THE COMPLETE GUIDE TO WIRING

DIY HOME ELECTRICAL INSTALLATIONS & REPAIRS WITH STEP-BY-STEP GUIDE

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The Complete Guide to Wiring

DIY Home Electrical Installations &
Repairs with Step-by-Step Guide

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DEDICATION

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Common Wiring Project

Electrical Wiring Color Coding System

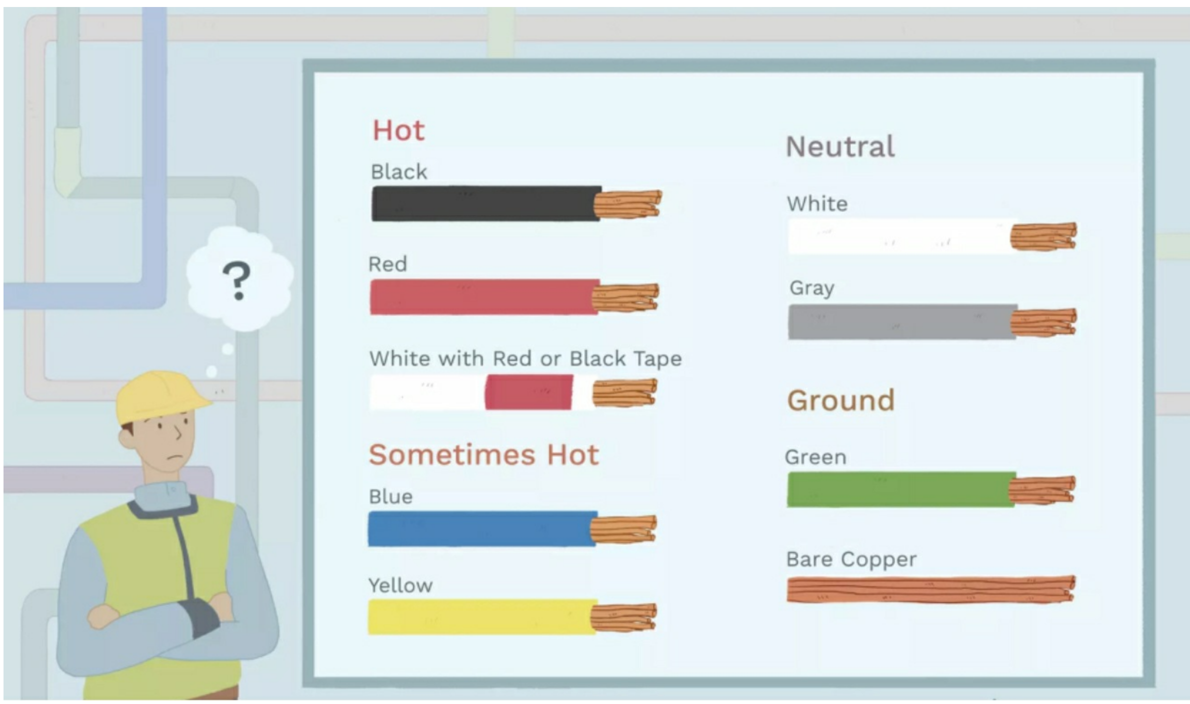
Opening up an outlet or light switch box, you might be confronted with a bewildering array of wires of different colors. Black, white, bare copper, and other colors closely intermingle, yet each one has a specific purpose.

Knowing the purpose of each wire will keep you safe and your house's electrical system in top working order.

Electrical Cable and Wire Color Markings

Non-metallic (or NM) 120-volt and 240-volt electrical cable come in two main parts: the outer plastic sheathing (or jacket) and the inner, color-coded wires. The sheathing binds the inner wires together, and its outer markings indicate the number of wires and size of wire (gauge) within the sheathing. The color of the sheathing indicates recommended usages. For example, white sheathing means that the inner wires are 14-gauge and yellow sheathing indicates that they are 12-gauge.

But looking deeper, the color of the wires inside of the sheathing reveals that different colored wires serve different purposes. The National Electrical Code (NEC) says that white or gray must be used for neutral conductors and that bare copper or green wires must be used as ground wires. Beyond that are general, industry-accepted rules about wire color that indicate their purpose.



Black Wires: Hot

Black insulation is always used for hot wires and is common in most standard household circuits.

The term "hot" is used for source wires that carry power from the electric service panel to a destination, such as a light or an outlet. Even though you are permitted to use a white wire as a hot wire by marking it with electrical tape, the opposite is not recommended or allowed. In other words, do not use a black wire as a neutral or ground wire, or for any purpose other than for carrying live electrical loads.

Red Wires: Hot

Red wires are used to designate hot wires.

Red wires are sometimes used as the second hot wire in 240-volt installations. Another useful application for red wires is to interconnect hardwired smoke detectors so that if one alarm is triggered all of the others go off simultaneously.

White Wires With Black or Red Tape: Hot

When a white wire is augmented with a red or black color marking, this often indicates that it is being used as a hot wire rather than a neutral wire. Typically, this is indicated with a band of black or red electrical tape (but other colors may be used) wrapped around the wire's insulation.

For instance, a white wire in a two-wire cable may be used for the second hot wire on a 240-volt appliance or outlet circuit. This white wire should be looped several times around with black electrical tape to show that it is being used for something other than a neutral.

Bare Copper Wires: Ground

Bare copper wires are the most common type of wire used for grounding.

All electrical devices must be grounded. In the event of a fault, grounding provides a safe pathway for electricity to travel. The current passes back to the ground or earth. Bare copper wires connect to electrical devices, such as switches, outlets, and fixtures, as well as metal appliance frames or housings. Metal electrical boxes also need ground connection because they are made of a conductive material. Plastic boxes are nonconductive and do not need to be grounded.

Green Wires: Ground

Green insulated wires are sometimes used for grounding.

Ground screws on electrical devices are often painted green, too. Never use a green wire for any purpose other than for grounding.

White or Gray Wires: Neutral

White or gray indicates a neutral wire.

When examining a white or gray wire, make certain that it has not been wrapped in electrical tape. This would indicate a hot wire. Older wires sometimes may lose their electrical tape wrapping. So, if the box has a loose loop of tape inside of it, there is the possibility that it may have come off of the neutral wire.

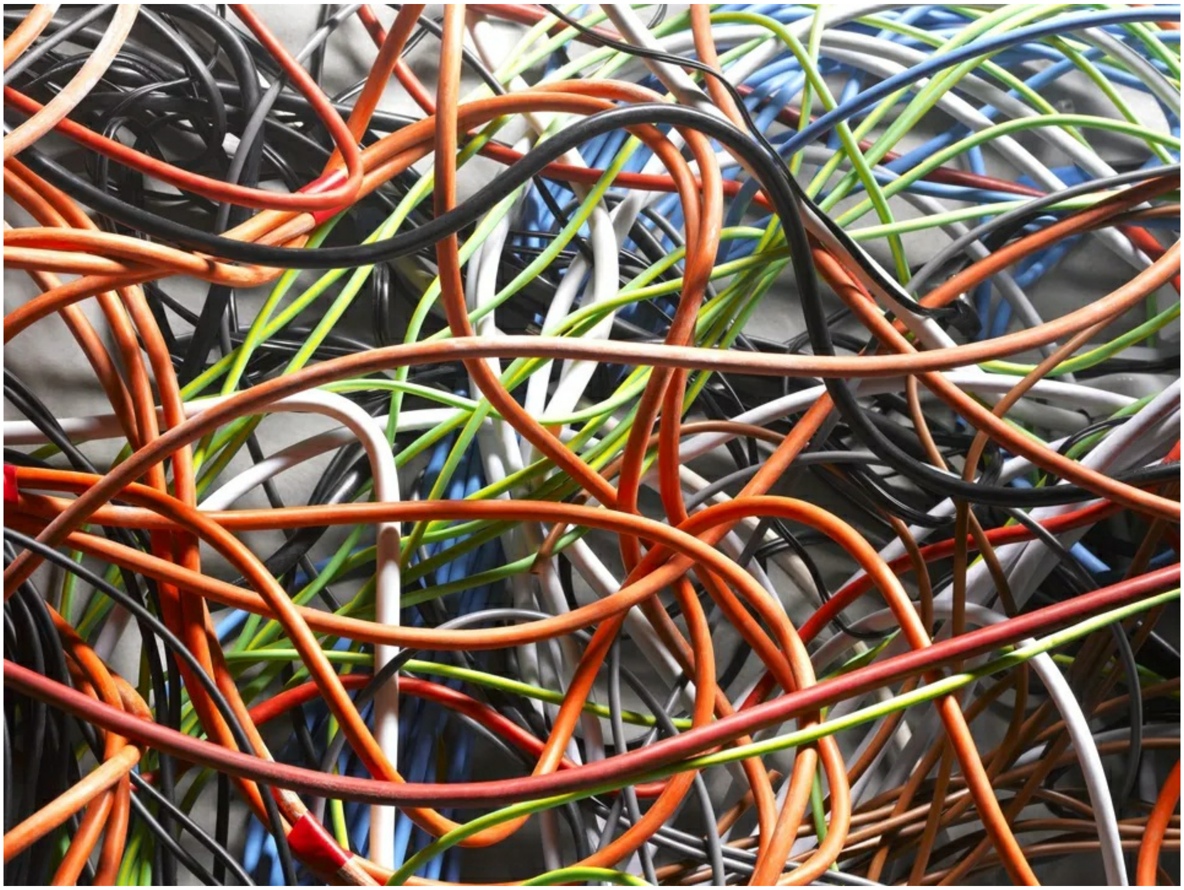
The term neutral can be dangerously deceiving as it appears to imply a non-electrified wire. It is important to note that neutral wires may also be carrying power and can shock you. While wires designated as hot (black or red insulated wires) carry power from the service panel (breaker box) to the device, neutral wires carry power back to the service panel. Thus, both hot and neutral wires have the potential to shock and injure you.

Blue and Yellow Wires

Blue and yellow wires are sometimes used as hot wires inside an electrical conduit.

Rarely are blue and yellow wires found in NM cable. Blue wires are commonly used for travelers in a three-way and four-way switch applications.

Matching Wire Size to Circuit Amperage



Whenever a circuit is extended or rewired, or when any new circuit is installed, it is critical that the new wiring is made with wire conductors that are properly sized for the amperage rating of the circuit. The higher the amperage rating of the circuit, the larger the wires need to be in order to avoid excess heat that can melt wires and cause fires. The proper circuit size, as indicated by amperage, is determined by several factors, including the planned load on the circuit, the number of outlets or light fixtures, and the length of the circuit. Once the proper amperage is determined, though, it is critical, that the wire gauge used in the circuit is appropriate for the amperage of the circuit breaker.

How Wires Are Sized

If you've shopped for electrical wire, you have likely noticed that there are many types and sizes of wire to choose from. Different types of wire are intended for different uses, but with any of these wire types, knowing the right wire size, or gauge, is key to making the right choice.

Wire is sized by the American Wire Gauge (AWG) system. Wire gauge refers the physical size of the wire, rated with a numerical designation that runs opposite to the diameter of the conductors—in other words, the smaller the wire gauge number, the larger the wire diameter. Common sizes include 14-, 12-, 10-, 8-, 6-, and 2-gauge wire. The size of the wire dictates how much current can safely pass through the wire.

Electrical current is measured in ampacity, and each wire gauge has a maximum safe carrying capacity. For standard non-metallic (NM) cable, these amperage capacities are:

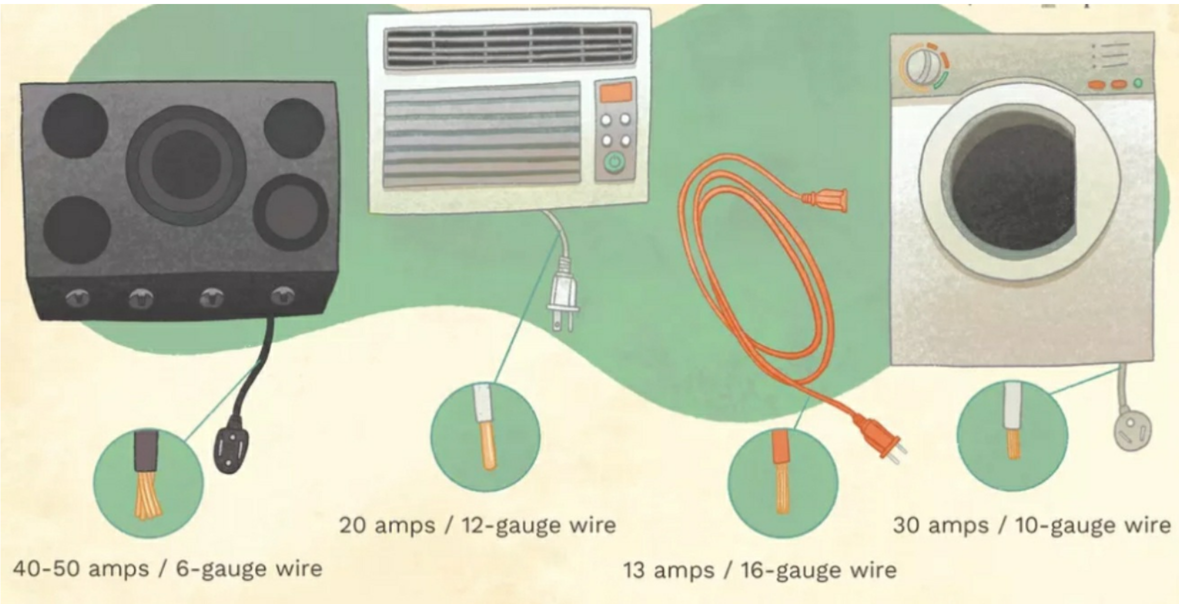
Amperage Capacities for Standard Non-Metallic (NM) Cable

14-gauge wire	15 amps
12-gauge wire	20 amps
10-gauge wire	30 amps
8-gauge wire	40 amps
6-gauge wire	55 amps
4-gauge wire	70 amps
3-gauge wire	85 amps
2-gauge wire	95 amps

These ratings are for standard copper NM sheathed cable, but there are instances where these amperage ratings vary. For example, there is aluminum wiring in some homes, and aluminum wires have their own ampacity-carrying capacity. Aluminum wiring was once widely used, but because it was found that aluminum had a greater expansion profile under load, it often loosened wire connections and sometimes caused electrical fires. That is not to say you are necessarily at risk just because you have aluminum wiring, because those connections may work forever if not overloaded. But an evaluation and replacement with copper wiring may be a good idea.

Stranded vs. Solid Wire

One more thing to keep in mind is to select the style of wire that best fits your needs. Some wire is stranded, while other wire consists of a solid copper conductor. In installations using metal conduit, the solid wire doesn't always pull as easily if the conduit has a large number of bends. But solid wire is usually easier to secure under screw terminals, such as those found on standard switches and receptacles. In standard usage, though, the wire conductors in conduit or NM cable for household wiring will be 14-, 12- or 10-gauge wire that is a solid copper conductor.



Why Wire Gauge Is Important

While circuit breakers or fuses offers good protection against overloading wires and overheating them, they are not absolute protection. Both these devices are designed to sense current overloads and to trip or "blow" before the wires can overheat to the danger point. But they are not foolproof, and it is still important to guard against exceeding the amperage rating of any given circuit by plugging too many appliances into them.

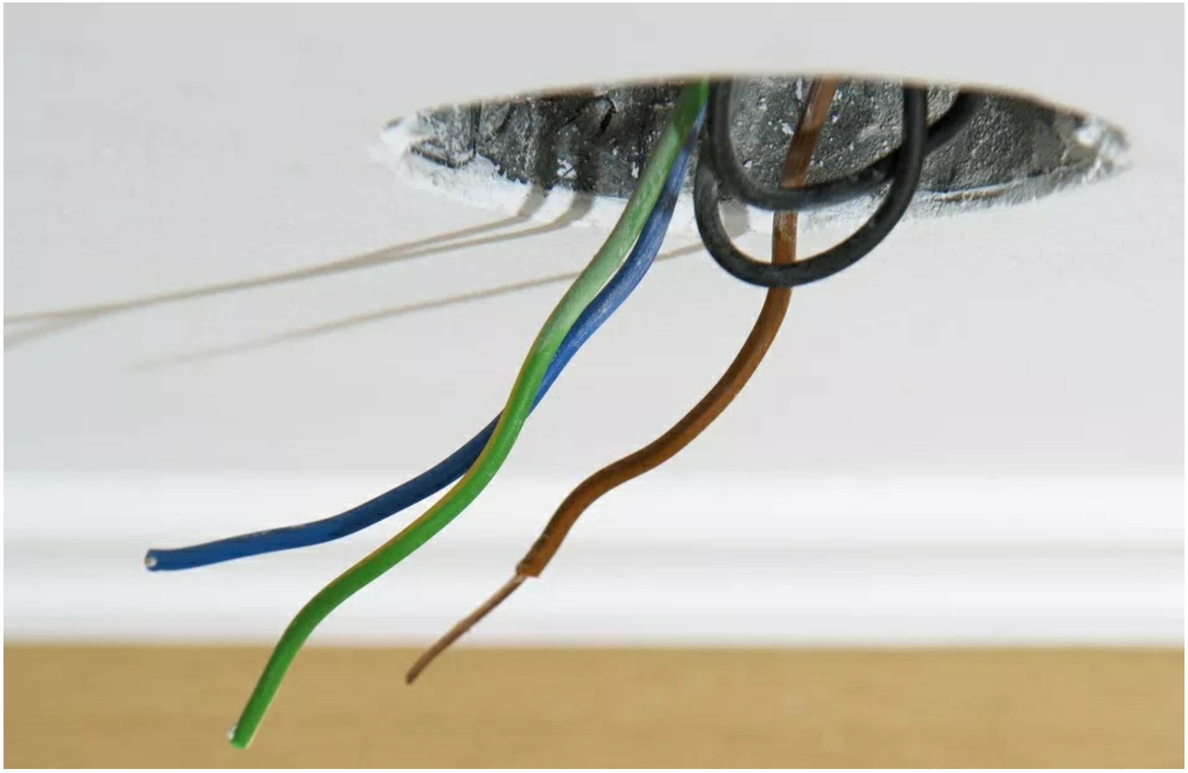
There is the potential for danger anytime a device or appliance tries to draw more power on a circuit than the wire gauge is rated for. For example, plugging a heater rated for 20 amps into a 15-amp circuit wired with 14-gauge wire poses a distinct danger. Should the circuit breaker fail to operate correctly, that heater will draw more current than the wires can safely handle, and could heat the wires to the point of melting the insulation around the wires and igniting surrounding materials.

On the other hand, there is no danger whatsoever by plugging appliances with mild electrical loads into circuits with heavier gauge wires and a higher amperage rating. The circuit will draw the power asked for by whatever is plugged into them and no more. So, for example, running a laptop computer with a very small amperage demand on a 20-amp circuit wired with 12-gauge wire is perfectly fine.

The potential for danger is most pronounced with the use of light household extension cords. Many a household fire has occurred when a light extension cord with 16-gauge wire is used to power a heater or heating appliance of some sort. Most manufacturers will discourage the use of any extension cords with portable heaters, but if one must be used, it has to be a heavy-duty cord with a high amperage rating that matches the amperage of the appliance and of the circuit it is plugged into.

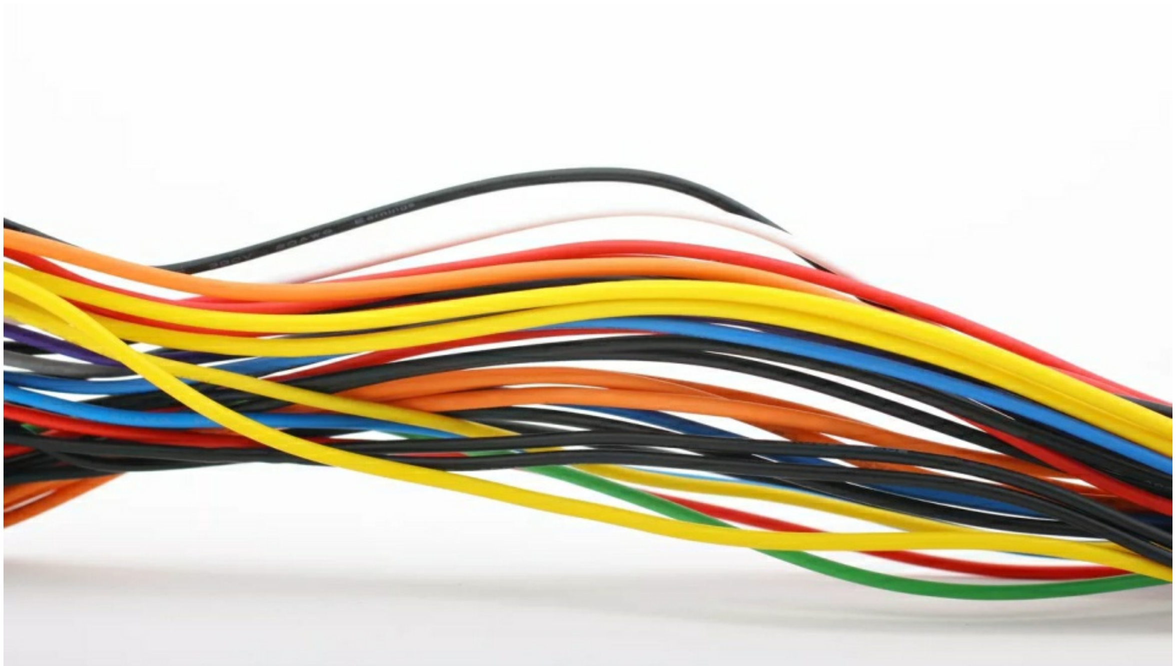
Wire Use	**Rated Ampacity**	**Wire Gauge**
Low-voltage lighting and lamp cords	10 amps	18-gauge
Extension cords (light-duty)	13 amps	16-gauge
Light fixtures, lamps, lighting circuits	15 amps	14-gauge
Kitchen, bathroom, and outdoor receptacles (outlets); 120-volt air conditioners	20 amps	12-gauge
Electric clothes dryers, 240-volt window air conditioners, electric water heaters	30 amps	10-gauge
Cooktops and ranges	40-50 amps	6-gauge
Electric furnaces, large electric heaters	60 amps	4-gauge

Common Types of Electrical Wire Used in the Home



Knowing the basic wire types is essential to almost any electrical project around the house. When you're installing new wiring, for example, choosing the right wire or cable is half the battle. And when you're examining existing wiring in your home, identifying the wire type can tell you a lot about the circuit the wiring belongs to—for example, when you open up a junction box and need to determine which wires go where. Wiring for modern homes is quite standard, and most homes built after the mid-1960s have similar types of wiring. Any new electrical installation requires new wiring that conforms to local building codes.

1. Wiring Terminology



It helps to understand a few basic terms used to describe wiring. An electrical wire is a type of conductor, which is a material that conducts electricity. In the case of household wiring, the conductor itself is usually copper or aluminum (or copper-sheathed aluminum) and is either a solid metal conductor or stranded wire. Most wires in a home are insulated, meaning they are wrapped in a nonconductive plastic coating. One notable exception is ground wires, which are typically solid copper and are either insulated with green sheathing or uninsulated (bare).

The most common type of wiring in modern homes is in the form of nonmetallic (NM) cable, which consists of two or more individual wires wrapped inside a protective plastic sheathing. NM cable usually contains one or more “hot” (current-carrying) wires, a neutral wire, and a ground wire.

As an alternative to NM cable, individual wires can be installed inside of a rigid or flexible metal or plastic tubing called conduit. Conduit is typically used where the wiring will be exposed and not hidden inside walls, floors, or ceilings.

These larger wires in your home are carrying circuit voltage, and they can be very dangerous to touch. There are also several wires in your home that carry much lesser amounts of "low-voltage" current. These are less dangerous, and with some, the voltage carried is so low that there is virtually no chance of shock. However, until you know exactly what kind of wires you are dealing with, it's best to treat them all as dangerous.

2. NM Cable

Often called “Romex” after one popular brand name, NM cable is a type of circuit wiring designed for interior use in dry locations. Most NM cables have a flattened tubular shape and run invisibly through the walls and floor cavities of your home. Almost all of the wiring in outlets and light fixtures a modern home is NM cable. The most common sizes and their amperage (amp) ratings are:

- 14-gauge (15-amp circuits)
- 12-gauge (20-amp circuits)
- 10-gauge (30-amp circuits)
- 8-gauge (40-amp circuits)
- 6-gauge (55-amp circuits)

NM cable is now sold with a color-coded outer jacket to indicate its wire gauge:

- White sheathing indicates NM cable with 14-gauge conductors.
- Yellow sheathing indicates NM cable with 12-gauge conductors.
- Orange sheathing indicates NM cable with 10-gauge conductors.
- Black-sheathed cable is used for both 6- and 8-gauge wire.
- Gray sheathing is not used for NM cable but is reserved for underground (UF) cable.

NM cable is dangerous to handle while the circuit handles are carrying voltage.

3. UF Cable

Underground Feeder (UF) is a type of nonmetallic cable designed for wet locations and direct burial in the ground. It is commonly used for supplying outdoor fixtures, such as lampposts. Like standard NM cable, UF contains insulated hot and neutral wires, plus a bare ground wire. But while sheathing on NM cable is a separate plastic wrap, UF cable sheathing is solid plastic that surrounds each wire. UF cable is normally sold with gray outer sheathing.

UF cable is also used for major circuit wiring, and it carries a dangerous amount of voltage as long as the circuits are turned on.

4. THHN/THWN Wire

THHN and THWN are codes for the two most common types of insulated wire used inside the conduit. Unlike NM cable, in which two or more individual insulated conductors are bundled inside a plastic sheathing, THHN and THWN wires are single conductors, each with its color-coded insulation. Instead of being protected by NM cable sheathing, these wires are protected by tubular metal or plastic conduit.

Conduit is often used in unfinished areas, such as basements and garages, and for short exposed runs inside the home, such as wiring connections for garbage disposers and hot water heaters. The letters indicate specific properties of the wire insulation:

- **T**: Thermoplastic
- **H:** Heat-resistant; HH means highly heat-resistant
- **W**: Rated for wet locations
- **N:** Nylon-coated, for added protection

THHN and THWN wires have colored sheathings that are generally used to identify their function in a circuit:

- **Hot wires**: Black, red, orange
- **Neutral wires**: White, brown
- **Ground wires:** Green, yellow-green

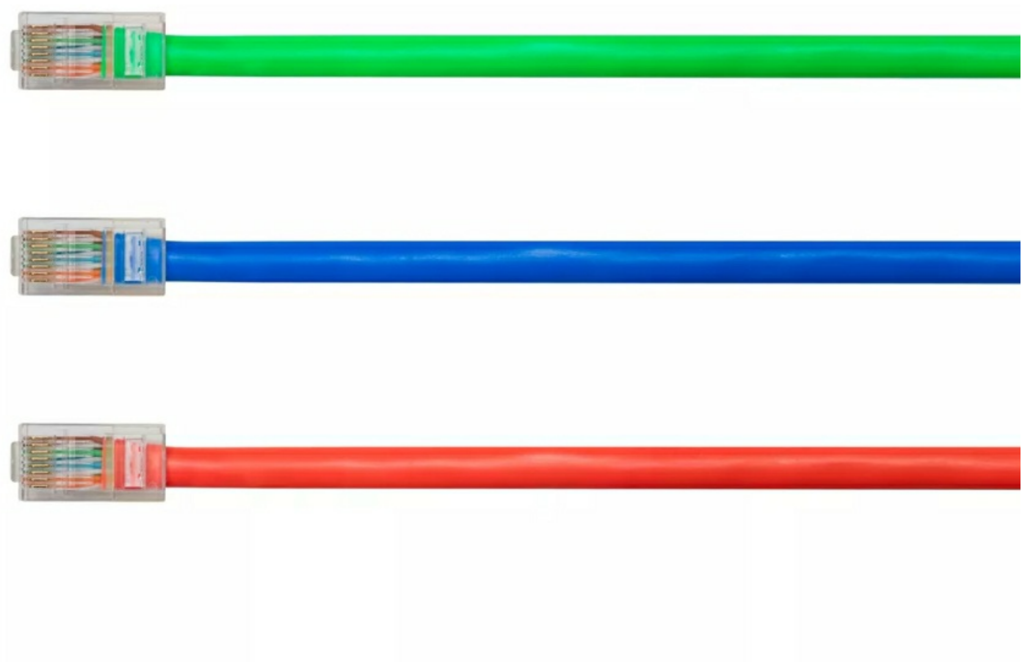
THHN and THWN wires are circuit wires that should never be handled when the circuits are turned on.

5. Low-Voltage Wire

Low-voltage wiring is used for circuits typically requiring 50 volts or less. Several common types are landscape lighting wire, sprinkler system connections, bell wire (for doorbells), speaker system wires, and thermostat wires. Wire sizes range from about 22 gauge to 12 gauge. Low-voltage wires typically are insulated and may be contained in cable sheathing or combined in twisted pairs, similar to lamp cord wire. It must be used only for low-voltage applications. These are typically very small wires that are much different from standard circuit wiring.

Serious shocks rarely occur with low-voltage wires, but it is still always best to turn off devices before working with them.

6. Phone and Data Wire



Telephone and data wiring are low-voltage wires used for “landline” telephones and internet hookups. Telephone cable may contain four or eight wires. Category 5 (Cat 5) cable, the most common type of household data wiring, contains eight wires wrapped together in four pairs. It can be used for both phone and data transmission and offers greater capacity and quality than standard phone wire.

Although data wiring does carry a small amount of voltage, anything under 30 volts is generally regarded as safe (a household circuit carries about 120-volts of power). However, there is always a danger of data wiring coming into contact with household wiring, so you should treat it with caution and avoid touching bare wires.

7. Coaxial Cable

Coaxial cable is beginning to grow less common, thanks to the use of other forms of data wiring, such as HDMI, for television data transmission.

Coaxial cable is a round jacketed cable that features an inner conductor surrounded by a tubular insulating layer, surrounded by a tubular conducting shield made of braided wire. It can be identified by the threaded connectors that are used to make unions and device hookups.

Coaxial cable was once the standard for connecting televisions to antenna or cable service delivery and is still often used to connect satellite dishes or to bring subscription television service to an in-home distribution point. It typically has black or white insulation and is perfectly round in shape, making it easy to distinguish from NM electrical circuit cables.

The minuscule amount of voltage carried by coaxial cable signals makes it very unlikely to cause shock of any type—provided the cables are not in contact with another source of current.

Sizing Electrical Wire for Underground Circuit Cable

Underground wire for a residential circuit usually is installed with underground feeder (UF) cable, which is rated for outdoor use and direct burial. Such an installation is typical when running a circuit to an outdoor location, such as a garage shed or other outbuilding, or to a yard light or water feature. Sizing the wires, or conductors, for an underground cable is no different than sizing for other household circuits and is typically based on the total load, or electrical demand, of the devices on the circuit. However, if the cable run is long, as underground runs often are, you may need to increase the wire size to account for voltage drop—a loss of voltage in the circuit caused by the natural resistance in the wires. Voltage drop occurs in any wire run, but it is rarely a problem with indoor wiring, where the distance from the circuit breaker panel to the end of the circuit is usually relatively short. Outdoor circuits, however, are often quite long and the voltage drop can be significant.

Understanding Voltage Drop

All conductors of electricity, including wires, impose some resistance to the flow of electricity. One effect of this resistance, also called impedance, is a loss of voltage. This is known as voltage drop and is represented as a percentage of the total voltage supplied at the power source of the circuit. If you measure the voltage of a circuit at the service panel (breaker box), you should get a reading of around 120 volts (for a standard circuit). If you take another measurement of the circuit at the farthest device from the panel and get a reading of 114 volts—a difference of 6 volts—that circuit has a 5 percent voltage drop (5 percent of 120 = 6).

Excessive voltage drop means that motors, appliances, and other devices don't run as fast or efficiently as they are designed to. This can lead to decreased performance, unnecessary wear, and even premature failure of electrical equipment. Voltage drop is also a waste of electricity because the energy is lost as heat rather than being available for use by the circuit devices.

Causes of Voltage Drop

Since voltage drop is caused by the resistance of conductors, the more conductors you have, the greater the voltage drop. When it comes to underground wire, the longer the wire, the greater the voltage drop. Wire size is another factor: Smaller-diameter wires have more resistance than larger-diameter wires. Copper wire has lower resistance than aluminum wire, but chances are good that you'll be using copper in any case. These days, the only aluminum used in most new residential projects is in the service entrance cables from the utility, although you may see aluminum show up on voltage drop tables.

How Load Affects Voltage Drop

Voltage drop increases as the load on a circuit increases, and overloading a circuit contributes to excessive voltage drop. In other words, if you put too many loads on one circuit and exceed the standard 80 percent safe capacity (1,440 volts for 15-amp circuits; 1,920 volts for 20-amp circuits), you'll add unnecessary voltage drop. The solution is simple: Keep the total load on the circuit to 80 percent or less of total capacity. This condition is assumed in many voltage drop calculations and tables.

Sizing the Conductors

The National Electrical Code (NEC) recommends a maximum voltage drop of 3 percent for individual household circuits (known as branch circuits). This is a good goal to shoot for when sizing the conductors for an underground cable. The following are the maximum lengths of cable you can use while still maintaining a 3 percent voltage drop for the given wire size (AWG) and circuit voltage. As an example, for a 120-volt circuit, you can run up to 50 feet of 14 AWG cable without exceeding 3 percent voltage drop.

For 120-volt circuits:

14 AWG	50 feet
12 AWG	60 feet
10 AWG	64 feet
8 AWG	76 feet
6 AWG	94 feet

For 240-volt circuits:

14 AWG	100 feet
12 AWG	120 feet
10 AWG	128 feet
8 AWG	152 feet
6 AWG	188 feet

Electrical Wiring Needed for a Bathroom

Bathrooms are damp and can use a lot of power. This creates special needs when it comes to wiring. This article will help you plan for appropriate electrical wiring to cover lighting, airflow, and safety devices in your bathroom. Everything from watertight lighting fixtures in bathing areas to effective ventilation to GFCI outlets for safety must be considered.

Lighting

We all know that bathrooms tend to be one of the darker rooms of the house. For that reason, plenty of lights should be installed to provide enough general illumination but also to enhance areas like mirrors, showers, closets, and bathtub areas.

Bath and shower areas must have special fixtures. Light fixtures for these areas carry one of two ratings: damp locations and wet locations. A bathing area, sometimes called the "shower zone," includes the tub or shower area itself and the adjacent room area measured three feet horizontally from the rim of the tub or shower stall (that is, measuring straight out into the room) and eight feet vertically from the tub rim (measuring straight up). Any light fixture in this zone must be at least rated for damp locations. However, if the fixture is potentially subject to spray from the shower, it must be rated for wet locations.

When it comes to lighting around the mirror, side lights are best. Overhead lighting, especially recessed lights, leave your face in shadow when you get close to the mirror. They also highlight how much your hair is thinning (isn't it better not to know?). Sidelights, such as wall sconces or vertical strip lights, can be combined with lights mounted on the wall above the mirror for fuller illumination.

Ventilation Fans

Bathrooms are notorious for being moist, and some don't have windows to remove the moisture and odors. Even if you have a window, a bathroom vent fan is more effective at exhausting moisture and odors, and you don't lose as much heat in the winter. Vent fans are required in all new bathrooms and remodels. You can install a vent fan with a built-in heater, but this has different wiring requirements than a standard fan without a heater (we'll get to the wiring in a minute).

Power Outlets

You can provide GFCI protection with a GFCI circuit breaker or by installing one or more GFCI outlets on the receptacle circuit. When using a single GFCI outlet for protection, it must be wired for "multiple-location" protection so that it protects all of the outlets downstream on the same circuit.

❖ ***Warning***

All outlets or receptacles in a bathroom must be GFCI-protected. This is a critical safety device to help prevent shock hazards, a very real concern in a bathroom.

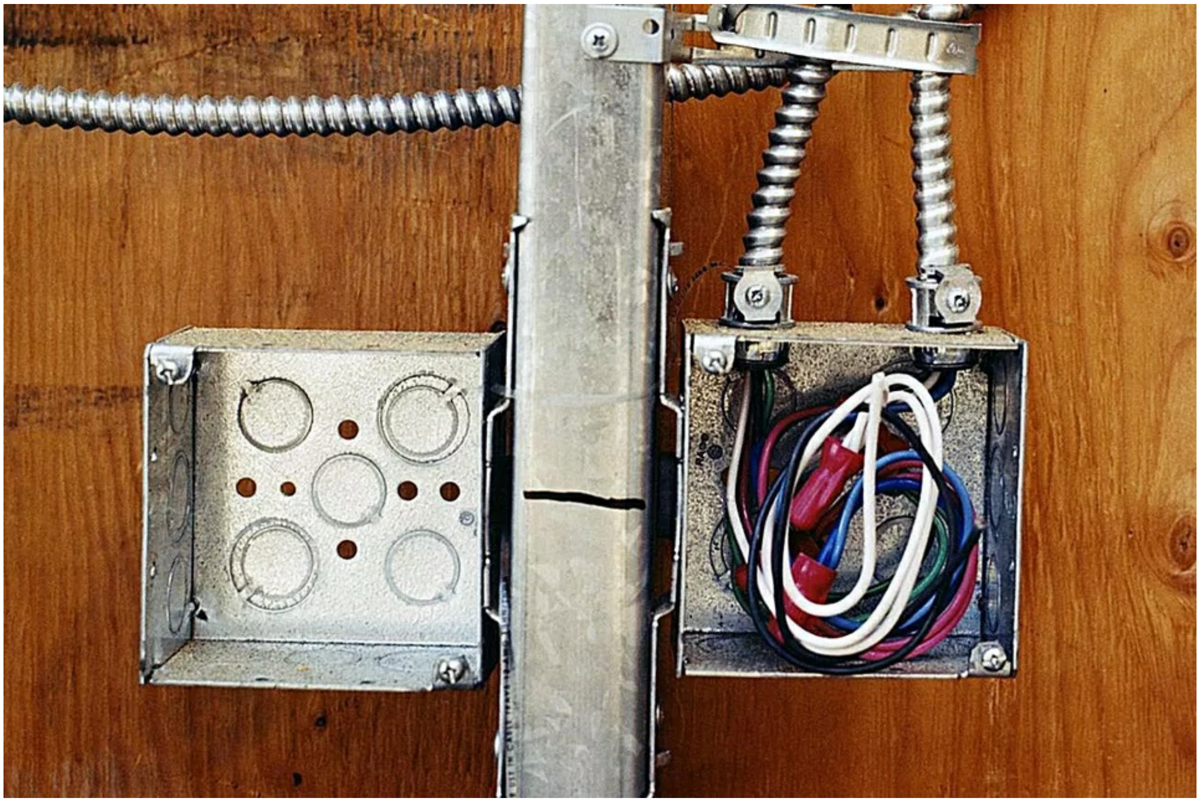
Bathroom Circuits

A basic wiring plan for a bathroom includes a 20-amp, GFCI-protected circuit for the receptacles and a 15-amp general lighting circuit for the switches, light fixtures, and vent fan. In some areas, the lighting and receptacles must be on separate circuits so that if a receptacle trips the circuit breaker, the lights won't go out. In other areas, it's permissible to install the lighting, receptacles, and a standard vent fan on a single 20-amp circuit provided the circuit serves only the bathroom and no other rooms.

If the vent fan has a built-in heater, it must have its own 20-amp circuit. This is called a "dedicated" circuit because it serves only one appliance or fixture. Heat lamps, wall heaters, and other built-in heating appliances may also require dedicated circuits.

Learn about bathroom wiring requirements in your area by contacting the local building department.

Determine Proper Electrical Wire Gauge, Ampacity, and Wattage Load



If you've ever gone to the store with the intent on buying some electrical wire for a project at home, you may have noticed that there are many types and sizes of wire to choose from. These electrical wires are used for powering all types of devices, appliances, and lighting in your home, but knowing what the right size wire is needed for each is the secret to a safe and effective wire choice.

Here are some great tips for determining the proper wire gauge, ampacity, and the maximum wattage allowed. Determining the proper size wire to use can be easy if you know what amperage and wattage a wire can carry per wire gauge. The trick is to have the right sized wired fitted to the power demand it will have on the circuit. Although some wires look the same and even look to be the same size, it doesn't mean that they can handle the amperage. For instance, copper wire can handle more than aluminum wire and should always be your choice of wiring to install in your home. Aluminum wiring was used years ago, being cheaper, but due to the softer wiring becoming heated and then becoming loose within the wiring connection points, the practice of using aluminum wire has faded. Copper wire is a superior choice and the standard in wiring techniques.

Wire gauge is the physical size of the wire, rated in gauge size. For instance, common sizes include 14-, 12-, 10-, 8-, 6-, and 2-gauge wire. The gauge of the wire dictates the amount of current that can safely pass through the electrical wire. Electrical current is measured as ampacity. As a guide, #14 wire is good for 15 amps, #12 wire is good for 20 amps, #10 wire is good for 30 amps. As the number gets smaller, the size of the wire gets larger and the amount of amps it can handle also gets larger. This little tip can help you choose the correct sized wire.

Ampacity is defined as the measurement of how much electrical current can flow through an electrical wire safely. This ampacity should match the circuit size, meaning the circuit breaker or fuse that protects it. Speaking of that, remember to calculate the circuit load at no more than 80% of the circuit protection. That would mean that a 20-amp circuit should not be loaded more than 16 amps safely. Let's think of a motor on this same circuit that has a startup amperage larger than that of the run ampacity. This practice leaves plenty of startup amperage left over, that being 20% or 4 amps, to get the motor spinning. This is also true with many appliances in your home that use compressors and motors to cool like refrigerators and freezer.

Appliances are marked with a tag that informs you of the maximum wattage (load) that it takes to run. The maximum wattage of the appliance should never exceed the maximum wattage rating of the circuit it is connected to. If it does, a dedicated circuit should be run that is capable of handling the load. We've seen overloaded circuits, appliances plugged into extension cords that were too light to handle the load, and plugged into power strips that were actually trying to melt due to the load. These are great instances of potential electrical fires due to the wrong sized extension cords. In the event that you don't know, there are special extension cords called appliance cords that are designed to handle the load of appliances.

One more thing to keep in mind is to select wire that best fits your needs. Some wire is stranded, while other wire is solid. The solid wire doesn't always pull as easy in conduit with a large number of bends but is much easier to place underwire terminals like those on switches and outlets.

Understanding How Electrical Wiring Is Labeled

Insulation on electrical wires is stamped with various codes and numbering that indicates the wire type and performance characteristics of the insulation. Similarly, nonmetallic (NM) cable, which contains multiple wires, has markings on the outer sheathing of the cable. Understanding the basic markings helps you choose the right type of wire or cable for your project.

Labels On Individual Wires

Individually insulated wires typically are used for installation inside of conduit or flexible metal cable. The coding system relates to the performance characteristics of the wire insulation. The most common types of wire used in residential construction are THHN and THWN. Here's what the letter mean:

- **T**: Thermoplastic, a heat-resistant plastic used on many types of wire
- **H:** Heat-resistant up to 167 degrees F
- **HH**: Heat-resistant up to 194 degrees F
- **W**: Moisture-resistant; suitable for damp and wet environments

N: Nylon-coated to resist damage from oil and gasoline

Labels On Nonmetallic Cable

NM cable (including Romex and other types) is labeled on the outside of its plastic outer jacket, or sheathing. Cables may carry a variety of numerical codes and lettering, and this varies by manufacturer and cable type. But the most important labels indicate the number and size of wires inside the cable as well as the appropriate use of the cable. The most common types of cable used in homes include:

- **NM-B**: Standard NM cable suitable for indoor use in dry locations; older versions of NM cable labeled "NM" (without the "B") have a slightly lower temperature rating than today's NM-B cable
- **UF**: Underground Feeder cable suitable for outdoor exposure and direct burial in the ground
- **SE**: Service Entrance cable; outdoor-rated cable for above-ground applications; commonly used to bring power from the utility's transformer to the customer's house
- **USE**: Underground Service Entrance cable; similar to SE cable but rated for direct burial

The numbering on NM cable indicates the wiring size and the number of wires inside the cable. The first number is the wire size or gauge; the second number is the number of insulated wires. For example, "14/2" cable contains two 14-gauge insulated wires. Cable labeled 12/3 contains three 12-gauge insulated wires.

In addition to the insulated wires, most NM cable also includes a bare copper ground wire. The ground wire is not included in the labeled number but is usually indicated as "G," "w/G," or simply "with Ground." For example, "12-2 WITH GROUND" means the cable contains two 12-gauge insulated wires and a bare copper ground wire.

Finally, cables usually include the name of the manufacturer and a maximum voltage rating, which is typically 600 volts—well above the 240 volts that are standard for home electrical service.

The Importance of Wire Size

Wire size relates to the diameter of the metal conductor of the wire, excluding any insulation. It is important because the size (along with the wire material and a few other factors) determines how much electrical current the wire can safely carry. Wire size is measured by the American Wire Gauge (AWG) system. The smaller the AWG number the larger the wire and, generally speaking, the more current the wire can carry without overheating.

Current-carrying capacity is rated in amperes or amps. The wiring in any circuit must have the proper amp rating for the circuit devices and the circuit breaker protecting the circuit. For example, 14 AWG wire is rated for 15 amps and should use on standard 15-amp circuits. Other common wire sizes and their amperage ratings include:

- 12 AWG—20 amps
- 10 AWG—30 amps
- 8 AWG—40 amps
- 6 AWG—55 amps

Wiring Typical Laundry Circuits

It is commonplace for homes today to have three different circuits supplying the laundry room. The first is a 20-amp circuit to supply the 120-volt power for the washing machine. The second is a 30-amp dedicated circuit for running an electric dryer. The third is a standard 15-amp lighting circuit that likely supplies light fixtures in other rooms as well as the laundry area.

Washer Receptacle

The 120-volt, 20-amp circuit supplies a receptacle for the washing machine. It is typically wired with 12-gauge, two-wire cable containing a hot wire, a neutral wire, and a ground wire. The receptacle is a 20-amp GFCI receptacle. What's special about this circuit is that it is a designated circuit, not to be confused with a dedicated circuit. While a dedicated circuit supplies only one appliance, a designated circuit is intended for single-use, not necessarily a single appliance. The "use" in this case is laundry, and you can plug both a washer and a gas dryer into the same receptacle. Of course, if you're set up for a gas dryer, you won't need the 240-volt dryer receptacle we'll discuss next.

Dryer Receptacle

Electric dryers run on both 240-volt and 120-volt power. The 240V is for the dryer's heating element. The 120V is for the timer, clock, buzzer, and other bells and whistles. If you buy an electric dryer today, it will require a special appliance cord with a four-prong plug. This plug must be used with a 120/240V receptacle. And that's our next laundry room circuit. This receptacle is typically supplied by a 10-gauge, three-wire cable with two hot wires, a neutral wire, and a ground wire. The circuit is protected by a 30-amp circuit breaker. Older dryers typically had three-prong cords that fit only three-slot receptacles. Installing these is no longer allowed by the National Electrical Code (NEC).

Lighting Circuit

A laundry room would be pretty hard to use without a circuit for lighting. As mentioned, light fixtures in laundry rooms are likely to be on the same circuit as the lighting for an adjacent room or hallway. Standard lighting circuits are 15-amp circuits and often include general-use receptacles as well.

GFCI Protection

The NEC requires GFCI (ground-fault circuit interrupter) protection for all standard receptacles serving laundry areas. This includes the 20-amp designated receptacle for the washer (and gas dryer, as applicable) and any general-use receptacles. GFCI protection is not required for a 30-amp electric dryer receptacle.

Installation Options

When laundry rooms are finished with drywall or other finish material, receptacles typically are installed in the normal fashion, with the electrical boxes recessed into the wall and with NM cable running to the boxes. Alternatively, laundry rooms in basements or garages may have concrete, concrete block, or unfinished framed walls, in which cases the electrical boxes may be surface-mounted. This calls for metal boxes and wiring running through metal (typically EMT) conduit. Instead of NM cable, the installer can use individual THHN insulated wires.

Repair Project
Replace a Light Fixture

Is there a light fixture you want changed out in your house? There's no need to call a handyman or pay Home Depot out the wazoo to come do it for you. With no electrical experience whatsoever, I was able to quickly learn how to perform this quick and simple home maintenance task by watching someone more capable than I just once. Today, I'm passing that knowledge onto you.

The great part about changing light fixtures is that it's a pretty universal process. The light boxes in your ceiling are all the same size, and it's always the same three wires being connected/disconnected. No need to research your particular situation other than making sure the size of the fixture itself fits okay in the space you're putting it! In general, you can go out and buy any light fixture, and put it up in your home where any light fixture already exists. (The exception being ceiling fans; those have an extra wire. Generally, you want to install a new ceiling fan where there already was one.)

This article is specifically for replacing old light fixtures with new ones. To install a fixture in a brand new place where there was no light before is an endeavor that's usually only suited for licensed electricians.

Let's get to it!

1. Turn off power to the old fixture.

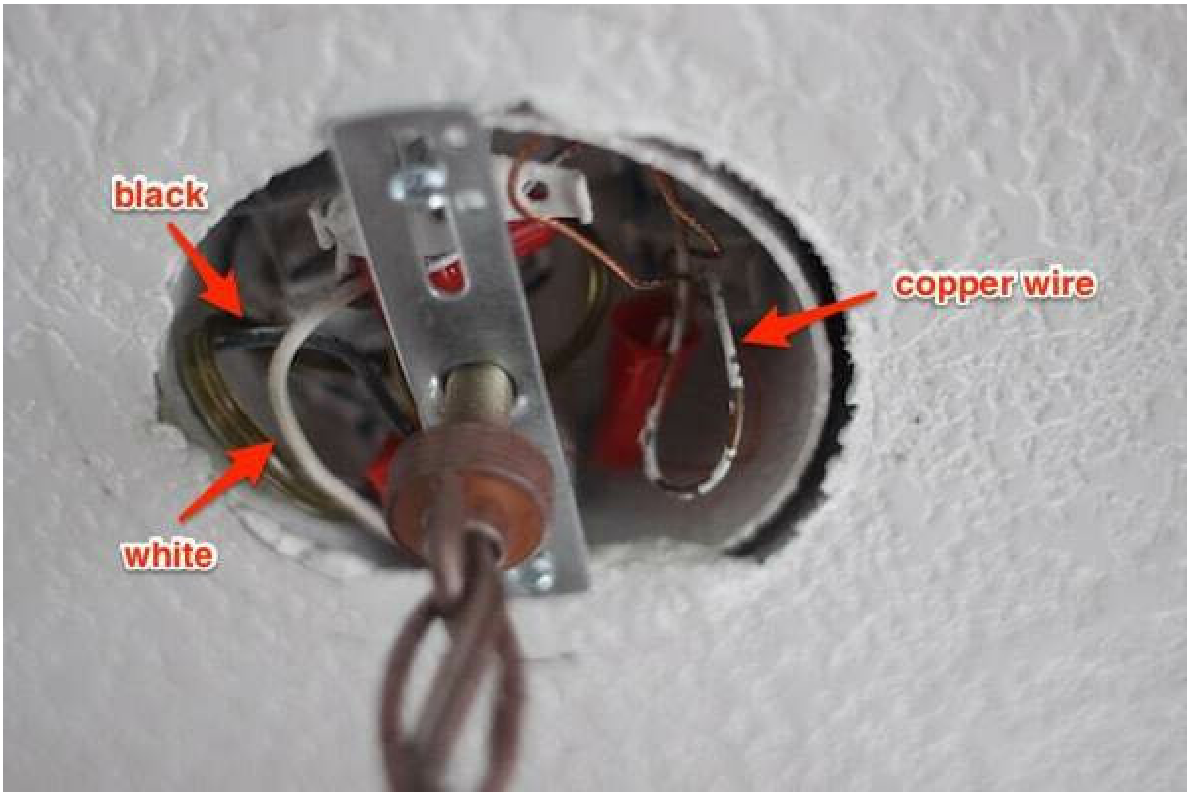
Your first task is to shut off power, at the source, to the fixture you're changing out. This means knowing where your electrical panel is, and flipping the right switch. When you do this, leave the light on that you're changing out, and when it shuts off, you'll know you got the right switch. (Labels in the panel should help too, but in my experience they're not always totally accurate.)

2. Remove the canopy to expose the wiring and fixture hardware.

The fixture I was replacing used a simple screw-on ring to hold up the canopy (and fixture). Each fixture is different, but no matter what it is, it should be pretty easy to figure out.

The canopy is the rounded, broad covering that lies flush to the ceiling and hides the ugly-looking wiring and hardware. There's usually some sort of screw holding the canopy in place; simply undo whatever mechanism is there and let the canopy drop down.

3. Unscrew the three wires: black, white, and copper.



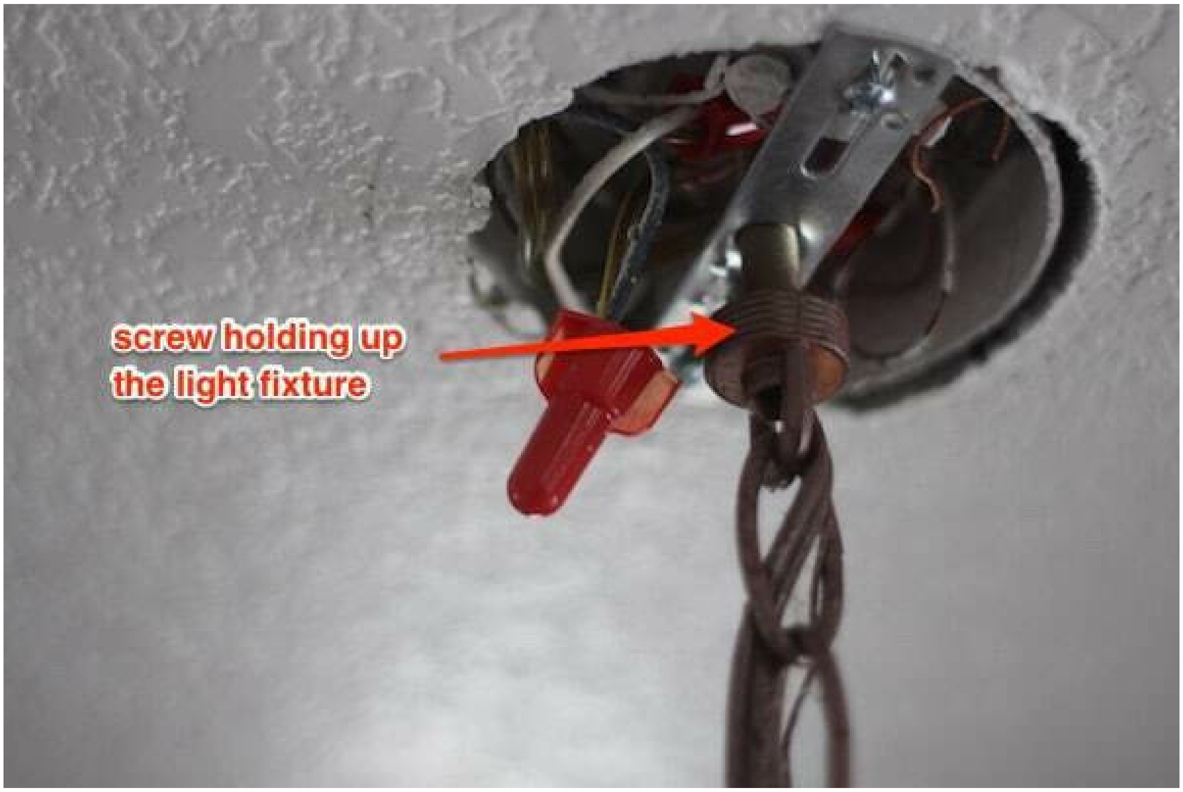
Three sets of wires, each held together by a red wire connector.

In a nutshell, when you're installing a light fixture, you're connecting three wires from the fixture to three wires installed in the ceiling, then mounting the fixture hardware. That's about all there is to it.

The red cap connects the wires from the ceiling to the fixture, and screws/unscrews just like anything else — lefty loosey, righty tighty.

So when you get the canopy off, you should see three three sets of wires — black, white, and green (or copper) — that need to be disconnected in order to remove the old fixture. Unscrew the wire connectors (the red parts in the image above), and separate the fixture wiring from the ceiling wiring.

4. Remove old light fixture.



Same image as above, this one pointing out how to remove the light fixture. Once the wires are disconnected, unscrew here and the fixture is off the ceiling. Again, this may vary given the light fixture you're working with.

After you've disconnected the wires, the old light fixture is generally free to be removed. There's no universal way they're attached to the ceiling or electrical box, but it's generally just a screw or two. Anchors aren't used, since you're anchoring is to the electrical box, which is firmly rooted in your ceiling. Helps to have another person handy, especially if it's a heavy and/or awkward light fixture.

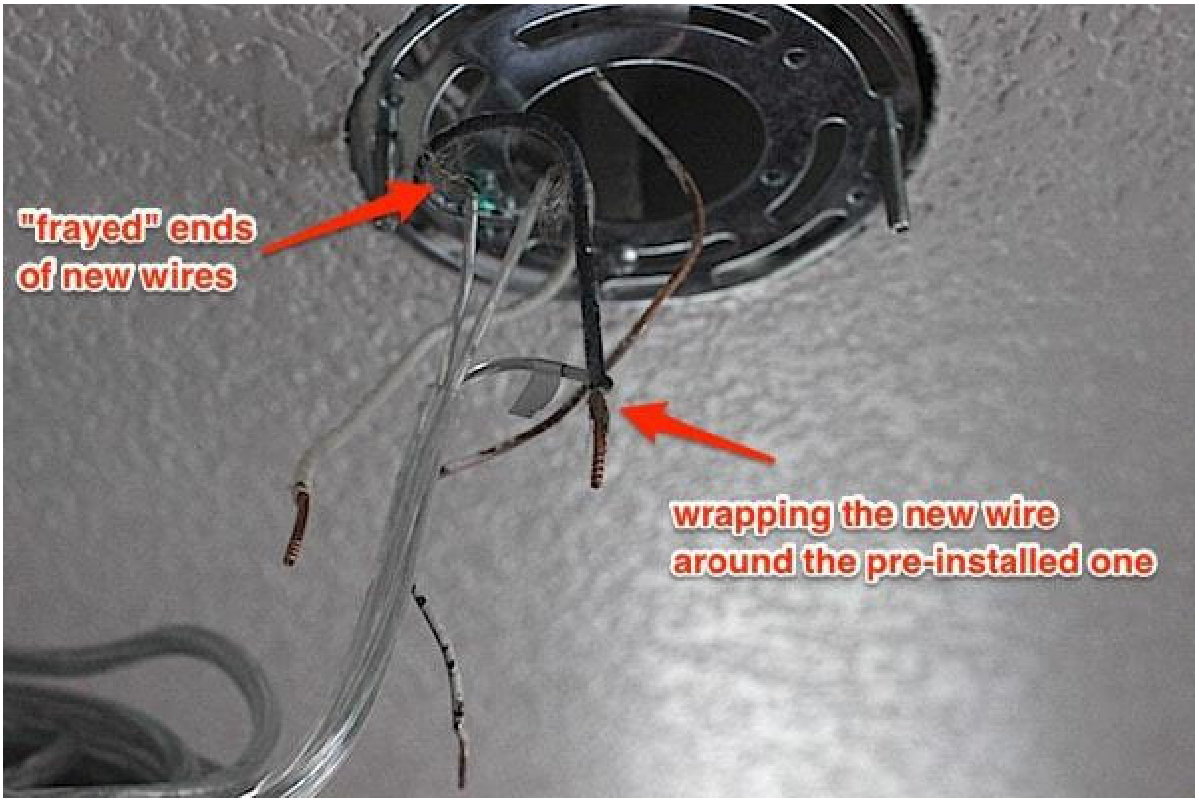
5. Install new bracket (sometimes).

Without the fixture, this is what your light box should roughly look like.

All light fixtures have a universally-sized, pre-wired box in the ceiling, which the three electrical wires descend from. There will be some sort of baseplate serving as the mounting hardware for your light fixture. It's either a single bar "strap" with a "nipple" screw (I hear you snickering…) or a circular, more universal mounting bracket. In all the light fixtures I've replaced, there's been a bar strap present, which I've replaced with a new mounting bracket, simply because that’s what has come with the fixture itself. Refer to your light fixture instructions for more guidance here, but if your fixture comes with a new bracket, you should use that.

New baseplate. The two screws holding it up to the ceiling are a universal distance apart. You can also see the green ground screw (more on that below).

6. Connect new fixture wires.



The wires descending from the ceiling will have bare ends, while the new wires will have what looks like frayed, silver ends. You can see that in the image above.

Twist the "frayed" threads on the end of the new black wire to the exposed end of the existing black wire, twist on a wire connector, and repeat with the white wire. The copper (or green) wire of the new fixture might be a little different; sometimes it connects to a green grounding screw and other times to a dedicated copper wire coming from the ceiling (electrical box). Refer to your light fixture instructions, and your individual situation: If there's a copper wire pre-installed in your ceiling, connect the new wire there. If you just have a small green screw on your mounting plate, wrap the new copper wire around that.

7. Secure the new fixture and adjust length (if there's a chain).

If there's a chain for the fixture — that is, it doesn't sit flush against the ceiling — now would be the time to adjust it to the proper length. Each fixture has a different mechanism for doing that, so refer to your individual instructions.

There's likely some extra chain/cord that needs to be shoved up into the ceiling, or hidden within the canopy. Do that at this time as well.

With all that taken care of, you can secure the new fixture, usually with just a couple screws into the mounting plate. It's much easier than putting up a new coat rack, or anchoring a heavy picture frame, in my opinion.

8. Restore power and test out the new fixture!

If you restore power and the light doesn't work, it's likely because either the white or black wires aren't fully connected. You'll have to pull down the fixture and inspect the wires and connections; I've had to do this just once among the handful of lights I've installed.

Repair a Chandelier

Older chandeliers often need repair. Many were manufactured with little regard to the heat the bulbs produce, and larger bulbs than recommended have often been installed. Overheating makes the wire insulation brittle. A typical fixture has cord running through tubes to the bulb sockets, allowing several opportunities for malfunctions.

Because sockets and the wires attached to them are near a hot bulb and often enclosed, they deteriorate. If all the lights do not work, the stem wire probably needs to be replaced. If some wiring needs to be replaced, consider rewiring the entire fixture—it won't take much longer.

If only one light fails to come on, try pulling up the contact tab inside the socket. Vacuum dust from the socket. If the bulb still does not light, remove the socket and test it.

A chandelier is often suspended by a chain, which must be securely anchored to the box hardware. The main wires run from the box down through the chain to a junction box. There they connect to wires that lead to individual light sockets.

Expect to spend nearly 3 hours dismantling, testing, and running new wires in a chandelier. You'll need to know how to test for power and strip and connect wires. Before you begin, line up a helper to assist with removing the fixture and lay a drop cloth on a work surface to cushion the fixture as you work on it.

What you need

Tools

Phillips screwdriver

Voltage tester

Continuity tester

Wire Strippers

Long-nose pliers

Cord wire

Electrician's tape

How to do it

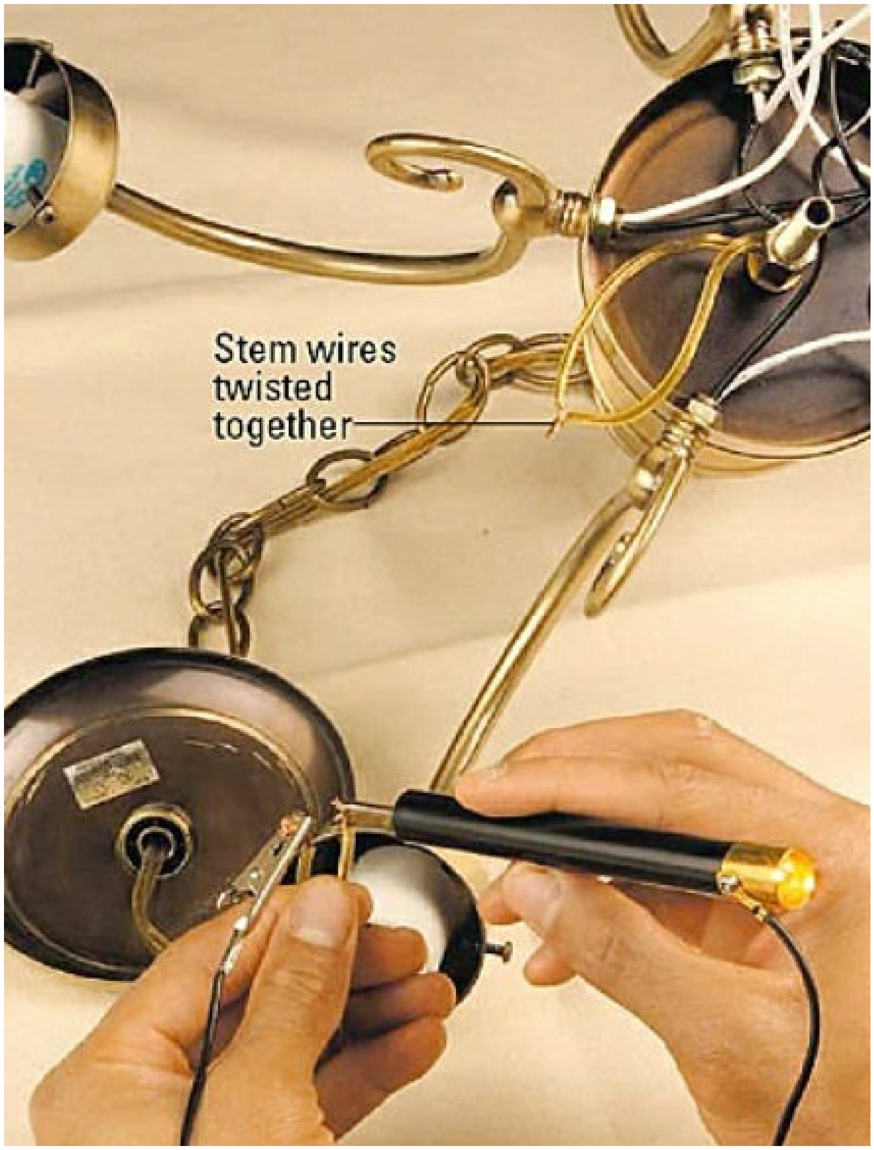
1. **Shut Off Power**

Shut off power to the circuit (in addition to flipping off the light switch). Support the chandelier. Loosen the screws or screw collar holding the canopy in place and slide it down. Pull the wires apart, restore the power temporarily, and test for power. Shut off the power again.

2. **Test Light**

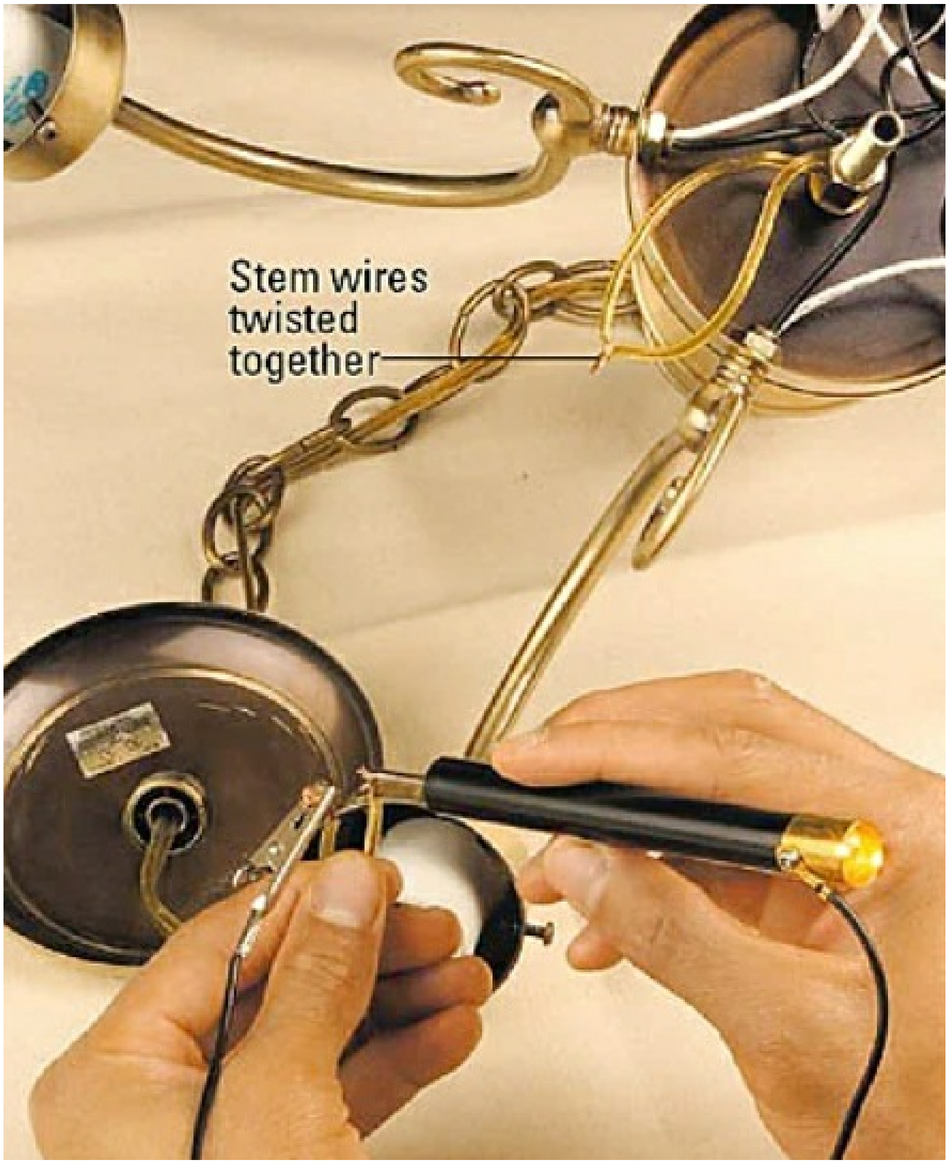
Attach a continuity tester clip to the metal threads inside the socket and touch the neutral (silver) terminal with the probe. Then clip onto the brass screw and touch the probe to the contact tab inside the socket. If the tester light does not come on for both tests, replace the socket.

3. **Test Wires**



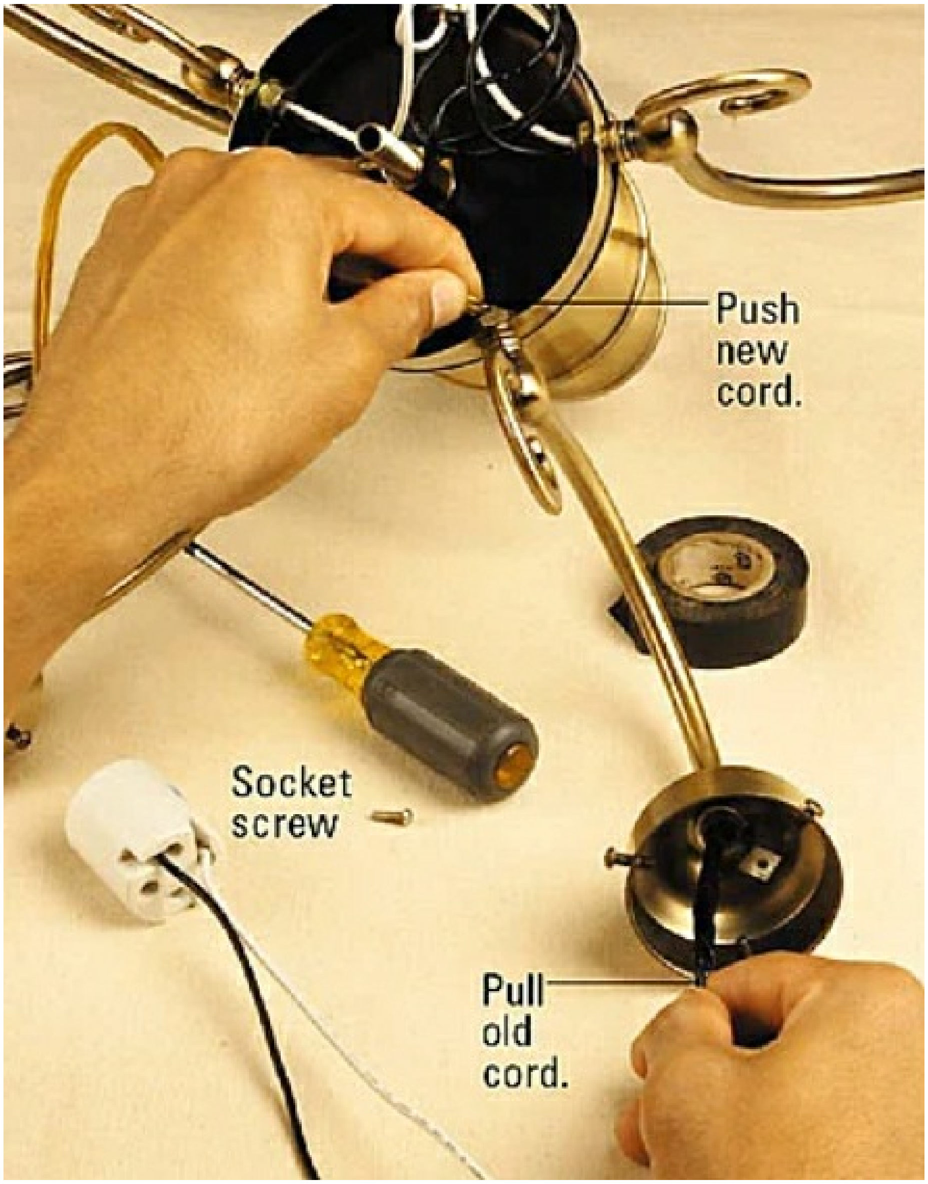
Disconnect the wires in the box, remove the chandelier, and place it on a work surface. Open the chandelier's junction box and pull out the wires. Test both the neutral (ribbed) and hot (smooth) wires for continuity.

4. Test Stem Wires



To test the stem wires, twist them together at the junction box. At the other end attach a continuity tester clip to one wire and touch the probe to the other wire. If the tester does not glow, replace the stem wires.

5. Replace Cord



To replace a cord, separate, strip, and splice the old cord to the new. Pull the old wire through until the new wire appears. Attach the new cord to the socket.

Ceiling Fan Repair

What you need

Screwdriver

Small pliers

Voltage meter

Wire nut

Ceiling fan instruction manual

If your ceiling fan is not working, it helps to troubleshoot the problem and fix it, rather than consigning it to a landfill and buying a new one.

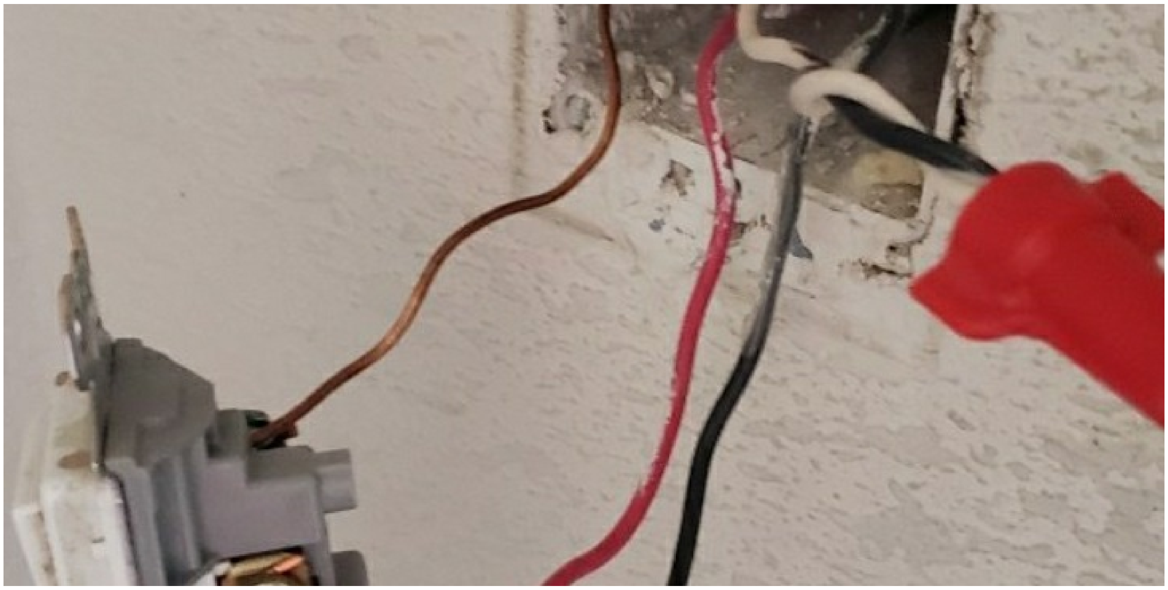
Step 1 - Check the Breaker Box Fuse

If your ceiling fan is not running, check the fuse at the breaker box to determine if it has blown. Replace it if necessary. Otherwise, turn off the power to the room where the ceiling fan is located.

Step 2 - Use the Voltage Meter

Unscrew the switch plate and remove it from the wall. Then, clip your voltage meter to the screws on either side of the switch. The meter will tell you if the screws are holding a charge or not, something you need to know before you pull out the switch housing to avoid getting shocked.

Step 3 - Rewire the Switch



Gently remove the switch from the box and unscrew the two wires from their terminals. Then, use a small set of pliers to straighten out the ends of both wires. Twist the bare wires together and use a wire nut to hold them in place.

Step 4 - Test the Switch

Once the wires are secured with the wire nut, turn the breaker for the room back on. You will know right away if the problem is with the light switch or the fan. If the fan turns on, then the switch is the culprit and needs to be replaced. If the fan doesn't turn on, then the problem is with the fan.

Step 5 - Dismantle the Ceiling Fan

Once you discover that your switch is working, move to checking the ceiling fan wiring. Again, turn off the electricity to the room at the breaker box and, if you have someone to hold up the ceiling fan while you work, then just unscrew it from the ceiling. If you don't have an assistant, you will need to remove the fan blades and then unscrew the ceiling fan from its mounting bracket.

Repairing Power Cords and Plugs

Major appliances have many components in common, making repairs easier. For example, once you've learned to repair a power cord on a refrigerator, you can apply the same skills to repairing a washing machine's power cord.

The following sections explain common devices that are used on major appliances and offers tips on how to repair them.

Power Cords and Plugs

Many appliance "breakdowns" are really due to worn, frayed power cords or plugs that no longer make proper electrical contact. To ensure safe operation, you should check all appliance cords for problems periodically and replace frayed or broken cords immediately. When you suspect a cord is faulty, remove it from the appliance and test it with a continuity tester. Clip the tester to one blade of the plug and touch the probe to one of the two wires -- or, if it's a plug-in cord, insert the probe into one of the two holes -- at the appliance end of the cord. If the tester lights or buzzes, move it to the other wire or hole and test again. Repeat this procedure to test the other blade of the plug. If the tester lights or buzzes at every test point, the cord is not faulty; if it fails to light or buzz at any point, the cord or the plug is faulty. You can pinpoint the defect by cutting off the plug and testing the cut end of the cord; if the tester lights or buzzes at all test points now, the plug is the defective part. The damaged component -- cord, plug, or both -- should be replaced.

Often, the hardest part of replacing an appliance cord is determining how the appliance comes apart so that you can remove the old cord and attach a new one. Sometimes all you have to do is remove the cover from a connection box. In other cases, as with a small hair dryer, the unit itself must be partially disassembled before you can reach the terminals. In nearly all cases, the cord is held in place by a clamp or by a fitted strain-relief device. To remove the cord, unscrew the terminal screws or pull the pressure connectors apart, loosen the clamp or remove the strain-relief device, and pull the cord out. Installation of the new cord is simply a reverse procedure. Be sure to save the strain-relief device and replace it on the new cord. If you damage the strain-relief device when you remove it, replace it with a new one of the same type.

In some equipment, the conductor ends are looped around terminal screws, making new connections easy. Carefully strip off the outer insulation (not the insulation on the inner wires) for about 2 inches at the end of the cord. Then, using a wire stripper, remove about 1/2 inch of insulation from the end of each conductor wire. Twist the exposed filaments of each wire clockwise into a solid prong. Loosen the terminal screws and loop each bare wire end clockwise around a screw. Tighten the screws firmly. Connect the wires at the appliance end of the new cord the same way the old wires were connected.

If only the plug on a major appliance is faulty, you can attach a new plug to the old cord. Male plugs, with two blades or with two blades and a grounding prong, plug into an outlet. Female plugs, often used at the appliance end of the cord, have terminal holes instead of blades. Male plugs can usually be taken apart so you can access the terminal screws. Female plugs may be held together by rivets or by screws. Screw-held plugs can be taken apart, but rivet-held plugs cannot be repaired.

When a plug malfunctions, open the plug, if possible, and check to make sure the conductor wires are properly attached to the plug's screw terminals. If the wires are loose, tighten the terminal screw. This may solve the problem; otherwise, the plug should be replaced. To attach a new male plug:

Step 1: Insert the cord end through the plug opening and pull it through for about five or six inches.

Step 2: Carefully strip off the outer insulation for about 2 inches. Then, using a wire stripper, remove about 1/2 inch of insulation from the end of each conductor wire.

Step 3: Twist the exposed filaments of each wire clockwise into a solid prong. After twisting the conductor ends, tie a tight knot with the inner wires of the cord. Then pull the plug down over the knot, leaving the exposed ends of the conductor wires sticking out. Loosen the terminal screws in the plug.

Step 4: On a two-wire plug, loop each wire around one prong and toward a screw terminal. Loop the bare wire end clockwise around the screw terminal and tighten the screw. If the screws are different colors, connect the white wire to the white screw and the black wire to the yellow screw. On a three-wire plug, use the same technique to connect each of the three wires to a terminal screw. Connect the green grounding wire to the green screw terminal.

Step 5: When the conductor wires are firmly secured to the terminal screws, slide the cardboard insulator over the blades of the plug. If the plug has a clamp-type sleeve, clamp it firmly around the cord.

In the next section, we will delve deeper into your appliances, and learn how to repair gaskets, wiring, switches, and thermostats.