

Lesson A4–7

Wiring Circuits

Unit A. Mechanical Systems and Technology

Problem Area 4. Electrical Systems

Lesson 7. Wiring Circuits

New Mexico Content Standard:

Pathway Strand: Power, Structural and Technical Systems

Standard: III: Apply principles of service and repair to mechanical equipment, structures, biological systems, land treatment, power utilization, and technology.

Benchmark: III-D: Troubleshoot from schematics to I service vehicle electrical systems.

Performance Standard: 1. Describe features and applications of electrical systems. 2. Interpret symbols and wiring diagrams. 3. Test and troubleshoot electrical systems and components (e.g., battery, charging, starting, lighting, instrumentation, accessories). 4. Troubleshoot and install instrumentation and data acquisition system (e.g., Global Positioning System (GPS), spraying, planting, harvesting monitors).

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Differentiate between branch and feeder circuits and describe the wiring of 120 volt and 240 volt branch and feeder circuits, including color coding and polarity requirements.
2. Explain wiring materials and installation methods as well as plan and wire circuits to function as specified.
3. Describe the use of incandescent, fluorescent, and high intensity discharge lighting.
4. Correctly size and use electrical boxes based on NEC requirements.

List of Resources. The following resources may be useful in teaching this lesson:

Recommended Resources. One of the following resources should be selected to accompany the lesson:

Books That Work. *Get Wired*. Computer program for use with Windows.

Cauldwell, Rex. *Wiring a House*. Newtown, Connecticut: The Taunton Press, 1996.

Colvin, Thomas S. *Electrical Wiring*. Winterville, Georgia: American Association for Vocational Instructional Materials, 1993. (Textbook and Workbook)

Johnson, Donald M., et al. *Mechanical Technology in Agriculture*. Danville, Illinois: Interstate Publishers, Inc., 1998. (Textbook, Chapter 5)

Mullin, Ray C. *Electrical Wiring Residential*. Albany, New York: Delmar Publishers, 1996.

VAS U3016a. *Electrical Wiring Procedures*. Urbana, Illinois: Vocational Agriculture Service.

Other Resources. The following resources will be useful to students and teachers:

Burke, Stanley R., and T.J. Wakeman. *Modern Agricultural Mechanics*. Danville, Illinois: Interstate Publishers, Inc., 1992. (Textbook, Chapter 18)

Phipps, Lloyd J., et al. *Introduction to Agricultural Mechanics*, Second Edition. Upper Saddle River, New Jersey: Prentice Hall Interstate, 2004. (Textbook, Chapter 17)

Phipps, Lloyd J., and Carl L. Reynolds. *Mechanics in Agriculture*. Danville, Illinois: Interstate Publishers, Inc., 1992. (Textbook and Workbook, Chapter 38)

Richter, H.P., and W. Creighton Schwan. *Wiring Simplified*. Minneapolis, Minnesota; Somerset, Wisconsin: Park Publishing, Inc., 1996.

VAS U3003c. *Planning for Electrical Wiring*. Urbana, Illinois: Vocational Agriculture Service.

List of Equipment, Tools, Supplies, and Facilities

Writing surface

Overhead projector

Transparencies from attached masters

Copies of student lab sheet

VAS/IAVAT Electrical Wiring Kit

Terms. The following terms are presented in this lesson (shown in bold italics):

3-way switches
4-way switches
Balanced load
Branch circuits
Cable
Conduit
Duplex convenience outlet (DCO)
Equipment grounding conductor
Feeder circuits
Fluorescent light
Grounded conductor
High intensity discharge (HID) light
Incandescent light
Individual branch circuit
Metallic conduit
National Electrical Code (NEC)
Nonmetallic conduit
Pole
Special purpose outlet (SPO)
Switch loop
Switch controlled split duplex receptacle
Throw
Ungrounded conductor

Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here:

If available, take students on a field trip to see a new house being constructed or an older home being remodeled. Ask them questions about where switches and duplex receptacles should be located or how to run wire from the service entrance panel to the particular place to be wired. If no house is available or time doesn't permit such a trip, ask the same questions in the classroom. Students will quickly realize that they have a lot of questions relating to the actual procedure of wiring circuits.

Summary of Content and Teaching Strategies

Objective I: Differentiate between branch and feeder circuits and describe the wiring of 120 volt and 240 volt branch and feeder circuits, including color coding and polarity requirements.

Anticipated Problem: How can you differentiate between branch and feeder circuits and how is the wiring of 120 volt different from that of 240 volt branch and feeder circuits? What are the color coding and polarity requirements of each?

- I. All circuits within a building originate in the building's service entrance panel. These may be branch circuits or feeder circuits.
 - A. **Branch circuits** originate in the service entrance panel and serve individual loads or groups of loads. A circuit breaker or a fuse will serve as overcurrent protection for branch circuit conductors. Branch circuits are generally 120 volts or 240 volts.
 1. 120 volt branch circuits are used to serve general purpose receptacle outlets and lighting fixtures. No more than 10 duplex convenience outlets (DCO's) or 10 light fixtures (150 watt maximum) should be wired on a single 20 ampere, 120 volt circuit. Included in a branch circuit are one ungrounded (hot) conductor, one grounded (neutral) conductor, and one equipment grounding conductor. When wiring with cable, the hot conductor is either normally black or red, the neutral conductor is always white, and the equipment grounding conductor is bare. 120 volt circuits should be planned and installed so that the load is balanced at the building's service entrance panel. **Balanced load** means the 120 volt load should be approximately the same on each of the ungrounded service conductors coming into the service entrance panel. In other words, the load should be similar on each side of the circuit breaker box. An unbalanced 120 volt load may cause tripping of the main disconnect.
 2. 240-volt branch circuits are used to serve specific loads, such as stationary motors and appliances, or special purpose outlets. A **special purpose outlet (SPO)** is an outlet sized receptacle and is installed to serve a specific plug-and-cord connected appliance. 240 volt circuits have two ungrounded (hot) conductors and an equipment grounding conductor. A grounded (neutral) conductor is not required in a regular 240 volt circuit. The two hot conductors are connected to the double pole circuit breaker at the service entrance panel and to the two brass colored terminal screws at the SPO. The equipment grounding conductor is connected to the neutral bar of the service entrance panel and to the green grounding screw at the SPO. When wiring with cable, the white conductor is used as a hot conductor, but must be identified with a black band or black tape at the SPO and at the service entrance panel.
 - B. **Feeder circuits** originate in the service entrance panel and supply power to a sub-panel. Overcurrent protection devices in the service entrance panel are sized to protect the feeder circuit conductors. The sub-panel will provide overcurrent protection for the

branch circuits originating there. The circuit connections for a feeder circuit are the same as for a 240 volt branch circuit.

Use the notes above to explain the difference between branch circuits and feeder circuits. It would be helpful to take students to a circuit breaker box and open the door so they can see the various circuits. Explain that most, if not all of the circuits in a breaker box will be branch circuits. An example of a feeder circuit might be a fuse box or circuit breaker box located in a garage or shed that receives its power from one of the breakers in the main breaker box. Also point out in the circuit breaker box that there are two columns of breakers. There should be about the same number of circuits on each side. Also, point out the amperage sizes on the toggles of the breakers. Most will be 15 amp or 20 amp, except for the larger 240 volt circuits, which may be larger.

Objective 2: Explain wiring materials and installation methods as well as plan and wire circuits to function as specified.

Anticipated Problem: What materials are needed and how do you install electrical circuits?

- II. When installing electrical equipment and materials, it is of extreme importance to follow approved guidelines and use approved devices and materials. The **National Electrical Code (NEC)** provides the accepted set of guidelines that should be followed.
 - A. Electric conductors or wires are made of copper or aluminum. Aluminum is less expensive and weighs less than copper. Copper offers less resistance to the flow of electricity, does not have as high of a rate of thermal expansion, and has less a problem with oxidation than does aluminum. For these reasons, copper wire is preferred over aluminum when wiring most branch circuits. Aluminum is often used in triplex cable as service conductors into a building.
 1. There are three basic conductors used in electric wiring. A **grounded conductor** is a conductor intentionally connected to ground. It is connected to the neutral bar in the service entrance panel (SEP) and is often referred to as a neutral conductor. In a 120-volt circuit, the grounded conductor is a normal current carrying conductor. According to the NEC, ungrounded conductors AWG #6 or smaller must have white or natural gray colored insulation. An **equipment grounding conductor** bonds conductive materials that enclose electrical conductors or equipment back to the system grounding electrode. This protects people and property from damage or injury in case of a ground-fault. During normal operation, this conductor carries no current. This conductor is usually uninsulated or bare. If it is insulated, it must be green or green with one or more yellow stripes. An **ungrounded conductor** originates at the circuit breaker or fuse. This conductor is usually black or red.
 2. Choosing the right type and size of conductor is also important. It may be necessary to refer to a table such as the one on page 146 of *Mechanical Technology in Agriculture*, to choose the correct size of conductor. Things that must be considered are the load in amps required, the type of wire being used, and the length of travel the wire must go from the SEP to the load.

- B. The NEC requires that single wires must be protected from physical damage. When wiring branch circuits, you generally do this by using cable or conduit.
1. A **cable** consists of two or more wires in a protective outer sheath or jacket. Each wire must be individually insulated, except for the equipment grounding wire, which may be bare. The cable may be described based on the cable type, the size of individual conductors, the number of current-carrying conductors within the cable, and whether or not there is an equipment grounding conductor present. Refer to TM: A4–7A as an example. The top cable is designated as Type NM 12-2 WG cable. The NM indicates that it is nonmetallic sheathed cable. The 12-2 indicates that the conductors are AWG No. 12 and that there are 2 normal current-carrying conductors in the cable. The WG indicates that the cable is “with ground”, meaning that a grounding conductor is contained in the cable. The lower cable in the TM: A4–7A is designated as Type UF 10-3 WG, which means that the cable is underground feeder cable, there are three current-carrying conductors present that are size AWG No. 10, and that the cable contains a grounding conductor. Cable should be secured at least every 4½ feet and within 12 inches of each cabinet, box or fitting using approved staples, cable ties, straps, or similar fittings. Sharp bends in the cable should be avoided.
 2. **Conduit** is a channel or tube through which conductors are run in order to provide the conductors with mechanical protection. The conduit is installed first and the conductors are then “fished” through it to make circuit connections. Conduit may be metallic or non-metallic. **Metallic conduit** is made of either galvanized steel or aluminum. It may also be rigid metal conduit, intermediate metal conduit (IMC), or electrical metallic tubing (EMT). They are different in their thickness and ability to withstand physical damage. If metallic conduit is properly installed and bonded, it may also serve as the equipment grounding conductor in a branch circuit. **Nonmetallic conduit** is usually made of polyvinyl chloride (PVC), but can also be made of high density polyethylene, fiberglass, nonmetallic fiber, etc. When properly installed, PVC conduit is dust-tight, watertight, and noncorrosive. It should be supported at regular intervals, depending on its size and must be supported within 3 feet of each box or other conduit termination point. Avoid running conduit from a cold area to a warm area to avoid moisture condensation in the conduit. The size of conduit required depends on the size of the wires used, type of insulation on the wires, the number of wires to be installed, and whether or not the wires are all the same type and size.
- C. Receptacle outlets provide a convenient means of connecting electrical equipment to the wiring system. Most outlets are the duplex convenience outlet or the special purpose outlet.
1. A **duplex convenience outlet (DCO)** is a general purpose outlet having two receptacles built into one device. They are available in 15 and 20 ampere, 120-volt ratings. The two halves of a DCO are connected by a removable tab between the two brass-colored ungrounded (hot) terminal screws and by a second removable tab between the two silver-colored grounded (neutral) terminal screws. Grounding type DCO’s have a green grounding screw where the branch circuit equipment grounding con-

ductor is attached. When wiring a single DCO, the ungrounded (black) conductor attaches to one of the brass-colored terminal screws on the DCO. The grounded (white) conductor attaches to one of the silver-colored terminal screws on the DCO. The equipment grounding conductor (bare or green) attaches to the green grounding screw on the DCO.

- a. When two or more 120-volt DCO's are on the same branch circuit and no switch is used, the DCO's are always hot unless shut off at the SEP. To wire, the first receptacle is connected to the circuit using short pigtail wires. These wires must have the same color insulation as the circuit conductors to which they are spliced. Insulated wire nuts are used to make the splices. At the last receptacle, the circuit conductors attach directly to the appropriate terminals and no pigtails are required. Refer to TM: A4-7B for a drawing.
 - b. Sometimes a DCO may be used so that a table lamp may be plugged into half of the DCO and turned on and off with a wall switch. A clock or television may be plugged into the other half of the DCO so that they have power whether the switch is on or off. This is referred to as a **switch-controlled split-duplex receptacle**. Refer to TM: A4-7C for a drawing of how it should be wired. 12-2 with ground cable is used between the source and the switch, 12-3 with ground is used between the switch and the receptacle. At the switch box, the two grounded wires are spliced together using a wire nut. (Never attach grounded or neutral wires to a single-pole switch.) The incoming ungrounded (black) wire is spliced to a short pigtail wire and to the black wire of the outgoing cable. The pigtail wire is attached to one of the switch's brass-colored terminal screws. The red wire (second ungrounded conductor) from the outgoing cable is connected to the other brass-colored terminal screw at the switch. At the receptacle outlet, the grounded conductor attaches to the silver-colored terminal screw. The equipment grounding conductor connects to the green grounding screw. The tab between the receptacle's two brass-colored terminal screws is removed. This allows the two outlets to operate independently. The incoming black ungrounded conductor attaches to the top brass-colored terminal screw. Since the black wire is not switched in this circuit, the top outlet will always be "hot". The red ungrounded conductor connects to the bottom brass-colored terminal screw. Since it is switched, the bottom outlet will be controlled by the switch.
2. A special purpose outlet (SPO) is installed to serve a specific machine or appliance. An SPO is usually installed on an **individual branch circuit**, which means that the equipment connected to the SPO is the only load on that circuit.
- D. Switches control one or more electrical loads by opening and closing the circuit serving the load(s). Switches may only be installed in the ungrounded or hot conductor(s) of a circuit.
1. Switches are rated for a specific maximum voltage and amperage. If designed to control motors, they may also be rated for a maximum horsepower.

2. Grounding-type switches provide grounding protection for the normally non-current carrying metal components of the switch and have a green grounding screw terminal.
3. A switch is often described based on the number of poles and throws it has. A **pole** is a movable contact within a switch. The term **throw** indicates the number of paths provided for current to flow through the switch.
4. Flush-mounted toggle switches are often called snap switches. When mounted in a box with a cover plate, only the insulated switch handle is exposed.
 - a. A single-pole single-throw (SPST) switch is used to control the load(s) in a circuit from a single location. It has two brass-colored screw terminals where the incoming and outgoing ungrounded conductors are attached. The switch's "on" and "off" positions are marked and should be installed so that the toggle is up when "on" and down when "off".
 - 1.) When using a SPST switch to control a light at the end of a run, only the ungrounded conductors from the incoming and outgoing cables attach to the brass-colored switch terminals. The grounded conductors from the two cables are spliced together at the switch box. At the lighting fixture, the ungrounded conductor connects to the brass-colored terminal screw and the grounded conductor connects to the silver-colored terminal screw. The equipment grounding conductor is connected to the metal fixture box with a grounding clip.
 - 2.) When using a SPST switch to control a light in the middle of a run, the grounded conductor from the source is connected directly to the silver-colored terminal of the lighting fixture. The ungrounded conductor must pass through the switch before returning to the light. The wires from the lighting fixture to the switch are called a **switch loop**. When cable is used to wire a circuit containing a switch loop, a white wire must be used as an ungrounded conductor and connected to the switch. According to the NEC, the white wire must supply the switch, and the black wire must return to the load.
 - b. Single-pole double-throw (SPDT) switches, commonly called **3-way switches**, are used in pairs to control lights from two different locations. They have three terminal screws: one common terminal and two traveler terminals. The common terminal is normally darker or marked as such. They are not marked "on" or "off" and are commonly used when rooms have two entrances, in long hallways, in stairwells, or other similar locations. Four points should be kept in mind in wiring 3-way switches:
 - 1) The grounded wire from the electrical supply connects directly to the silver-colored terminal of the load and is never switched or interrupted.
 - 2) The ungrounded wire from the electrical supply connects to the common terminal of the first 3-way switch.
 - 3) The ungrounded black wire from the brass terminal of the load connects to the common terminal of the second 3-way switch.

- 4) To complete the circuit, the traveler terminals of the two 3-way switches are connected together using 3-wire cable (or individual wires in conduit).
 - a.) Refer to Transparency Master TM: A4–7D to see how to wire a 3-way switch circuit controlling a lighting fixture at the end of the run.
 - b.) Refer to Transparency Master TM: A4–7E to see how to wire a 3-way switch circuit controlling a lighting fixture in the middle of the run.
- c. Double-pole double-throw (DPDT) switches, commonly called **4-way switches**, are used in a circuit with a pair of 3-way switches and are used to control lighting fixtures from three or more locations. They have four terminals, which are all traveler terminals. Four points should be kept in mind in wiring 3-way and 4-way switch circuits:
 - 1) The grounded conductor from the electrical supply is connected to the silver terminal of the load.
 - 2) The ungrounded conductor from the electrical supply is connected to the common terminal of one 3-way switch.
 - 3) The traveler terminals of both 3-way switches are connected to the traveler terminals of the 4-way switch.
 - 4) The ungrounded black wire from the brass terminal of the load connects to the common terminal of the other 3-way switch.

Refer to Transparency Master TM: A4–7F to see how to wire a 3- and 4-way switch circuit controlling a lighting fixture at the beginning of the run. The notes above will help in explaining wiring methods and procedures. Use the transparency masters that were referenced in the text of this objective in your explanation and discussion. It is important to have students wire various circuits using the devices in the discussion above. The use of the Electric Wiring Kit is recommended. You may use any of the above example circuits to get started or you may design your own circuits. Another useful resource is the Wiring Exercises Transparencies Set available from ITCS (formerly Vo-Ag Services). Students need to diagram circuits, which they should have learned in Lesson 6 of this section on electricity, before they begin the actual wiring. Complete LS: A4–7A to reinforce the discussion of the various wiring methods and procedures. As an additional activity, allow students to utilize the computer program, “Get Wired” and work through the various chapters and simulation as it relates to wiring and procedures.

Objective 3: Describe the use of incandescent, fluorescent, and high intensity discharge lighting.

Anticipated Problem: How are incandescent, fluorescent, and high intensity discharge lights used?

- III. There are three primary types of lights used in agricultural buildings- incandescent, fluorescent, and high intensity discharge.
 - A. An **incandescent light** glows because of the heat produced as current flows through a high resistance tungsten filament. The filament is enclosed in a glass bulb to prevent it from burning up by combining with oxygen in the air. Incandescent bulbs, compared to

other types, are less expensive, widely available, and operate well under most conditions including low temperatures. They do not require a “warm-up” period when energized. They should be considered where light is needed for short periods and/or where lights are frequently turned “on” and “off”.

- B. A **fluorescent light** tube is a glass tube filled with a gas and has a small filament in each end. The inside of the tube is coated with a fluorescent material. The gas inside the tube is commonly a mixture of argon gas and mercury vapor. The two filaments are coated with a chemical material that emits electrons when heated. Fluorescent lights are more efficient and have a much longer service life than incandescent lights. They also reduce glare and shadows in a room or building. Fluorescent lights are more expensive to purchase than incandescent lights and are difficult to start at low temperatures or when humidity levels are high. Turning a fluorescent light “on” and “off” frequently will reduce their service life.
- C. **High intensity discharge (HID) lights** include mercury, metal halide, high-pressure sodium, and low-pressure sodium lights. HID lights have long service lives, are very energy efficient, and operate well at low temperatures. They require several minutes to start. Once an HID light has been switched “off”, it cannot be restarted until it cools off. HID lights are best used where lights are left “on” for at least three hours and work best when mounted at least 12 feet high.

Have students offer their own suggestions as to the differences in the three types of lights. Use the notes above to supplement student discussion. Use TM: A4–7G to compare the differences in each type of light. Offer examples of locations where each type of light is being used within your own school, home or work area.

Objective 4: Correctly size and use electrical boxes based on the National Electrical Code (NEC) requirements.

Anticipated Problem: What are the National Electrical Code (NEC) requirements in regard to size and use of electrical boxes?

- IV. Boxes and fittings are used to keep cable and conduit in place and prevent damage to it.
 - A. Boxes must secure the cable or conduit connected to the box and prevent mechanical strain on the wiring connections. Boxes attach to the building structure and provide support for switches, receptacle outlets and fixtures. Boxes also enclose all wiring connections, providing protection and preventing accidental contact with uninsulated components.
 - B. Various types of fittings are used to secure the conduit or cable to the box. The type of fitting to use will depend on the type of connection needed and the location of the connection, such as in a dry vs. damp or wet area.
 - C. It is important to select the correct size of box for your application. A box must have adequate volume for all of the conductors and devices that will be in the box. A box that is too small makes work more difficult, increases the time required for wiring tasks, and

makes a short circuit more likely. The correct size of box to use depends on the size of the conductor being used and the number of equivalent conductors to be used in the box. Refer to the National Electrical Code (NEC) for the appropriate table in sizing a box. General rules to follow in determining the number of equivalent conductors in a box are:

1. Each conductor passing through a box without being spliced or connected to a device is counted as one conductor.
2. Each conductor connecting to a splice or a device is counted as one conductor. However, if a conductor is contained completely within the box (such as a pigtail splice), it is not counted.
3. All grounding conductors in a box are counted as only one conductor.
4. A switch or receptacle counts as two conductors.
5. Each of the following types of fittings is counted as one conductor: cable clamps, fixture studs, hickies, and straps. Each type of fitting is only counted once, even if two or more of the same fittings are present.

Have a variety of the above mentioned devices on hand to demonstrate how boxes are sized and used. Use the notes above to discuss with students the procedure used in sizing boxes. Students may refer to pages 175-178 in Mechanical Technology in Agriculture text for further explanation. If possible, students should refer to the National Electrical Code (NEC) for tables that will allow them to determine the correct sizes of boxes.

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught differently. Questions at the end of chapters in the textbook may also be used in the review/summary.

Application. Application can involve the following student activities using attached lab sheet:

LS: A4-7A — Electrical Wiring Methods and Procedures Worksheet

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is attached.

Answers to Sample Test:

Part One: Matching

1=f, 2=g, 3=e, 4=a, 5=c, 6=d, 7=b, and 8=h

Part Two: Completion

- 1=black, red (any order)
- 2=Nonmetallic
- 3=3-way switches
- 4=incandescent
- 5=high intensity discharge (HID)
- 6=size of conductor
- 7=white
- 8=brass, silver

Part Three: Short Answer

1. It is used when a table or floor lamp is plugged into one receptacle that will be controlled by a wall switch, whereas the other outlet may be used for a television or clock that would need power whether the light is turned off or on.
2.
 - a. nonmetallic sheathed cable
 - b. AWG 14 wire with 3 normal current-carrying conductors
 - c. with ground conductor
3. more expensive, heavier
4. less

Test

Lesson A4–7: Wiring Circuits

Part One: Matching

Instructions. Match the term with the correct response. Write the letter of the term by the definition.

- | | |
|------------------------------------|---------------------------------|
| a. feeder circuits | e. cable |
| b. pole | f. special purpose outlet (SPO) |
| c. conduit | g. throws |
| d. duplex convenience outlet (DCO) | h. branch circuits |

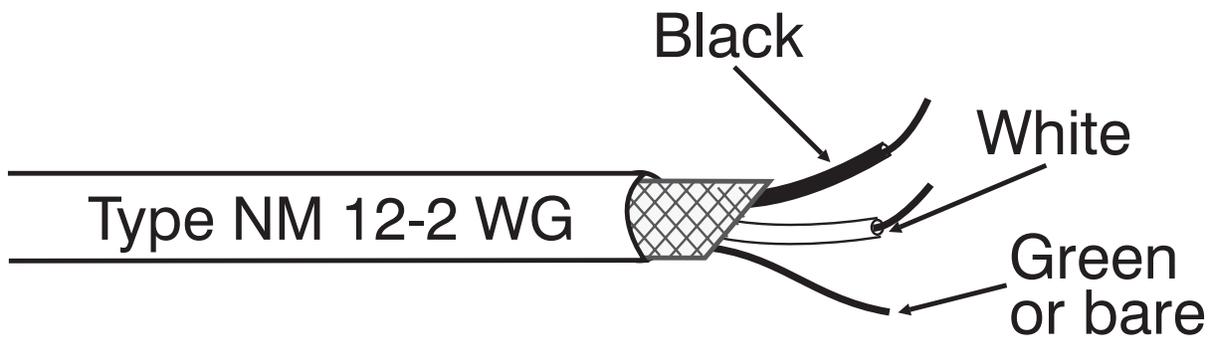
- _____ 1. A receptacle outlet that is sized and installed to serve a specific appliance.
- _____ 2. The number of paths for current to flow through a switch.
- _____ 3. Consists of two or more wires in a protective sheath.
- _____ 4. These originate in the service entrance panel and supply power to a subpanel.
- _____ 5. A channel or tube through which conductors are run.
- _____ 6. A general purpose outlet having two receptacles built in one device.
- _____ 7. A movable contact within a switch.
- _____ 8. These originate in the service entrance panel and serve individual loads or groups of loads.

Part Two: Completion

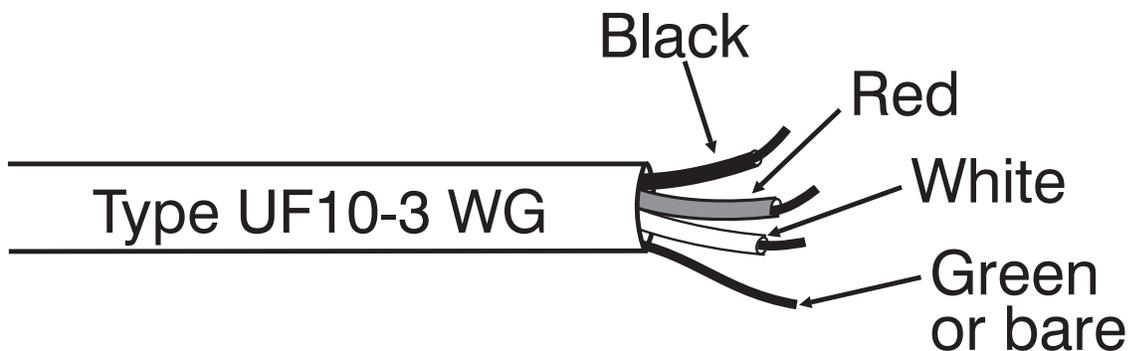
Instructions. Provide the word or words to complete the following statements.

1. The ungrounded conductor is usually _____ or _____ in color.
2. _____ conduit is usually made of PVC.
3. _____ are always used in pairs and are used to control lights from two different locations.
4. A(n) _____ light is best used when the light needs to be frequently turned “on” and “off”.
5. Mercury and metal halide are examples of _____ lights.

TYPICAL CABLE CONSTRUCTION



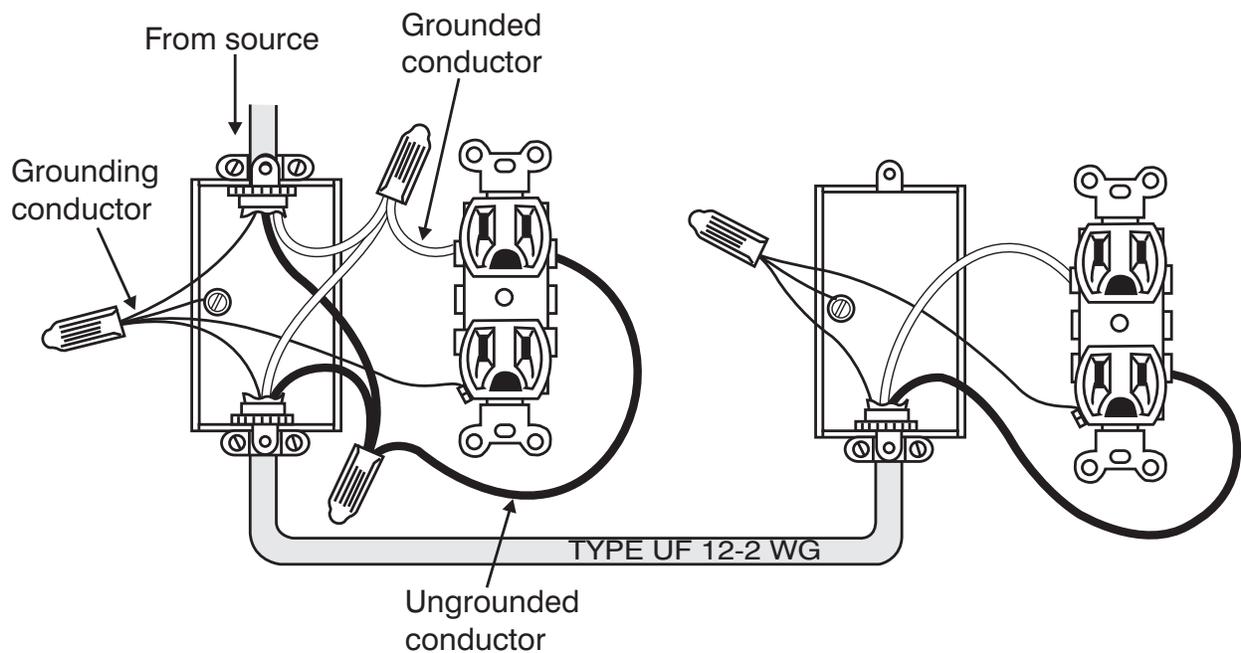
Nonmetallic sheathed cable



Underground feeder cable

(Courtesy, Interstate Publishers, Inc.)

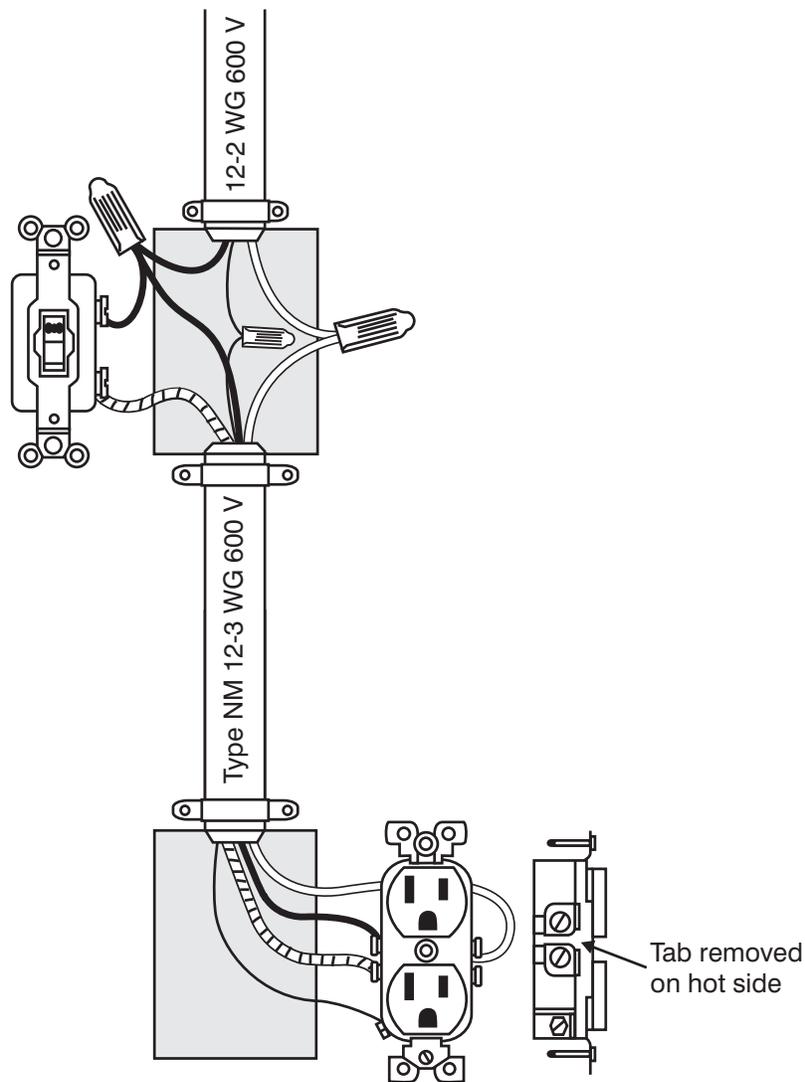
WIRING CONNECTIONS FOR TWO OR MORE UN-SWITCHED DCOS



(Courtesy, Interstate Publishers, Inc.)

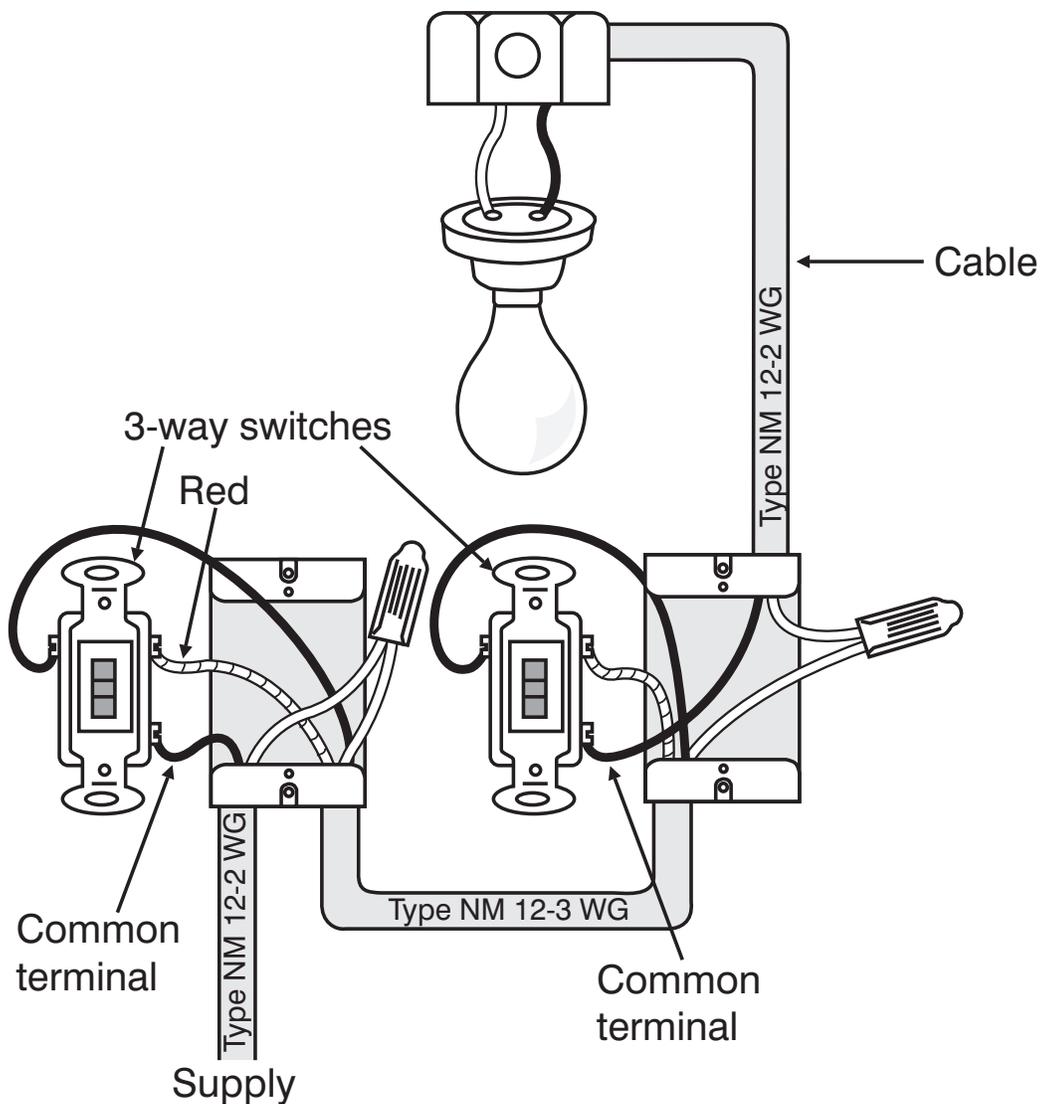
TM: A4-7C

SPLIT DUPLEX RECEPTACLE WITH TOP ALWAYS HOT AND BOTTOM CONTROLLED BY SWITCH



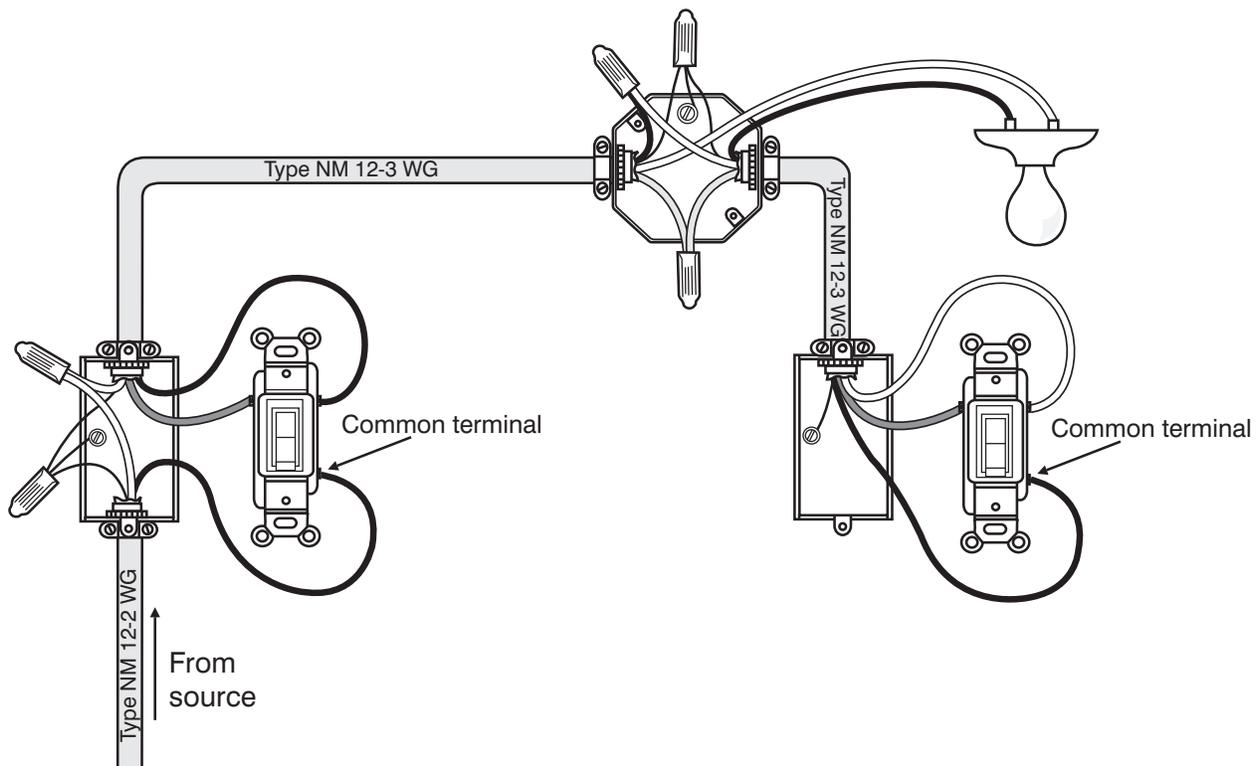
(Courtesy, Interstate Publishers, Inc.)

3-WAY SWITCH CONTROLLING A LIGHTING FIXTURE AT THE END OF THE RUN



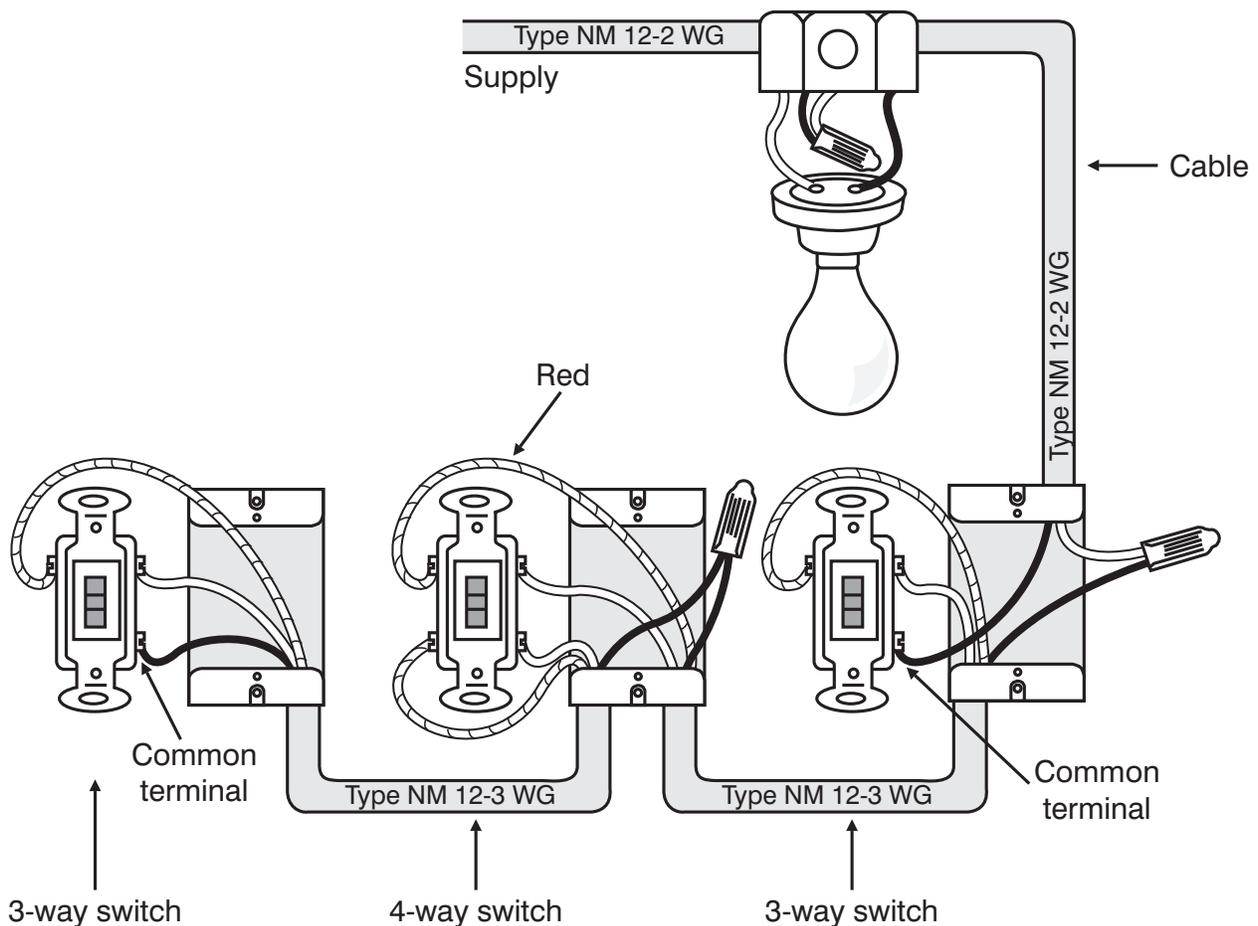
(Courtesy, Interstate Publishers, Inc.)

3-WAY SWITCH CONTROLLING A LIGHTING FIXTURE IN THE MIDDLE OF THE RUN



(Courtesy, Interstate Publishers, Inc.)

3-WAY AND 4-WAY SWITCH CIRCUIT CONTROLLING A LIGHTING FIXTURE AT THE BEGINNING OF THE RUN



(Courtesy, Interstate Publishers, Inc.)

COMPARISON OF DIFFERENT TYPES OF LIGHTS

1. Incandescent Lights

- a. Less expensive**
- b. Widely available**
- c. No warm-up required**
- d. Operate well in most conditions**

2. Fluorescent lights

- a. More efficient and longer life than incandescent**
- b. Reduce glares and shadows indoors**
- c. Difficult to start at low temperatures or in high humidity conditions**

3. High intensity discharge (HID) lights

- a. Long service life**
- b. Very energy efficient**
- c. Operate well at low temperatures**
- d. Require several minutes to start**
- e. Once turned “off”, must cool before restarting**

Lab Sheet

Electrical Wiring Methods and Procedures Worksheet

Purpose: Students will enhance their understanding of wiring methods and procedures by using text materials to answer the following questions.

1. Number 14 gauge wire is _____ than number 12 gauge wire.
2. The maximum number of wires permitted under a screw terminal is _____.
3. In order to control a light from four places, use _____ single-pole switches, _____ 3-way switches, and _____ 4-way switches.
4. Insulated wire nuts called _____ connectors are used to splice conductors.
5. The direction the conductor must go around a screw terminal is _____.
6. The source for circuits in a house is the _____.
7. The National Electrical Code requires that receptacles be spaced so that no point on a wall line is more than _____ feet from a receptacle.
8. Receptacles on a kitchen counter should be located _____ inches above the counter top.
9. Wall receptacles (other than above kitchen counters) should be _____ inches above the floor.
10. Locate switches _____ inches from the floor to the bottom of the box.
11. Each convenience outlet in a bathroom must be protected by a _____.
12. How would the following types of cable be designated?
 - a. Cable containing two No. 12 wires and a grounding wire: _____
 - b. Cable containing three No. 10 wires and a grounding wire: _____
13. Either a _____ or _____ ampere circuit breaker may be used with No. 12 wire.

Lab Sheet Key

Electrical Wiring Methods and Procedures Worksheet

Purpose: Students will enhance their understanding of wiring methods and procedures by using text materials to answer the following questions.

1. smaller
2. one
3. zero, two, two
4. solderless
5. clockwise
6. service entrance panel
7. six
8. eight
9. 12-14
10. 48
11. GFCI
12. a. 12-2 w/g
b. 10-3 w/g
13. 15-, 20-