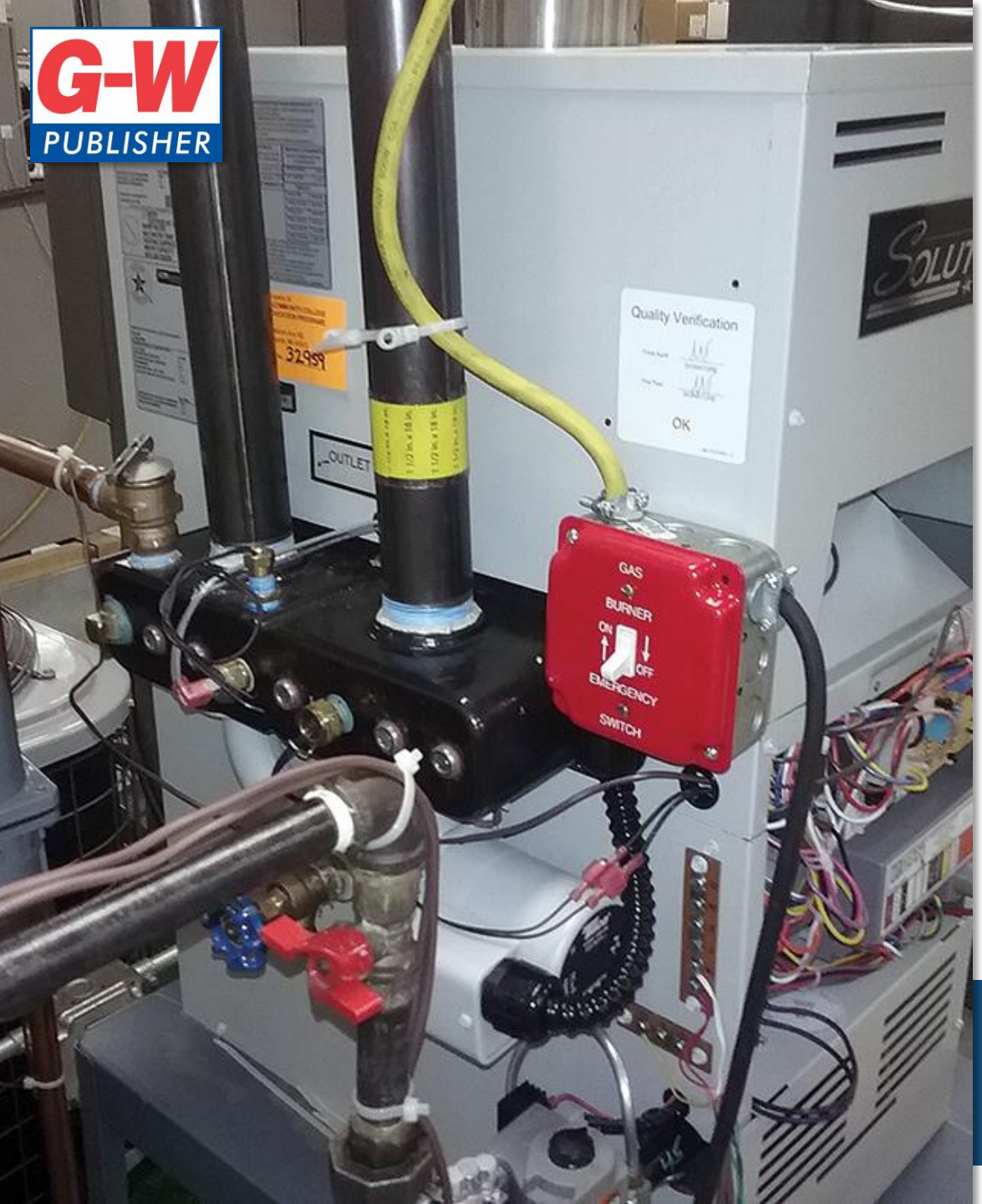

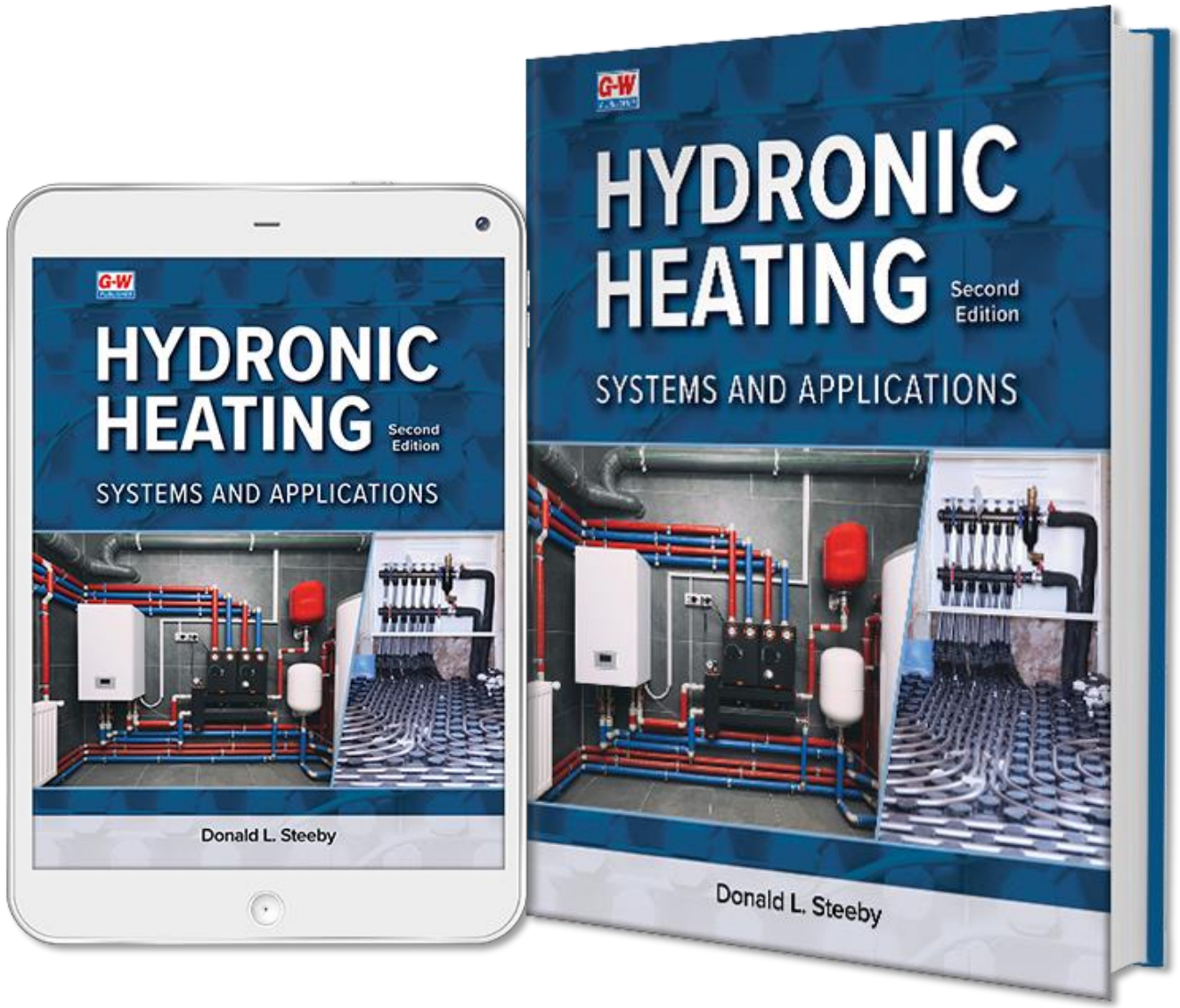

Hydronic Heating: Systems and Applications

Designed by Educators, Built for Educators

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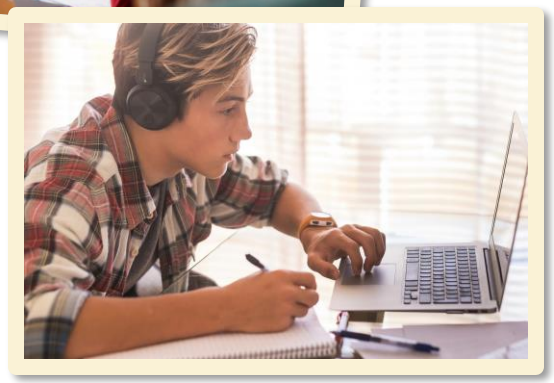
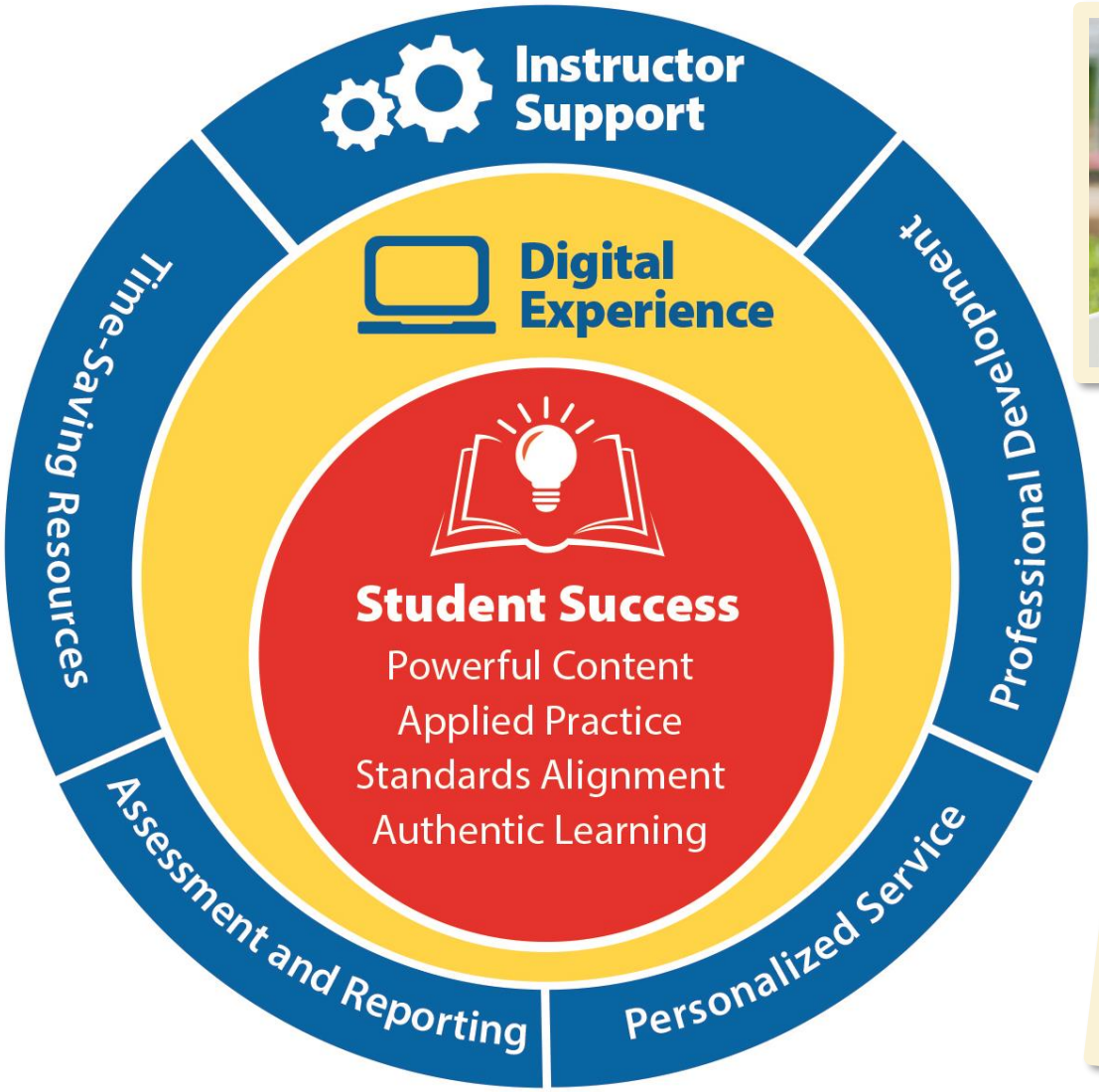
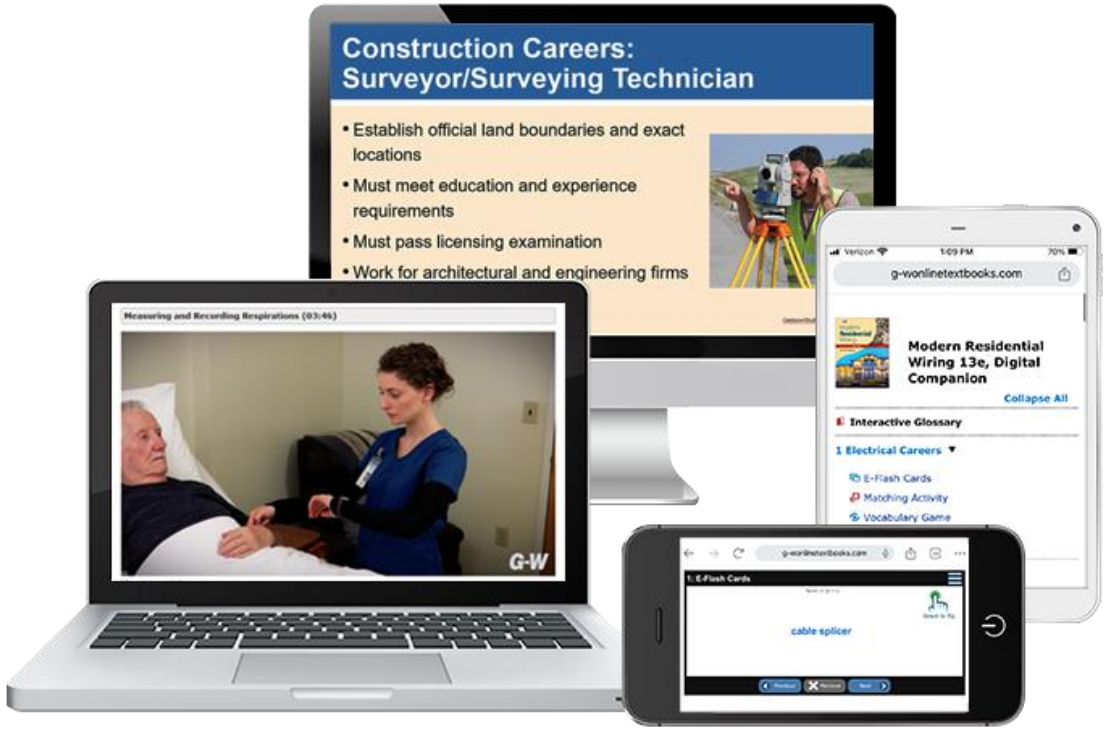




Student Success Is At the Heart of What We Do



- ✓ Prepare for class
- ✓ Reinforce new concepts
- ✓ Assess learning

Ready-to-Implement Online Instructor Resources

Hydronic Heating: Systems and Applications: Lesson Plan

Instructor: *Date:*
Course: *Unit:*

Chapter 1: Human Comfort and Heat Transfer

Learning Outcomes

- 1.1 Hydronic Heating
  - 1.1-1 Demonstrate how heat energy travels from warm to cold.
- 1.2 Basic Hydronic Configuration
  - 1.2-1 Explain the evolution of hydronic heating systems.
- 1.3 Modern Hydronic System Configurations
  - 1.3-1 Describe the functionality of a modern hydronic heating system.
- 1.4 Heating and Human Comfort
  - 1.4-1 Compare the various piping configurations that are available for radiant floor heating.
- 1.5 Benefits of Using Hydronic Heating
  - 1.5-1 Describe the benefits of using hydronic heating over other conventional sources.
- 1.6 Principles of Heat Transfer
  - 1.6-1 Describe how heat is transferred by conduction, convection, and radiation.
  - 1.6-2 Explain the process of heat transfer through both air and water.
- 1.7 Heat Transfer through Piping
  - 1.7-1 Diffe
  - 1.7-2 Dem

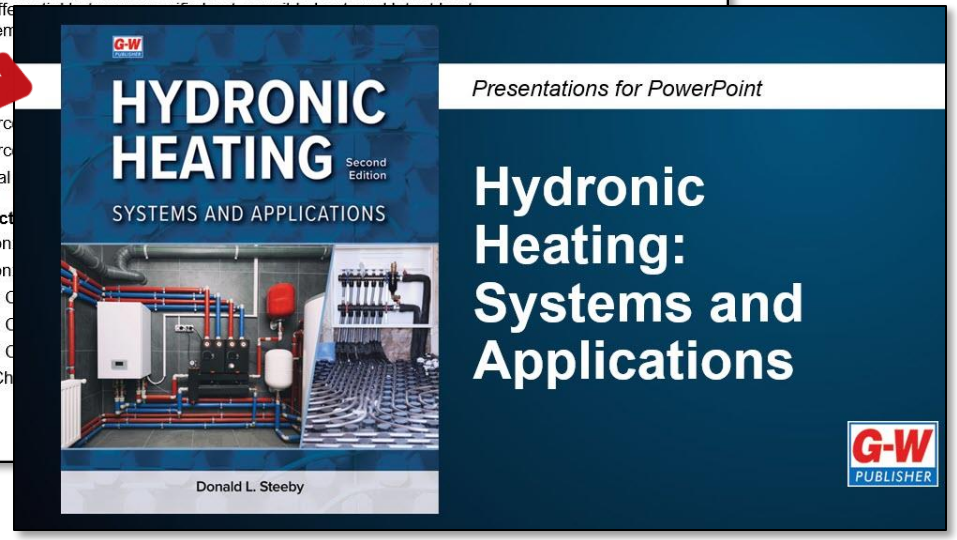
Instructional

- Textbook/eBoo
- Instructor Resourc
- Instructor Resourc
- Other instructional

Resources for Pract

- Digital Companion
- Digital Companion
- Textbook/eBook: C
- Textbook/eBook: C
- Textbook/eBook: C
- Lab Workbook: Ch
- Other resource:

Assessment



Lesson Plans, PowerPoint Presentations, and Answer Keys

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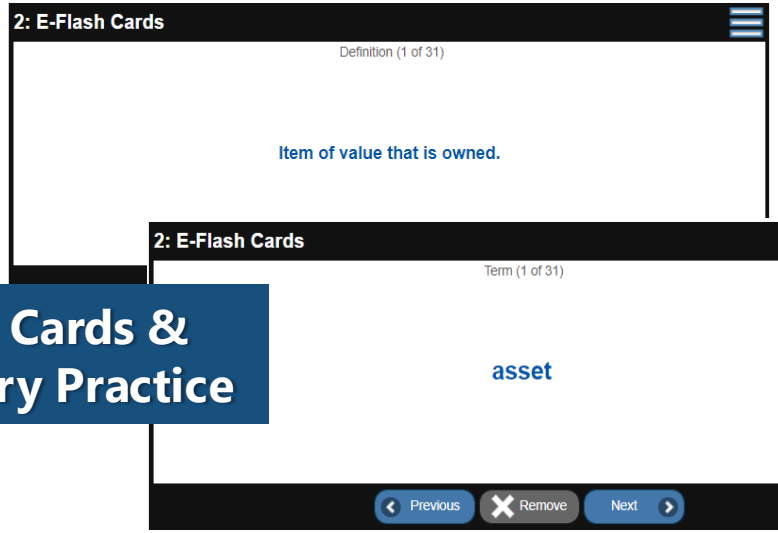
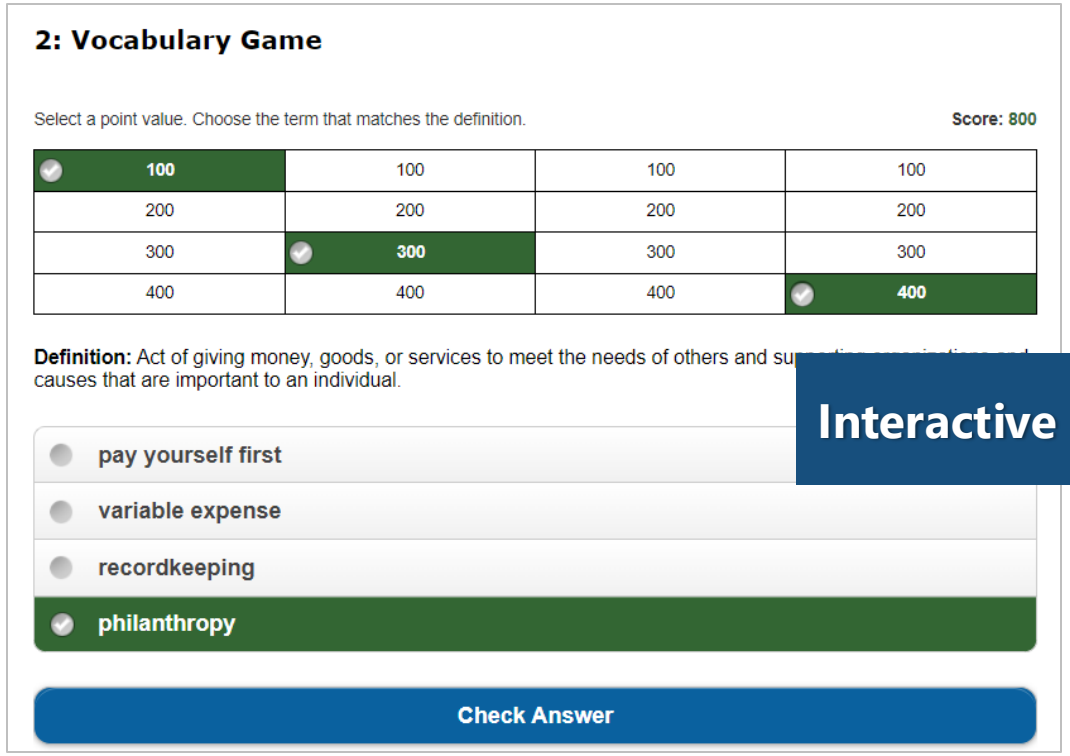
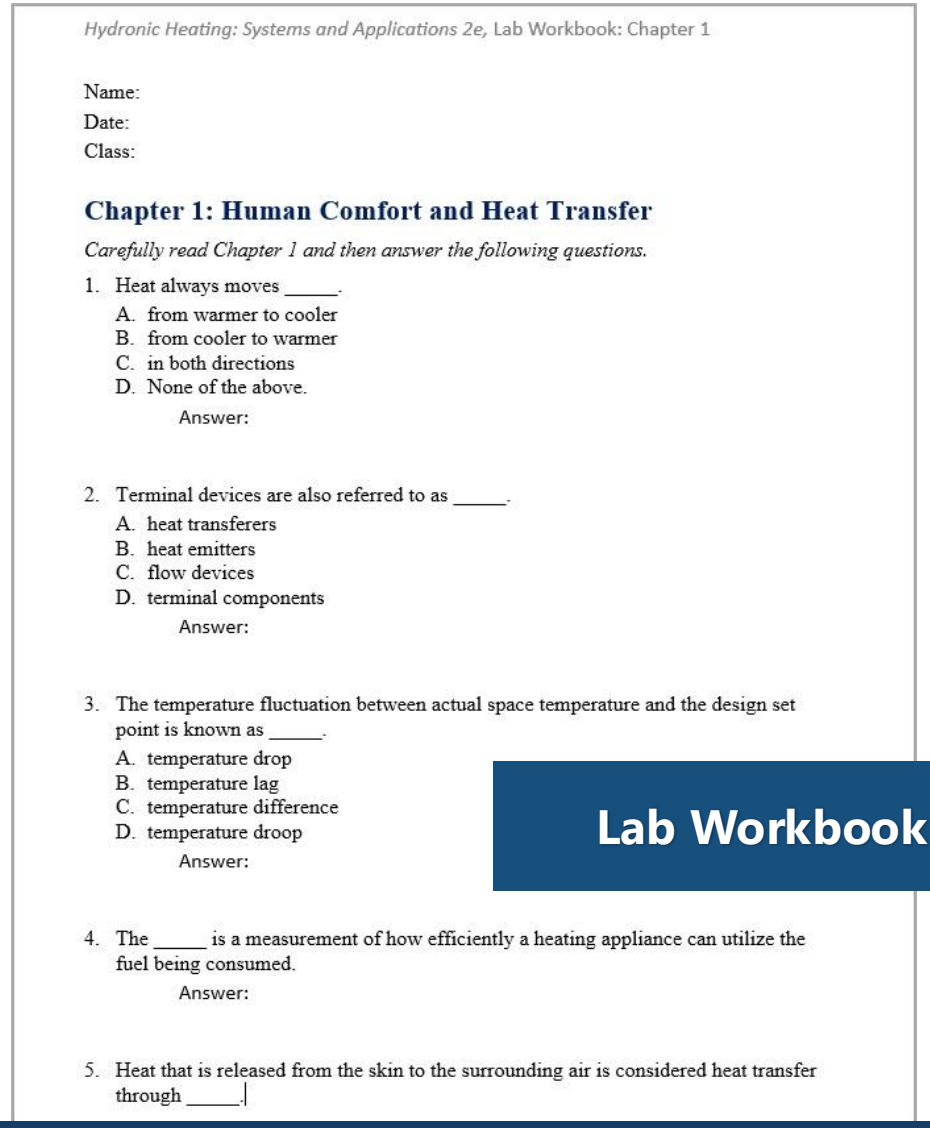


E-Flash Cards & Vocabulary Practice



Interactive Activities



Hydronic Heating: Systems and Applications 2e, Lab Workbook: Chapter 1

Name:
Date:
Class:

Chapter 1: Human Comfort and Heat Transfer

Carefully read Chapter 1 and then answer the following questions.

1. Heat always moves _____.
   A. from warmer to cooler
   B. from cooler to warmer
   C. in both directions
   D. None of the above.
   Answer:

2. Terminal devices are also referred to as _____.
   A. heat transferers
   B. heat emitters
   C. flow devices
   D. terminal components
   Answer:

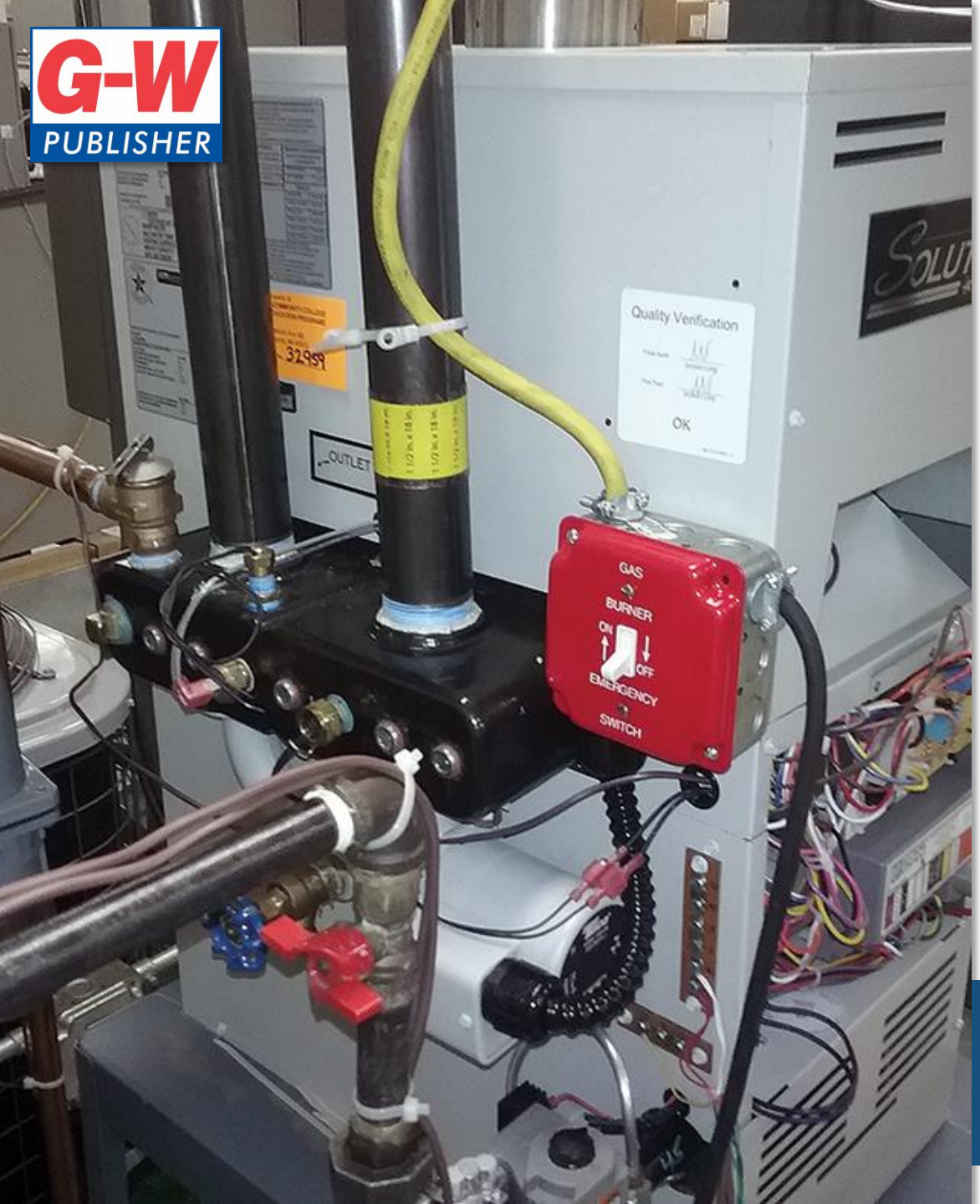
3. The temperature fluctuation between actual space temperature and the design set point is known as _____.
   A. temperature drop
   B. temperature lag
   C. temperature difference
   D. temperature droop
   Answer:

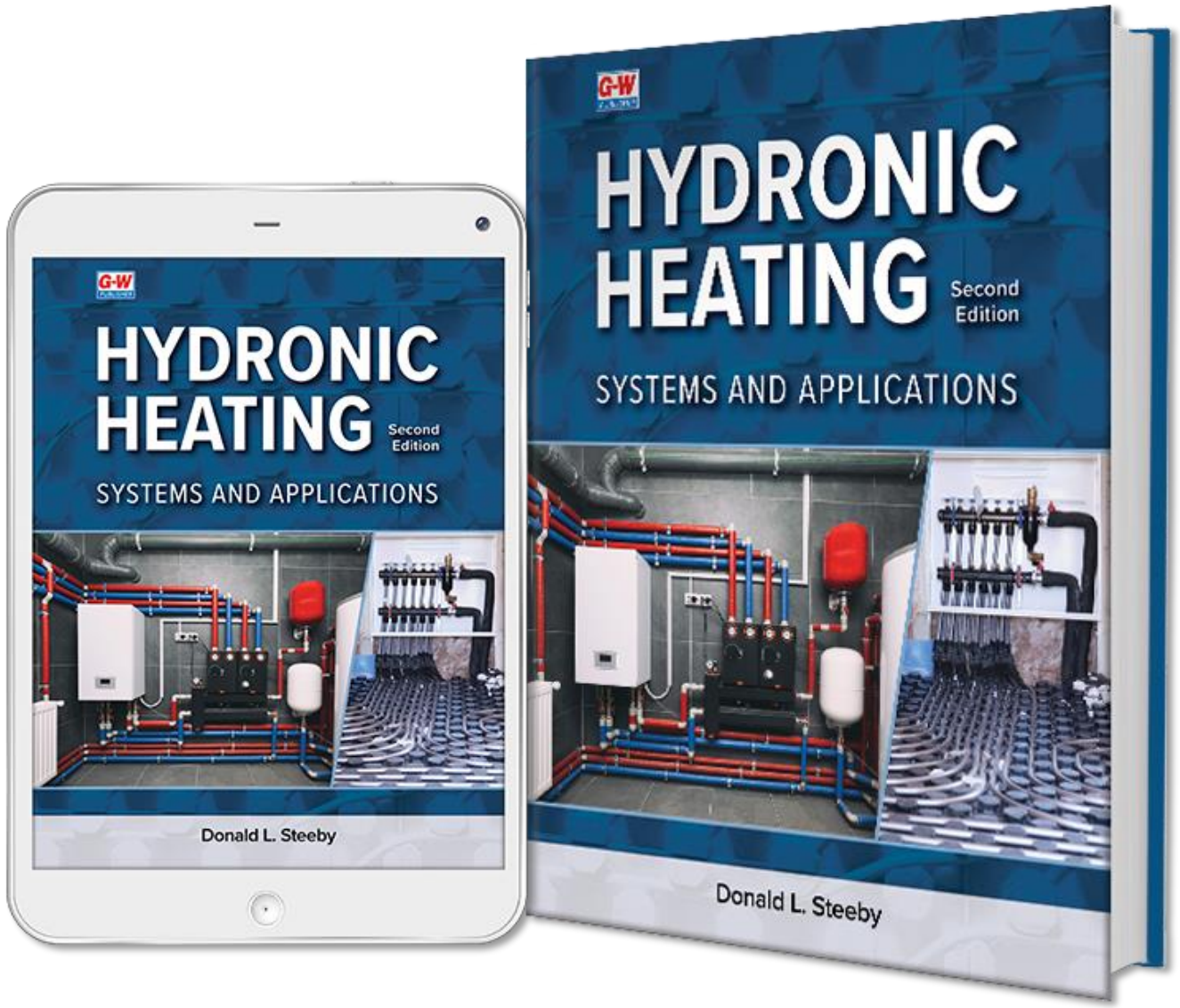
4. The _____ is a measurement of how efficiently a heating appliance can utilize the fuel being consumed.
   Answer:

5. Heat that is released from the skin to the surrounding air is considered heat transfer through _____.

Lab Workbook

Integrate G-W Digital Resources





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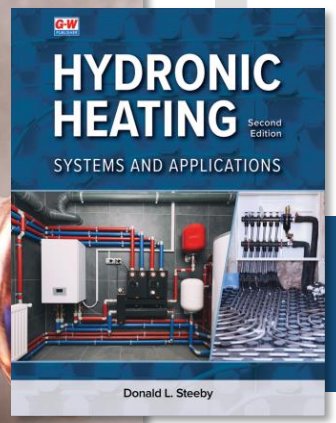

Brief Contents

1.3 Modern Hydronic System Configurations

Hydronic heating systems slowly began to modernize with the onset of controls, such as thermostats, aquastats, and devices that can reset the supply hot water temperature based on the outdoor air temperature. Controls such as these serve to increase comfort within the conditioned space as well as improve the boiler's efficiency. The boiler's fuel supply became modernized as the use of wood as the main source of heating fuel progressed to coal, then to natural gas and propane, and even electricity.

Systems today still depend on a boiler, terminal devices, and piping. There are also improvements that have been made throughout the years that advanced the overall efficiency and comfort of modern hydronic systems. These improvements can be broken down into the following categories:

- Safety
- Controls
- Innovative hydronic systems
- Renewable fuel sources

Today's modern hydronic systems incorporate safety devices, such as pressure relief valves, low water cut-outs, and backflow preventers, to protect boiler operators and building occupants. Boiler fuel systems, such as gas and oil used to heat the boiler water, include their own safety mechanisms to ensure that the boiler ignites cleanly and completes a lockout if there is an interruption in its fuel supply, **Figure 1-7**.

Controls continue to advance technologically for improved climate control and overall system efficiency. Devices and technologies that have improved space temperature control and provided great cost savings include web-based thermostats for homes and businesses, direct digital controls for commercial buildings, and wireless communications. Boiler control technologies have resulted in greater system efficiency, lower fuel combustion emissions, and overall cost savings. See **Figure 1-8**.

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Figure 1-7. Pressure relief valves are an important safety device on today's boilers.

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Figure 1-8. An example of a modern, web-based thermostat.

TROUBLESHOOTING

Sensible Heat Formula

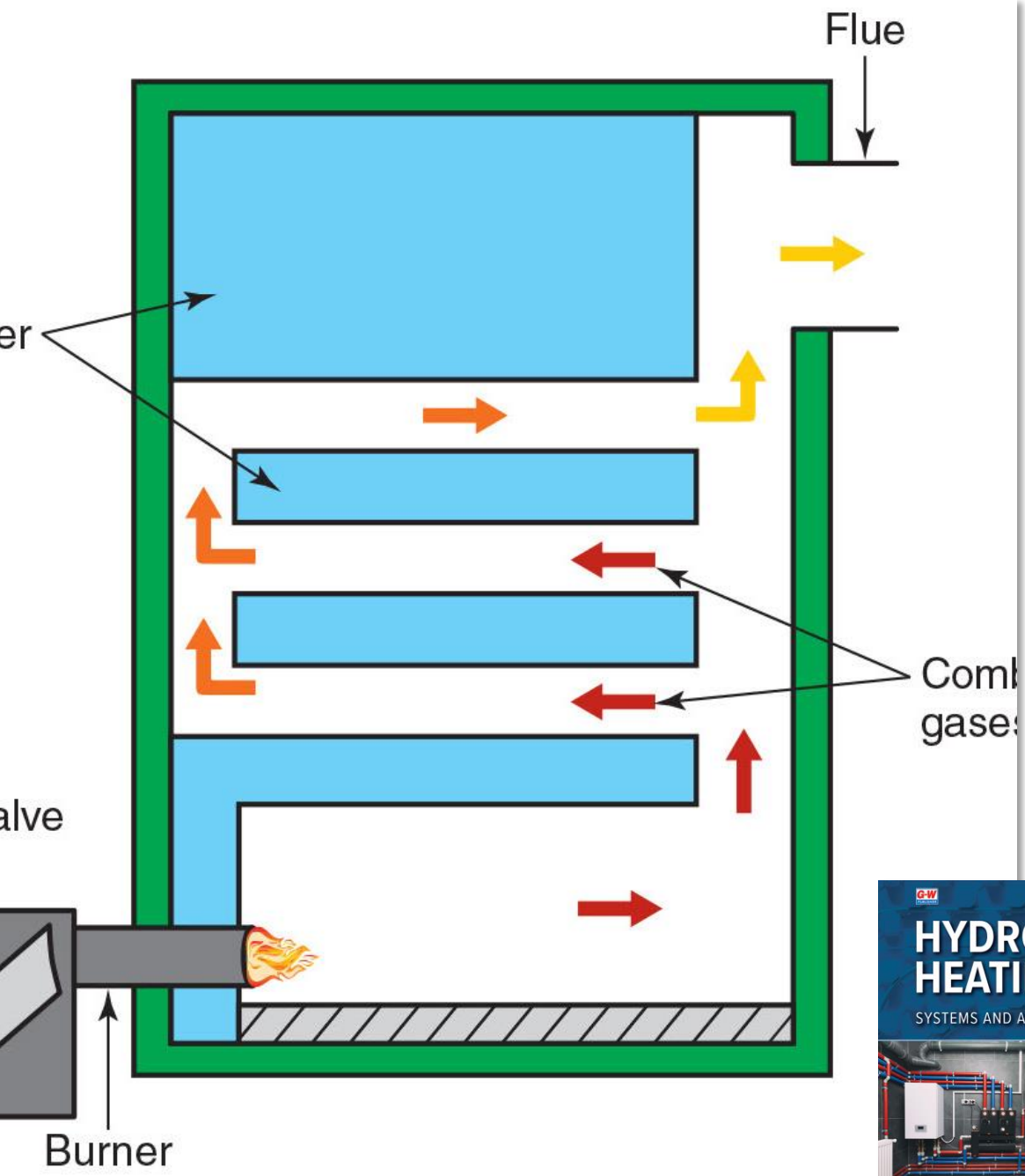
The sensible heat formula for water can be a useful tool to determine whether a boiler is maintaining its rated Btu/hr output. As an example, first calculate what the actual Btu/hr output of the boiler should be based on its efficiency. For example, if the input of a 150,000 Btu/hr boiler were rated at an AFUE efficiency rating of 80%, the actual output would be: 150,000 × 0.80 = 120,000 Btu/hr. ***AFUE*** is an acronym for ***Annual Fuel Utilization Efficiency***, which is a measurement of how efficiently a heating appliance can use the consumed fuel.

Next, determine the flow rate in gallons per minute. This can be determined using a measuring device such as a flow meter or by referencing the circulating pump's specifications. Now measure the temperature difference between the inlet and outlet of the boiler water once it has reached its steady operational state. For instance, a boiler has a flow rate of 10 GPM and a ΔT of 20°F. Using the sensible heat formula, we can now calculate:

$$10 \text{ GPM} \times 20^{\circ}\text{F} \times 500 = 100{,}000 \text{ Btu/hr}$$

By performing this calculation, we can see that this particular boiler is operating below its rated output. It is now the technician's job to determine why this boiler is not functioning at its peak efficiency.

Student Textbook



Wet-base boiler

Learning Outcomes

After completing this chapter, you will be able to:

- **1.1-1** Demonstrate how heat energy travels from warm to cold.
- **1.2-1** Explain the evolution of hydronic heating systems.
- **1.3-1** Describe the functionality of a modern hydronic heating system.
- **1.4-1** Discuss why heating is necessary to maintain human comfort.
- **1.5-1** Describe the benefits of using hydronic heating over other conventional sources.
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- **1.6-2** Explain the process of heat transfer through both air and water.
- **1.7-1** Differentiate between specific heat, sensible heat, and latent heat.
- **1.7-2** Demonstrate how the sensible heat formula is used to calculate Btu capacities.

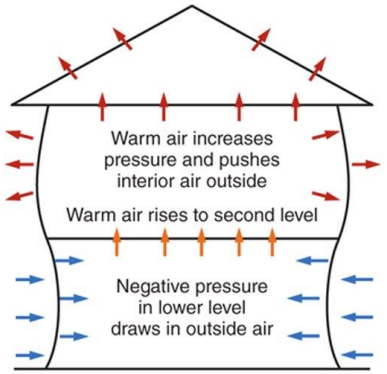
Technical Terms

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
Annual Fuel Utilization Efficiency (AFUE)
boiler
comfort zone
conduction
convection
enthalpy
heat

Introduction

Since the beginning of recorded time, humans have known that they must learn to stay warm in order to survive. With the discovery of fire, people soon realized how to harness the power of combustion as a method of effective heat transfer, **Figure 1-1**. As they became domesticated, they learned how to heat their domiciles and found new ways to make fuel sources more efficient.

As heating sources evolved, people applied basic physics to improve various methods of keeping warm. For example, the principle of convective currents—that hot air rises and cold air falls—was utilized to power boilers and circulating pumps even before electricity was available. This principle has been applied to older gravity-type heating systems, and it is the basis of modern terminal units and their placement in hydronic heating systems, **Figure 1-2**.



Chapter Review

Summary

- Heat always travels from a warm location to a colder location. When a substance is heated, its atoms move more rapidly, causing them to collide with slower-moving colder atoms. When faster-moving warmer atoms encounter slower-moving colder atoms, they transfer their kinetic energy. (1.1-1)
- A basic hydronic system consists of a boiler, a terminal device, and connecting piping. (1.2-1)
- Early systems usually consisted of cast-iron boilers and galvanized, black-iron, or cast-iron piping. They burned wood or coal. Early boilers and terminal units included few to no controls to regulate temperature. (1.2-1)
- Improvements have been made throughout the years that have advanced the efficiency and comfort of modern hydronic systems. These include improvements in the areas of safety; controls, such as thermostats and aquastats; innovative hydronic systems, such as radiant heating arrangements and new piping material like copper and PEX; and fuel sources, from natural gas, propane, liquid petroleum, oil, and electricity to renewable sources like solar, geothermal, and biofuels. (1.3-1)
- Desired indoor comfort conditions will vary among individuals. Heating is necessary to maintain human comfort and may differ between individuals depending upon their physiological makeup. (1.4-1)

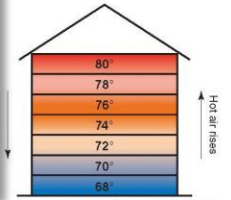


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Figure 1-15. Heat stratification creates a large temperature difference in a building, causing two different temperature zones in the same area.

dust allergies or asthma. Conventional forced-air heating systems have a greater potential to circulate harmful allergens in the air throughout a home or building. This issue is compounded if the home or building owner fails to change the furnace air filter on a regular basis, **Figure 1-17.** Hydronic heating systems therefore provide a healthier environment for occupants.

Air that has been heated and circulated through ductwork can drastically reduce humidity levels due to increased infiltration of drier outdoor air. Because of

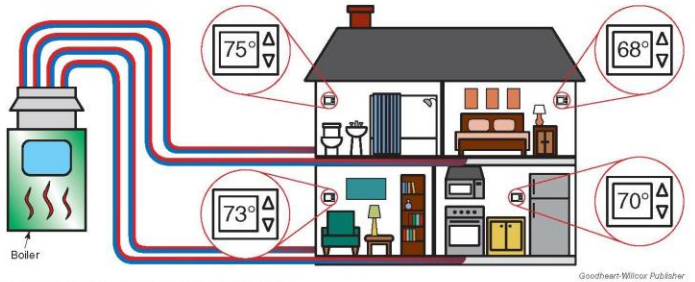

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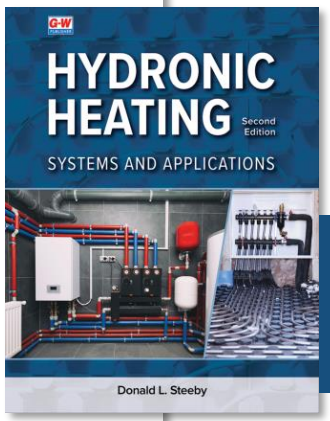
Figure 1-16. Hydronic heating allows for zoning flexibility.



What's New to the Edition

1 Human Comfort and Heat Transfer

Chapter Outline

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- **1.5-1** Describe the benefits of using hydronic heating over other conventional sources.
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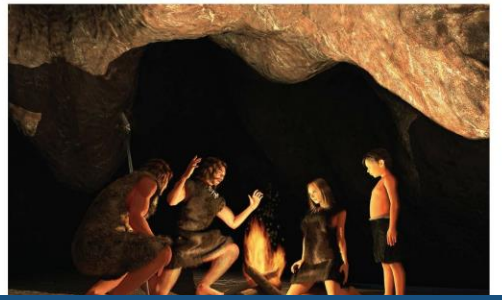
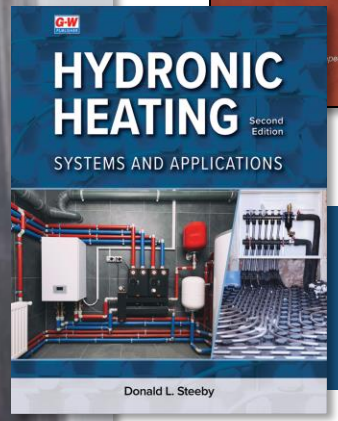


Technical Terms

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- Annual Fuel Utilization Efficiency (AFUE)
- boiler
- comfort zone
- conduction
- convection
- enthalpy
- heat
- heat transfer
- hydronic heating system
- latent heat
- order of operations
- piping
- psychrometric chart
- radiation
- relative humidity
- sensible heat
- sensible heat formula
- set point
- specific heat
- stratification
- temperature difference
- temperature droop
- terminal device
- thermostat



Chapter-Opening Materials

GREEN TIP

High-Efficiency Boilers and Sealed Combustion

Direct vented, high-efficiency boilers offer an additional advantage beyond increased fuel savings: sealed combustion. Because combustion air is drawn directly into the burner chamber from outdoors, these boilers prevent negative pressures that can occur in the home or building during burner operation of low- and medium-efficiency boilers. This reduces thermal losses directly associated with installing vents in walls and ceilings.

DID YOU KNOW?

The *Blue* in Blueprints

The development of blueprints dates back to 1842. John Herschel, a chemist, developed the process by taking an image drawn on semi-transparent paper and weighing it down on top of a sheet of paper that was pre-coated with a chemical mixture of potassium ferricyanide and ferric ammonium citrate. Once the drawing was exposed to light, the exposed parts of the print became blue, while the drawn lines remained white.

With today's modern computer-aided design programs, as well as modern drafting and printing methods, blueprints are not really blue anymore—but the name remains the same.

PROCEDURE

Lifting Heavy Objects

1. Position feet shoulder-width apart.
2. Bend at your knees.
3. Lift the load smoothly, without any sudden movements.
4. Keep the load close to your body while lifting. Do not extend your arms away from your body.
5. Keep your body straight while lifting and holding the load. Do not twist your back or turn to the side.
6. Lift heavy objects with a partner. Do not try to lift a heavy load by yourself.

CODE NOTE

Combustion Air Venting Installation

Installation of combustion air venting must comply with local requirements and with the National Fuel Gas Code, ANSI Z223.1 for US installations and CSA B149.1 for Canadian installations. Inspect finished vent and air piping thoroughly to ensure all are airtight and comply with the instructions provided with the boiler as well as all requirements of applicable codes.

TECH TIP

Heat Transmission Multipliers

Manual J and *Manual N* will also combine the effects of U-values and design temperature differences into factors known as heat transmission multipliers (HTM). These HTM values are also listed in various tables and can help reduce the vast amount of data needed to perform accurate load calculations.

For instance, a wall has a U-value of 0.05 and a temperature difference of 70 degrees. The HTM for this wall is: 0.05 × 70 = 3.5. If l area equals 200 square feet, the heat loss calculation e 200 × 3.5 = 700 Btu/hr.

TIMEOUT FOR MATH

Order of Operations

HVAC technicians are required to perform mathematical calculations on the job. In order to compute any answer accurately, calculations must be completed in the proper sequence using the ***order of operations***. This mathematical notation refers to which operations should be done first, and in what order. One method of understanding the mathematical order of operations is by referring to the mnemonic PEMDAS, which can be remembered as **P***lease* **E***xcuse* **M***y* **D***ear* **A***unt* **S***ally*. The proper order of operations is as follows:

1. Parentheses
2. Exponents
3. Multiplication and Division (left to right)
4. Addition and Subtraction (left to right)

These rules must be followed in order to obtain the correct answer for a math calculation. Note that calculations are performed left to right for multiplication and division as well as for addition and subtraction in the last steps.

Practice by solving the following equations:

$$4 + 5 \times 8$$

Using PEMDAS, complete the following steps in the correct order:

$$5 \times 8 = 40$$

$$4 + 5 \times 8 = 4 + 40$$
$$= 44$$

Try another equation:

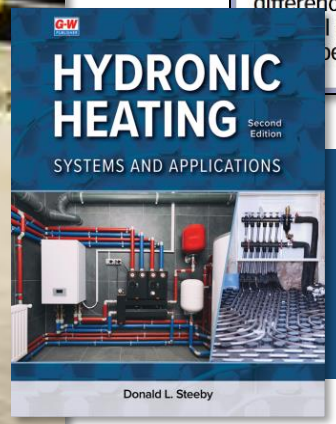
$$(2 + 3) \times (9 - 3)$$

First, solve the equations within the parentheses:

$$(2 + 3) = 5$$
$$(9 - 3) = 6$$

Now multiply the solutions from within the parentheses:

$$5 \times 6 = 30$$



Additional Features

Chapter Review

Summary

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- Desired indoor comfort conditions will vary among individuals. Heating is necessary to maintain human comfort and may differ between individuals depending upon their physiological makeup. (1.4-1)
- A psychrometric chart is used to determine proper indoor temperature and humidity conditions, based on the properties of air and moisture. (1.4-1)
- The comfort zone sets the boundaries in which the average person will maintain optimum comfort based on the temperature and humidity of the conditioned space. (1.4-1)
- Hydronic systems offer numerous benefits compared to other conventional heating systems, including comfort factor, zoning flexibility, health reasons, humidity factor, higher efficiency, and installation versatility. (1.5-1)
- Heat moves from one point to another by conduction, convection, or radiation. Conduction occurs when there is physical contact between two types of materials. Convection involves moving heat through a fluid source, such as air or water, through forced or natural means. Radiation is the transfer of heat through light waves. (1.6-1)
- Water has a greater heat-carrying capability than air because of its higher density. (1.6-2)
- Specific heat is the amount of heat needed to raise the temperature of a substance by 1°F. (1.7-1)
- Sensible heat is heat that can be measured by temperature. (1.7-1)
- Latent heat is the amount of heat measured in Btu to convert water from one state of matter to another. (1.7-1)
- The sensible heat formula is used to calculate total Btu based on flow rates and temperature difference. (1.7-2)

Know and Understand

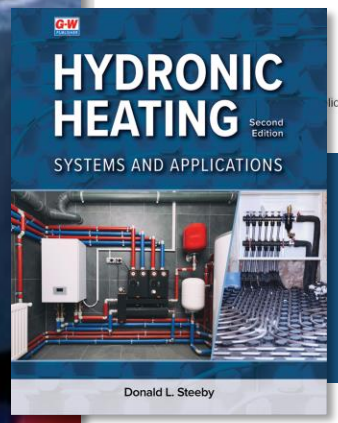
1. Heating fuels used in early hydronic heating systems include _____. (1.1-1)
   A. geothermal
   B. propane
   C. coal
   D. liquid petroleum
2. The three components of a basic hydronic heating system are _____. (1.2-1)
   A. boiler, terminal device, and piping
   B. valves, dampers, and cranks
   C. boiler, thermostat, and radiator
   D. conductor, convector, and radiator
3. *True or False?* Copper piping is among the improvements that have been made to modern hydronic heating systems. (1.3-1)
4. *True or False?* Comfort can mean different things to different people based on their metabolism, age, weight, and even gender. (1.4-1)
5. A psychrometric chart establishes the ____, the boundaries in which an average person maintains optimum comfort based on the temperature and humidity of the conditioned space. (1.4-1)
   A. latent heat
   B. comfort zone
   C. thermal equilibrium
   D. aquastat settings
6. *True or False?* Air is a more efficient means of heat transfer than water. (1.6-2)
7. The amount of heat required to change the state of matter without changing the temperature is defined as which of the following? (1.7-1)
   A. Sensible heat
   B. Specific heat
   C. Latent heat
   D. Convection
8. When performing mathematical calculations, what is the first step in the order of operations? (1.7-2)
   A. Exponents
   B. Division
   C. Multiplication
   D. Parentheses
9. *True or False?* Enthalpy is the latent heat minus the sensible heat content of a substance. (1.7-2)

Apply and Analyze

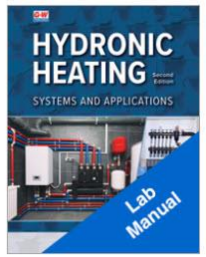
1. How do the early types of heating fuels compare with those used today? (1.2-1)
2. Define the term *temperature droop*. How does it affect human comfort? (1.4-1)
3. List and describe the benefits of using a hydronic heating system over other conventional methods of heating. (1.5-1)
4. How is heat transferred by conduction, convection, and radiation? Give examples of each (1.6-1)
5. Describe the difference between the specific heat of air and the specific heat of water. (1.6-2)
6. Solve the following math problem using the proper order of operations: $(5 + 4) \times (10 - 3)$. (1.7-1)
7. What would be the flow in gallons per minute through a heating system if the heating output capacity of the boiler were 150,000 Btu/hr, the supply water temperature were 160°F, and the return water temperature were 130°F? (1.7-2)
8. Explain the difference between sensible heat and latent heat. (1.7-2)

Critical Thinking

1. What is a psychrometric chart? Explain how is it used in the HVAC industry. (1.4-1)
2. Using the specific heat formula for water, calculate the Btu/hr output of a terminal unit that has 4 GPM of water flowing through it and a temperature difference of 20°F. (1.7-2)
3. Using the pressure/enthalpy chart, how many Btu are required to convert water (liquid) to steam (vapor)? What term is used for this conversion of water to steam? (1.7-2)



End-of-Chapter Content



Hydronic Heating 2e, Lab Manual Assignments

These activities provide students with an opportunity f
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Chapter Review ▼

Hydronic Heating: Systems and Applications 2e, Lab Workbook: Chapter 1

Name:
Date:
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Chapter 1: Human Comfort and Heat Transfer

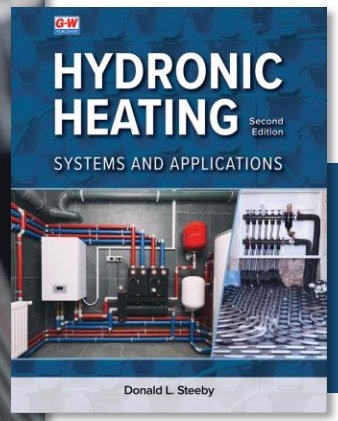
Carefully read Chapter 1 and then answer the following questions.

1. Heat always moves _____.
   A. from warmer to cooler
   B. from cooler to warmer
   C. in both directions
   D. None of the above.
   Answer:

2. Terminal devices are also referred to as _____.
   A. heat transferers
   B. heat emitters
   C. flow devices
   D. terminal components
   Answer:

3. The temperature fluctuation between actual space temperature and the design set point is known as _____.
   A. temperature drop
   B. temperature lag
   C. temperature difference
   D. temperature droop
   Answer:

4. The _____ is a measurement of how efficiently a heating appliance can utilize the fuel being consumed.
   Answer:



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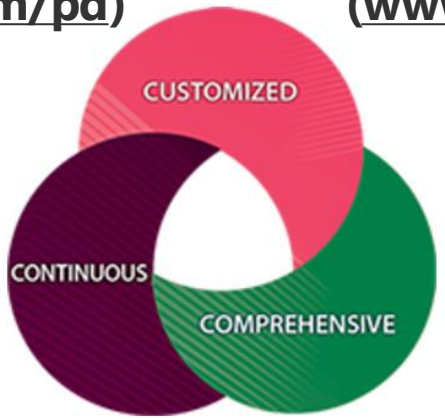

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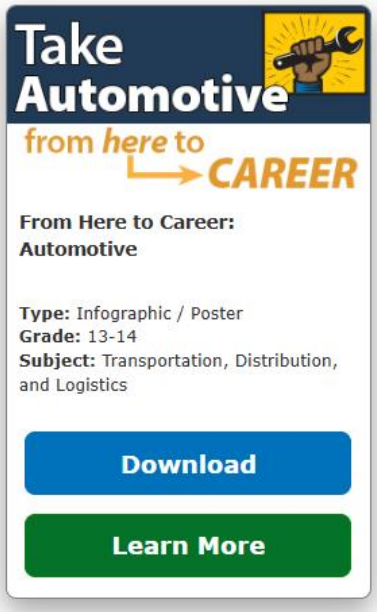

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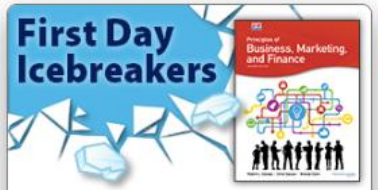

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Subject: Business, Marketing, and Finance

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