Practical Exercise

Wiring HVAC Circuits

Contents

Wiring HVAC Circuits

INTRODUCTION

Welcome to the *Wiring HVAC Circuits* practical exercise! As you know, HVAC stands for heating, ventilation, and air conditioning. This exercise includes topics related to HVAC systems and incorporates material presented in the *Electric Heating, Controls for Air Conditioning,* and *Reading Electrical Schematic Diagrams* study units. The purpose of this exercise is to help you apply your program learning to some real-life situations.

In this shipment, you've learned about the electrical heating and control systems commonly located in buildings. In addition, you've learned a great deal about the diagrams that electricians must read and sketch in everyday practice. Anyone working with electrical systems will eventually encounter electrical-powered heating, ventilation, and air-conditioning systems. No matter what type of electrical work you perform, you'll need to accurately interpret electrical drawings.

Throughout this program, you'll be given the chance to apply what you've already learned by completing practical exercises. In this practical exercise, you'll complete some suggested activities that will help you learn more about reading electrical drawings, troubleshooting circuits, and understanding electrical heating systems. All of these activities provide challenges that are encountered by those who work with electricity on a day-to-day basis. The suggested activities are fun, hands-on activities you may want to try on your own. At the end of the suggested activities section, we'll ask you to answer some questions about what you've learned. These questions will be graded as an examination.

The suggested activities contained in this practical exercise are optional, but the examination at the end of the exercise is required and must be submitted to the school for grading. Since the suggested activities are designed to help you increase your learning and enhance your understanding of wiring HVAC circuits, we strongly recommend that you attempt to complete as many of the activities as possible.

When you're ready, work your way through the practical exercise. After you've completed the examination, submit only your answers to the examination to the school headquarters for grading. When submitting your answers, use one of the answer options described in your first shipment. Remember that even though this exercise contains examination questions, we've designed it to be fun, challenging, and interesting.

Applying your knowledge to real-life situations will help you recognize how much you've learned. The practical exercise will be a rewarding experience that will give you confidence in your newly acquired skills.

We hope you enjoy this practical exercise!

SUGGESTED ACTIVITIES

It's time to take a break and have some fun. The following are some hands-on activities that you may want to try in order to enhance your learning. None of these activities will be graded. However, these activities will help you expand your practical understanding of the electrician's profession. We recommend that you read through the exercises. Doing the suggested activities will help you apply your knowledge to some practical situations. At any time you can proceed to the graded examination located at the end of this booklet.

Activity 1: Learning More about Modern Thermostats

At some point in your career, you'll probably be expected to supply both labor and materials to complete a job. Often the material will include equipment, such as electric heaters and thermostats. This first activity involves a shopping adventure. This activity will help you learn more about different types of thermostats that you'll someday need to supply at the job site. You probably won't want to purchase a thermostat right now; however, you can learn some very useful lessons while "shopping" for thermostats. In this activity, you'll be asked to compare several different types and manufacturers of thermostats.

Let's begin with a review of the basics of thermostats. Recall that a thermostat is a simple device that automatically regulates the temperature of a room by varying the output of a piece of equipment, such as an electric heater or air-conditioning unit. Thermostats are widely used in commercial and residential construction and in other applications where temperatures must be controlled. Even automobile engines have thermostats to control the coolant flow through the cooling system.

Most thermostats depend on the expansion of a material. The expansion corresponds to an increase in temperature. Thermostats often incorporate a bimetallic element that includes two strips made of different metals. These metal strips are bonded together. If one end of this bimetallic strip is fixed, an increase in temperature will elongate one metal strip more, causing the strip to curve. This motion actuates an electrical contact or relay. You should also recall that the limited forces generated by a thermostat often require either mechanical or electrical amplification, accomplished using relay switches, in order to move an actuator. Thus, the bimetallic element within a common residential thermostat often includes a mercury-contact switch. The switch amplifies the current flow to a level that's high enough to operate the furnace controls. Other thermometric devices, such as *thermocouples* and *resistance thermometers,* can also be used as the temperature-sensing elements for thermostats, when the variation in the electrical signal produced is amplified to operate the heating system's controls.

During your shopping activity, you'll see that programmable thermostats are very popular. Since the cost of heating and/or cooling a house can be relatively high, programmable thermostats can reduce energy consumption through the use of scheduling or setbacks. No matter where you live, one of the best ways to help you save energy and money is to install a programmable thermostat. Older and less expensive types of programmable thermostats allow for only one or two cycles of operation. For example, in a heating season, you can set back the temperature to a lower, cooler temperature during the night hours while everyone is sleeping. You can also set a warmer temperature for the morning when the occupants are awake and active. In other words, the programmable thermostat will automatically adjust the setpoint based on the schedule of operation that the occupant determines. Scheduling and setbacks are terms used when describing the use of a programmable thermostat. A user would schedule in lower temperature periods known as setback periods while programming the thermostat. The result is reduced energy consumption and lower utility bills.

The latest versions of residential setback thermostats include features that program multiple cycles. A different program can be set for each day of the week. In addition, several newer programmable thermostats can provide separate programs for cooling or heating. It's important to remember that all of these thermostats include the ability to manually override the program at any time.

In this activity you'll shop for a thermostat. In the next activity you'll explore the methods by which thermostats are installed. Throughout the evolution of heating and cooling systems, there have been many types of thermostat controls installed. The new setback thermostats are designed to work with most systems and come with specific, easy-to-follow wiring diagrams. Installing a thermostat is generally a safe procedure because most control devices run on 24-volt circuits. This low voltage doesn't present a shock hazard.

However, some systems, especially those that control electric heat, use standard 120/240-volt residential current and can pose a shock hazard.

In this activity, you'll be asked to compare several different types of thermostats. You'll compare the thermostats' intended use, optional and standard features, voltage, basic internal operation, cost, and manufacturers. By doing this comparison, you'll learn that costs vary widely with quality and features. For example, depending on its quality and available features, a single thermostat can vary in price from $5.00 to $50.00. You may also find that equipment cost may decrease as the quantity of thermostats purchased increases. Finally, the place you purchase equipment (catalogs, professional suppliers, or retail stores) will also have an impact on its price. The goal of this activity is to help you learn more about equipment features and costs through a hands-on shopping activity.

Now, it's time to get started. To complete this activity, you'll need to visit several locations to look at thermostats. When you're choosing locations to visit, try to include at least one large home building center, one smaller hardware store, and one professional electrical supply house. By visiting these different types of stores, you'll be able to see how the prices and selection vary in different locations. You'll probably find that the home center has more variety and lower prices than the hardware store. However, the electrical supply house will typically have the highest-quality thermostats. In some cases, you'll find the same equipment at more than one location.

At each location, note the various types of thermostats available and the names of the common manufacturers. Then, compare the prices from one manufacturer to the next. You'll note that some thermostats come with a lifetime guarantee while others don't. Select the thermostats that impress you the most at each location. These thermostats may include those with the greatest number of positive features, those that are protected by a lifetime warranty, those that are more reasonably priced, and so on. Using the table, write down the model, store, price, voltage, warranty, operating method, and special features. Try to fill in the entire table with information on 15 different thermostats. One of the columns in the table asks you for information on "Special Features." To help you in this exercise, examples of some common special features on thermostats are listed here.

- *5 plus 2-day program.* This programming feature allows the homeowner to program weekdays differently than weekends to account for different occupancy schedules within the home. Upgraded units even offer 7-day program flexibility, which allows the occupant to vary the schedule for each day of the week.

- *4 programs per day.* Most programmable thermostats offer this feature. With this feature, the occupant can determine four different periods during the day that require different heating and cooling levels. For example, a program schedule for a weekday in the winter would be a sleep period with a lower temperature setting, a morning wake-up period with a higher-adjusted temperature setting, a work and school period with a lower setpoint temperature, and a final evening period with a more comfortable, higher temperature.

- *Auto programming.* This feature offers a standard weekly energy- saving program. Auto programming is helpful for users who don't want to be bothered with any type of programming.

- *Temporary manual override.* The temporary manual override feature allows users to temporarily modify the predefined thermostat settings. An example of the usefulness of this feature is the need to increase the setpoint temperature in the winter when the outdoor temperature drops suddenly and rapidly.

- *Vacation override.* This feature allows the user to override the standard schedule during vacation periods when the home will be unoccupied.

- *LCD display.* A digital visual display that's easy to view.

- *Soft-touch keypad.* Electronic thermostats are typically set by pressing a series of buttons. In this case, the buttons correspond to different programming options such as day of the week, program name, setpoint temperature, etc. Some thermostat models incorporate flush surfaces without protruding buttons. The absence of protruding buttons makes the surfaces easier to clean, and the flush surface is typically better sealed against dust.

- *Filter change indicator based on hours of fan-on time.* This feature helps to keep the furnace or A/C running at maximum efficiency by allowing the homeowner or installer to specify the correct filter change interval. When the fan-on time reaches this interval an illuminated indicator light on the cover of the thermostat reminds the homeowner to change the filter.

- *Low battery indicator.* Many electronic thermostats are equipped with backup batteries. Batteries within a programmable thermostat ensure that the programs will not be lost in the event of a power outage. This indicator warns the homeowner to replace old batteries

- *Relay switching.* This feature provides maximum compatibility with the latest heating and cooling systems by allowing the thermostat to control a greater variety of equipment types.

- *Overheat protection.* This feature prevents lock-up in the heat mode. During the heating season, this safety feature ensures that the furnace will not overheat.

- *Warranty (Limited one year).* A limited one-year warranty typically means that the homeowner can exchange a faulty thermostat for a new one during the first year of use.

- *Fahrenheit or Celsius temperature readings.* Allows the user to select the temperature reading scale.

- *12- or 24- hour clock.* Gives the user a choice between standard and military time.

- *Heat On/Cool On indicators.* Clearly tells the user if the unit's on or off.

When you've completed your comparison-shopping list, you should have a much better idea of how much thermostats cost and how the various features of thermostats affect the price.

Activity 2: Installing a Programmable Thermostat

THERMOSTAT COMPARISONS: SHOPPING ACTIVITY

Model	Store	Price	Voltage	Warranty	Operating Method	Special Features

Now that you've shopped for thermostats, you should next consider how you would install a programmable thermostat in your home. In Activity 2, you'll build on your knowledge of thermostats by exploring how these devices are installed. You don't need to purchase or install a thermostat to work you way through this suggested activity. Even if you have purchased a thermostat, don't install it now. Use this activity to work through the installation instructions, making sure to observe all the details. Keep in mind that if you've purchased a thermostat, your programmable device will come with an owner's manual and specific installation directions, which you should read before installing the thermostat. Refer to Figure 1 to familiarize yourself with the process. Then carefully follow the generalized installation directions for a programmable thermostat in the table that follows.

Before you remove any wires, label each wire, and make a diagram of the position of each wire and what terminal each wire is connected to on the thermostat. Most replacement setback thermostats come with stick-on wire identification tags that make this process easy. It's very important that you identify each wire before you remove it. With a two-wire system it doesn't matter which wire is attached, but it does matter on a five-wire system since there are twenty-five possible combinations. If you incorrectly wire the thermostat, there's a possibility you'll damage the device. After you've completed labeling all of the wires, disconnect them.

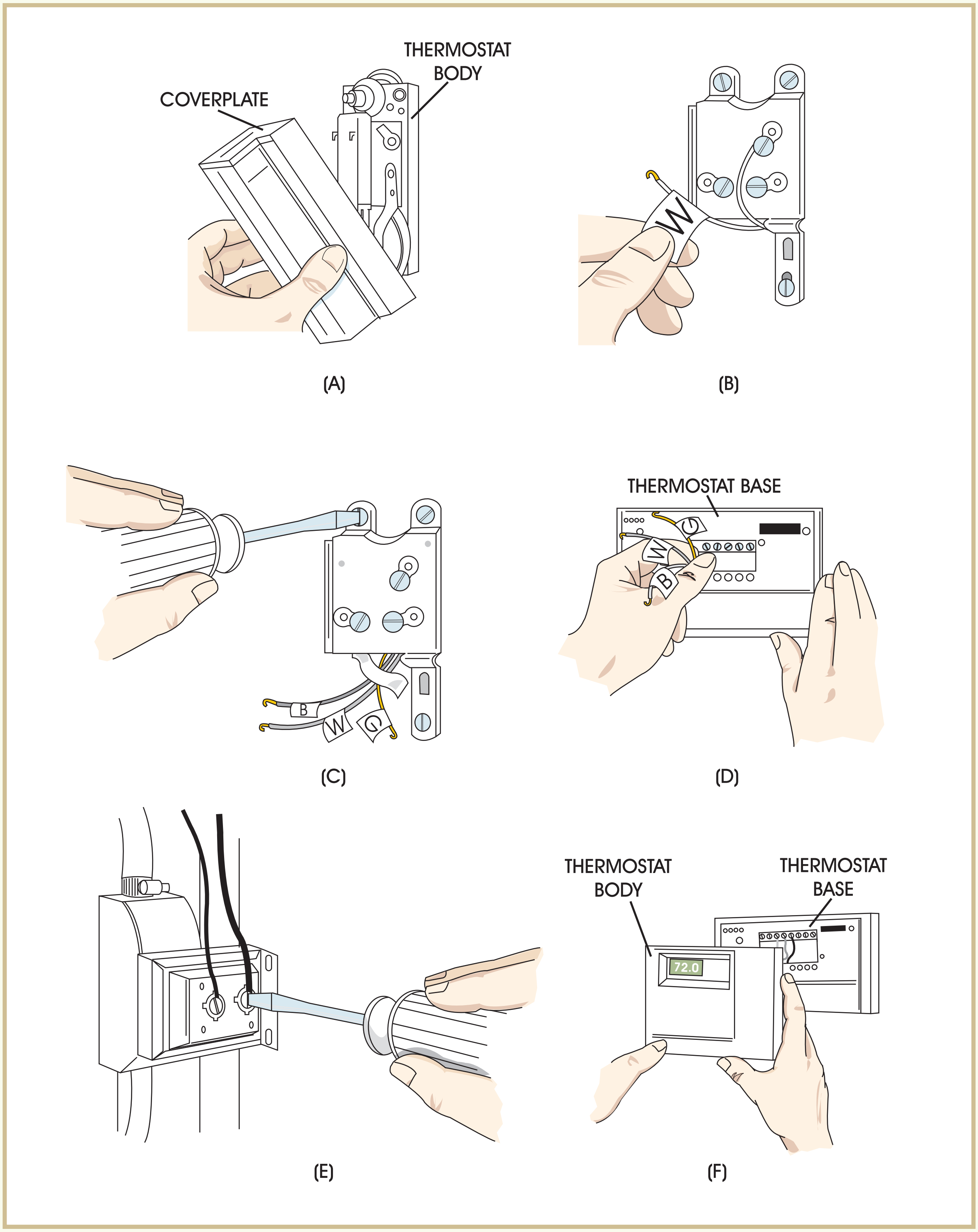

FIGURE 1—Installing a Programmable Thermostat

DIRECTIONS FOR INSTALLING A PROGRAMMABLE THERMOSTAT	
	Existing Thermostat Voltage:___________
Step	**Instructions**
1	First, turn the power off to the furnace at the main switch or open the circuit breaker serving the furnace.
2 (See Figure 1A)	Remove the cover of the existing thermostat, and unscrew the thermostat body-mounting screws to extract the old thermostat.
3 (See Figure 1B)	Before you remove any wires, label each wire, and make a diagram of the position of each wire and what terminal each wire is connected to on the thermostat. Most replacement setback thermostats come with stick-on wire identification tags that make this process easy. It's very important that you identify each wire before you remove it. With a two-wire system it doesn't matter which wire is attached, but it does matter on a five-wire system since there are twenty-five possible combinations. If you incorrectly wire the thermostat, there's a possibility you'll damage the device. After you've completed labeling all of the wires, disconnect them.
4 (See Figure 1C)	Next, remove the thermostat base by loosening the mounting screws. Tape the wires to the wall to prevent them from slipping into the wall cavity.
5 (See Figure 1D)	Thread the low-voltage wires through the base of the new thermostat. Mount the thermostat base on the wall using the screws included with the thermostat. Some manufacturers provide location templates; others direct you to use the base of the thermostat as a template. In either case, mark the location of the mounting screws on the wall and then drill the specified-size hole (typically a -inch hole) for each wall anchor. Tap the wall anchor into the hole, and install the mounting plate or body of the thermostat with the screws provided. If required, level the thermostat. Some thermostats don't use a mercury switch, so it's not important that they be mounted perfectly level. If you are installing a thermostat with a mechanical check-type timer, you should take care to level the thermostat or the thermostat will not display accurate temperatures readings.
6	Wire the thermostat. Connect the low-voltage wires to the appropriate screw terminals on the thermostat base. Follow the installation diagram in your new thermostat's owner's manual. Two-wire systems are very easy to connect. Most thermostats have a row of screw terminals. Connect either wire to the terminal marked with a "W" and the other wire to the terminal marked "R." Loosen the screw, push the wire under the terminal arm, and then tighten the screw. Of course, if the specific installation directions provided by the manufacturer instruct you to connect these wires differently, follow those directions.
7 (See Figure 1E)	Now locate the low-voltage transformer that powers the thermostat. The transformer is usually located near the heating equipment or inside a furnace access panel. Tighten any loose wire connections, and make sure the wires and insulation are in good condition.
8 (See Figure 1F)	Install the battery (typically 9-volt) in the thermostat body if required and attach the body to the thermostat base. Return the power to "on" to the furnace. Program the thermostat according to the instructions in the owner's manual. Remember to refer to the definitions of several terms, related to programmable thermostats, found in Suggested Activity 1.

The second part of this activity is completely optional. If you own your residence, you should now consider purchasing a programmable thermostat and installing it. By doing this you'll use the information you've learned in Suggested Activity 1 about shopping for thermostats, as well as the information you just learned in this suggested activity about installing the device. Try to apply what you've learned in your study units, and be sure to reference the installation manual for the specific thermostat you're installing.

First, carefully remove the cover from the existing thermostat located in your home. You'll probably find that it has two, three, or even five or more thin wires connected to it. Most control devices run on 24-volt circuits. This low voltage doesn't present a shock hazard. However, some systems, especially those including electric heat, use standard house 120-volt house current. If your thermostat is connected to thin wires coming directly out of a hole in the wall, then chances are you are dealing with a 24-volt system. If the thermostat is connected to an electrical box, use caution because a 120-volt system is most likely in place. Remember that whether you're working on a 24-volt or 120-volt system, be sure to turn the power to the circuit off at the circuit breaker, then take the time to use your multimeter to make sure there's no power at the thermostat. Good luck with the installation, and remember to always read the directions first.

Activity 3: Troubleshooting Thermostats and Installing Ceiling Fans

The activities that you just completed required you to shop around for thermostats and to explore how these devices are installed. Activity 3 will help you to further explore thermostats as well as ceiling fans using the World Wide Web. Before the job starts, you may not know exactly how to install a particular device. While the component installation tasks described here aren't very complex, you'll find that the ability to use the World Wide Web as a tool will often help you answer much more complex installation and material selection questions.

You should carefully follow the steps listed below so that you can explore the web for information on how to install and troubleshoot a standard, residential grade thermostat.

Installing a Thermostat

1. First, visit the following Web site: **http://www.homedepot.com.** At this address, you will find Home Depot's Web site. If you are unable to locate or access this site, try to find the site for a different chain of home-remodeling stores. Use the information you find there to answer as many of these questions as possible. You may also want to examine the Web sites of several thermostat providers (such as Honeywell). Many of these sites include online installation and product-selection guides.
2. In the *Search Tips* box, type the word "thermostats," and press the enter key on your keyboard.
3. Then, scroll down the page to find the results of your search, and select the *Everyday Electrical* option.
4. Finally, choose the *Programmable Thermostats* option.

After reviewing this topic, spend a few minutes answering the following questions regarding the installation of a programmable thermostat. When you've completed this suggested activity, check your answers with those provided in the back of this booklet.

1. What tool(s) is/are required?

   ____

2. What materials are required to complete the activity?

   ____

3. How many steps are required?

   ____

4. How long will this activity take?

   ____

5. What skill level is required to do this activity?

   ____

6. Summarize each step and, if desired, include a sketch to better communicate the step.

Troubleshooting a Thermostat

1. Turn your attention back to the web page, and find the section *Related Topics.*
2. Select the *Troubleshooting Your Thermostat* activity.

After reviewing this topic, spend a few minutes answering the following questions regarding the recommended procedure for troubleshooting a programmable thermostat. When you've completed this suggested activity, check your answers with those provided in the back of this booklet.

1. What tool(s) is/are required?

   ____

2. How many steps are required?

   ____

3. How long will this activity take?

   ____

4. What skill level is required to do this activity?

   ____

5. Summarize each step and, if desired, include a sketch to better communicate the step.

   ____

   ____

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Installing a Ceiling Fan

1. Now find your way back to the Home Depot's main page at **http://www.homedepot.com**.
2. Select the *Install It* icon.
3. Click on the *Electrical* option.
4. Under the *Fans* heading, choose *Ceiling Fans.*

After reviewing this topic, spend a few minutes answering the following questions regarding the installation of a residential ceiling fan. Remember that installing a ceiling fan is an inexpensive way to reduce energy costs and improve comfort within a home. The fan circulates air near the ceiling cavity, which, in turn, causes air currents to develop within the room. In the winter, warm air trapped near the ceiling is circulated to lower, occupied areas of the room. The circulation of air improves comfort and saves energy. In addition, the movement of air within the room will improve the ventilation within the space by introducing fresh, outdoor air. During the summer months, a ceiling fan circulates air through the occupied areas within the home, thereby improving comfort and ventilation. When you've completed this suggested activity, check your answers with those provided in the back of this booklet.

1. What tool(s) is/are required to install a ceiling fan?

   ____

2. What materials are required to complete the activity?

   ____

3. How many steps are required?

   ____

4. How long will this activity take?

   ____

5. What skill level is required to do this activity?

   ____

   ____

   ____

6. Summarize each step and, if desired, include a sketch to better communicate the step.

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Activity 4: Designing an Electric Heating System

As an electrician, you'll need to understand how to properly select and install electric heating systems in residential and commercial buildings. This activity explores different types of electric heaters and installation details. After completing the questions, you'll layout an electric heating system for a small residence.

Part A

Let's get started. Read the following questions and provide the appropriate answers in the spaces provided. When you've completed this portion of the activity, check your answers with those provided in the back of this booklet.

1. Electric baseboard heating systems within a home are typically installed so that each baseboard is responsible for heating

   ____

2. An electric baseboard heating unit in a room is controlled by a thermostat located on the _______ or on the unit itself.
3. If there are multiple baseboard heaters in a room, control is typically provided by a _______ thermostat.

4. The two basic components of a baseboard heating system are the _______ and the _______.
5. The element produces _______ when electrical current passes through it.
6. Each element assembly contains a series of metal plates called _______, which help send heat to a broader area.
7. The _______ simply tells the element when to activate and deactivate.
8. Explain how an electric baseboard unit transfers heat to the room in which it's located.

   ____

   ____

   ____

   ____

9. Wall heaters are designed so that each heater is responsible for heating a particular area. A thermostat, which can be located on the wall or on the unit itself, controls each unit. In addition to the thermostat, the basic components in a wall heater are the _______ and the _______.
10. Explain how a wall heater works.

    ____

    ____

    ____

    ____

11. Cable heating systems heat _______ in the room, not the air itself.
12. Cable heating systems are designed so each room is heated individually. Each room is controlled by a thermostat which tells the system when ____________________.
13. With a cable heating unit, cable wiring is looped diagonally throughout the _______.

14. Heat radiates from the wires in the ceiling down to furniture and other surfaces in the room, warming them. The heat is then conducted from those surfaces to the _______.

Part B

Now that you've brushed up on your basic knowledge of electric heating systems, you're ready to practice your skills of designing an electric heating system for the small residence shown in Figure 2.

Carefully review Figure 2. You'll notice that the home consists of two bedrooms, one bathroom, a foyer, and a large kitchen/living room area. In order to design and layout the heating plan for this home, you must first calculate the heat loss of each room in the home. The following steps will lead you through this process:

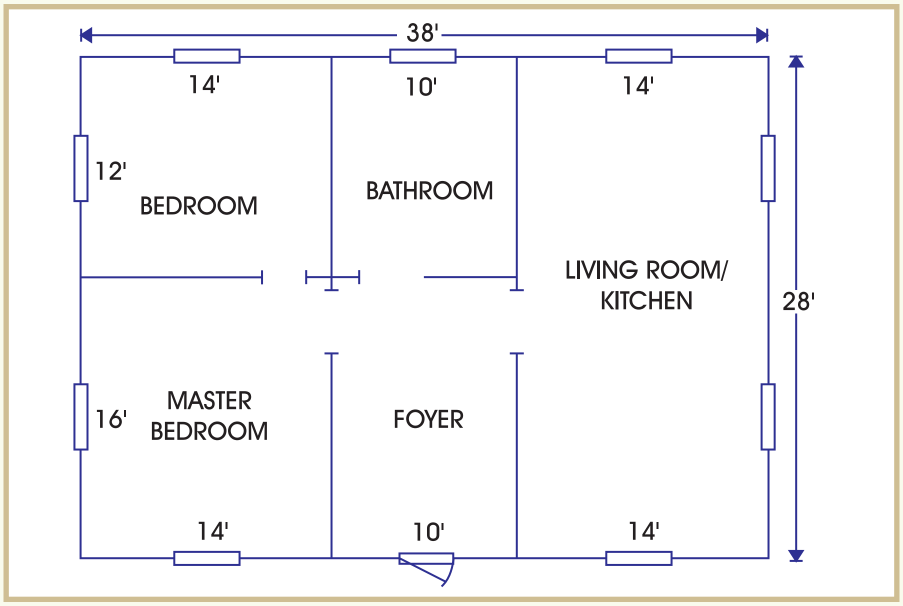


FIGURE 2—Floor Plan for a Small Residence for Heating Calculation

Step 1: Figure 3 shows a cross-section of the home's exterior wall. Begin this exercise by calculating the wall's U-value. You can insert R-values directly into the spaces provided on Figure 3 by using the R-values for common building materials listed in Table 1. After you've completed calculating the total R-value for the wall, remember to convert the total R-value to a U-value.

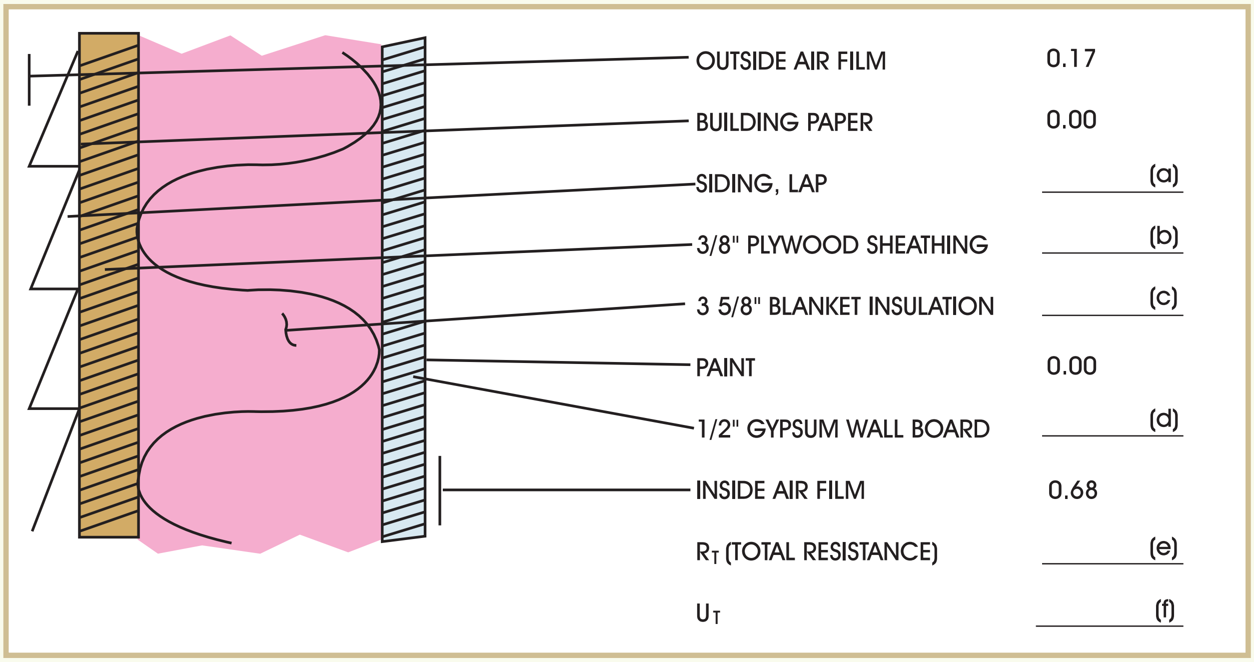
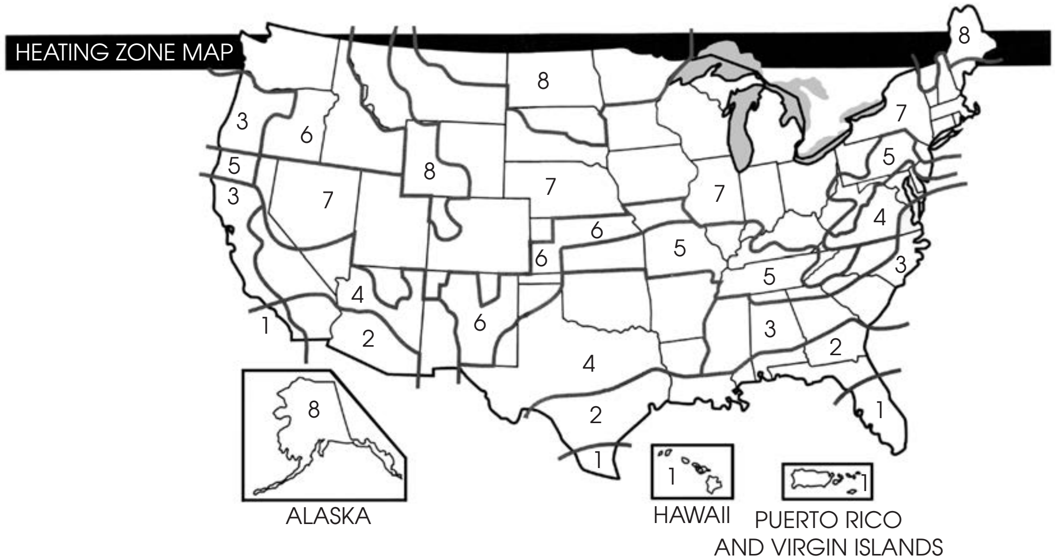


FIGURE 3—This is a cross-sectional view of the home's exterior wall.

Step 2: Based on the R-values you gathered in *Step 1,* use Figure 4 to determine whether or not the home has sufficient insulation for the occupied areas. First base your answer on new construction, then assume the home is an existing structure. Assume that the home will be built in Pittsburgh, PA.

The heating/insulation zone and recommended wall insulation R-value for Pittsburgh, PA, are _______ and _______.

Table 1		
COMMON BUILDING MATERIALS INSULATING VALUES		
Material	**R Value**	**U Value**
Air Space, 3/4″	.91	1.098
Batt or Blanket insulation — 1″	3.70	.270
Batt or Blanket insulation — 2″	7.4	.135
Batt or Blanket insulation — 3 5/8″	13.4	.075
Batt or Blanket insulation — 6″	19.0	.053
Batt or Blanket insulation — 6 1/2″	22.0	.045
Brick, common — 4″	.44	2.27
Beadboard Plastic	4.0	.25
Built-up Roofing	3.0	.333
Cellulose Fiber Blown In — 3 1/2″	13.0	.077
Concrete, Block — 8″	1.11	.900
Concrete, Block (Cores filled with vermiculite) — 8″	1.94	.515
Concrete, Poured — 10″	1.0	1.0
Expanded Polyurethane — 1″	6.25	.16
Expanded Polyurethane — 2″	12.50	.08
Extruded Styrofoam — 1″	5.40	.185
Flexicore — 6″, 8″, 10″	.89	1.124
Glass Block	2.38	0.420
Gypsum Board — 1/2″	.45	2.222
Insulation Board — 1/2″	1.52	.657
Plaster with metal lath — 3/4″	.23	4.347
Plywood — 3/8″	.47	2.127
Roof Deck — 1″	2.78	0.360
Sheathing and flooring — 3/4″	.92	1.086
Shingles, asbestos	.21	4.76
Shingles, wood	.78	1.282
Siding, drop — 3/4″	1.28	.781
Steel Doors: 1 3/4″ mineral fiber core	1.70	0.59
1 3/4″ urethane foam core with thermal break	5.26	0.19
1 3/4″ polystryrene core with thermal break	2.13	0.47
Siding, lap	.78	1.282
Surface, inside (air film)	.68	1.470
Surface, outside (15 mile per hour wind)	.17	5.882
Windows: Single glass, outdoor exposure	.88	1.136
Double glass, 1/4″ apart	1.54	.649
Double glass, 1/2″ apart	1.72	.581
Triple glass, 1/4″ apart	2.13	.469
Wood: Hardwoods (Maple, Oak, etc.) — 1″	0.91	1.099
Softwoods (Pine, Fir, Cedar, etc.) — 1″	1.25	.80
Wood Doors — 1 1/2″	2.04	0.49
Wood Doors — 1 1/2″ w/Storms	3.7	0.27



Recommended R-Values for Existing Houses in Eight Insulation Zones[a]								
Component	**Ceilings Below Ventilated Attics**		**Floors Over Unheated Crawlspaces, Basements**[b]		**Exterior Walls (Wood Frame)**		**Crawl Space Walls**[c]	
Insulation Zone	Oil, Gas, Heat Pump	Electric Resistance	Oil, Gas, Heat Pump	Electric Resistance	Oil, Gas, Heat Pump	Electric Resistance	Oil, Gas, Heat Pump	Electric Resistance
1	19	30	0	0	0	11	11	11
2	30	30	0	0	11	11	19	19
3	30	38	0	19	11	11	19	19
4	30	38	19	19	11	11	19	19
5	38	38	19	19	11	11	19	19
6	38	38	19	19	11	11	19	19
7	38	49	19	19	11	11	19	19
8	49	49	19	19	11	11	19	19

a. These recommendations are based on the assumption that no structural modifications are needed to accommodate the added insulation.
b. R-value of full wall insulation, which is 3 1/2 thick, will depend on material used. Range is R-11 to R-13. For new construction R-19 is recommended for exterior walls. Jamming an R-19 batt in a 3 1/2 inch cavity will not yield R-19.
c. Insulate crawl space walls only if the crawl space is dry all year, the floor above is not insulated, and all ventilation to the crawl space is blocked. A vapor barrier (e.g., 4-or 6- mil polyethylene film) should be installed on the ground to reduce moisture migration into the crawl space.

FIGURE 4—Recommended R-Values for Insulation Based on Geographic Area

Step 3: Assuming that the residence is located in Pittsburgh, PA, use Table 2 to determine the outside design temperature and annual degree days for the home.

The outside design temperature for Pittsburgh, PA, is _______.

There are _______ annual degree days for this location.

When you've completed this portion of the activity, check your answers with those in the back of this booklet.

Table 2					
OUTSIDE DESIGN TEMPERATURES AND ANNUAL DEGREE DAYS					
State and City	**Outside Design Temperature °F in Common Use**	**Annual Degree Days**	**State and City**	**Outside Design Temperature °F in Common Use**	**Annual Degree Days**
Birmingham, AL	10	2780(a)	St. Louis, MO	0	4469
Mobile, AL	15	1529	Helena, MT	-20	8126
Flagstaff, AZ	-10	7525(a)	Omaha, NE	-10	6160(a)
Phoenix, AZ	25	1492	Concord, NH	-15	7612(a)
Little Rock, AR	5	2982(a)	Atlantic City, NJ	5	4741
Los Angeles, CA	35	1451	Newark, NJ	0	5252(a)
Sacramento, CA	30	2600	Albuquerque, NM	0	4389(a)
San Francisco, CA	35	3069	Binghamton, NY	-10	6556
Denver, CO	-10	5673	Buffalo, NY	-5	6838(a)
Hartford, CT	0	6139(a)	Ithaca, NY	-15	6914
District of Columbia	0	4258	New York, NY	0	5050
Miami, FL	35	173	Raleigh, NC	10	3075
Pensacola, FL	20	1435	Cincinnati, OH	0	4532
Tampa, FL	30	674(a)	Cleveland, OH	0	5717
Atlanta, GA	10	2811	Columbus, OH	-10	5277
Augusta, GA	10	2138(a)	Toledo, OH	-10	6394
Savannah, GA	20	1710(a)	Oklahoma City, OK	0	3519
Pocatello, ID	-5	6976(a)	Portland, OR	10	4143
Cairo, IL	0	3756	Erie, PA	-5	6116
Chicago, IL	-10	6310(a)	Philadelphia, PA	0	4523
Springfield, IL	-10	5225	Pittsburgh, PA	0	5048
Fort Wayne, IN	-10	6287(a)	Providence, RI	0	5607
Indianapolis, IN	-10	5134	Charleston, SC	15	1769
Davenport, IA	-15	6091	Columbia, SC	10	2284
Sioux City, IA	-20	7012(a)	Chattanooga, TN	10	3384(a)
Topeka, KS	-10	4919	Nashville, TN	0	3513(a)
Wichita, KS	-10	4571	Amarillo, TX	-10	4345(a)
Louisville, KY	0	4279	Corpus Christi, TX	20	1011(a)
New Orleans, LA	20	1175	Dallas, TX	0	2272(a)
Shreveport, LA	20	2117(a)	Houston, TX	20	1276
Portland, ME	-5	7681(a)	Salt Lake City, UT	-10	5463
Baltimore, MD	0	4203	Norfolk, VA	15	3119
Boston, MA	0	5791(a)	Richmond, VA	15	3720
Detroit, MI	-10	6404(a)	Seattle, WA	15	4438
Grand Rapids, MI	-10	6474	Spokane, WA	-15	6852(a)
Duluth, MN	-25	9574	Parkersburg, WV	-10	4750
Minneapolis, MN	-20	7853(a)	Green Bay, WI	-20	8259(a)
Vicksburg, MS	10	2000	Madison, WI	-15	7300(a)
Kansas City, MO	-10	4888(a)	Milwaukee, WI	-15	6944
(a) Indicates temperatures recorded at airport stations. All others were recorded at city stations.					

Part C

You'll now use the information you just collected to calculate the total heat loss in each room within the residence that's shown in Figure 2. Use the U-values listed in Table 1 for common building materials to complete this exercise. As you determine the heat loss for each room, enter the information in Table 3. Assume that the exterior walls in the home are the same as the wall shown in Figure 3 and that the indoor design temperature in the winter is 70° F. In addition, the exterior door in the home is a $1^1/_2''$ wood door with a storm door, and the windows consist of double glass with $^1/_2''$ spacing. The goal of this exercise is to calculate the heat loss for each room. Before completing the worksheet, remember to convert the Btu values to watts by dividing by a factor of 3.413. After you've completed the heat loss worksheet, compare your answers to those in the back of this booklet.

Part D

Using the heat loss values that you entered in Table 3, design an electric heating plan for the home using baseboard heaters. Sketch the design along with your recommended thermostat locations on Figure 2. Keep in mind that the heating units are available in lengths up to several feet with wattage ratings between 100 and 500 watt per linear foot. Therefore, the units can be put together to make up nearly any length or heating capacity. For the purposes of this exercise, let's assume that the electric resistance heaters will have a capacity of 400 watts per linear foot.

You should add 10% to the heat loss values that you obtained in your worksheet prior to selecting the equipment to ensure that the installed system is capable of maintaining the heating load. For example, if you calculated a heat loss of 800 watts in the bathroom, add 10% or 80 watts to this value. This additional 10% is known as a safety factor. Next, determine the length of resistance heater required for a load of 880 watts. Remember to always size up when selecting heater length. For instance, the bathroom described above with an 880 watt adjusted load would require 3 feet of heater with a capacity of 400 watts per linear foot.

Table 3

HEAT LOSS WORKSHEET

Name of room		**Foyer**		**Master Bedroom**		**Bedroom**		**Bathroom**		**Living/ Kitchen**	
Room Size		10 ft × 16 ft		14 ft × 16 ft		12 ft × 14 ft		10 ft × 12 ft		14 ft × 28 ft	
Ceiling Height		8 ft		8 ft		8 ft		8 ft		8 ft	
Running Feet - Exposed Wall		10 ft		30 ft		26 ft		10 ft		56 ft	
Sources of Heat Losses with a Design F	(1) Heat Loss Factor U	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU
Gross Exposed Walls		80 sq ft		240 sq ft		208 sq ft		80 sq ft		448 sq ft	
Windows				24		24		12 sq ft		48 sq ft	
Doors		19.5 sq ft									
Net Exposed Walls		60.5 sq ft		216 sq ft		184 sq ft		68 sq ft		400 sq ft	
Ceiling	.046	160 sq ft		224 sq ft		168 sq ft		120 sq ft		392 sq ft	
Floor	0.097	160 sq ft		224 sq ft		168 sq ft		120 sq ft		392 sq ft	
Infiltratioin (2)	1.08	1,280 cu ft		1,792 cu ft		1,344 cu ft		960 cu ft		3,136 cu ft	
Sub Total-BTU (3) Sub Total-Watts											

(1) Heat loss factor is determined by evaluation of the building components.
(2) Infiltration heat loss is calculated by converting one air change per hour to cfm by dividing the volume of each room, in cu ft, by 60. The heat loss is then equal to cfm air change times 1.08 times the design F difference.
(3) The heat loss in Btu is converted to watts by dividing by the factor 3.413.

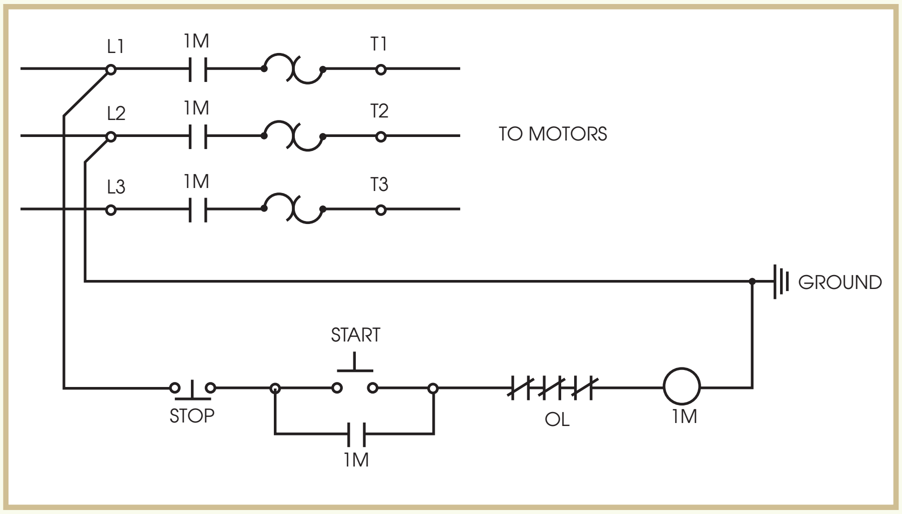
While doing your layout, remember that, for comfort reasons, it's recommended to place the electric resistance heaters on exterior walls and under windows. In addition, thermostats should be placed in an area of the room where the temperature of the air is not directly affected by sunlight or heat from the heater itself. When you've completed this portion of the activity, check your design with the one at the end of this booklet.

Activity 5: Understanding Electric Control Symbols and Diagrams

The ability to read standard electric control diagrams is an essential skill the electrician must develop. These diagrams tell you what type of work you'll be doing and help you to accurately interpret the proper hookup in a wiring diagram. In this activity, you'll practice identifying the meaning of these diagrams.

Look at the ladder logic diagram shown in Figure 5. Complete the following exercise based on Figure 5.

FIGURE 5—Sample Ladder Logic Diagram



In order to do this exercise, you'll need to interpret several standard wiring symbols and to identify the type of equipment this diagram represents and the type of power/control used in the wiring scheme. Try to complete as much of this activity as possible without looking in your study units.

1. Figure 5 represents a _______ , which might be used to power a fan or pump.
2. L1, L2, and L3 signify the _______ terminals with identification.
3. The symbol identified as 1M and located next to L1, L2, and L3 represent the _______.
4. OL represents a/an _______ that, in this case, is normally _______.

5. Start and stop _______ are used for control.

Electricians not only interpret and follow ladder logic diagrams but also sometimes need to change them. Look at the wiring diagram shown in Figure 5 once again. Now imagine that a low-voltage power source is desirable for the control power. Redraw the ladder logic diagram shown in Figure 5 with low-voltage provided for the start-stop controls.

When you've completed this suggested activity, check your answers with those provided in the back of this booklet.

Activity 6: Residential Air-conditioning System Control Diagram

Included in your study material is a stand-alone schematic diagram titled *Residential Cooling System.* It represents a system that removes heat (provides cooling) but doesn't provide heat. You'll need to refer to the schematic to answer the following questions. When you've completed this activity, check your answers against those in the back of this booklet.

1. The diagram includes the condensing unit, evaporative unit, and the thermostat. Which one of the units should be installed outside the building or residence?

   ____

   Why must this unit be installed outside?

   ____

2. Locate the control circuit transformer. What's the primary voltage of the control transformer?

   ____

   What's the secondary voltage of the control transformer?

   ____

3. The red wire (R) from the control transformer to the thermostat is the control wire that must contact other wires within the thermostat to energize parts of the system. Trace this wire from the secondary side of the control transformer through the thermostat. The fan switch is shown in the *Auto Fan* position. If the fan switch is changed to the *On Fan* position, contact is made between the red wire and the green wire. Which relay does this cause to become energized?

____

4. When the selector switch is set to *Cool* and the TC contacts close, calling for cooling, the red wire (R) makes contact with the yellow wire (Y) through the TC contacts. With the fan switch in the *Auto Fan* position, the red wire (R) also makes contact with the green wire through the TC contacts, energizing EFR and causing the fan to run. If the lower pressure switch is closed when the conditions described above occur, which relay becomes energized?

____

5. If LP1 and the TC contacts in the thermostat are closed, CR opens CR1 contacts, shutting off the compressor crankcase heater, and closes CR2 contacts. Which fan is then started?

____

6. When CR2 closes, as described in the Question 5, the control circuit is completed through three safety switches: LP2, HP, and T. These switches protect the system against extremely low Freon pressure (LP2) should LP1 switch fail, extremely high Freon pressure (HP), and high compressor motor temperature (T). If these three safety switches are closed, which piece of equipment starts along with the condenser fan motor?

____

7. What's the coil-operating voltage of CMR, and the motor-operating voltage of CFM and EFM?

____

8. What's the coil operating voltage of EFR and CR?

____

9. Assume that the thermostat contacts are closed, the switch calls for Cool, and the low-pressure switch (LP1) opens due to low Freon pressure in the system. Determine the operating status of each of the following components under these conditions. Indicate that status by writing OFF, ON, OPEN, or CLOSE on the line next to the component.

   Control Relay (CR) _______
   Crankcase Heater (CH) _______
   Condenser Fan Motor (CFM) _______
   Compressor Motor Relay (CMR) _______
   Compressor Motor (CM) _______
   Evaporator Fan Motor (EFM) _______

10. Referring to the thermostat, if the cool switch is turned to the Off position, will the EFM run with the fan switch in the *Auto Fan* position? ______

    If the cool switch is turned to the *Off* position, will the EFM run with the fan switch in the *On Fan* position? ______

11. Write an answer that explains why there's a fuse shown on each side of the CFM and the EFM, based on what you've learned about branch circuit protection.

____

____

____

12. Assume that the compressor motor is running and overheats, causing the T switch to open. Indicate what the effects will be on the following equipment by placing a check on the appropriate line:

Compressor Motor (CM)	ON _____	OFF _____
Compressor Fan Motor (CFM)	ON _____	OFF _____
Evaporator Fan Motor (EFM)	ON _____	OFF _____
Crankcase Heater (CH)	ON _____	OFF _____

CONCLUSION

We hope that you've enjoyed these suggested activities. Now, when you're ready, proceed to the graded portion of the practical exercise. This part of the exercise is completed in the same way as the other examinations for the program. Remember, if you feel that you need to review, you can refer to your course materials at any time. When you're finished with this examination, send your answers to the school for grading. Good luck!

Answers to Installing a Thermostat

1. Screwdriver
2. Programmable thermostat, masking tape
3. 8
4. 3 to 4 hours
5. Basic electrical and mechanical skills are all you'll need.
6. a. Turn off the power to your heating and air-conditioning system at the main service panel. Remove the old thermostat cover plate.

   b. Unscrew the thermostat mounting screws, and remove the thermostat body.

   c. Label the low-voltage wires to identify their screw-terminal locations using masking tape. Then disconnect the wires.

   d. Remove the thermostat base by loosening the mounting screws. Tape the wires to the wall to prevent them from slipping into the wall cavity.

   e. Thread the low-voltage wires through the base of the new thermostat. Mount the thermostat base on the wall using the screws included with the thermostat.

   f. Connect the low-voltage wires to the appropriate screw terminals on the thermostat base. Follow the installation diagram in your new thermostat's owner's manual.

   g. Locate the low-voltage transformer that powers the thermostat. The transformer usually is located near the heating/air-conditioning system or inside a furnace access panel. Tighten any loose wire connections, and make sure the wires and sheathing are in good condition.

   h. Install the battery or batteries in the thermostat body, and attach the body to the thermostat base. Restore power, and program the thermostat as desired.

Answers to Troubleshooting a Thermostat

1. Screwdriver, wire stripper or combination tool
2. 3
3. 1 minute
4. Anyone can accomplish
5. a. Turn off power to the heating/air-conditioning system at the main service panel. Remove the thermostat cover plate.

   b. Remove the thermostat body by loosening the mounting screws with a screwdriver.

   c. Inspect the wire connections on the thermostat base. Reattach any loose wires. If the wires are broken or corroded, they should be clipped, stripped, and reattached to the screw terminals. Replace the thermostat body and cover plate. Restore power at the main service panel.

Answers to Installing a Ceiling Fan

1. Circuit tester, screwdrivers, adjustable wrench, nut driver, wine stripper
2. Electrical fixture box, cable clamps, metal brace bar, wire connectors
3. 7
4. 3 to 4 hours
5. You should already have a few electrical projects under your belt before you tackle installing a ceiling fan. The easiest ceiling-fan installations are those that simply replace an existing centrally- mounted light fixture (you'll want to choose a fan with its own built-in light in that case).

6. a. Turn off power to the existing light fixture at the main service panel, test for power, and remove the existing fixture and electrical box. Attach a 1 1/2-inch-deep metal light-fixture box to the brace bar using a U-bolt and two nuts.

   b. From the attic, position the brace between ceiling joists so the bottom legs are flush with the bottoms of the joists. Rotate the bar by hand to force its end spikes into the joists.

   c. Attach the included stove bolts to the adapter plate with locknuts. These are the bolts that will support the fan. Insert the adapter plate into the box so the ends of the U-bolt fit through the holes on the adapter plate.

   d. Secure the adapter plate by screwing two locknuts onto the U-bolt. Open one knockout for each cable that will enter the electrical box, and attach a cable clamp to each knockout.

   e. Tighten the brace bar one full rotation with a wrench to anchor it tightly against the joists. Feed the existing circuit cable into the electrical box, and secure it with a cable clamp.

   f. Place the ceiling fan's mounting plate over the stove bolts extending through the electrical box. Pull the circuit wires through the hole in the center of the mounting plate. Attach the mounting nuts, and tighten them with a nut driver.

   g. Hang the fan motor from the mounting plate's built-in mounting hook. Connect the wire leads using wire connectors: the black circuit wire to the black wire lead from the fan; the white circuit wire to the white lead; and the grounding wires to the green lead. Finish assembling the fan and the light fixture according to the manufacturer's directions.

Answers to Activity 4

Answers to Part A

1. all or a portion of an individual room
2. wall
3. single
4. element, thermostat
5. heat
6. fins
7. thermostat
8. Cold air is drawn over the heated fins from the bottom of the baseboard and directed into the room by a deflector hood. The heated air rises and forces the cold air to the floor, and the process repeats itself.
9. element, fan
10. Cold air is drawn into the bottom of the heater, where it passes over the heated element and is then directed out to the room by the fan. The heated air rises and forces the cold air to the floor, and the process repeats itself.
11. surfaces
12. to turn on and off
13. ceiling
14. air

Answers to Part B

1. R-values for Figure 3(a) .78 (b) .47(c) 13.4(d) .45(e) 15.95 (f) .063
2. Zone 7, R19 is recommended for walls in new construction, R11 for existing construction.
3. 0° F, 5048

Answers to Part C

Remember that heat loss in Btu equals U × temperature difference × square footage of surface area. The table on the next page lists the solutions for the heat loss calculations.

Answers to Part D

Use the wattage-heat loss for each room (from Part C) to calculate the total heater lengths for each room. For the foyer, the calculation is 1128 (room's total heat loss in watts) × 1.1 (safety factor) ÷ 400 watts/foot (heater rating) = 3.1 feet. Remember to round up to 4 feet.

The figure on the next page shows a likely solution to the electric baseboard heater placement problem. Note that while your answer may differ somewhat, the total baseboard heater length in each room should be about the same. Also, it's important that your placement of thermostats, relative to baseboard heating units, follows acceptable conventions.

Answers to Activity 5

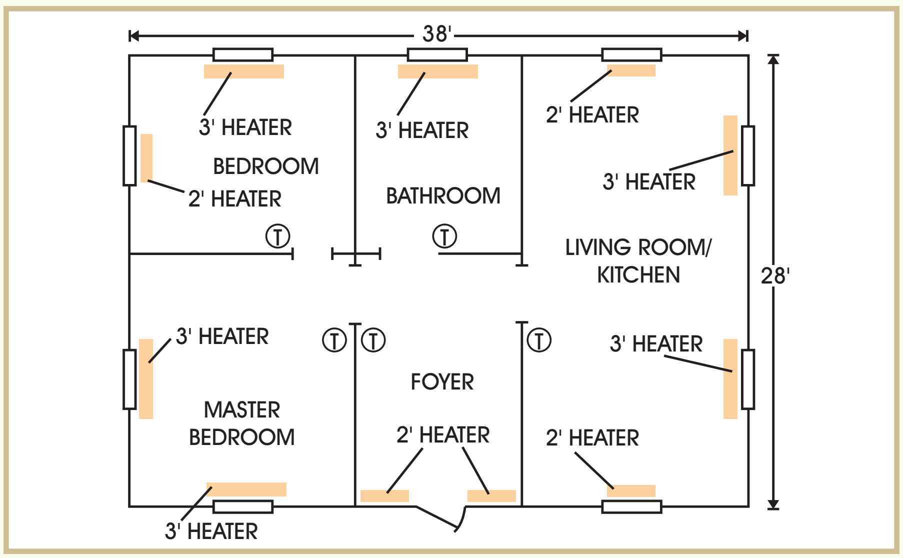
1. motor starter
2. line wiring

Table 3

HEAT LOSS WORKSHEET

Name of room		**Foyer**		**Master Bedroom**		**Bedroom**		**Bathroom**		**Living/ Kitchen**	
Room Size		10 ft × 16 ft		14 ft × 16 ft		12 ft × 14 ft		10 ft × 12 ft		14 ft × 28 ft	
Ceiling Height		8 ft		8 ft		8 ft		8 ft		8 ft	
Running Feet - Exposed Wall		10 ft		30 ft		26 ft		10 ft		56 ft	
Sources of Heat Losses with a Design F	(1) Heat Loss Factor U	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU	Area or Volume	Heat Loss BTU
Gross Exposed Walls	—	80 sq ft	—	240 sq ft	—	208 sq ft	—	80 sq ft	—	448 sq ft	—
Windows	0.581	—	—	24	976	24	976	12 sq ft	488	48 sq ft	1,952
Doors	0.27	19.5 sq ft	369	—	—	—	—		—		—
Net Exposed Walls	0.063	60.5 sq ft	267	216 sq ft	953	184 sq ft	811	68 sq ft	300	400 sq ft	1,764
Ceiling	.046	160 sq ft	515	224 sq ft	721	168 sq ft	541	120 sq ft	386	392 sq ft	1,262
Floor	0.097	160 sq ft	1,086	224 sq ft	1,521	168 sq ft	1,141	120 sq ft	815	392 sq ft	2,662
Infiltratioin (2)	1.08	1,280 cu ft	1,613	1,792 cu ft	2,258	1,344 cu ft	1,693	960 cu ft	1,210	3,136 cu ft	3,951
Sub Total-BTU (3) Sub Total-Watts			3,850 1,128		6,429 1,184		5,162 1,512		3,199 937		11,591 3,396

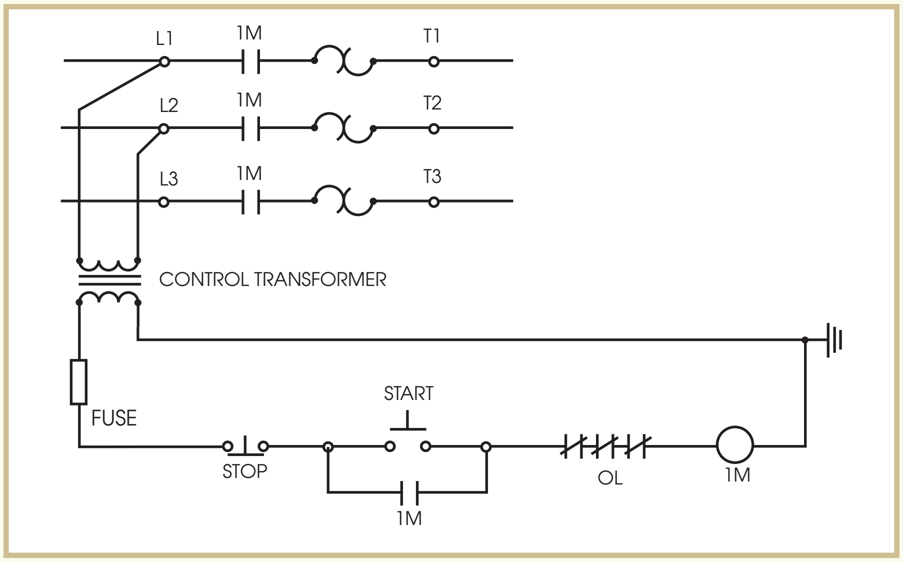
(1) Heat loss factor is determined by evaluation of the building components.
(2) Infiltration heat loss is calculated by converting one air change per hour to cfm by dividing the volume of each room, in cu ft, by 60. The heat loss is then equal to cfm air change times 1.08 times the design F difference.
(3) The heat loss in Btu is converted to watts by dividing by the factor 3.413.



3. coil contacts
4. overload, closed
5. push buttons

Answers to Activity 6

1. Condensing unit. It must exhaust the heat transferred from the inside air to the outside air.
2. Primary voltage is 240 V. Look at the taps supplying voltage to the primary side. They're connected to the line side of the 240-volt circuit that supplies the condensing motor. Secondary voltage is 24 V. The tag above the thermostat identifies the rating of the cooling thermostat as 24 volts.



Motor Starter with Low-Voltage Control Power

3. Evaporator fan relay (EFR). Trace the green wire from the thermostat to the 24-volt ladder diagram below the transformer.
4. Control relay (CR). Trace the yellow wire from the thermostat to the 24-volt ladder diagram.
5. Condenser fan motor (CFM). As stated in *Question 4,* the yellow wire causes the control relay (CR) to energize, which in turn closes the normally open contacts (CR2) and permits the condensing fan motor (CFM) to start.

6. Compressor motor (CM). When all the safety switches are in their normally closed position and CR2 closes, the compressor motor relay (CMR) is energized. This closes the normally open CMR1 contacts located on the load side of the 240-volt supply to the compressor motor (CM), permitting the compressor motor (CM) to start.
7. 240 VAC. Follow the ladder diagram from these components and notice how they're tapped from the 240-volt supply of the condensing motor.
8. 24 VAC. Locate the components and notice how they're located on the secondary side of the control transformer.
9. Control Relay (CR) — OPEN

Control Relay (CR)	OPEN
Crankcase Heater (CH)	ON
Condenser Fan Motor (CFM)	OFF
Compressor Motor Relay (CMR)	OPEN
Compressor Motor (CM)	OFF
Evaporator Fan Motor (EFM)	ON

10. NO. The red wire (R) connection to the green wire (G) needed to run the fan is opened when the cool switch is in the *OFF* position.

    YES. The red wire (R) connects to the green wire (G) when the fan switch is in the *ON* position.
11. Because all ungrounded conductors in branch circuits must have overcurrent protection, and these are branch circuits shown in ladder diagram format
12.

Compressor Motor (CM)	OFF
Compressor Fan Motor (CFM)	ON
Evaporator Fan Motor (EFM)	ON
Crankcase Heater (CH)	OFF

Wiring HVAC Circuits

EXAMINATION NUMBER

00680602

Whichever method you use in submitting your exam answers to the school, you must use the number above

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When you feel confident that you have mastered the material in this study unit, go to http://www.pennfoster.edu and submit your answers online. If you don't have access to the Internet, you can phone in or mail in your exam. Submit your answers for this examination as soon as you complete it. *Do not wait until another examination is ready.*

Examination

Questions 1–20: Select the one best answer to each question.

1. Two students are discussing how programmable thermostats work. Student A says that a piece of material within the thermostat changes length depending on moisture content of the air and that temperature is related to this change in moisture. Student B says that there's a material within the thermostat that changes its length based on temperature and that the measured temperature is related to the change in length. Which of the following statements is correct?

   A. Only Student A is correct.
   B. Only Student B is correct.
   C. Both students are correct.
   D. Neither of the students is correct.

2. In a home that has 120 V service, heating is provided by electric resistance heat with an overall resistance of 40 Ω. How much heating power will the electric resistance heater generate?

   A. 0.03 kW
   B. 0.48 kW
   C. 0.36 kW
   D. 4.8 kW

3. In the same home that has 120 V service, the thermostat controlling the electric resistance heaters consumes 5 watts of power. How much resistance in Ω is associated with the thermostat?

A. 24 Ω
B. 480 Ω
C. 4.8 Ω
D. 2880 Ω

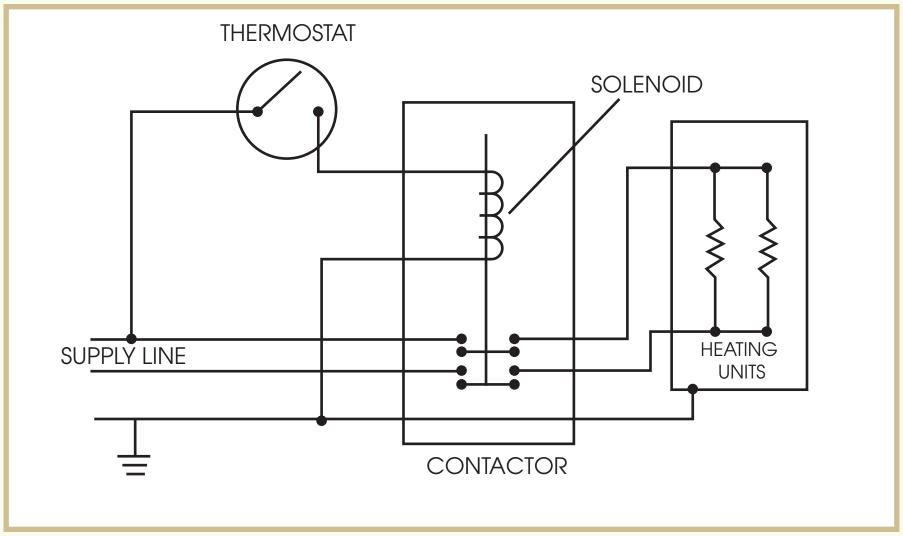
4. Two students are discussing electric heaters. Student A says that the most common convection-type heating unit used is an electric floor-insert heater. Student B says that electric cabinet heaters are the most common natural-convection type electric heaters. Which of the following statements is correct?

A. Only Student A is correct.
B. Only Student B is correct.
C. Both students are correct.
D. Neither of the students is correct.

5. Which of the following statements is true regarding the double-pole thermostat with a contactor, illustrated in Figure A-1?

A. The double-pole switch disconnects one side of the power supply to the heating unit.
B. The contactor allows the thermostat to control higher loads than it conducts.
C. The contactor prevents arcing.
D. The thermostat is supplied with low voltage.

FIGURE A-1—Use this illustration to answer Question 5.



6. In determining the heat loss for a home, you are given the following information regarding a large picture window for the living room. The window must be 50 square feet in area with a maximum heat loss of 500 watts. You are to assume that in the winter the indoor to outdoor temperature difference across the glass could reach 70°F. You must determine which option to choose based on the following data of available window options:

   Option A: For $450 per unit, you can purchase a window with double glass spaced 1/4″ apart. The U-value of this window is 0.649.

   Option B: For $650 per unit, you can purchase a window with double glass spaced 1/2″ apart. The U-value of this window is 0.581.

   Option C: For $850 per unit, you can purchase a window with triple glass spaced 1/4″ apart. The U-value of this window is 0.469.

   Which option is the most economical, considering price and conformance to the 500-watt heat-loss limitation?

   A. Option A
   B. Option B
   C. Option C
   D. None of the options are acceptable.

7. Which of the schematics in Figure A-2 shows a break in the circuit?

   A. Circuit 1
   B. Circuit 2
   C. Circuit 3
   D. Circuit 5

8. Which of the schematics in Figure A-2 shows a faulty ground?

   A. Circuit 2
   B. Circuit 3
   C. Circuit 4
   D. Circuit 5

9. Which of the circuits in Figure A-2 will result in an energized lamp?

   A. Circuit 1
   B. Circuit 2
   C. Circuit 3
   D. Circuit 5

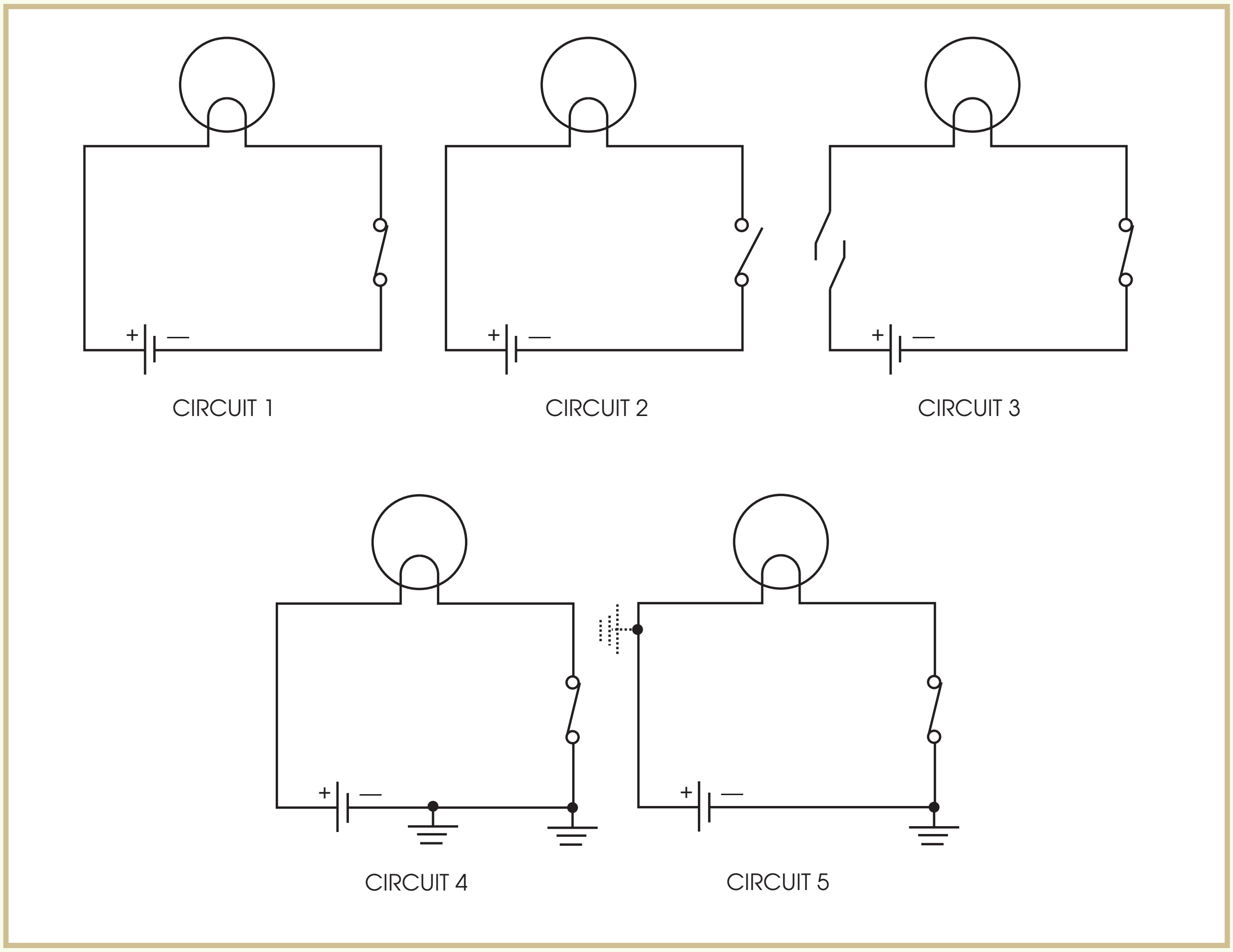


FIGURE A-2—Use this illustration to answer Questions 7, 8, and 9.

10. Two students are discussing the flow of electricity. Student A says that voltage is a measure of the amount of electron flow in a circuit. Student B says that power is the product of voltage and current. Which of the following statements is correct?

A. Only Student A is correct.
B. Only Student B is correct.
C. Both students are correct.
D. Neither student is correct.

11. In a proportional control system, if A = 1.5, Kp = 0.8, the setpoint temperature is 75°F and the actual temperature is 72°F, what is the controller's output?

A. 2.1
B. 3.9
C. 5.2
D. 15.3

12. Look at the symbols shown in Figure A-3. Which symbol represents a device used to produce an alarm signal in the event of high temperature?

A. Symbol A
B. Symbol B
C. Symbol C
D. Symbol D

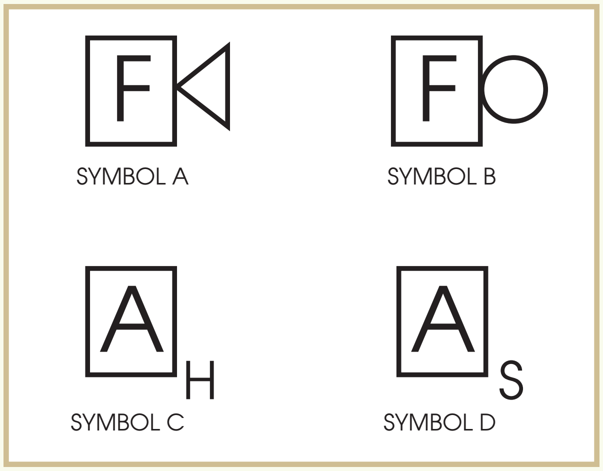


FIGURE A-3—Use this illustration to answer Questions 12 and 13.

13. Look at the symbols shown in Figure A-3. What are the similarities and differences between Symbol A and Symbol B?

A. Both symbols represent an alarm station; however, Symbol A includes a bell and Symbol B includes a horn.
B. Both symbols represent a fire alarm; however, Symbol A includes a horn and Symbol B includes a bell.
C. Both symbols represent an alarm station; however, Symbol A includes a horn and Symbol B includes a bell.
D. Both symbols represent a fire alarm; however, Symbol A includes a bell and Symbol B includes a horn.

14. Examine the schematic symbols in Figure A-4. Which symbol represents a manhole?

A. Symbol 1
B. Symbol 2
C. Symbol 3
D. Symbol 4

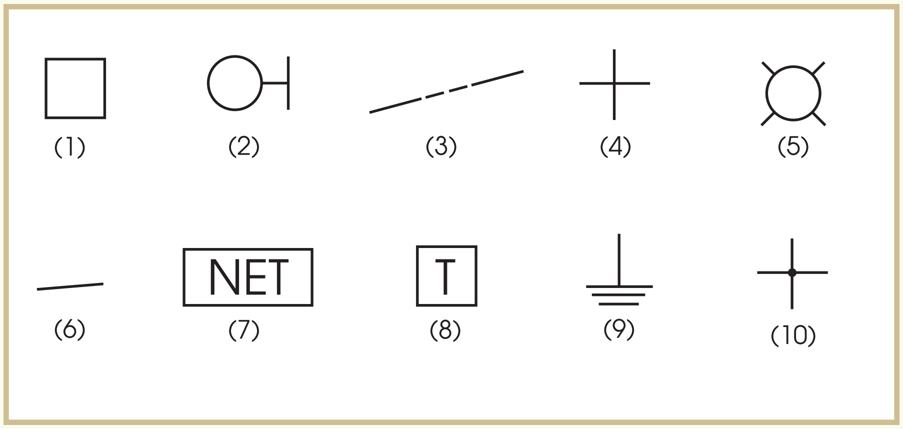


FIGURE A-4—Use this illustration to answer Questions 14, 15, and 16.

15. Which of the schematic symbols illustrated in Figure A-4 represents a direct burial cable?

A. Symbol 3
B. Symbol 4
C. Symbol 5
D. Symbol 6

16. Refering to Figure A-4, which of the following statements is correct?

A. Symbols 4, 5, and 6 represent conductors.
B. Symbols 4, 6, and 10 represent conductors.
C. Symbol 4 represents connected conductors.
D. Symbol 8 represents connected conductors.

17. Several students are discussing different types of heating and air-conditioning systems. They are very fascinated with the system that distributes high-velocity heating and cooling air in two separate ducts. What is the name of this system?

A. Unit ventilator system
B. Fan-coil unit
C. Bi-duct boiler system
D. Dual duct system

18. The primary energy source for the controller in a typical control system is either

A. solar, electric, or pneumatic.
B. solar, electronic, or electric.
C. electric, pneumatic, or electronic.
D. damper, motor, or valve.

19. If a valve's position is constantly changing to achieve the desired setpoint, which of the following control actions is used?

A. On-off
B. Adjustable
C. Modulating
D. Finite

20. Two students are discussing the contacts found in the ladder logic diagrams for fan motor control. Student A says that auxiliary contact symbols are often found in the diagrams. Student B says that load contacts and overload contact symbols are often shown in the diagrams. Which of the following statements is correct?

A. Only Student A is correct.
B. Only Student B is correct.
C. Neither student is correct.
D. Both students are correct.