

Lesson A4–6

Preparing and Using Schematics

Unit A. Mechanical Systems and Technology

Problem Area 4. Electrical Systems

Lesson 6. Preparing and Using Schematics

New Mexico Content Standard:

Pathway Strand: Power, Structural and Technical Systems

Standard: X: Use available power source to plan and apply control systems.

Benchmark: X-B: Reference electrical drawings to design, install, and troubleshoot control systems.

Performance Standard: 1. Develop and read schematic drawings for a control system. 2. Identify and describe uses of various components of control systems; (i.e., transistors, relays, HVAC, logic controllers). 3. Discuss the importance of maintenance schedules. 4. Identify system performance problems and apply troubleshooting techniques.

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

1. Identify and draw various symbols used in drawing wiring diagrams or schematics.
2. Describe rules to follow in diagramming various circuits.
3. Draw and explain diagrams of circuits using keyless lampholders, pull-chain lampholders, duplex receptacles, and single-pole switches.
4. Draw and explain diagrams of circuits using lampholders with 3-way and 4-way switches.
5. Draw and explain diagrams of circuits using a combination single-pole switch and receptacle with a lampholder and applications where receptacles are split for switching.

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:

Transparency Set. *Wiring Exercises Transparencies*. Urbana, Illinois: Vocational Agriculture Service.

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

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

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

List of Equipment, Tools, Supplies, and Facilities

Writing surface
Overhead projector
Transparencies from attached masters
Copies of student lab sheets
Electrical Wiring Kit from IAVAT

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

3-way switches
4-way switches
Combination single-pole switch and receptacle
Control or common terminal
Duplex receptacle
Keyless lampholder
Pull-chain lampholder
Switch loop connection
Traveler terminal

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:

Present a problem to students on the board or overhead projector such as the one described here: You are going to wire a new room you are building onto your home. The room will be on its own circuit. In the room, you will want a light in the ceiling controlled by a switch and four duplex receptacles. The receptacles should be wired so that the top receptacle on each is always "hot". The bottom receptacle should be controlled by an additional switch that is to be mounted next to the switch controlling the ceiling light. The

power will come into the room through the box where the switches are located. Ask students how they would go about wiring the room. Will they use 2-wire or 3-wire cable and where? Which wires will be connected to which terminals, etc.? Students should soon realize that they really don't know how to complete the task. You might ask them if they are going on a trip, how do they choose the right roads to take them to their desired destination? Their response should be to use a road map in order to get to their destination as quickly as possible and use the least amount of gas, etc. Explain that wiring is much the same way. In order to wire correctly and in the most efficient manner, they need some sort of "road map" to get them there. The diagrams they will construct will serve as their "road map" so they can wire an exercise correctly and most efficiently from the very beginning.

Summary of Content and Teaching Strategies

Objective 1: Identify and draw various symbols used in drawing wiring diagrams or schematics.

Anticipated Problem: What symbols are used for various electrical devices and how are they drawn?

- I. In order to successfully draw a wiring circuit on paper, one needs to use various symbols that represent the equipment and techniques that will need to be followed in wiring. The following are symbols that will be used in this lesson. It is important to note that other resources may use different symbols. The exact symbol itself is not as important as how to construct diagrams that will allow the wiring activity to be accomplished correctly.
 - A. In cable, there are four different colors or kinds of wire that one will use depending on the type of wire that is being used. Using 12-gauge wire as the example, there are four types of cable that one may buy. One is 12/2 with ground, which has one black conductor, one white conductor, and a bare ground conductor. A second cable is 12/2 without ground, which is the same as 12/2 with ground except that no bare ground conductor exists. A third type of cable is 12/3 with ground, which has one black conductor, one white conductor, one red conductor, and one bare ground conductor. The last type is 12/3 without ground which is like the 12/2 without ground. It has the three colored conductors, but no bare conductor. The symbols used for conductors and their respective colors are:
 1. black wire
 2. white wire
 3. red wire
 4. bare ground wire
 - B. Various devices are used as lampholders, switches, and receptacles. They are:
 1. duplex receptacle
 2. keyless lampholder (light)
 3. pull-chain lampholder

4. single-pole switch
 5. three-way switch
 6. four-way switch
 7. combination single-pole switch and receptacle
- C. Additional symbols are used to identify terminals and indicate if wires are spliced or just crossing over. They are:
1. brass-colored terminal
 2. silver-colored terminal
 3. green-colored terminal
 4. wires spliced
 5. wires crossing but not connected

Use above notes as a guide while teaching this objective. Have two pieces of cable available to show the students so they can understand the numbers and colors of wires in each cable. The cables needed are one section of 12/2 with ground and one section of 12/3 with ground. This will be important later in understanding how to diagram and why particular colors of wires are selected. Use TM: A4-6A, A4-6B, A4-6C, A4-6D, and A4-6E to discuss the various symbols used to represent the items discussed above. Allow students to see the actual device as you discuss it so they can visualize the device from the symbol. Have students complete LS: A4-6A to understand how to draw the symbols for each of the items discussed above. In order to diagram, it is important to know how to draw the various symbols.

Objective 2: Describe rules to follow in diagramming various circuits.

Anticipated Problem: What rules should be followed in diagramming various circuits?

- II. In order to successfully diagram circuits there are a few rules and order to follow in the diagramming process that will be helpful. Again, there are probably many different techniques to diagramming a circuit. The following represents one.
- A. Generally, black and red conductors carry “hot” power or current from the source (SEP) to the devices within the circuit. The white conductor is always used to carry the current back to the source. This conductor is often referred to as the neutral conductor. There may be some applications that would require a white conductor to actually carry “hot” current. This is referred to as a switch loop connection and will be discussed later. When completing the diagram, it may be helpful to draw the white, neutral conductor from the source to its final destination within the circuit, first.
 - B. Duplex receptacles and pull-chain lampholders are normally wired so that they have “hot” or unswitched power at all times. **Pull-chain lampholders** have a switch built into the device. The lampholder is turned on and off by pulling the string or chain connected to the lampholder. **Duplex receptacles** are a device that will receive two plugs. In the case where you want half of a duplex receptacle controlled by a switch, you would not wire the entire receptacle hot.

- C. **Keyless lampholders** are an example of a device that must have a switch to turn the power “on” or “off”. Switching is always done in the ungrounded or “hot” conductor.
- D. On occasion it may be more convenient to bring the source into the lampholder first and then go to the switch. This is called a switch loop. In a **switch loop connection** using two-wire cable, it is necessary to use the white wire as the hot line to the switch.
- E. **3-way switches** are always used in pairs. They are needed when one wishes to control a light from two different locations. 3-way switches have three screws or terminals, one is called **control or common terminal**. It is often darker colored than the other two terminals. The other two terminals are called **traveler terminals**. When the toggle switch is in one position, the common terminal carries current to one traveler terminal. When the toggle switch is in the other position, the common terminal carries current to the other traveler terminal. When diagraming and wiring 3-way switches, the hot current always enters the control terminal of one of the switches and always exits out of the control terminal of the other switch. The traveler terminals from one of the switches must connect to the traveler terminals of the other switch with no interference.
- F. **4-way switches** are used to control the same light(s) from three or more locations. One or more 4-way switches must be used with two 3-way switches. There are four terminals on a 4-way switch and are all considered traveler terminals. 3-way switches are always wired on ends where switching is needed, and the 4-way switches are wired between the two 3-way switches. Two traveler terminals from the 4-way switch connect to the two traveler terminals from one of the 3-way switches. The other two traveler terminals from the 4-way switch connect to the two traveler terminals of the other 3-way switch. When more than one 4-way switch is used, the traveler terminals connect from one switch to the next.
- G. A **combination single-pole switch and receptacle** is used when a switch and receptacle are desired in the same box. In most cases, the receptacle is always wired “hot” and the switch is used to control a light or series of lights. In special cases, the switch may also be wired to control the receptacle.

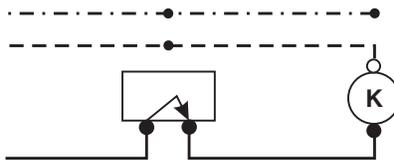
Use the notes above to discuss with the students the rules to follow in beginning to diagram various circuits. It is important that students understand when and how particular devices should be used for various applications. Use TM: A4–6F to discuss rules to follow when wiring. It could also be used as a handout for students to refer to as they become familiar with diagraming and then wiring.

Objective 3: Draw and explain diagrams of circuits using keyless lampholders, pull-chain lampholders, duplex receptacles, and single-pole switches.

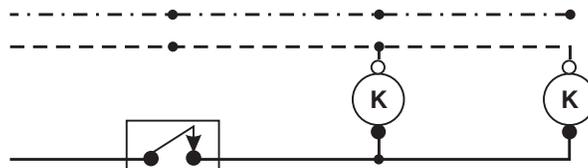
Anticipated Problem: How do you diagram electrical circuits using keyless lampholders, pull-chain lampholders, duplex receptacles, and single-pole switches?

III. Many different wiring applications can be completed using keyless lampholders, pull-chain lampholders, duplex receptacles, and single-pole switches. Several examples of circuits and diagrams will follow.

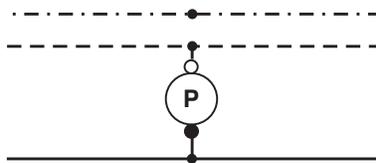
A. A feed-through connection coming through a single-pole switch to control a keyless lampholder.



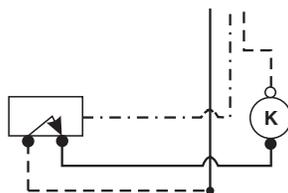
B. A feed-through connection coming through a single-pole switch to control two keyless lampholders. Pigtail connections are necessary in the first octagon box.



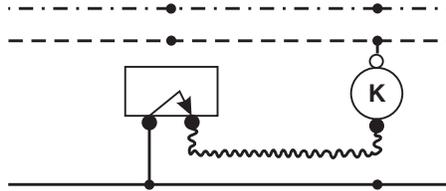
C. A pull-chain lampholder with a line coming in and a line extending beyond the lampholder.



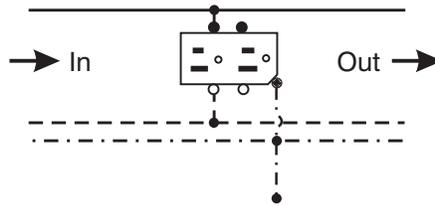
D. A single-pole switch controlling a keyless lampholder with a line coming in and a line extending beyond the lampholder. A three-wire cable is required between the switch and the lights in order to carry unswitched power beyond the lights.



- E. A single-pole switch controlling a keyless lampholder when the power comes in through the box where the light is located. This application is referred to a switch loop connection.



- F. A duplex receptacle with an unswitched line in and out.

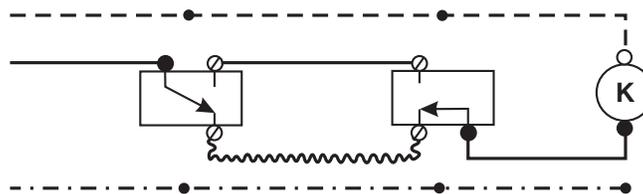


For each of the above applications, have the students draw the symbols correctly and in the correct sequence. Students should attempt to diagram the various exercises, keeping in mind the rules from TM: A4–6F. Use the illustrations above to assist students in mastering the diagramming procedure. You may wish to diagram the first couple of exercises on the board until the students feel comfortable diagramming. If needed, reproduce the pictorial and diagram illustrations above for the students to see what the diagrammed exercise would actually look like. It may also be necessary to stop and actually complete an exercise so students can visualize the diagram in terms of a real exercise.

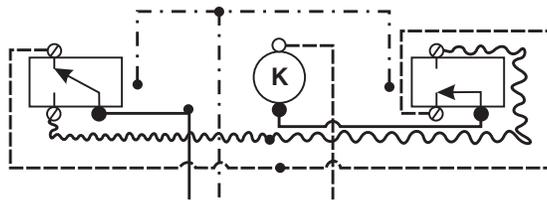
Objective 4: Draw and explain diagrams of circuits using lampholders with 3-way and 4-way switches.

Anticipated Problem: How do you diagram circuits using lampholders with 3-way and 4-way switches?

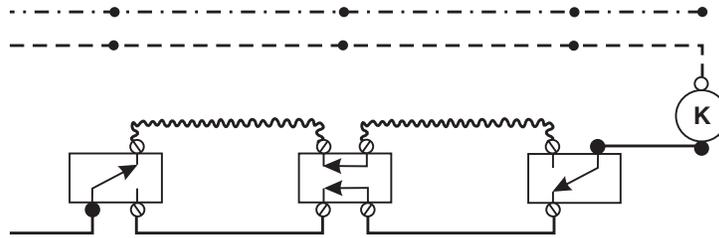
- IV. Many homes have a need to control a light or lights from more than one location. This may be necessary in a stairway where you would want to turn a light on at the bottom of stairs and shut it off when you are at the top of the stairs.
- A. Two 3-way switches controlling a keyless lampholder with the power coming in through the first switch.



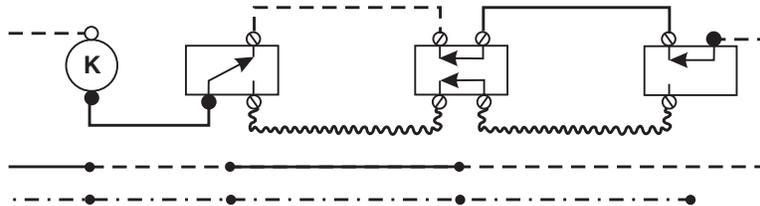
- B. Two 3-way switches controlling a keyless lampholder with the lampholder being between the two switches. The power comes in through the box with the light in it.



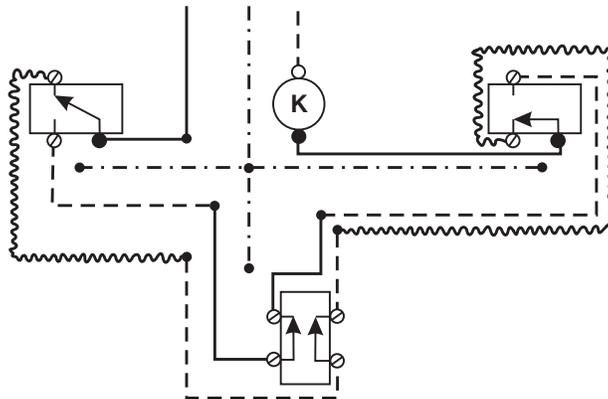
- C. Two 3-way switches and one 4-way switch controlling a keyless lampholder. Power enters through the first 3-way switch.



- D. Two 3-way switches and one 4-way switch controlling a keyless lampholder. The power enters through the lampholder which is located at the front of the circuit.



- E. Two 3-way switches and one 4-way switch controlling a keyless lampholder. The lampholder is located in the center of the switches.



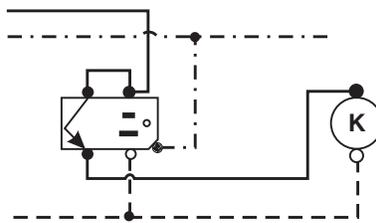
For each of the above applications, have the students draw the correct symbols in sequence. Students should attempt to diagram the various exercises, keeping in mind the rules from TM: A4–6F. Use the illustrations above to assist students in mastering the diagramming procedure. If needed, reproduce the pictorial and diagram illustrations above for the students to see what the diagrammed exercise would actually look like.

Objective 5: Draw and explain diagrams of circuits using a combination single-pole switch and receptacle with a lampholder and applications where receptacles are split for switching.

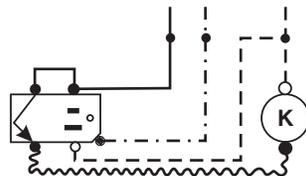
Anticipated Problem: How do you diagram circuits using a combination single-pole switch and receptacle with a lampholder and applications where receptacles are split for switching?

V. In special situations, you may need to have the switch and receptacle located in the same box. In other situations, a duplex receptacle could be used for plugging in a table lamp that could be turned “on” and “off” using a wall switch. The other half of the receptacle could be used for a clock or other electrical device that would require power at all times. The following diagrams will demonstrate how to diagram and wire these applications.

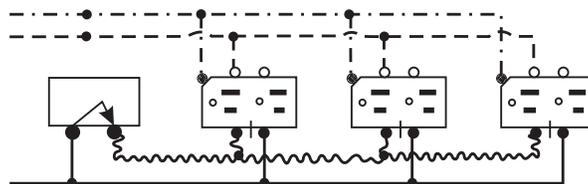
A. A combination single-pole switch and receptacle and a keyless lampholder. The power comes in through the switch and receptacle, the receptacle is wired “hot” at all times.



B. A combination single-pole switch and receptacle and keyless lampholder. The power comes in through the lampholder and then goes to the switch and receptacle. The receptacle is wired “hot” at all times.



C. Three duplex receptacles split so that one receptacle on each duplex is always “hot” and the other is controlled by a single-pole switch. The switch is located at the beginning of the circuit.



For each of the above applications, have the students draw the correct symbols in sequence. Students should attempt to diagram the various exercises, keeping in mind the rules from TM: A4–6F. Use the il-

illustrations above to assist students in mastering the diagramming procedure. If needed, reproduce the pictorial and diagram illustrations above for the students to see what the diagrammed exercise would actually look like. Have students complete LS: A4–6B to demonstrate that they can correctly diagram various electrical circuits.

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses and success on lab sheets can be used in determining which objectives need to be reviewed.

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

Symbols for Electricity Exercises – LS: A4–6A

Diagramming Electrical Exercises – LS: A4–6B

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=d, 2=e, 3=b, 4=f, 5=c, and 6=a

Part Two: Completion

1=two, one

2=black, white, red, bare (any order)

3=pull-chain

4=white

5=black

Part Three: Short Answer

1. a=single-pole switch
b=keyless lampholder
c=three-way switch
d=duplex receptacle
e=four-way switch
2. a=refer to objective 4-C for scoring
b=refer to objective 3-D for scoring
c=refer to objective 5-A for scoring

Test

Lesson A4–6: Preparing and Using Schematics

Part One: Matching

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

- | | |
|---------------------------|--------------------------------|
| a. duplex receptacles | d. 3-way switches |
| b. switch loop connection | e. control or common terminals |
| c. 4-way switches | f. traveler terminals |

- _____ 1. These are always used in pairs. They are necessary when wanting to control a light from two different locations.
- _____ 2. Often a darker color. It is the terminal that power must enter through to one 3-way switch and exit out of from the other 3-way switch.
- _____ 3. A term used to describe a situation when it is necessary for the white wire in cable to carry “hot” or ungrounded current.
- _____ 4. These terminals are always connected to each other between 3-way and/or between 4-way switches.
- _____ 5. These are used in conjunction with other switches when it is necessary to control a light(s) from three or more locations.
- _____ 6. These are often referred to as outlets. They will receive two plugs.

Part Two: Completion

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

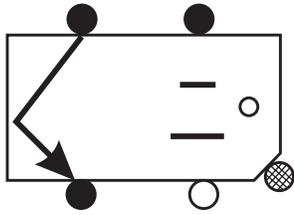
- To control a light from three places, use _____ three-way switch(s) and _____ four-way switch(s).
- 12/3 cable with ground will have one _____ wire, one _____ wire, _____ wire, and one _____ wire.
- A light that has its own built-in switch is called a _____ lampholder.
- A neutral wire is always _____ in color.
- A solid line is used to represent a _____ (color) wire when diagraming a circuit.

Part Three: Short Answer

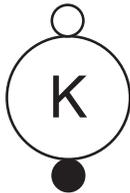
Instructions. Provide information to answer the following questions.

1. Identify each of the following symbols:

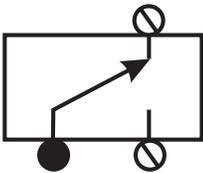
a.



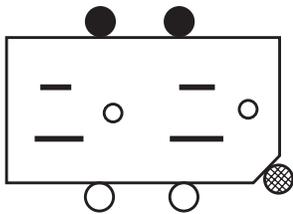
b.



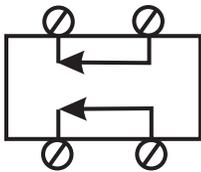
c.



d.



e.



2. Correctly diagram the following circuits:

a. ——(3-way switch)——(4-way switch)——(3-way switch)——(keyless lampholder)

b. ——(single-pole switch)——(keyless lampholder)——

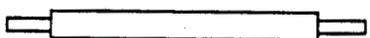
c. ——(combination single-pole switch and receptacle)——(keyless lampholder)

ELECTRICAL SYMBOLS

Pictorial



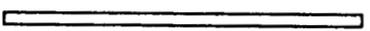
Black Wire



White Wire



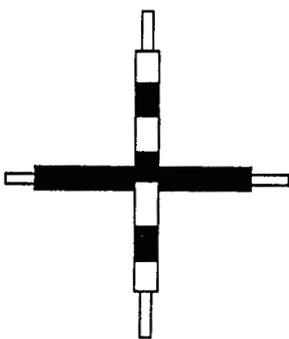
Red Wire



Green or Bare Wire

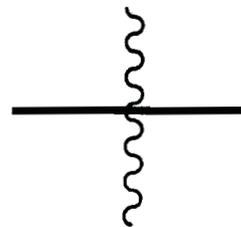
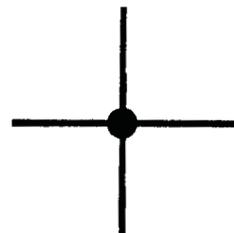


Wires Spliced



Wires Cross
(not connected)

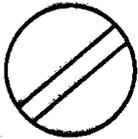
Schematic



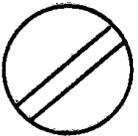
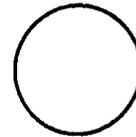
ELECTRICAL SYMBOLS

Pictorial

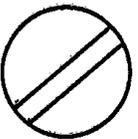
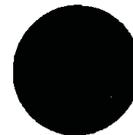
Schematic



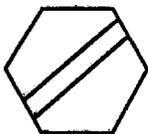
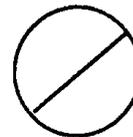
Neutral Wire Terminal



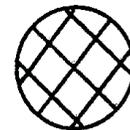
Hot Wire Terminal



Traveler Wire Terminal



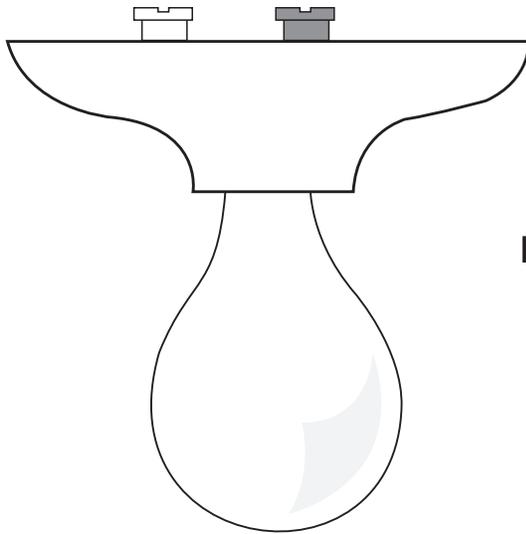
Grounding Wire Terminal



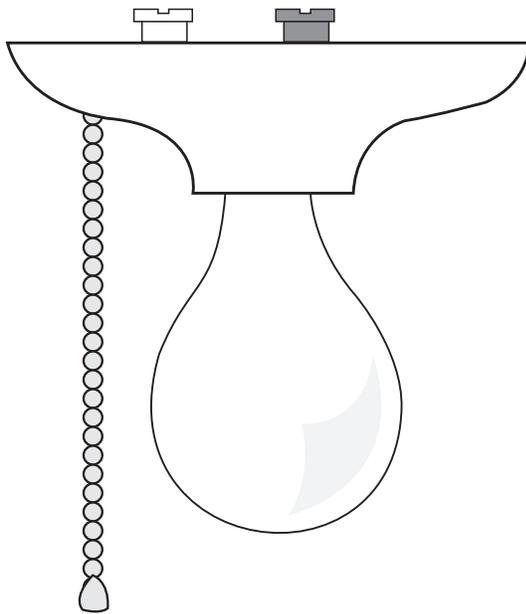
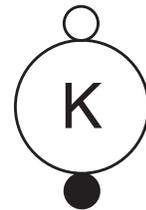
ELECTRICAL SYMBOLS

Pictorial

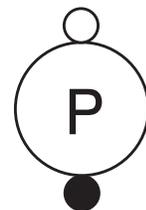
Schematic



Keyless Lamp Fixture

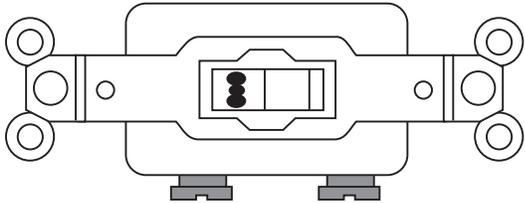


Pull-chain Lamp
Fixture



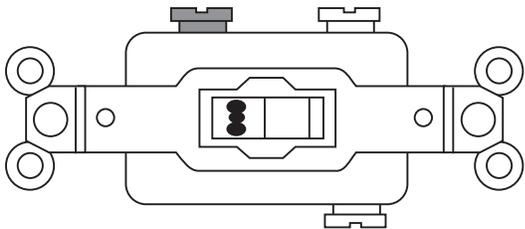
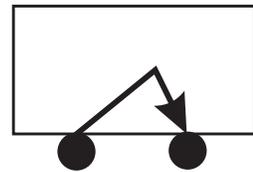
ELECTRICAL SYMBOLS

Pictorial

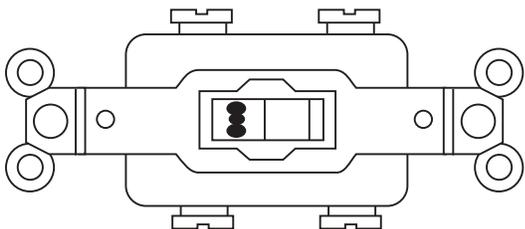
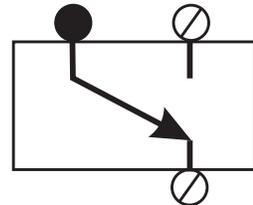


**Single-pole Switch
(SPST)**

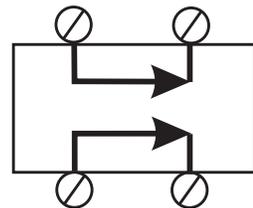
Schematic



**Three-way Switch
(SPDT)**

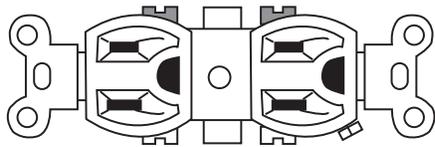


**Four-way Switch
(DPDT)**

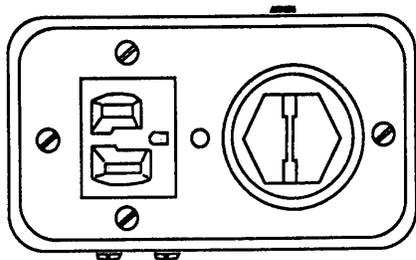


ELECTRICAL SYMBOLS

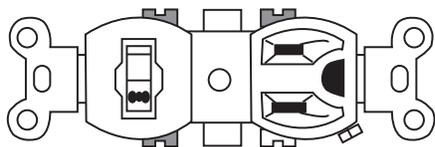
Pictorial



Duplex Receptacle

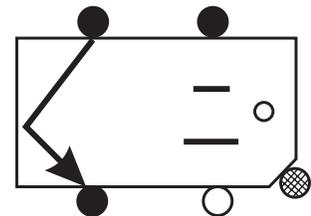
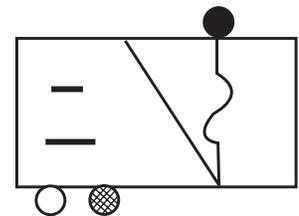
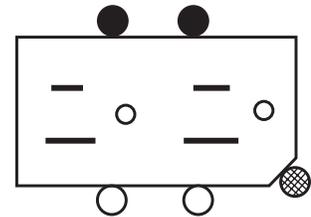


Fused Receptacle



Single-pole Switch and Receptacle

Schematic



RULES TO FOLLOW WHEN WIRING

- 1. The neutral wire goes without interruption to every place in the circuit where current may be used such as light fixtures and receptacles.**
- 2. The neutral wire is connected to the silver-colored terminal of all light fixtures and receptacle outlets.**
- 3. The neutral wire is never connected to a switch or other control device.**
- 4. The neutral wire is always white, but the white wire is not always neutral. In a switch loop installation, the white wire in cable may be used as a hot wire.**
- 5. The black or red wire is always connected to a brass-colored terminal of a lamp fixture or receptacle outlet.**
- 6. The green, or bare, grounding wire is connected to the grounding terminal of a grounding-type electrical fixture.**
- 7. When wiring with cable, all wires must be spliced or connected to a terminal screw in each box.**

- 8. Only one wire is allowed to be fastened under a terminal screw.**
- 9. When wiring with cable, check the number of wires needed between each box. Use the correct colors based on what is available in cable. For example:**
 - a. if 2 wires are needed, use black and white plus ground**
 - b. if 3 wires are needed, use black, red, & white plus ground**
 - c. if 4 wires are needed, use 2 black & 2 white plus ground**
 - d. if 5 wires are needed, use 2 black, 1 red, & 2 white plus ground, etc.**
- 10. When connecting 3-way switches, regardless of their arrangement, it helps to follow a standard procedure:**
 - a. Connect the neutral (white) wire directly to the silver colored terminal of the light.**
 - b. Connect the hot wire to the common terminal of one 3-way switch.**
 - c. Connect the black wire from the common terminal of the other 3-way switch to the light.**
 - d. Connect the traveler wires to the traveler wire terminals of the 3-way switches.**
 - e. Connect the grounding wires to all metal boxes and fixtures in the circuit.**

Lab Sheet

Symbols for Electricity Exercises

Purpose: Students will be able to correctly identify and draw symbols to represent various electrical devices.

Instructions: Draw the correct schematic symbol for each electrical device or wiring application.

1. black wire—

2. white wire—

3. red wire—

4. pull-chain lampholder—

5. keyless lampholder—

6. silver terminal—

7. brass terminal—

8. single-pole switch—

9. 3-way switch—

10. 4-way switch—
11. wires spliced—
12. wires crossing, but not connected—
13. duplex receptacle—
14. combination single-pole switch and receptacle—

LS KEY: A4-6A

Lab Sheet Key

Symbols for Electricity Exercises

(Refer to TM: A4-6A Through TM: A4-6E for scoring)

Lab Sheet

Diagramming Electrical Exercises

Purpose: Students will be able to correctly diagram several different circuits.

Instructions: Using the correct symbol, diagram the following electrical circuits.

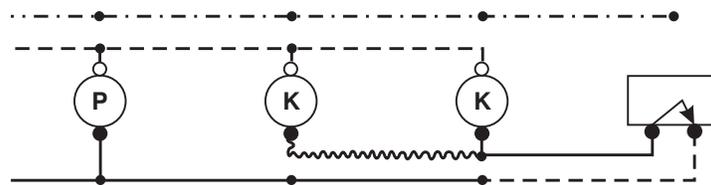
1. Line in->—(pull-chain lamp)—(keyless lamp)—(keyless lamp)—(single-pole switch)
2. Line in->—(3-way switch)—(keyless lamp)—(keyless lamp)—(3-way switch)
3. Line in->—(single-pole switch)—(keyless lamp)—(duplex receptacle)—Line out—
4. Line in->—(3-way switch)—(4-way switch)—(3-way switch)—(keyless lamp)
5. Line in->—(combination single-pole switch and receptacle)—(keyless lamp)—(keyless lamp)

Lab Sheet Key

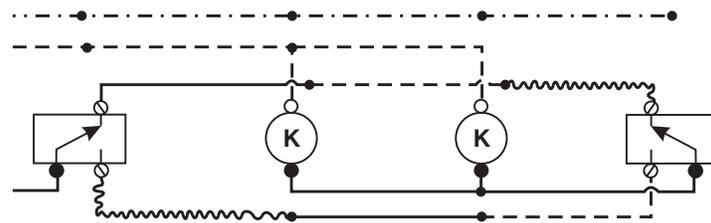
Diagramming Electrical Exercises

(ground wires have been omitted for clarity)

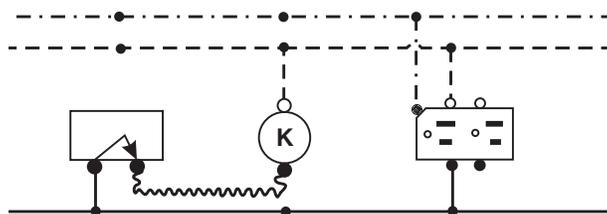
1. Line in->—(pull-chain lamp)—(keyless lamp)—(keyless lamp)—(single-pole switch)



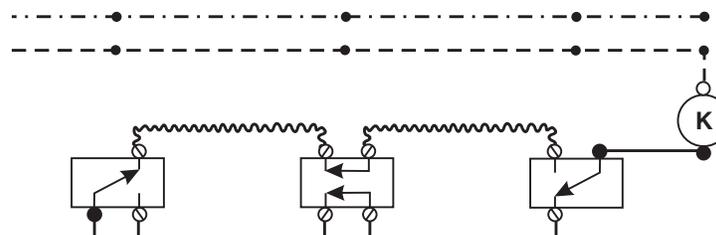
2. Line in->—(3-way switch)—(keyless lamp)—(keyless lamp)—(3-way switch)



3. Line in->—(single-pole switch)—(keyless lamp)—(duplex receptacle)—Line out—



4. Line in->—(3-way switch)—(4-way switch)—(3-way switch)—(keyless lamp)



5. Line in->—(combination single-pole switch and receptacle)—(keyless lamp)—(keyless lamp)

