a greater-than-normal resistance to the current flowing around it. This generates heat and can destroy insulation, which can cause a fire. No. 12 wire is rated to carry maximum of 20 amps; No. 14 wire is rated to carry up to 15 amps.

Cable
House circuits are usually wired with nonmetallic-sheathed cable, with metal-armored cable or with insulated wires running through metal or plastic pipe called conduit. For most projects, you

will be working with flexible nonmetallic-sheathed cable known by the trade name Romex. It contains insulated power, neutral wires and a ground wire. Armored cable is called BX. Inside the flexible metal sheathing are insulated power and neutral wires and a ground wire. The use of BX cable sometimes is restricted by code. Check your local codes. BX also is restricted to indoor-use or dry locations. It sometimes is specified for use where power wires need extra sheathing protection. Conduit, according to code, can be galvanized steel pipe or plastic pipe. There are three types of metal conduit: rigid, which is preferred for outdoor use; intermediate, and electrical metal tubing or EMT, a type popular for house wiring. Standard conduit diameters are 1/2, 3/4, 1 and 1¼ inch. There are fittings to join conduit for straight runs and at 45-degree angles. The material is bent with a tool called a hickey.

Cord
This is stranded wire encased in some type of insulation, such as plastic, rubber and cloth. Zip cord, for example, is two wires, usually No. 18 gauge, encased in a rubber-like insulation and held together with a thin strip between wires. The wires easily come apart by unzipping them; hence the name zip cord. Cord is used for lamps, small appliances, and cord sets that have plugs and/or receptacles on one or both ends of the cord.

Selecting Wire By Insulation
Wire, both solid, single strands and cable, is available with many different types of insulation. You must select the right wire for the location in which it will be used.

Flame retartdant? Moisture resistant? Buried?

Wire (Cable) Connectors
Cable, or more specifically the wires inside the cable sheathing, may be connected in several ways: with wire connectors, crimped connectors, split-bolt connectors, and solder. The code specifies that all connections (splices) must be made inside a box.

Wire Connectors Wire connectors or connectors that do not use solder are sized according to the size of the wires to be spliced. They are used widely and code-approved.

Crimped Connectors These fasteners are similar to wire connectors, but they sometimes are not permitted by code in local areas. Check your local code. To use crimped connectors, strip about 1/2- to 3/4- inch of insulation off the wires to be connected. Twist the wires together with pliers so the joint is well wrapped and tight. Then insert the wire ends in the connector and crimp the end of the connector with a tool made especially for this job.

Split-Bolt Connectors These connectors are available in assorted sizes to correspond with wire sizes. Split-blot connectors are basically designed to be used with the larger wire sizes. From No. 6 gauge and larger. Strip about 1/2- to 3/4-inch insulation off the wires to be joined. Thread the wires into the connector loop and tighten the nut with pliers or an adjustable wrench or nut driver. Then wrap the splice with several layers of plastic electrical tape.

Solder Connections You may solder wires together for a strong, tight splice. It is time consuming to do so, however. Use only rosin-core solder to create the soldered splice. Wrap the splice with electrical tape to match wire insulation.

How To Strip Off Wire Insulation
To remove the insulation from wires you can use a jackknife, but an inexpensive wire stripper is a better tool. First cut the wire to the right length. About 3/4 inch of insulation should be stripped off the wire for the best terminal connection.

1. **Matching the Wire to the Stripper**. Put the wire in the hole in the handle that matches the wire size. For example, for a lamp wire, the hole will be No. 18 or No. 16.

2. **Rotating the Stripper**. Lightly grip the handles of the stripper in a closed position with the wire inserted in the correct hole. Then rotate the stripper around the wire a couple of times.
3. **Pulling Off the Insulation**. With the handles still closed, pull the wire out of the stripper. The handles will grip the insulation and the pulling action will strip it off.
4. **Tapering the Insulation**. There are special wire strippers that provide a tapered cut. This is preferred over a square cut.

Using A Knife If you use a jackknife to remove the insulation, be very careful to cut only the insulation and not the wire. Cut completely around the insulation and then pull it off with your fingers.

Stripping Cable Insulation You can buy a stripping tool to slice the insulation on cable. Once stripped, the insulation then has to be trimmed with a knife or scissors. You also can use a utility knife to make the first cut. Be extremely careful that you do not cat the insulation on the wires inside the cable as you slice the outside insulation covering. For most connections, you will need to strip back the outer insulation about 3 to 4 inches.

Making Wire Splices
According to the code, all wire splices must be enclosed in a switch, outlet, fixture, or junction box.

Stranded Wires Strip off about 3/4 inch of insulation. With your fingers, twist each wire individually so the stands are tightly together. Then, with your fingers, twist the two wires together.

Solid To Stranded Wires Strip off about 3/4 inch of insulation from both wires. Twist the stranded wire tightly, then wrap it around the solid wire with your fingers. Then with pliers, bend over the solid wire to secure the stranded wire to the solid wire.

Solid To Solid Wire Strip off about 3/4 inch of insulation from both wires. With pliers, spiral one piece of solid wire around the other piece, making the twist fairly tight, but not tight enough to break the wire.

Wiring Procedures
As described here, extra effort must be made when connecting aluminum wire to terminals. It is also a smart idea to apply the same rules to copper wire when connecting it.

1. **Strip, Loop and Hook**. Remove about 3/4 inch of insulation from the wire. Use wire strippers, if possible. Loop the end of the bare wire with needlenose pliers. Just grip the wire in the jaws of the pliers and wrap it around the jaws, which are rounded. This automatically forms the loop of the size that is required for terminals. Then place the loop around the terminal screw with its opening to the right.

2. **Tightening The Terminal**. When the loop is in place, tighten the terminal screw so the screw and contact plate make full contact with the wire. 3. **Giving A Half Turn**. When the wire is snug under the terminal screw, give the terminal screw another half turn.

Switches

A switch controls the flow of power in an electrical circuit. When the switch is on, electricity flows through the circuit from its source to a point of use.

Types Of Switches
Most residential switches are toggle types, also called snap switches. Others include dimmer, pilot-light, time-clock and silent switches.

Single-Pole Switches A switch with two terminals is called a single-pole switch; it alone controls the circuit. The incoming hot wire is hooked to one terminal screw, and the outgoing hot wire is connected to the other screw.

Three-Way Switches A switch with three terminal screws is called a three-way switch. One terminal is marked COM, or "common;" the hot wire is connected to this terminal. The other terminals are switch leads. Two three-way switches are used to control a circuit from two places.

Double-Pole Switches A double-pole switch has four terminals. It is normally used to control 240-volt appliances. A four-way switch also has four terminals. Three four-way switches are used in a circuit to control one outlet or fixture from three separate places. Both switches look the same, but only a double-pole switch has ON-OFF markings.

Reading The Switch
Switches are stamped with code letters and numbers. Learn how to read these codes so you buy the right products. UL or UND LAB means that the switch is listed by Underwriters' Laboratories, a testing organization. AC ONLY means that the switch will handle only alternating current. CO/ALR is a wire code indicating that the switch will handle copper, copper-clad, and aluminum wire. 15A-120V means that the switch will handle 15 amperes and 120 volts of power. A new switch must have the same amp and volt rating as the switch it replaces.

Removing Switch Plates
If you have trouble removing an old switch or outlet cover plate, try cutting around the edge of the cover with the tip of a utility knife.

Testing Switches
When you flip a switch and the circuit does not work, the fault may not be in the switch. It could be in the fixture or a fuse. After checking the fuse, test the switch, using this procedure:

1. **Shutting Off Power**. Remove the fuse or set the breaker in the switch circuit to OFF.
2. **Testing Terminals**. Remove the switch plate. Touch voltage tester probes to black and white wire terminals to check that the power is off.
3. **Turning the Switch ON**. Touch the continuity tester probe and clip to the terminals. The tester should light with a good switch.
4. **Turning the Switch OFF**. Turn the switch OFF. Touch terminals with a probe and clip. Continuity tester should not light with a good switch.
5. **Testing Mounting Strap**. Fasten tester clip to switch mounting strap. Touch probe to one terminal, then the other and flip switch ON and OFF each time. The tester should not light in any position. If the switch fails, replace it.

Working With Single-Pole Switches
It is not difficult to replace or add a single-pole switch. The process may vary slightly, depending on your house wiring and whether the switch is grounded or not. A grounded switch has an extra terminal screw at the base that is green or shows the letters GR. This redundant grounding system is more reliable than systems that do not connect the ground to the switch. If wires are encased in metal conduit, the conduit is usually grounded, but not always. When replacing a switch or adding a new one, buy switches with a ground-terminal screw, even though it may be necessary to modify your wiring, as explained in this section. Detach only those wires that are connected to the switch itself.

Single-Pole To Fixture One of the easiest switch/light wiring hookups is a single-pole switch controlling a light fixture. Follow these procedures:
1. **Running Wire**. Turn off the power at the main service entrance. If the circuit is a new one, run the wire from the service panel to the switch and light, but do not connect it to the panel. Have an electrician do this.
2. **Cutting Wire**. Cut the wire at the switch.

3. **Stripping Wire**. Use wire strippers to strip off about 1/2 to 3/4 inch of wire insulation on each end.
4. **Connecting Wires**. Connect the black wires to the terminals, hooking the wire loops around the terminals in the direction the screw tightens. The white wire bypasses the switch. Connect the grounding wires in the cable from the light and in the power cable to a pigtail (a short wire of the same gauge) that is attached to the grounding terminal in the box. Use a wire connector.

Single-Pole Switch Controls Fixture Constant Power to Outlet In this single-pole connection the power is supplied by a two-wire cable with ground. A three-wire cable with ground goes to the light and a two-ground goes to the light and a two-wire with cable ground to the outlet.

1. **Wiring the Switch**. With a length of black-insulated wire pigtail (same gauge wire), connect the black power wire to the switch and then to the black wire in the tree-wire with ground cable. Wrap the wire nut with electrician's tape. Now connect the white wire from the power source to the white wire in the tree-wire cable. Use a wire nut and tape it. Connect the red wire in the three-wire cable to the open switch terminal. Finally, connect the cable grounding wires (green or bare) to a pigtail that is attached to the box ground terminal.
2. **Wiring the Outlet**. Connect the black wire to the brass terminal and the white wire to the silver terminal of the outlet, using the two-wire with ground cable. With a pigtail, splice the ground and connect it to the box and the outlet ground terminal.
3. **Wiring the Ceiling Box**. Connect the black wire from the switch to the black wire from the outlet. Add a wire nut and wrap with tape. Connect the grounding from the switch box cable to pigtails from the receptacle ground terminal and the box ground terminal.
4. **Wiring the Light Fixture**. Connect the red wire from the switch to the black light wire, if the light is prewired. If it is not, then connect the red wire to the brass-colored light terminal. The white wire is spliced to the light's white wire or connected to the light-colored terminal on the light.

Single-Pole Switch Controls Fixture & Outlet; Power from Fixture In this hookup, power runs through the light fixture to a switch and then to an outlet. This circuit requires three-wire cable with ground and two-wire cable with ground, plus pigtail wire.

1. **Wiring the Ceiling Box**. Power is supplied by a two-wire cable with ground into the box at the light. Splice the black wire from the power source to the red wire of the three-wire cable. Splice the white wire to the white wire of the three-wire cable and hook the black wire to the black wire of the light fixture. Also, splice the white wire of the power source cable to the light. Use wire connectors and tape the connectors.
2. **Wiring the Light Fixture**. The black wire connected to the red wire of the three-wire cable is fastened to the brass terminal of the light. The white wire, connected to the power source and the white wire of the three-wire cable, is fastened to the silver terminal of the light fixture. Or the wires are spliced to the white and black wires of a prewired light.
3. **Wiring the Switch**. Fasten the red wire to the top brass terminal of the switch. Make a pigtail of black-insulated wire and connect it to the bottom brass terminal of the switch. Then connect the pigtail to the black wires in the fixture and receptacle cables. Connect the white wire to the white wire in the cable that goes to the outlet. Use wire connectors. The grounding wire (green) is pigtailed and fastened to each box.
4. **Wiring the Outlet**. Fasten the black wire to the brass terminal and the white wire to the silver terminal. Break the tab if half of the outlet will be switch-operated. Connect the ground with a pigtail to the box.

Single-Pole Switch Controls outlet Only Turn off the power before beginning work and use a two-wire cable with ground throughout. This project shows how to wire a switch for a light or other device that has been operating from an outlet.

1. **Wiring the Outlet**. Connect the incoming white wire from the power source to the silver terminal on the outlet. Connect the outgoing black wire to the bottom brass-colored terminal on the outlet. Then connect the incoming black wire to the outgoing white wire. Mark the white wire HOT by wrapping black electrical tape around it. The ground wire is pigtailed to the metal box, to the outlet grounding screw and to the outgoing ground valve. Twist wire connectors around all splices and wrap the joints with electrical tape.
2. **Wiring the Switch**. Connect the white wire to the top brass-colored terminal. Then wrap this white wire with electrical tape to indicate a hot wire. Connect the black wire to the other switch terminal. Fasten the ground wire to the junction box. If the switch has a ground terminal, pigtail the ground wire and connect it at the box and the switch grounding terminal.

Making Terminal Connections

To make terminal connections, you will need approximately 6 inches of wire in the box. Strip about 1/2 to 3/4 inch of insulation from the ends of the wires without nicking the metal conductor. Use a pair of needlenose pliers to bend each wire end into a hook around the terminal screw with the opening to the right. Tighten each screw, securing its wire. Fold the extra wire like an accordion and place the switch or receptacle in its box. The wire is stiff but use your finger, not pliers, to avoid damaging it.

Single-Pole Switch Controls Split Outlet; Power from Outlet Use this hookup when you want a single-pole switch to control half of an outlet with the other half of the outlet (bottom) hot at all times. This installation might be in a living or family room where you want to control table lamps along a circuit with a switch, but want other outlets hot at all times. A two-wire with ground cable is used throughout this circuit with the power coming through the outlet. If this project involves a new circuit, make all the wiring/outlet/switch hookups and then let an electrician connect the circuit to the power supply. Turn off the power before doing any work on the circuit.

1. **Wiring the outlet**. The black wire, using a pigtail, is connected from the power source to the bottom brass terminal of the outlet. The white wire is connected to the upper silver terminal of the outlet. Wrap the white wire running from the outlet to the switch with electrical tape to indicate that it is now a hot wire. This wire is then spliced to the black wire pigtail and incoming black power wire. The ground is connected, with a pigtail, to the metal box and the grounding terminal of the outlet. Use a screwdriver or pliers to remove the tab between the brass terminals of the outlet. The switch will then control the upper half of the outlet and the bottom half will be hot at all times.
2. **Wiring the switch**. The black power wire is connected to one brass terminal of the single-pole switch. The white wire, coded black with electrical tape, is connected to the other brass terminal. The ground wire is screwed to the metal box. It may be pigtailed and connected to the switch ground terminal if the switch has aground terminal.

Adding Or Replacing Three- Way Switches

Three-way switches control the power to a light or other electrical device from two separate points. An example is a light in a hallway that can be operated from both the first floor and the second floor. Another example is a light in a garage and also from the kitchen or living room. Three-way switches require a three-wire system: a power wire and two interconnecting wires called travelers. A fourth, grounding wire also is required except with metal conduit. The proper cable is marked 12/3 WITH GROUND or 14/3 WITH GROUND. Two three-way switches also are required. Each switch has three terminal screws on the side or back: two on one side, one on the other side. One terminal will be a distinctive color – often black – or will be marked COM, for common. This terminal is for the prime power wire, the black wire in a cable. The other two terminals are for so-called traveller wires that interconnect the switches. When a white wire is used as a traveller in a three-way switch hookup it must be marked with black tape because it too carries power.

Code Requirements
The NEC specifies that all wire must be splice inside a switch, outlet or junction box. If you splice wire outside the box and there is an electrical fire at this point, your fire insurance coverage could be void. If you are simply replacing a switch – removing the old switch and installing a new switch – additional wire will not be necessary. In this situation, just connect the new switch to the same wires as the old switch. **Note**: You cannot add a three-way switch circuit using two-wire with ground cable. To add a three-way switch circuit, you will need either a three-wire with ground nonmetallic or BX armored cable, or three wires (black, red, white) to pull through metal conduit. The conduit itself can act as a grounding wire.

How Much Wire? To figure how much wire you need, measure the distance between the new outlet and the power source. Add an extra foot for every connection you will make along the line. Then, to provide a margin for error, add 20 percent more. For example, if you measure 12 feet of cable between a new and existing receptacle, add another 2 feet for the two connections, making the total 14 feet. Then add 20 percent, about 3 feet, to the total. To so this job you should buy 17 feet of cable. As mentioned above, wire may not be spliced outside a box. Inside a box, the wire must be spliced together using a twisted wire splice covered by a wire may be attached to a fixture, switch and outlet terminals. To make connections, pull the wire through boxes about 6 inches. Then cut the wire and strip the insulation from the end.

Wiring Three-Way Switches On the following pages, you will find wiring diagrams for three-way switches. By following the paths of individual wires carefully, you can make the connections properly. Whether you are installing a new circuit or are adding three-way switches to an existing circuit, be sure to identify which wire brings the power into each switch box. It must go to the common terminal of the switch. This is the key to wiring the switches correctly. When adding new circuit with three-way switches, you should install the wiring for the project and then have a professional electrician connect the circuit to the main service panel.

Solving The Puzzle In wiring three-way switches you will use two-wire (black and white) and three-wire (black, white, red) cables with ground to make connections between two switches and one or more fixtures, all in individual boxes. Electricians use the procedure described here to make the work go faster. n Run lengths of cable from box to box in the circuit. Add enough to make the connections, as explained above. n IF the power source cable comes into a switch box, connect its black wire to the common terminal of the switch there. If the power cable comes into the fixture box, connect its black wire to the black wire running to one of the switches and connect that to the common terminal. n The power cable white wire must connect to the silver terminal of the fixture. IF the power comes into the fixture box, connect is directly. If it comes into a switch box, connect it to the white wire of the other cable there. Depending on the hookup, that may go to the fixture box, where you can connect it. If it goes to the other switch box, connect it to the white wire that goes to the fixture. n Connect the common terminal of the second switch to the black wire that goes to the fixture box, and there connect to the brass fixture terminal. n Two unconnected wires remain at each switch, red and black or red and white, depending on the layout. Connect these traveller wires to the two open terminals on each switch. If one wire is white, tape both ends black to mark it as a hot wire. If the travellers pass through the fixture box, connect them there: red to red and black to black (or taped whites together). n Where there are two or more grounding wires, connect them with a pigtail to the ground terminal in the box. Where there is only one grounding wire, connect it to the box terminal.

Two Switches Control One Fixture; Power from Switch In this circuit, the power cable comes into the first switch box. The path goes through the second switch and on to the fixture. To install this circuit, you will need three-wire cable with ground between the two switches, and two-wire cable with ground between the second switch and the fixture. Local codes may require the use of conduit, especially for an outdoor light. Turn off the power to this circuit at the service panel before starting work.

1. **Wiring No. 1 Switch**. Power enters first switch box on a two-wire cable with ground. Hook the black or power wire to the common terminal on the switch. Connect the white wire to the white wire of the three-wire cable going to switch No. 2. Connect the red and black wires in the three-wire cable to the two lower terminals on switch No. 1. Connect the grounding wires in both cables to a pigtail connected to the box ground terminal.
2. **Wiring No. 2 Switch**. Connect the black and red wires in the three-wire cable from switch No. 1 to the two lower terminals of the switch. Connect the white wire to the white wire of the two-wire cable that goes to the light. Connect the black wire in the light cable to the common terminal of switch No. 2. Connect the cable grounding wires to a pigtail attaches to the box.
3. **Wiring the Fixture**. Connect the black wire in the two-wire cable from switch No. 2 to the black lead or brass terminal of the fixture. Connect the cable white wire to the white fixture lead or silver terminal. Connect the cable grounding wire to the box grounding terminal.

Two Switches Control One Fixture; Power from Fixture In this setup, the power comes into the light fixture on a two-wire cable with ground. The power is wired to pass through the fixture box to the two switches and then return to the fixture. A two-wire cable with ground is used between the fixture and one switch, and a three-wire cable with ground between the two switches. In this circuit the white wire in both cables become a hot wire. Therefore it must be marked with black tape. Turn off the power at the service panel before starting work.

1. **Wiring No. 1 Switch**. Connect the black wire from the cable between switches to the common terminal. Tape the white wire black and connect it to one lower terminal. Connect the red wire to the other terminal. Connect the grounding wire to the box terminal.
2. **Wiring No. 2 Switch**. Connect the red wire from the cable between switches to one lower terminal. Tape the white wire in this cable black and connect it to the other lower terminal. Tape the white wire in the fixture cable black and connect it to the black wire in the switch cable. Connect the black wire in the fixture cable to the common switch terminal. Connect the cable grounding wires to a pigtail to the box ground terminal.
3. **Wiring the Fixture**. Connect the black wire in the cable from switch No. 2 to the black power wire. Tape the white wire in the switch cable black and connect it to the black fixture wire or brass terminal. Connect the white wire in the power cable to the white fixture wire or silver terminal. Connect the cable grounding wires to a pigtail to the box terminal.

Fixture Between Three-Way Switches; Power from Switch Here, a light fixture is between two three-way switches with power coming to the first switch on a two-wire cable with ground. The power passes through the fixture box to the second switch and returns to the second switch and returns to the fixture. A three-wire cable with ground is used between both switches and fixture. The cable grounding wire (bare or green) is connected to the box of switch No. 2, and to pigtails in the fixture and switch No. 1 boxes. The white wire in the cable between the fixture and switch No. 2 becomes a hot wire in this circuit, so it must be marked with black tape as illustrated and explained in steps 2 and 3.
1. **Wiring No 1 Switch**. Connect the incoming black power wire to the common terminal of the switch. Connect the white wire to the white wire of the three-wire cable to fixture box. Connect the red and black wires of that cable to the other two switch terminals. Check ground wire connections.
2. **Wiring the Fixture**. Connect the red wires of the two switch cables together. Wrap black tape onto the white wire coming from switch No. 2 and connect it to the black wire coming into the fixture from switch No. 1. Connect the white wire from switch No. 1 to the white lead or silver terminal of the fixture. Connect the black wire from switch No. 2 to the black lead or brass terminal of the fixture. Check ground wire connections.
3. **Wiring No. 2 Switch**. Wrap black tape around the white wire. Connect the incoming black wire to the common terminal. Connect the white wire taped black to the terminal below the common terminal. Connect the red wire to the terminal on the opposite side. Check ground wire connections.

Fixture Between Three-Way Switches; Power from Fixture

In this hookup you can use three-wire cable with ground very easily. The power comes through the light ceiling box. Then you connect it to the switches, which are powered on separate lines from opposite sides of the fixture. Note that the white wire in the power source cable connects directly to the silver terminal of the fixture. The black power wire is connected to the common terminal on switch No. 2. Power is fed back and across to switch No. 1 by white wires coded with black tape to indicate that they are hot between the switches.

1. **Wiring No. 1 Switch**. The black wire in the cable from the fixture box connects to the common terminal. The white wire is taped black; it and the red wire connect to the other two switch terminals. The grounding wire connects directly to the switch box.
2. **Wiring the Fixture**. The white wire of the power source cable connects to the white lead or silver terminal of the fixture. The black power wire connects to the black wire of the cable to switch No. 2. The red wires of the switch cables connect together, and the white wires of these cables, taped black, connect together. The black wire from switch No. 1 connects to the black lead or brass terminal of the fixture. The grounding wires all connect to a pigtail attached to the box.
3. **Wiring No. 2 Switch**. The connections are the same as at switch No. 1. The black power wire goes to the common switch terminal. The white wire is taped black. It and the red wire go to the other two terminals. The grounding wire connects directly to the box.

Two Three-Way Switches Control Two Fixtures; Power from Switch Power comes into switch No. 1 on a two-wire cable with ground. Three-wire and two-wire cables with ground are used between the four boxes. Note that two white wires specified below must be taped black because they become power-carrying wires.

1. **Wiring No. 1 Switch**. Connect the black wire in the incoming power cable to the common switch terminal. Connect the white wire to the white wire of the out-going three-wire cable. Connect the outgoing red and black traveller wires to the other two switch terminals. Pigtail the grounding wires to the box.
2. **Wiring the Fixture**. In No. 1 fixture box, connect the black from switch No. 1 to the black in cable No. 1 to the next box. Connect the red traveller to the white wire – taped black – in cable No. 1. Connect the whites from switch No. 1 and cable No. 2 to the silver terminal of the fixture. Connect the black wire of cable No. 2 to the brass fixture terminal. In No. 2 fixture box, tape the white wire in cable No. 1 black and connect it to the red traveller to switch No. 2. Connect the black in cable No. 1 to the white – taped black – going to switch No. 2. Connect the black wires from cable No. 2 and the switch cable to the brass fixture terminal. Connect the white wire in cable No. 2 to the silver fixture terminal. In both fixture boxes, pigtail all grounding wires to the box terminals.
3. **Wiring No. 2 Switch**. Connect the incoming black wire to the common terminal of the switch. Tapes the white wire black and connect it to one open terminal; connect the red wire to the remaining terminal. Connect the grounding wire to the box terminal.

Two Three-Way Switches Control Two Fixture; Power from Fixture In this arrangement, power comes into one fixture box on a two-wire with ground cable. The two fixture boxes have a three-wire leg between them, as do the switch boxes and fixture box requires only a two-wire cable. The (green) grounding wires are connected to the metal boxes throughout the run.

1. **Wiring No. 1 Fixture**. Connect the black wire of the power source cable to the black wire in the three-wire leg to the next box. Connect the white power cable wire to the white wire in the ongoing leg and to the silver fixture terminal. Connect the red wire in the ongoing cable to the brass fixture terminal.
2. **Wiring No. 2 Fixture**. Connect the black wire from the first fixture box to the black wire in the cable to switch No. 1. Connect the white wire from the first box to the silver fixture terminal. Connect the red wire to the white wire – taped black – to the switch, and with a pigtail to the brass fixture terminal.
3. **Wiring No. 1 Switch**. Connect the black wire coming from the fixture box to the common terminal. Tape the white wire of that cable black and connect it to the black in the three-wire cable that goes to switch No. 2. Tape the white traveller in the cable to switch No. 2 black. Connect it to one open switch terminal and connect the red traveller to the other terminal.

4. **Wiring No. 2 Switch**. Connect the incoming black wire to the common switch terminal. Tape the white wire black and connect it to one open switch terminal. Connect the red to the other terminal. **Two**

Three-Way Switches Control End-Of-Run Fixtures
In this hookup, the two lights are at the end of the circuit with the power coming through the first switch, running to a second switch, and then on to the light fixtures. Since only two-wire cable is needed for the fixture-to-fixture and the fixture-to-switch wiring, you will save money if either or both of these legs in the run are long. Note that in this circuit the red and black wires in the three-wire cable between the switches are the traveller wires. Throughout the circuit, the grounding wires connect to each other and to pigtails to the metal boxes.
1. **Wiring No. 1 Switch**. Connect the incoming black power wire to the common terminal. Connect the power cable white wire to the outgoing white wire. Connect the outgoing red and black traveller wires to the open switch terminals.
2. **Wiring No. 2 Switch**. Connect the incoming red and black to the two lower switch terminals. Connect the incoming and outgoing whites together. Connect the outgoing black to the common terminal.
3. **Wiring No. 1 Fixture**. Connect the incoming and outgoing black wires together and to the brass fixture terminal. Connect the two white wires together and to the silver fixture terminal.
4. **Wiring No. 2 Fixture**. Connect the incoming black wire to the brass fixture terminal and connect the white wire to the silver terminal. Connect the grounding wire to the box terminal and check that the grounding connections are correct and secure in the other three boxes.

End-Wired Switches; Power From Fixture Power is furnished by a two-wire cable with ground coming into the first fixture box. It is routed to the first switch, then by the traveller wires to the second switch and finally back to the lights. One traveller is red, the other is a white were marked with black tape. The grounding wires are pigtailed to the metal fixture boxes and connected directly to the switch box terminals. As in the previous two-light hookups, the switches operate both lights, but the wiring arrangement ensures that even if one bulb should burn out, the other will still work.
1. **Wiring No. 1 Fixture**. Connect the incoming power cable black wire to the black wire going to switch No. 1. Connect the power cable white wire to the white in leg No. 2 to the other fixture and to the silver terminal of the fixture in this box. Connect the black wire in leg No. 2 between fixtures to the brass fixture terminal. Connect the red wire from switch No. 1 to the black in leg No. 1 to the other fixture. Tape the white from switch No. 1 black and connect it to the black in leg No. 1.
2. **Wiring No. 2 Fixture**. Connect the white in leg No. 2 to the silver fixture terminal. Connect the black in leg No. 2 to the black to switch No. 2 and to the brass fixture terminal. Connect the black in leg No. 1 to the red going to switch No. 2. Tape the whites in the leg No. 1 and switch No. 2 cables black and connect them together.
3. **Wiring the Switches**. Both switches are wired the same way. Connect the incoming black wire to the common terminal. Tape the white wire black and connect it to one lower terminal. Connect the red wire to the other terminal.

Installing Incandescent Dimmer Switches
A dimmer switch allows you to select different intensities of light to create a mood or to conserve electricity. You must not use them to control receptacles into which you may plug appliances or power tools. This could result in damage to the dimmer switch. Dimmer switches are available in several styles: toggle-type, rotary-type and slide-type. You can replace any standard single-pole switch with a dimmer. A three-way switch will require a special three-way dimmer.
1. **Connecting New Switch**. Splice the leads on the switch to the incoming hot wire in the box and to the outgoing wire to the fixture. One of these will be black, the other will be white taped black. Use wire connectors and tape them in place. Then mount the switch in the box.
2. **Setting the Dimmer**. Turn on the power. Push the dimmer control knob onto the dimmer switch shaft. Then turn the control knob so the light is turned down to its low lighting capacity. Now turn the knurled adjustment nut, located at the base of the shaft on which the control knob fits,

counterclockwise with pliers until the lamp flickers. Then turn the nut clockwise until the lamp stops flickering. The adjustment is made.
3. **Installing the Cover Plate**. When the control knob is set to your satisfaction – high to low light – remove the control knob and mount the faceplate on the switch housing. It screws on just like a conventional faceplate. Then reinstall the control knob. Test the light from high to low. When the knob is on the high setting, the light should be fully on. When it is on low, the light should be at its lowest level. If not, you will have to remove the faceplate and adjust the nut.

Three-way Dimmer In a three-way circuit, you replace only one of the two conventional switches. To function correctly, a three-way dimmer must be paired with a conventional three-way toggle switch. Turn off the power. Tag the black wire on the common terminal. Then disconnect the old switch. Connect the hot wire of the dimmer switch to the tagged hot wire in the box. Connect the two traveler or switch wires of the dimmer to the two traveler wires in the switch box.

Receptacles

Receptacles, essential in modern living, are not indestructible, though they sometimes seem that say. When you must replace one, the task is fairly simple.

Replacing Receptacles

Before you replace a receptacle (outlet), or even remove the faceplate covering it, turn off the power to the outlet circuit. You can check to see if the power is off by plugging in a lamp. Or you use a tester.

Receptacles are housed in metal or plastic boxes similar to switch boxes. The boxes are covered with a faceplate usually held by a single screw. Behind the faceplate, the receptacles are held by two mounting screws to a metal mounting strap and the box. When these screws are removed, the receptacle may be pulled gently from the box.

To replace a receptacle, you do not have to do anything to the box and you do not have to replace any wiring. You replace only the receptacle.

If the box is tilted a bit left or right in the wall, do not try to straighten it. The wide slots in the receptacles mounting strap will let you shift the receptacle to get it aligned vertically. Then tighten the mounting screws.

The Wiring Layout

Although you do not replace any wires, consider the position of the receptacle in the circuit. This affects the way the receptacle is wired. The box falls either at the middle or at the end of a circuit. Determine the position by the number of cables, or sets of wires, that enter the box through openings in the back or sides.

Each set of wires includes one or two hot wires covered with black or red insulation, which carry live current. If you spot a wire taped with black electrical tape, consider this wire a hot wire.

Each set of wires also includes one with white insulation. Often miscalled "neutral" from earlier wiring practice, the white wire carries power whenever any device in a circuit is operating. It completes the path that must run from service entrance panel to device, back to panel.

If there is an equipment grounding wire, it will be bare or in green insulation. This wire provides a path to quickly trip the branch circuit breaker in case a hot wire in a piece of grounded equipment comes in contact with the metal equipment case.

"End-of-the-run" wiring has only one set of two or three wires entering the box. The black and white wires attach to the terminal screws. The bare or green wire, the grounding wire, loops around screw attached to the metal.

"Middle-of-the-run" wiring has two sets of wires entering the box. The hookup varies according to the type of receptacle and the type of ground system used.

Replacement Data

When you buy a replacement (or new) receptacle, be sure you get the one that matches the circuit. The markings and ratings on old and new equipment must match. The markings below are those found on receptacles.

- Underwriters' Laboratories (UL) and Canadian Standards Association (CSA) monograms indicate that the receptacles have been tested and listed by these organizations. The associations are not connected with the government or special code groups.
- Amperage and voltage ratings are figures that indicate the maximum amperage and voltage a receptacle can handle. For instance, a rating of 15A – 125V means that the receptacle can carry a maximum of 15 amperes of current at no more than 125 volts.
- The type of current indicated on the receptacle is the only one that the receptacle can use. Receptacles that are used in houses and condominiums in the United States and Canada are marked AC ONLY, which means they are designed for use only with alternating current.
- Check the types of wire that the receptacle can handle. The wire in your home must match it. The wire in your home will be copper (CO or CU), copper-clad aluminum (CO/ALR), or solid aluminum (ALR). Make sure that the receptacle design can use that wiring.

Receptacle Types

The types of receptacles vary. There are some designed exclusively for use outside; some are made to handle heavy-duty equipment such as major appliances; some are integrated into light fixtures, and some are combined with switches.

The most common home receptacle is the duplex receptacle that is rated at 15 amperes and 125 volts. A duplex receptacle has two outlets and accommodates two pieces of equipment.

Receptacle Wiring

- Side-wired receptacles, the most common, have two terminal screws on each side. One pair is brass or black in color, the other is silver. A brass terminal always connects to a hot (red or black) wire, a silver terminal only to a white wire. When the break-off link between brass terminals is removed each terminal will bring power to just one of the two outlets in the receptacle.
- Back-wired receptacles have openings at the rear in which circuit wires are inserted. Some receptacles have both side- and back-wire terminals.
- New receptacles also have a green terminal at the bottom to which the equipment grounding wire connects.

Each half of such a receptacle has three openings on the front: two slots for plug blades, and a half-round hole for a grounding prong. In polarized outlets the left slot is wider than the "hot" slot on the right, brass terminal side.

Modern Receptacles

Receptacles are sturdy devices but they can wear out or fail, usually from damage caused by inserting plugs carelessly, with excessive force, and disconnecting devices by yanking on the cord. If plugs fit loosely or fall out, replace the receptacle.

Is The Receptacle Working? Two Tests

The best outlet-testing procedure is to use an inexpensive voltage tester. It has no power, and the test light glows only if the probes connect points where voltage is present.

Another way to test an outlet is with a table lamp. Simply plug the lamp into the outlet and turn the lamp on. If the outlet works, do not fix it. The voltage tester, however, will provide you with a better reading on the outlet and circuit.

1. **Testing Power Path**. Using a voltage tester, insert a probe into each slot of an outlet. If the wiring is correct and the outlet is working, the bulb will glow.

2. **Testing the Ground**. To see if the grounding system is working properly, insert one probe in the left outlet slot and the other in the ground-prong hole. The tester should not light. Next check between the ground-prong hole and the right, hot, outlet slot. Now the tester should light. If the outlet fails any test, turn off the power, check the circuit, and replace the receptacle if necessary.

You also can check outlets with an inexpensive three-prong circuit tester that tests for power, grounding and faults such as reversed black and white wire connections.

Replacing A Side-Wired Receptacle

1. **Removing the Outlet**. Turn off the power at the main service panel. Remove the faceplate, which is held by a screw. Remove the two screws holding the outlet in the mounting bracket using a standard slot screwdriver. Then gently pull the outlet from the box far enough to expose the terminals.

2. **Noting the Hookup**. You will see one or two sets of wires in the box that are connected to the receptacle. Make a note of these connections or tag wires. Black power wires go to the brass terminals; white wires go to the silver terminals; bare or green wires to the ground terminal. Connect a new receptacle that way.

3. **Disconnecting/Reconnecting**. Remove the wires from the terminals, remove the old receptacle and reconnect the new receptacle. The wires go around the terminals in a clockwise direction. As you tighten terminals, you lock the wires. Then reinstall the outlet in the box.

Buy The Right Receptacle
Make sure that the replacement receptacle has the same voltage and amperage rating as the original one. Typical household outlets are illustrated above.

End-Of-Run Receptacle
These are the last outlets on a circuit. Only one brass and one silver terminal are connected at the end of a run. Pigtails will probably connect box and green terminal to grounding wire.

Middle-Of-Run Outlets
These receptacles are connected to all wires coming from the box. All grounding wires are spliced together and connected by pigtail to the box ground terminal. If needed, tag wires for reconnection.

<u>Plugs and Cords</u>

Replacing plugs and cords ranks among the easiest electrical projects to do. Replacement products are readily available and inexpensive. Only basic hand tools are required.

Replacing Plugs & cords
Although it may seem like a complicated job, replacing a plug or a cord or both, is quite simple.

Electrical Plugs
Many lamps and plug-in electrical devices in use today still have a standard-wired or clamp-type plug, neither of which is recognized by the current National Electrical Code. You many find them for sale, however, in electrical departments.

If you are replacing a plug, make sure that the plug meets code requirements. Do not attempt to repair a broken or damaged plug. A replacement is not costly and you are assured that the new plug will perform properly.

Many plugs are permanently attached to electrical cords. That is, you cannot disassemble the plug to disconnect the cord. In this situation, cut the cord immediately behind the plug, strip the insulation and replace the bad plug with a new plug.

Electrical Cords
A variety of line cords is available for lamps and appliances. When replacing a plug, be sure to check the cord for wear and tear. If you see damage, replace the cord along with the plug. Match the cord to the plug and appliance. For example, do not replace heater cord with zip cord.

Replacing a Standard Plug

1. Removing Old Plug. With a knife, cut the cord in back of the plug you are replacing. Replace a worn or damaged cord.
2. Stripping Insulation. With wire strippers, remove about ¾ inch of insulation from the wire ends.
3. Inserting Wire into Plug. Thread the cord into the plug. The cord should fit the plug opening tightly.
4. Tying an Underwriters' Knot. Split the cord and/or insulated wires inside the cord so you can tie an Underwriters' knot to prevent the cord from pulling loose from terminal screws.
5. Pulling the Knot Tight. Pull hard on the ends of the wires to tighten the knot. Then pull the cord down into the base of the plug.
6. Wiring Around Prongs. The wire connections go clockwise around the plug prongs and to the terminal screws in the base.
7. Wiring around Terminals. If the wire is stranded, twist it tight and then wrap it around the terminals in the direction the terminal screws turn. Then tighten the terminals.
8. Installing the Insulator. Install the cardboard insulator over the prongs and push it down flush.

Replacing a Molded Plastic Plug
Under code provisions, new plugs for home lamps and appliances must be molded in plastic around the cord; they cannot be removed or replaced. Plugs also must be polarized: the prongs are two different shapes that fit a polarized outlet only one way.
If the line cord is damaged only at plug, disconnect cord, cut off the damaged part and attach a new plug. If both plug and cord are damaged, replace both with polarized products.

<u>Fluorescent Fixtures</u>

The three main parts of a fluorescent fixture are the fluorescent tube, which may be straight or circular, the starter and the ballast. Defects in these components cause most fluorescent fixture problems.

The Tube

A fluorescent tube produces light in this way: Inside a tube, the electric current jumps or arcs from a cathode at one end of the tube to an anode at the other end. The tube is filled with mercury and argon gases. As the arc passes through the gases, it causes them to emit invisible ultraviolet light. To make the light visible, the inside of the tube is coated with phosphor powder that glows when hit by ultraviolet light.

The Starter
The starter is a switch that closes when activated by an electric current. After a momentary delay, the starter allows current to energize gases in the tube. There are two types of starters: replaceable ones, which are about 3/4 inch in diameter with two contacts protruding from one end, and a rapid-start fixture.
The starter is built into the ballast and cannot be replaced independently of the ballast.

The Ballast
The ballast is a box-like component usually about 6 to 7 inches long. It is a kind of governor that monitors electrical current so that it is at the level required to provide proper light operation. There are two types of ballasts: choke ballasts limit the amount of current flowing through the tube. Thermal-protected ballasts, found in fixtures that hold long fluorescent tubes, incorporate transformers and choke coils. When the lights is turned on, a transformer steps up the voltage to deliver a momentarily high surge of electricity, causing the tube to glow.

Replacing A Fluorescent Ballast
Turn off the circuit breaker or remove the fuse that supplies power to the circuit. Then remove the tube(s), and take off the cover. Jot down the number codes on the old ballast and take them to the store with you, to make sure you buy the right ballast replacement.

1. Disconnecting the Wires. Remove the wire connectors or loosen the terminal screws to disconnect the ballast wires. The wire connections of the ballast you are replacing are the same or similar to those shown on this page. Notice that ballast wires are color-coded. A ballast wire of a given color is always connected to the fixture wire of the same color. A thermally protected ballast must be connected in the same way. If the complexities of the wires confuse you, make a simple color-coded diagram before you disconnect any wires.

2. Removing the Ballast. The ballast you are removing is heavier than you might think. Be careful. Have a helper hold the ballast while you remove the fasteners that attach it to the fixture. Note carefully the alignment of the ballast in the fixture and then take it down.

3. Connecting a New Ballast. Again, with a helper holding the new ballast, line up the ballast so that it is in the same position that the previous ballast held. Screw the new ballast to the fixture. Match the color codes of the wires and twist these wires together with your fingers or pliers. Then thread the connected wires into wire connectors. Wrap the wire connectors with a couple of layers of plastic electrical tape. As a final step, before you replace the cover, turn on the power and test the light.

Installing A Fluorescent Fixture
To replace a fluorescent fixture, first turn off the power to the circuit and remove the old fixture from the ceiling.

Circular Fixtures
In the center of the ceiling box, add a threaded stud, if one is not present. The fixture hangs on this stud. Add a reducing nipple to the stud. Have a helper hold the fixture while you connect the power wires: black to black, white to white. Attach wire connectors to the splices and wrap them with electrical tape. Push the wires into the box, thread the nipple through the hole in the center of the fixture, and secure the fixture with a cap nut.

One-Tube Fixtures
You will need a hickey and nipple if the box has a stud. If not, you can attach the fixture to a nipple and strap screwed to the ears in the box. First splice the fixture wires to the house wires, attach wire connectors, and wrap the splices with plastic electrical tape. Then attach the fixture to the ceiling box with the nipple, a washer and a locknut. Have a helper hold the fixture while you assemble and fasten it to the ceiling box. When the fixture is stable, drive a couple of sheet-metal screws through the fixture housing into the ceiling at each end.

Large Fixtures
Fixtures with more than two tubes usually have a center cutout that is used when hanging the fixture from an octagonal box. The fixture uses a stud, hickey, nipple, and a mounting strap inside the housing. The assembly is held with a locknut. Connect the wiring with wire connectors. Then push the wires into the box and secure the fixture.

Repairing Fluorescent

Eliminating Flickering
If a tube has the flickers, remove it. Straighten bent pins with pliers. Then burnish the pins lightly with fine-grit abrasive or steel wool.

Replacing Pull-Chain
With pliers, loosen and remove the knurled nut and locknut that hold the switch in the fixture housing. Disconnect the switch wires. If they cannot be disconnected, cut them, leaving a couple of inches for reconnection. Lift out the entire switch. Make wiring connections with wire connectors. Tape the connectors, then set the new switch in place. Secure with locknuts.

Replacing Toggle Switches
The technique for replacing toggle switches is the same as chain switches, except that power wire terminal screws are attached to the switch. Remove the wires, install a new switch, and rewire it.

Ceiling Fans

The installation of a ceiling fan involves two critical measurements. There must be at least 7 feet of clearance from the floor in which the fan will be installed. The blades also must be free to rotate; there can be no obstruction in the path of the rotation. Check the vertical space in the room. Also check the length of fan blades for proper blade clearance.

Ceiling fans operate on regular house power. No electric transformers or special switching devices are needed. You can connect them directly to the wires in a ceiling box listed for this purpose. If you are running cable to a new ceiling box for the installation, the wire size should correspond with the wire size that you are tapping into. If you are creating a new circuit, the wire size should be AWG No. 12/2 with ground.

Switching Choices
Installing a switch also can be considered. If the room in which the fan is installed has a ceiling light controlled by a wall switch, the fan hookup is simple: Remove the light fixture and substitute the fan. If the light fixture has a switch on it, you can buy a fan that is controlled by its own switch.

To control the fan with a wall switch, you have the following options:

- Tap into a source of power elsewhere in the room, such as an outlet;
- Tap into the fan; or

- Run a switch loop from the ceiling box to the wall. If you have an attic crawl space in your home (and you have access to it), you may be able to tap into the wiring in the crawl space,. Use either the existing ceiling box, or a different nearby ceiling box. You also could add a junction box from which the ceiling box and fan receive electricity.

Ceiling-Fan Mounting Options
Brackets must be attached to the framing, and the electrical box must be listed for this specific use. Check the box; it should be securely attached to the joists. If the box feels loose, drive a couple of round-head wood screws through the mounting holes into the framing members.

J Hook (Isolation Type)
An isolation mount is installed on or in the box. It absorbs vibration, torque and sound. The hanger pins must be fastened into the ceiling framing, not into the box alone. Make sure the ceiling box is securely fastened to joists.

Flushing Mounting
To install the fan on a finished ceiling where there is no outlet or wiring, you must open the ceiling and add framing between the joists to fasten the box or screw directly to framing joist. Do not use an adjustable hanger bar, it may not be strong enough.

Surface Mounting
If you mount the fan on an exposed beam ceiling, position the fan between beams, using a 2x4 or 2x6 length of wood between the beams to hang the fan. You also can use a special hanging bracket. There must be 6 inches of space for the bracket. It also may be used where attic crawl space is not available for mounting and wiring the fan.

The blocking between beams can be spiked to the beams. Install the box to the beams. The fan is mounted on the box or a J hook also screwed into the box. You can frame the box in wood or other materials to hide it. If you decide to do this, make sure that the box is screwed directly to framing joist.

Fan and Light Switch on Wall
In a dual-control wall switch, the black power wire is connected to a black wire going to the switch. The black and blue fan wires also connect to the switch. Connect the white wires; connect the green wires. If the box does not have a green grounding wire, connect the green fan wire to the box. Put pull chain on fan on high speed.

Transformer and Switch on Wall
If the fan has a three-speed transformer, you can control it with a wall switch or variable control. Connect the fan's black wire to the black switch wire. The blue wire is connected to the incoming black power wire and connects to the fan's blue wire. The white wires are connected and the green wires are connected. If you want variables speed on the fan, leave the pull chain on the fan at the high-speed setting.

Installing Ceiling Fans

Most ceiling fans are assembled the same way. There may be slight variations between fan manufacturers, but the differences will be noted in the instructions enclosed in the fan package. Wire colors also may vary.

1. Turning off Power. Turn off the electric power to the ceiling box at the main electrical service panel. Do not flip a wall switch and assume that the power is turned off. Go to the main service panel and flip the appropriate circuit breaker or remove the fuse. If there is any doubt, use a voltage tester.

2. Removing Fixture. Remove the ceiling fixture and disconnect the black and white wires from the terminals or wire connectors. If the ceiling light is controlled by a wall switch, the fan also may be controlled by the wall switch. If the light is not controlled by a wall switch and you want to control the fan with a wall switch, you will have to fish cable through the ceiling and down the wall to create a switch loop. If you want to control the fan with the fan switch, simply connect the fan to the power wires inside the ceiling box.

3. Securing Ceiling Box. Be sure the ceiling box is securely mounted to the ceiling framing. Double-check to make sure it is. The best insurance is to drive a couple of screws through holes in the box into solid material. Assemble the mounting bracket according to manufacturer's instructions. Attach the bracket into the ceiling box alone. Be certain the product conforms to electrical codes.

If the box is mounted on a pitched ceiling or beam, you have to use either a to use a swivel hanger or an angle kit that you can buy at the store. The kits are no furnished in the fan package. An angle hanger allows the fan to hang level although the box sits at an angle. The fan can be supported by a hook, but you will need a block of wood in which to drive the hook. We recommend a short length of 4x4. Predrill it and bolt it to the beam or ceiling. The power wire can be stapled along the top or bottom edge of a beam and then connected into the electrical ceiling box. You can paint or stain the cable so it matches the beam.

4. Assembling Down Rod. Position the down rod though the canopy of the fan. Run the electrical wires from the fan through the down-rod assembly. Use a stout string to pull them through if necessary. There will be power circuit wires and a switch wire. There also may be a forth, grounding wire, depending on the brand and type of fan you are installing. The usual insulation colors identify the power circuit wires: black for the hot line and white. The switch wire is usually blue-insulated, but may have red insulation in some fans. The grounding wire will be bare or have green insulation.

Insert the down rod into the motor adaptor and fasten it. Insert the bolt provided. Then insert and spread the cotter pin. Finally, tighten the setscrew counter-clockwise.

5. Lifting Fan into Position. With a helper, lift the fan into position at the ceiling without the blades attached. Put the vaulted ceiling mount or swivel into the hanger bracket. The fan now should be supported on the ceiling with a swivel-type ball-and-socket bracket or J hook.

6. Connecting Wires. Connect the fan to electrical power. In a general hookup, the white wire goes to white, and black goes to black. The ground wire connects to the ceiling box via a screw or clip, or the ground is spliced to an incoming ground wire.

7. Hooking up the Light Kit. If the fan has a light kit, remove the switch housing on the fan and the center screw. Screw the light kit onto the bottom plate. You will need a helper to hold the kit assembly in position while you connect the fan's blue wire to the light's black wire and the fan's white wire to the light's white wire. Use wire connectors for splices and wrap the wire connectors with electrical tape. Screw on the bottom plate and light, and attach the glass.

8. Assembling Fan Blades. Put the fan blades into the folder. Then fasten the holder to the fan motor. The unit is now assembled.

9. Testing Fan Operation. Turn on the power and make sure that the fan operates at all speeds, forward, and reverse. If the fan has a light kit, turn on the lights. If you notice any blade wobble, measure from the ceiling to the tip of each blade. If the blades are not even, exert light pressure on the blade that is out of alignment so it matches the other blades. You may have to loosen setscrews that hold the blades in position, if the fan has them. All blades must be uniform.

Otherwise, the blades will wobble and jump and exert extra wear and tear on the fan mounting assembly.

Troubleshooting
If the fan does not run or the lights don't work, you can make these checks:

- Is the power turned on at the main service panel? Has a fuse blown or breaker tripped while you were connecting the fan?
- Is the wall or fan switch in the proper mode?
- Is the light switch on the fan in proper mode?
- Are the power wires properly connected in the ceiling box?
- Are the switch wires properly connected in the ceiling box?

Fan Switch on Fan
If the fan has a three-speed pull chain near the bottom of the motor, the blue and black fan wires are connected to the black-power wire in the box. The white-insulated wires are joined; the green ground wire is fastened t the ceiling box. Use wire connectors and tape. Optional light is operated independently of the fan by a pull chain.

Light Switch on Wall
The light is controlled by a wall switch. You control the fan with the three-speed chain. You also can have a separate wall switch to control a ceiling-fan light kit. The black wire in the fan connects to the incoming black power wire and to another black wire going to the switch. The blue switch wire connects to the blue fan wire. The white wire in the fan connects to the white wire in the box. The green wire connects to the green wire in the box or to the box itself.

Ceiling Fixtures
Ceiling fixtures may provide much of the general and the more specific task lighting needed in your home. A central ceiling fixture will add to the general lighting, while track lighting provides focused light where it is needed.

Changing A Ceiling Fixture
The job of replacing a ceiling light, such as one over a dining table, with a chandelier is a simple job. Some professionals call this a "change-out."

1. Removing Old Fixture. Turn off the power, and then depending on the style of the fixture, remove the globe, light diffuser and bulbs from the fixture. The canopy, escutcheon or fixture base is held to the ceiling electrical box with a locknut or fixture bolts. To remove these fasteners, turn them counterclockwise. This will expose the contents of the ceiling box.

2. Disconnect Wires. Have a helper hold the fixture while you disconnect the black and white wires from the fixture. If a helper is not available, you can make a hook support from a bent coat hanger to hold up the fixture.

If there are more than two wires in the box, note the configuration and connections. The other wires could be switch and grounding wires. If the fixture is held by a hickey and nipple or a nut and stud, unscrew these connectors, releasing the fixture.

3. Wiring Fixture. Have a helper hold up the new fixture or support it with a coat hanger arrangement while you connect the fixture wires to the circuit wires. Most fixtures are prewired; remove 3/4-inch insulation from the wires for connection. Mate and twist the black wire of the fixture to the black wire of the circuit; do the same with the white wires and ground wires, if any. Use wire connectors and tape them.

4. Mounting Fixture. The fixture is supported by mounting devices in or on the box.

Automotive Electrical System

Parts of:
Engine starting - starter - ignition switch.
Engine Operation -
Safety lights
Headlights
Tail lights
Driving Lights
Reverse Lights
4-way (Hazard) Flashers
Directional Lights
Windshield washer/wiper
Horn - Mechanical or electrionic
Battery/Charging
Alternator
Voltage Regulator
On-Board Computer with "fault" lights
Other:
Dome Light
Heater Blower;
A/C Clutch
A/C Solinoid
Electrical Door Locks
Electric Windows
Radio, CD and Cassette with speakers and wires

Dangerous Voltages

The following section is not intended as an absolute guide to electronics safety. Many factors, most of which are beyond the control of this author, contribute to the degree of hazard that you are subject to while working on electronic circuits. Use care and critical judgement at all times. Safety is your personal responsibility!

The human body is damaged by the flow of current through it. Tissue damage occurs via heating, just like a burn. More importantly, significant body functions such as heart beat and breathing can be affected by electrical shock.

Dry skin has a fairly high resistance, so you normally don't feel anything when touching low voltages (say below 35V). Therefore, with some caveats, if your circuit is operating on +15V and -15V maximum, you can safely poke around in it while it is under power. Circuits that operate with higher supply voltages should be treated with more care.

Wet skin has a much lower resistance than dry skin. If you perspire, as most of us do, your skin resistance can be lowered such that you may feel a minor shock from low voltages (I have felt 24 volts). Blood, having a saline component, is quite a good conductor. Accidental shock via an open wound is quite possible, and could be quite dangerous.

Metal jewelry is a very good conductor. If you have a power supply that can deliver high current, your class ring would be happy to provide the conduction path. Here the danger is heat rather than shock. The ring will conduct as much current as the supply will deliver. If you short out a car battery with your ring, the ring will literally vaporize! Imagine what that would feel like on your ring finger! Vaporizing metal wouldn't be fun in the eyes either!

In summary, always observe the following precautions. Remove all rings, bracelets, necklaces, etc. before working on live electronic circuits. Keep your hands dry at all times. Wear full coverage bandages on all open wounds. Respect all circuits, especially those that have high voltage, or high current capability.

Some Unsorted Items

Some of the things that NOT covered in this course: AC power generation and distribution; Series and Parallel AC circuits. Most theoretical voltage and currents "laws" such as Kirchoff's voltage law Ohm's Law is covered. This course is NOT providing comprehensive training of electrical wiring and troubleshooting. Rather, gives a good grounding in concepts and showing how to obtain more information independently, from sources such as the World Wide Web.

Tool use
Screwdivers
Hammer
Carpenters Square - Framing Square
Round wire gauge
Saws - Kerf of teeth; cut on forward stroke; hacksaw ; keyhole saw
Hole saw - measure first, dill pilot hole

Test Equipment Use
Digital Milti Meter (DMM)
Continuity Tester
Handheld Voltage Test Light

Resistivity of wire
- Transformer, magnetic device - efficiency/loss.
- Fuse - thermal device - visual confirmation (blown or lack of continuity)
- Loose Wires
-Corrosion, interference.
- Floor plan; table of CBs 1,2,3... What circuit breaker controls which area. Don't overload the circuit. Why?
- Electrical Load - Voltage rating, wattage rating on plate or sticker.

Power Tools. Cord care. Don't hold onto the cord and dangle the drill. Also: When removing the plug from the outlet.

You must find out if there are any local rules, laws or "CODES" (regulations) that need to be adhered to. If you do your job well, poeple will tell others and your good reputation will spread. You may become "visible" to local officials.

Circuits - Branch circuits from the main box.

Fuses - The intentional "weak link" in the system. The wirw in a fuse is much smaller than the wire that carries the current to the outlet or socket. This is done this way so that the fuse will heat up first.

Remember that Horse Power (abbreviated HP), Watts and VA are all different ways to express the same thing. They are units of "work" (energy). 1 HP = 746W 1 HP is the equivalent amount of power to raise 55 pounds 1 foot in one second. 1 HP is the equivalent amount of power to raise 25 Kilograms 30 centimetres in 1 second.

Table of copper conductors. How many amps can each carry? Circular Mils. Mils are the units used to measure thickness.

Cicuit breaker: ON, OFF, TRIP, RESET positions.

Tool - Cable ripper - How used and it also has gauge holes in it.

Voltage drop - 2 bulbs in parallel get dimmer. Why?

Refrigerators have some contacts that can arc. clean them.

1 Define electricity.
2 Identify how electricity works and explain the differences between two and three wire systems
3 List the basic tools for electrical repairs.
4 Explain the functions of plug fuses, circuit breakers, and cartridge fuses.

Glossary of Electrical Terms

ampere (or amp): Refers to the rate at which electrical power flows to a light, tool, or an appliance. The amount of current passing a given point at a given time. Each electrical device has an amperage rating and each circuit is rated for the total number of amperes it can safely deliver.

box: A device used to contain wiring connections.

cable: Two or more wires that are grouped together and protected by a covering or sheath.

circuit: A continuous loop of electrical current flowing along wires or cables. A continuous path for electrical current. In a household electrical system, a branch circuit begins at the service panel, runs to various switches, outlets and fixtures and returns to the service panel.

circuit breaker: A safety device that interrupts an electrical circuit in the event of an overload or short circuit.

conductor: Any material that allows electrical current to flow through it. Copper wire is an especially good conductor.

conduit: A metal or plastic tube used to protect wires.

continuity: An uninterrupted electrical pathway through a circuit or electrical fixture.

current: The movement of electrons along a conductor. The movement (flow) of electrons, measured in amperes.

feed wire: A conductor that carries 120-volt current uninterrupted from the service panel.

fuse: A safety device, usually found in older homes, that interrupts electrical circuits during an overload or short circuit.

grounding wire: A wire used in an electrical circuit to conduct current to the earth in the event of a short circuit. The grounding wire often is a bare copper wire. The bare copper or green insulated wire in a cable. It drains off current that escapes its normal path to the service panel, causing a fuse to blow or a circuit breaker to trip.

hot wire: Any wire that carries voltage. In an electrical circuit, the hot wire usually is covered with black or red insulation. A wire that carries current forward from the source. Often identified by black (or red) insulation.

insulator: Any material, such as plastic or rubber, that resists the flow of electrical current. Insulating materials protect wires and cables.

meter: A device used to measure the amount of electrical power being used.

neutral wire: A wire that returns current at zero voltage to the source of electrical power. Usually covered with white or light gray insulation. Also called the grounded wire.

overload: A demand for more current than the circuit wires or electrical device was designed to carry. Usually causes a fuse to blow or a circuit breaker to trip. Occurs when a combination of lights, tools and appliances is drawing more amperage than the circuit is designed to handle. Normally, the fuse will blow or the circuit breaker will trip, interrupting the flow of electricity to the circuit.

pigtail: A short wire used to connect two or more circuit wires to a single screw terminal.

polarized receptacle: A receptacle designed to keep hot current flowing along black or red wires, and neutral current flowing along white or gray wires.

power: The result of hot current flowing for a period of time. Use of power makes heat, motion, or light.

receptacle: A device that provides plug-in access to electrical power.

screw terminal: A place where a wire connects to a receptacle, switch, or fixture.

service panel: A metal box usually near the site where electrical power enters the house. In the service panel, electrical current is split into individual circuits. The service panel has circuit breakers or fuses to protect each circuit.

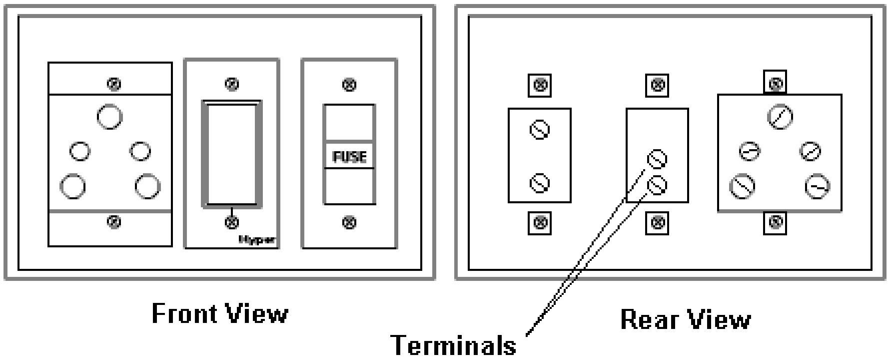
short circuit: An accidental and improper contact between two current-carrying wires, or between a current-carrying wire and a grounding conductor. When an exposed "hot wire" touches a neutral wire or a grounded metal box, the circuit will heat up suddenly. The fuse or circuit breaker will shut off the power immediately.

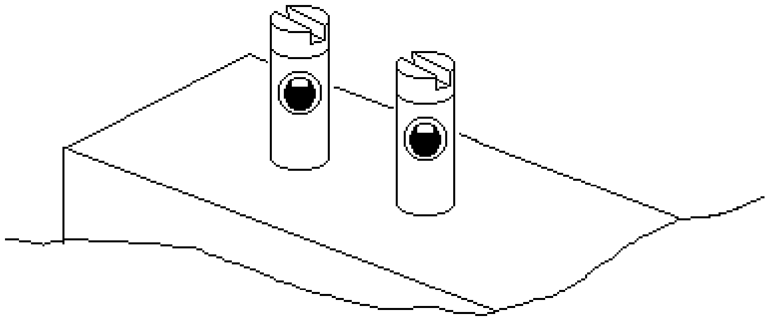
switch: A device that controls electrical current passing through hot circuit wires. Used to turn lights and appliances on and off.

voltage (or **volts**)**:** A measurement of electricity in terms of pressure.

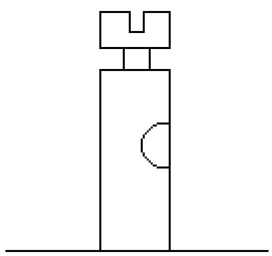
wattage (or **watt**)**:** A measurement of electrical power in terms of total energy consumed. Watts can be calculated by multiplying the voltage times the amps. The rate at which electrical devices consumes energy. Usually listed on a sticker or plate on the lamp or appliance.

wire nut: A device used to connect two or more wires together.

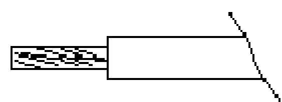




Perspective View of Terminals



Side View of Terminal

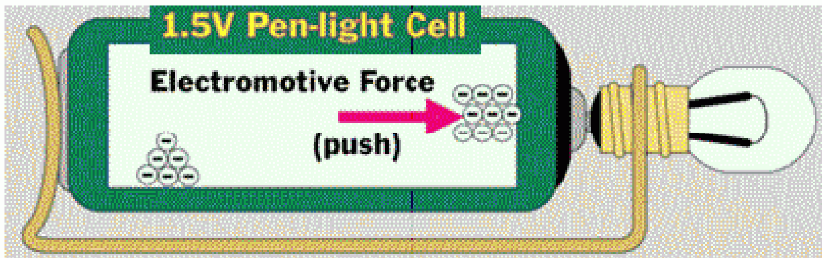


Stripped Wire

Electricity - Voltage and Current

Voltage Everyone uses this term, even though they might not understand it. You probably know that a single cell from a flashlight creates an electrical force of 1.5 Volts. You also know that a transistor radio battery (with the snaps on the top) creates an electrical force of 9 Volts. (There are six little cells of 1.5 Volts each inside of the 9 Volt battery.) You know that household electrical outlets are 110 or 120 Volts, and you know that "High Voltage" is dangerous. What else should you know about voltage? Again, lets look at the atomic level.

Electrons don't move from atom to atom without a reason. When electrons are flowing, there is an electrical force somewhere, pushing them along. In older text books, you might see references to ElectroMotive Force, or "EMF". We usually refer to this force as "Voltage".



This picture illustrates a single cell pocket flashlight. The 1.5 Volt cell is pushing the electrons through the bulb and the wire. Without this push, the electrons would be happy to remain stationary. When the battery gets old, its internal push gets weaker and weaker. (That's why the bulb gets dim.)

Current Again, everyone uses this term without really knowing what it means. In very simple terms, current is the flow rate of the electrons in the circuit. How is that different from voltage? Let's use a water tank and a pipe as an example. In some neighborhoods you'll see a water tank raised high above the ground on strong legs. The water in this tank has been raised up there to give it pressure. A series of pipes carry the water down from the tank, under ground, into your house, and then to each sink, bathtub, and toilet. The water in your pipes is under pressure because the water in the tank is pushing down on it. This pressure is similar to Voltage. Voltage is the pressure pushing on the electrons in a circuit. If all of the faucets in your house are closed, no water flows through the pipes. If you open one faucet, some water flows. If you open all of the faucets, a lot of water flows. This flow of water is similar to electrical Current. Current is the flow rate of electrons through the circuit.

Are Voltage and Current Related? Voltage and current are not the same thing, although they are closely related. In simple terms, *Voltage causes Current.* Given a Voltage and a path for the electrons, current will flow. Given the path, but no Voltage, or Voltage without the path, there will be no current.

Alessandro Volta An Italian professor of physics. In 1791, Volta was experimenting with metals and acids. He touched a silver spoon and a piece of tin to his tongue (saliva is slightly acidic) and connected them with a piece of copper wire. He experienced a "sour" taste, and realized he was experiencing an electrical phenomenon. (Touch the two terminals of a 9 volt transistor radio battery to your tongue to experience this for yourself.) After more experiments, Volta was able to assemble a pile of cells to form a battery. Each cell was a disk of zinc and a disk of silver, separated by a layer of brine-soaked pasteboard. We now refer to that original battery as a Voltaic Pile. In Volta's honor, we refer to electrical pressure as "Voltage" and we measure the amount of electrical pressure in units of "Volts".

Andre Marie Ampere A French mathematician, often referred to as "The Newton of Electricity". Ampere experimented with electricity and magnetism, and the relationship between the two. In the early 1800's he realised that electrons were moving through conductors in a flow. In his honor, we measure the amount of flow in units of "Amperes", often shortened to "Amps".

What Causes Voltage? Electrons and Protons are "charged" particles. Electrons have a negative charge, and Protons have a positive charge. Like-charged particles repel. Opposite-charged particles attract. A piece of material with more Protons than Electrons will have a positive charge. Likewise, a piece of material with more Electrons than Protons will have a negative charge. Each charged particle that is out of balance exerts some electrical pressure as it tries to get back into balance. Electrons push, as they try to get away from each other. Protons pull, as they try to attract electrons towards them. The total amount of pressure between two points is measured as Voltage.

How Does A Battery Work? In a battery, a chemical reaction causes electrons to move away from one terminal and towards the other. The terminal that they move away from is becomes positively charged, and the terminal that they move towards becomes negatively charged. When the battery is on the shelf, or in a circuit that is turned off, the electrical pressure builds up to the point where the chemical reaction essentially stops. When the battery is in a circuit and current is flowing, the chemical reaction is going on, moving new electrons into position as the previous electrons flow out through the circuit. As the chemicals that support the battery action become depleted, the battery gradually looses its ability to generate a charge at its terminals.

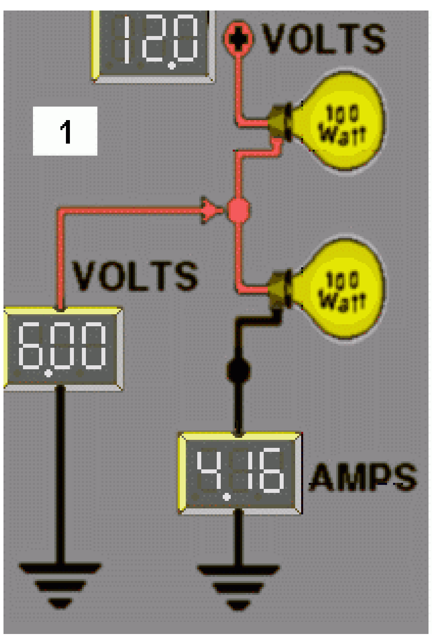
What Causes Current? Given a path, electrons will flow away from a negative charge and towards a positive charge. In our simple example (the single cell flashlight), current flows through the light bulb on its way from the negative battery terminal towards the positive battery terminal.

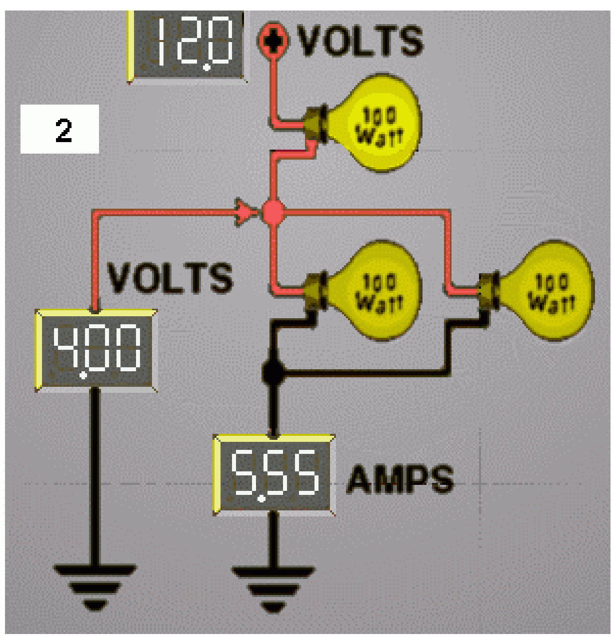
Questions for Students: Q: Consider a short piece of insulated wire. Is there current flowing in this wire? A: Yes. Not really correct. There might be a few electrons moving about, but no organized flow, thus no current. A: No. Correct. There is no voltage acting on the electrons, so there is no flow. And there is no complete circuit to provide a return path for the electrons. Q: If the two ends of the wire are connected together to form a complete circuit, is there now current flowing? A: Yes. Not really correct. Again, there might be a few electrons moving about, but no organized flow and no current. A: No. Correct. There is no voltage acting on the electrons, so there is no flow, even though there is a complete circuit. A wire is only a conductor; it is not a voltiac cell. **Additional Note:** Actually, current can be caused to move in this loop of wire using a magnetic field (see AC sources). But in the absence of a magnetic field, there is no force acting on the electrons, so there is no current.

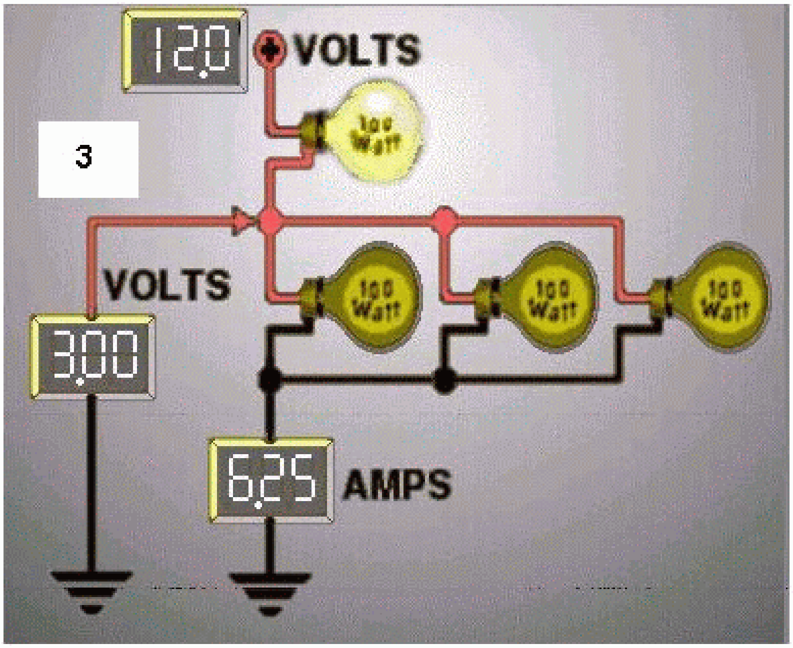
--- E I R P ---

The Relationship between

Voltage, Current & Resistance in the Consumption of Power







Mister Ohm's Law

$E = IR$	$E = \frac{P}{I}$	$E = \sqrt{PR}$
$R = \frac{E}{I}$	$R = \frac{P}{I^2}$	$R = \frac{E^2}{P}$
$I = \frac{E}{R}$	$I = \frac{P}{E}$	$I = \sqrt{P/R}$
$P = EI$	$P = \frac{E^2}{R}$	$P = I^2R$

1 6.0 Volts x 4.16 Amps = 50 Watts

2 4.0 Volts x 5.55 Amps = 66 Watts

3 3.0 Volts x 6.25 Amps = 75 Watts

E Electromotive Force measured in VOLTS
I *Intensity* [1] measured in AMPS
R Resistance measured in OHMS
P Power measured in WATT

[1] Early word used term Intensity for electricity in wire.

Resistor as a CONVERTOR

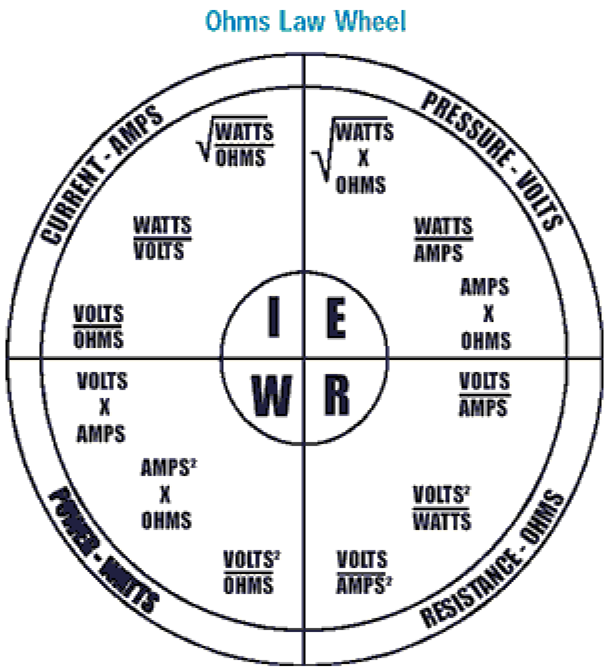
CURRENT to VOLTAGE | | VOLTAGE to CURRENT

1)_ You have a 12 volt car battery.
2)_ You connect two 6 volt 25 Watt bulbs in series across the battery.
2a_ Bulb: 6 Volts, 25 Watts = 1.44 OHMS = 4.166 AMPS (1.44 x 4.166 = 6)
3)_ Measure the voltage across both bulbs: you will measure 6 volts across each. (R = 2.88 OHMS, I = 4.166 AMPS)
4)_ Now place another 6 volt 25 Watt bulb in parallel with either bulb--say the bulb closest to ground. (R = 2.16 OHMS, I = 5.55 AMPS)
5)_ Again measure the voltage across both bulbs:
6)_ The single bulb (top) will measure 8 volts. (1.44 OHMS)
7)_ The two bulbs (bottom) will measure 4 volts. (0.72 OHMS)
8)_ Of course both voltages will equal 12 volts.

DISCUSSION: If we think of the bulbs as resistors (they are within reason), notice that there is 6 volts *dropped* across one bulb in the first example. In the second example, when the second bulb is added, more current is made to flow, and the voltage across the single bulb went from 6 volts to 8 volts. In both cases the single bulb (resistor) is

CONVERTING the CURRENT to a VOLTAGE: The more current the more voltage. Example #1: 4.166 AMPS across 1.44 OHMS = 6 Volts Example #2: 5.55 AMPS across 1.44 OHMS = 8 Volts

CONVERTING the VOLTAGE to a CURRENT: Notice that adding the second bulb in parallel increased the Current; conversely, taking away that bulb will decrease the current. So changing the total resistance across the 12 Volt battery has converted a fixed **VOLTAGE** to a changing **CURRENT**.



Switches - Switch Types - Switches as Used in Electrical Circuits

To explain things as briefly as possible, electricity is a flow of electrons. Substances that allow electrons to flow freely are called conductors and those that don't are called insulators.

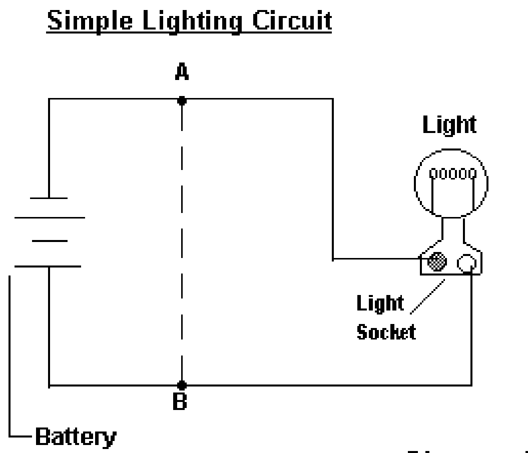
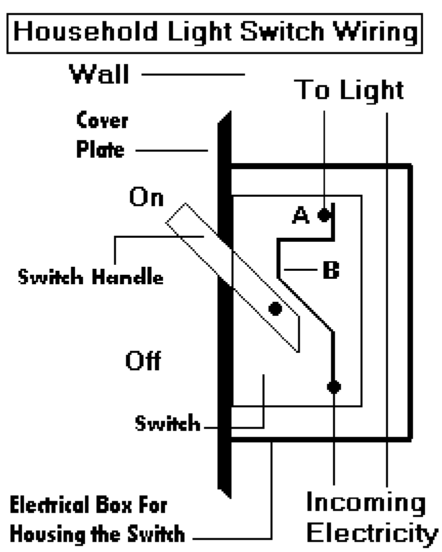


Diagram 1

Diagram number 1 illustrates an extremely simple circuit. (For the moment, ignore the dotted line and the points A and B). The battery is represented by 4 lines (the longer line being positive and the shorter one negative). Starting from the negative end of the battery, electrons "circle" through one wire, pass through the light bulb, pass through the other wire and then return to the battery thereby completing the circuit. See? Quite simple.
This is all well and good but there are 2 drawbacks to this circuit 1) the light always stays on and 2) the power is constantly being used. How can we turn the light bulb 'off'? Well, we could unscrew the bulb from the socket but in the real world this is very inconvenient. (Light bulbs are inside fixtures, on ceilings and so on). Perhaps we could disconnect the power at the source. This too is very inconvenient. You would have to go down to your basement to shut the power off. Or - *much more dangerous* - you would have to disconnect the electrical supply wire before it reaches the light socket.
Is there a safe way to interrupt the electron flow without physically touching the wire? Sure. It is called a SWITCH !!!
The *inside* of a typical household wall switch has a strip of metal (B), making contact with point 'A', completing the circuit and thereby conducting electricity to the light. This would obviously be the 'ON' position. When the insulated lever is moved down to the 'OFF' position, it pushes the metal strip away from point 'A', breaking the circuit and turning the light 'OFF'.
This type of switch (having a lever which "flips" it on and off) is called a toggle switch.

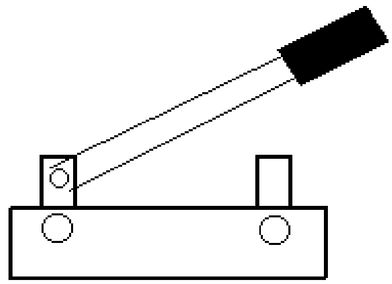


Because of being well-insulated and mounted in a box, household switches are a safe way for turning electrical devices on and off.
Finally, let's talk about that dotted line in Diagram 1. Now what would happen if point A and point B were to touch OR if they were connected with a wire or other conductor? Well, the light bulb would turn 'off', the wires and the battery would get very warm very fast and the electrons would simply travel from the battery to point A to point B and then back to the

battery. Notice that in this new circuit , the electrons are travelling a path (or circuit) that is *shorter* than the original one. Hence you have just learned what a "short circuit" is and how its name is derived! Short circuits are dangerous. They cause wires to heat, circuit breakers to 'trip' and can even start fires.

S W I T C H E S

There are many different *types of switches:* toggle, rotary, pushbutton, "rocker", "pull-chain", slide, magnetic, mercury, timer, voice-activated, "touch-sensitive", and many others. Heck, even the Clapper™ is another type of switch ! The *"knife switch"* (rarely seen nowadays) is the type that most easily demonstrates the functioning of a switch.



Knife Switch

Today, use of knife switches has been confined to 1) heavy-duty industrial applications and 2) demonstration purposes - science projects for example. The knife switch has a metal lever, insulated at the 'free end' that comes into contact with a metal 'slot'. Since the electrical connections are exposed, knife switches are never seen in household wiring.

Light Switch Circuit

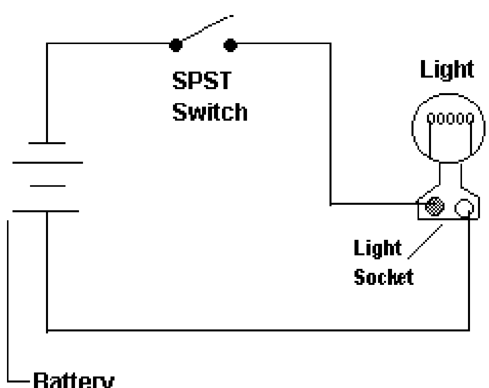
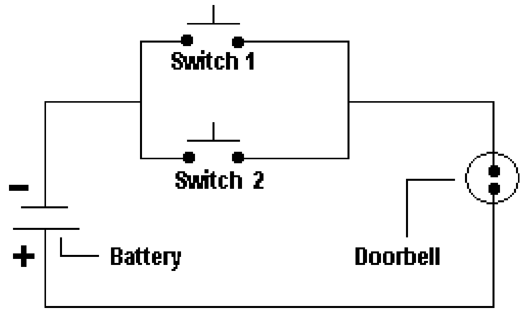


Diagram 2

Referring to *Diagram 2*, the wiring is very similar to Diagram 1 except a switch has been added. Compare this to the Typical Household Light Switch diagram. Pretty much the same principle at work wouldn't you say? This type of switch is a Single Pole Single Throw (or SPST). This means that it controls one wire (pole) and it makes 1 connection (a throw). Yes, this is an on/off switch, but a 'throw' only counts when a connection is made. 'Off' is not considered a 'throw'. Also notice that only 1 wire has to be switched. (Following the circuit from one end of the battery to the other you can see why this is so).

As it is, this circuit alone could be your science project. A variation could be substituting a push-button switch and putting a 'buzzer' or 'doorbell' where the light is. Now you have a good demonstration of how a doorbell is wired. Pushbutton switches are *usually* "momentary on". That is to say the connection is made only when you press the button. There are "momentary off" pushbutton switches, but using one in a doorbell circuit would mean the bell would be constantly on *until* someone pressed the button. Impractical don't you think? (The comedian Tim Conway joked that his father wired a doorbell in just this way. When there was silence someone would say "Hey somebody's at the door").

A practical use of the *momentary off* switch is the "mute button" on your telephone. If a momentary on switch were used, it would be very annoying to press the button constantly as you talked and released it only for muting. This shows how each type of switch has its specific applications.

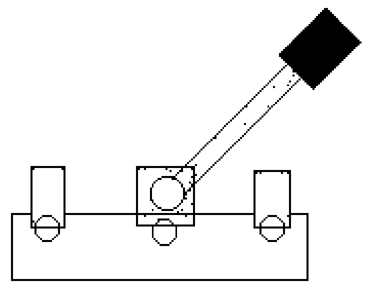


Dual Button Doorbell Wiring

The above diagram shows an interesting variation of doorbell wiring. The 2 doorbell buttons do not have to be right next to each other. One button could be at a front door and the other at a side door. If you follow the circuit, you can see that pressing *either* button will cause the doobell to ring. The 2 switches are said to be wired in *parallel.*

The next type of switch (no diagram) is the Double Pole Single Throw (DPST). These switches are used when there are 2 'live' lines to switch but can only turn on or off (single throw). These switches are not used much and are usually found in 240 volt applications.

Single Pole Double Throw Switches



SPDT Knife Switch

Diagram 3 makes use of the Single Pole Double Throw Switch. The common terminal is the middle terminal in the SPDT Knife Switch or if you are using a household switch, it would be the brass colored terminal. (the other 2 would be silver colored). This circuit clearly demonstrates what happens when the SPDT switch is moved back and forth. Light A goes on and B goes off, B goes on and A goes off and so forth. You can see that this popular switch would have *many* practical applications: the transmit/receive button on a "2-way" radio, the "high/low beam" switch for your car headlights, the pulse/tone dialing switch on your telephone, and so on.

SPDT Light Switching Circuit

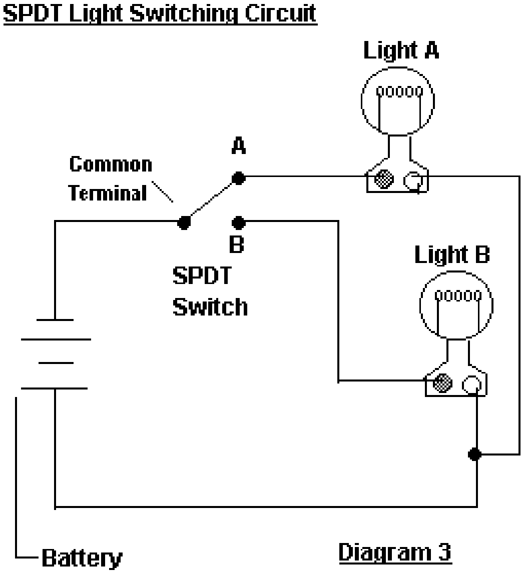


Diagram 3

If you are using the SPDT knife switch, you have a "center off" position, which an ordinary wall switch would NOT have in which case you will need to add an SPST switch for shutting this circuit off. (In electronics work, many SPDT switches have a middle position in which the electricity is turned off to BOTH circuits. It is an SPDT center off switch. Also, some electronic SPDT switches have a "center on" position. The best example of this type of switch is the "pickup" selector on an electric guitar which can choose the rhythm, treble or both pickups for 3 varieties of sounds).
Diagram 4 (below) depicts what is probably the most common use for the SPDT switch - the 3 way light switching circuit. Electricians incorrectly call the SPDT switch a "3 way switch". The proper terminology should be "three terminal switch". However the term 3-way switch has stuck and it's a misnomer we'll just have to live with.

"3-Way Switch" Wiring Diagram

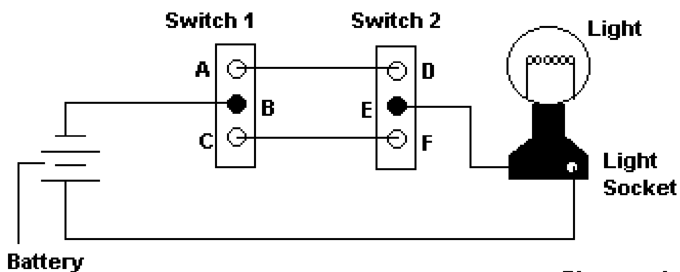
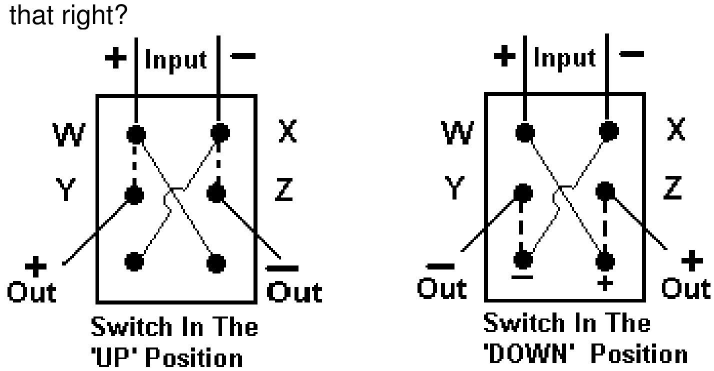


Diagram 4

So, how does this work? Let's say that Switch 1 is at the bottom of a stairway and Switch 2 is at the top. Suppose Switch 1 is in a 'down' position (B & C connected) and Switch 2 is in an 'up' position (D & E connected). The light bulb is off. Now someone comes to the bottom of the stairs and flips Switch 1 'up'. If you follow the circuit you can see why the light bulb would now turn on because A & B and D & E are connected. When the person reaches the top of the stairs, Switch 2 is flipped 'down', E & F are now connected and so the light bulb goes off. Another person shows up at the bottom of the stairs and flips Switch 1 'down', connecting B & C thereby turning the light on again. The person reaches the top of the stairs, flips Switch 2 'up' connecting D & E and the light bulb goes off. Notice that in the case of the second person, a downstroke turns the bulb on and an upstroke turns the bulb off. If you have such switches in your house OR if you have purchased household wall switches for this circuit, you now see the reason why they do NOT have the words on and off printed on them.
Don't you think this switching arrangement would make a great science project?

The Double Pole Double Throw Switch

A simple way to think of this switch is imagining 2 SPDT switches side by side with the 'handles' attached to each other. Perhaps the most popular use for this switch is 'phase or polarity reversal'. So, how does the DPDT switch accomplish this? First, *you* have to wire the 2 'top' and 2 'bottom' terminals in a 'criss-cross' fashion. The top 2 terminals become the input and the middle two terminals become the ouput. Now, referring to the bottom left diagram, the switch is in the 'up' position, W & Y are connected, as are X & Z. The polarity is maintained because the input and output are directly connected. No problem seeing that right?



Now let's see what happens when the switch is in the 'down' position (right diagram). The + input goes from the 'W' terminal, down to the lower right and then up to the 'Z' terminal. The negative input goes from the 'X' terminal and out through the 'Y' terminal. See what has happened? With one flip of a switch, polarity has been reversed. What applications does this have? For one thing, electric guitar players use this type of switch to put one pickup out of phase with the other, producing a thin, 'squawcky', 'inside-out' kind of sound. In the 'old days' before 3 prong plugs, power switches on some electrical devices used this switching arrangement to switch polarity in case the plug was in the outlet the "wrong way".

Another important (though not very common) use is to put this switch between 3-way switches so that the same light may be switched from *many* different locations. Referring to Diagram 4, if A & B and E & F were connected, the bulb would be off. But now think of the wires going from A to D and C to F. If their connections were reversed, (A to F, C to D), the light bulb would turn on again. So, how would we be able to reverse the polarity of these 2 wires? By using the polarity reversing switch ! (See Diagram 5 below).

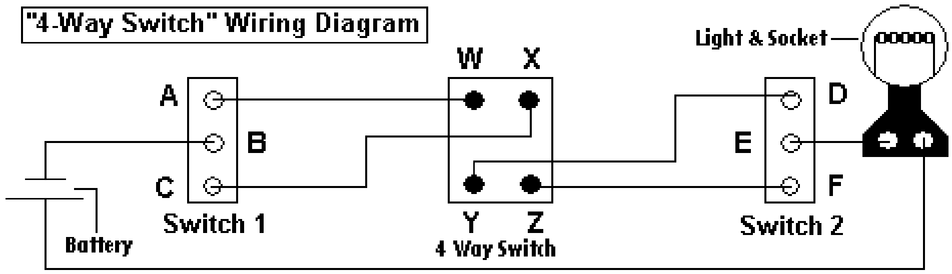


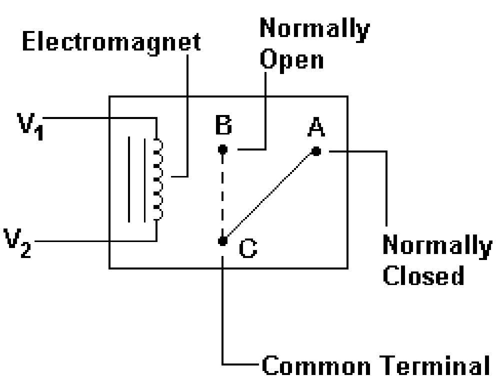
Diagram 5

Incidentally, electricians have once again stuck us with another misnomer by calling this a "4-way" switch. Can you see what the 4-way switch is? It is a DPDT switch, wired for phase reversal without the bottom 2 terminals exposed (they don't have to be). If you can buy a 4-way switch, great. If not, you know how to make one right? Also, you don't have to limit yourself to using just one 4-way switch. If you were to attach another 4-way switch from the 'Y' 'Z' terminals to the 'W' 'X' terminals of the next switch, you could have the same light switched from a 4th location. Or you could add a 5th or 6th, etc. Now wouldn't that make an impressive science project?

Relays

IMPORTANT !!! DO NOT use wall current !!!
ALL of these circuits can be built using batteries (dry cells) only !!!

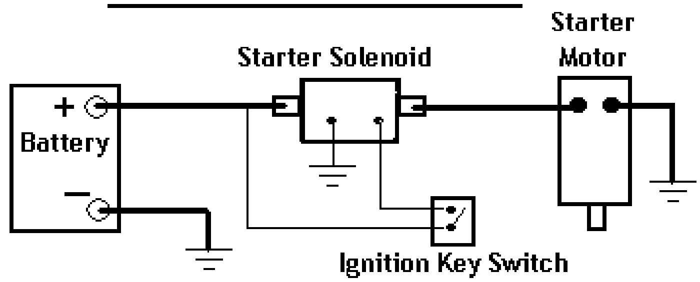
We are now going to discuss a special kind of switch - the relay.



SPDT Relay

Notice in the above diagram that a relay uses an electromagnet. This is a device consisting of a coil of wire wrapped around an iron core. When *electricity* is applied to the coil of wire it becomes *magnetic*, hence the term *electromagnet.*
The A B and C terminals are an SPDT switch controlled by the electromagnet. When electricity is applied to V1 and V2, the electromagnet acts upon the SPDT switch so that the B and C terminals are connected. When the electricity is disconnected, then the A and C terminals are connected. It is important to note that the *electromagnet* is magnetically linked to the *switch* but the two are NOT linked electrically.
There is another type of relay called a solenoid that basically works on the same principle. The solenoid electromagnet consists of wire wrapped around a tube containing an iron cylinder called a "plunger". When electricity is supplied to the wire coil, the "plunger" moves through the tube and activates a switch.
At this point you might be wondering about the purpose of all this. Why switch an electromagnet just so it can control another switch? Why not just use one regular switch? One important application is illustrated in the diagram below.

Automobile Starter Circuit



NOTE: the symbol indicates a ground connection. Since a great percentage of an automobile consists of metal, using the automobile itself as one "side" of a circuit saves a tremendous amount of wire.

When the ignition key is turned all the way to the "start" position, it allows electricity to flow to the starter solenoid (relay) which then connects the battery to the starter motor. So why do we need this solenoid "middle man" ? Couldn't we just eliminate it and connect the ignition wires to the + battery terminal and the other wire to the starter motor? The important point here is that the electromagment is using a small amount of current to control a large amount of current to the starter motor. (Remember that the electromagnet and the switch are NOT connected electrically). Have you noticed that all of the wires (except the ignition wires) are purposely drawn with thick lines? The reason being that some circuits (such as the starter) in a car require a tremendous amount of current. (If you look at an automobile's battery cables, you will notice they are quite thick.) Connecting the ignition wires to the battery and then to the starter motor would cause these thin wires to conduct much more current than they were designed for. These wires would become very hot and the insulation would start to smoke. (The same would hold true for the ignition switch). After starting the car for just a few times, the wires and the switch would be in bad shape.

We do have a second choice. We could use thick battery cables for the ignition wires and use a heavy duty ignition switch. This isn't very practical either. Do you think it would be easy to squeeze cables into the steering column *and* to squeeze in a heavy duty ignition switch too? Therefore, the use of a solenoid is the most practical solution.

Electricity - Schematic Diagrams I

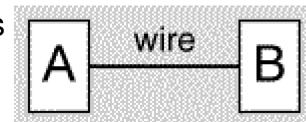
Teacher's Notes

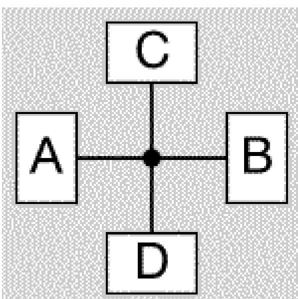
Schematic Symbols

Engineers need to record their circuit ideas so that they can be shared with others. To record and share their circuits, they use schematic diagrams. Schematic diagrams are a form of short-hand. Rather than drawing each item in a pictoral way, each item is represented by a symbol. Once you learn the symbols, you can read any circuit diagram.

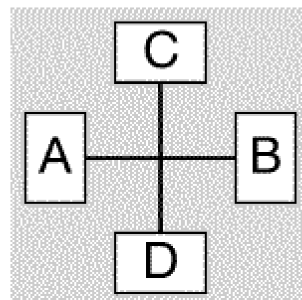
Connections

The first concept of schematic diagrams is "connection". Items in the diagram at the right are connected via wires (just like in the real world). In this picture, item A is connected to item B using a wire.



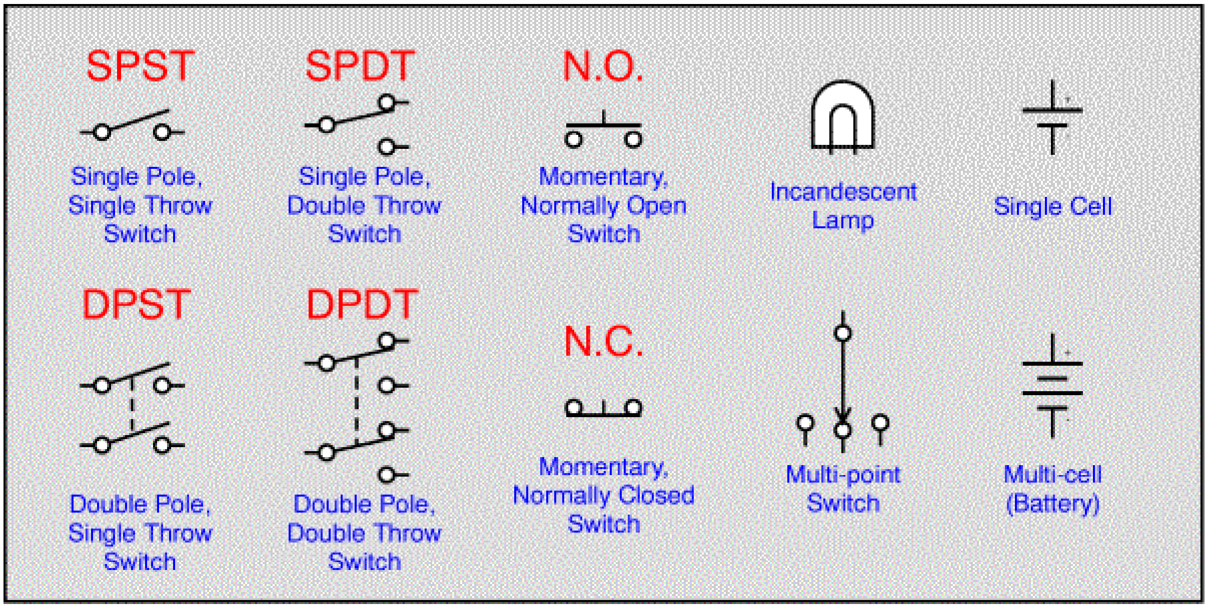


To show multiple items connected together, we use a dot at the point where the wires cross, to show that they are connected. In the diagram at the left items A, B, C, and D, are all connected together.



When wires cross without the connection dot, they are **not connected.** In the diagram at the right, item A is **only** connected to item B, and item C is **only** connected to item D.

Components
As mentioned above, in a schematic diagram each type of component is represented by a symbol. Here are the symbols for several types of switches, a lamp, a single cell, and a battery. We'll be using these symbols to create schematic diagrams on the next page.



<< Lamps   Schematics II >>

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Electricity - Schematic Diagrams I - Teacher's Notes

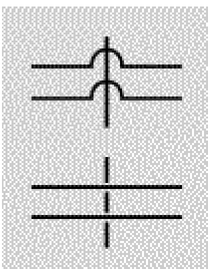
schema

A Greek word, meaning plan or diagram. The original schema were drawings of the heavens, showing the position and relationships of the stars.

diagramma

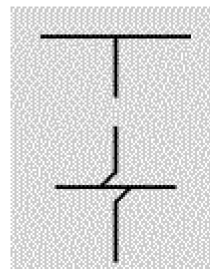
A Latin word, meaning a line drawing used to explain a concept or plan.

Showing Connections



Our notation for representing wires that cross without connecting has changed within the last 50 years. In earlier times, two wires that did not connect would be shown as "not touching", like the top figure to the left. Later, some draftsmen would show "not touching" like the lower figure to the left.

Likewise, our notation for representing wires that connect has also changed. In earlier times, it was only legal to show a connection with three wires, and the dot at the connection was not required (see the top right). A connection of four wires at the same point was not legal, and so draftsmen would use the notation shown at the lower right when they needed to show four wires connecting.



Poles and Throws

Every new subject comes with its own vocabulary! Sometimes words that you already know are just used in a new way. The word "pole", for example, has a number of obscure meanings. You already know that magnets have a "north pole" and a "south pole". We don't say so any more, but in the old days batteries had a "positive pole" and a "negative pole". We still say that components have a "polarity", meaning that it matters which end is more positive and which end is more negative.

Even though we don't refer to battery terminals as poles anymore, we still refer to switches as having poles. In this case, we mean how many circuits can the switch control independently of each other. A single pole switch can control one circuit. A double pole switch can control two circuits, and so on.

Ever heard someone say "throw the switch"? We use the word "throw" to describe how the switch can be used. Just as a switch has some number of poles, it also has some number of "throws". If a switch has a single connected position (i.e. it can be either on or off) then we say it is a "single throw" switch. If a switch has two different "connected" positions, then we say it is a "double throw" switch.

Switches are made in all combinations of poles and throws. A single circuit, single position switch is called "single pole - single throw" or SPST for short. Likewise, there are SPDT (single pole - double throw), DPST (double pole - single throw), and DPDT (double pole - double throw) types. I own an 8P10T (8 pole - 10 throw) switch that was once used by the telephone company.

Momentary Switches

A push-button switch is considered to be "momentary"; it doesn't stay in place when you remove your finger. Your door-bell button is a "normally open" (N.O.) momentary switch. When you push it, the circuit is connected and so the bell rings. When you release it, it disconnects the circuit, and the bell stops ringing. The switch for the light inside your refridgerator is a "normally closed" (N.C.) momentary switch. If nothing is pushing on it, the circuit is connected (when the door is open, the light is on). When the door is closed, it pushes against the switch, disconnecting the circuit.

A Cell or a Battery?

The word "battery" means a collection or arrangement of several items. Thus a single D cell is not really a battery; it's not a collection, it is a single item. A 9 volt transistor radio battery on the other hand, is actually 6 cells inside of a single can, so it is properly called a battery. Over the years the distinction has been fading. Now single cells are often called batteries too.

Questions for your students:

Q: Why do we use schematics instead of pictoral drawings?
A: Even the ancient Greeks and Romans understood that not everyone is an artist. A diagram is fairly easy to draw, and a lot easier to understand that a photo-realistic drawing. Diagrams leave out some of the information we don't need or care about. For example, who cares what color the battery is? The circuit should work with batteries of any color! How long is that wire? Long enough to connect the two components! Any wire that reaches is long enough!

Q: How many symbols are there for electrical and electronic components?
A: I don't know. Probably no-one does know. New symbols are invented when necessary to represent newly invented components. For electricity, there are about a dozen important symbols. You've already seen many of them. For electronics their are probably 40 or 50 that everyone knows and uses, and another 30 or 40 that are only used by specialists.

Back to **Electricity - Table of Contents**

Wattage Usage For Generators

Application / Equipment	Watts
Space Heater	1200
Weed Trimmer	850
Clothes Dryer (Gas)	720
Light Bulb (100w)	100
Small Radio AM/FM	50
Radio, CB	50
Fan	200
Television	350
Microwave Oven	1200
Air Conditioner (12,000 BTU)	3250
Furnace Fan (1/3 hp blower motor)	600
Vacuum cleaner	600
Sump pump (1/3 hp)	700
Refrigerator/freezer	800
Deep Freezer	500
Circular saw 6"	800
Floodlight	1000
Drill 1/2" Electric	1000
Toaster	1200
Coffee maker	1200
Skillet	1200
Chain saw 14" Electric	1200
Water well pump (1/2 hp)	1000
Hot plate/range (per burner)	1500
Table saw 10"	2000
Elect. Water Heater	3000
12V DC Battery Charger	120

The formula for determining load in watts is:

$$\text{Watts} = \text{Amps} \times \text{Volts}$$

or

$$P_{(watts)} = I_{(current)} \times E_{(voltage)}$$

Note: 1 kW = 1000 watts

Koinonia School of Practical Trades - Final Test

Name: ____

Multiple Choice Questions

Circle the letter of the correct answer.

1. What does "wire gauge" refer to?
   a. It is a device used to measure the length of wire..
   b. It refers to the thickness of a certain type of wire.
   c. It refers to the hardness of wire.
   d. It is a device used to measure the strength of wire.

2. In house wiring, what function do electrical switches perform?

   a. When turned off, they interrupt the flow of current.
   b. When turned off, they interrupt the flow of voltage..
   c. Both a. and b.
   d. Neither a. nor b.

3. In house wiring, how do fuses perform their function?
   a. They light up when too much voltage is present.
   b. They heat up and a piece of heated metal inside allows a spring loaded switch to open and interrupt the circuit when their current rating is exceeded.
   c. They expand and change color to indicate circuit failure.
   d. They heat up, melt and interrupt the circuit when their current rating is exceeded.

4. In house wiring, how do circuit breakers perform their function?
   a. They light up when too much voltage is present.
   b. They heat up and a piece of heated metal inside allows a spring loaded switch to open and interrupt the circuit when their current rating is exceeded.
   c. They expand and change color to indicate circuit failure.
   d. They heat up, melt and interrupt the circuit when their current rating is exceeded.

5. When using a voltmeter, what normal voltage might you expect to measure at a power outlet in the home.
   a. 240 Watts
   b. 110 Watts
   c. 230 Volts
   d. 230 Amps

6. What would be the the first thing you would check if some (not all) of the lights in the house stopped working at the same time?
   a. Check the fuses or the circuit breakers.
   b. Check each light fixture.
   c. Check the light switches and then check the fuses or the circuit breakers.
   d. None of the above

7. Which one of the following makes a ceiling fan turn?
   a. Strong electrostatic force.
   b. Electromagnetic fields.
   c. Inductive feedback.
   d. Rotational inductions.

8. How do you reset a circuit breaker?
   a. Turn the dial to the right until it clicks.
   b. First push it fully to the "off" position, then fully to the on position.
   c. A circuit breaker melts and cannot be reset.
   d. Remove the breaker from the service panel, adjust the reset screw and reinstall the breaker.

9. How many terminals are there on a standard flourescent tube light?
   a. 2.
   b. 3.
   c. 4.
   d. 6.

10. What device can you use to measure electrical continuity?
   a. An ohm meter.
   b. A Voltmeter.
   c. Both a. and b.
   d. Neither a. nor b.

True or False Questions. Circle the correct answer.

11. True False Gathering information is part of the troubleshooting process.

12. True False A light bulb can be used as a switch.

13. True False A short circuit is better than an open circuit.

14. True False AC voltage come from a battery.

15. True False DC voltage comes from the mains (the wires from the street).

16. True False High Resistance causes heat dissipation.

17. True False Water Conducts Electricity.

18. True False Fuses are an intentional weak link in a circuit.

19. True False Concerning wire gauge thickness: 22 AWG is thicker than 20 AWG.

20. True False In flourescent tube lights "choke" and "ballast" are the same thing.

21. True False In an automobile, the starter is a kind of fuse.

22. True False A cell or battery produces electricity through a chemical process.

23. True False A connection point on a device can be called a terminal.

24. True False A battery and a wire are all that are needed to make a useful circuit.

25. True False You can make a circuit without using a switch.

26. True False The "Load" is the part of the circuit that does the "work".

27. True False Insulators make good conductors of electricity.

28. True False Certain kinds of wire strippers can strip different wire gauges.

29. True False A "Branch" circuit uses wood to conduct electricity.

30. True False A vehicle battery provides 50 volts to the system.

31. True False Some switches can have three teminals on them.

32. True False A special "Test Light" can be used to verify AC voltage is present.

33. True False A Digital Multi-Meter can only measure AC and DC Voltage.