HVAC/R TECHNOLOGY

As you read in the introduction to this course, HVAC/R technicians are known for performing a very broad range of tasks on a variety of equipment. Their work most often requires working alone or in small groups. This means they must rely on their own problem-solving, troubleshooting, and critical-thinking skills to repair a system that may be unlike any other they've ever seen. Obviously, the requirement to regularly solve unique problems makes this a challenging job. The basis for your problem-solving skills comes from a strong understanding of *how* HVAC/R systems work and, even more importantly, *why* they work as they do. For that reason, you're study of HVAC/R technology begins with the study of the physical principles that explain why these systems operate the way they do. Grasping these fundamental concepts makes it easier to tackle problems with equipment that you've never seen before, often with the aid of limited or (in the worst case) nonexistent repair manuals.

When you complete this lesson, you'll be able to

- Explain the effect heating, air conditioning, and refrigeration have on our lives
- Describe the various types of HVAC/R jobs and the certifications related to each
- Explain how to work safely and avoid accidents
- Understand the physical properties, laws, and definitions that apply to the HVAC/R field
- Convert temperature and pressure values from one scale to another

Lesson 1

ASSIGNMENT 1

Read this introduction to Assignment 1. Then, study Unit 1, "Introduction to Heating, Ventilation, Air Conditioning, and Refrigeration," and Unit 2, "Being a Professional HVAC/R Technician," on pages 1–19 in the textbook, *Fundamentals of HVAC/R*.

Working as an HVACR technician requires a great deal of technical knowledge. As you browse through your textbook, you'll notice material relating to state-of-the-art computer modules, sophisticated electronic controls, and specially formulated chemical refrigerants, all of which are found in today's comfort-control systems. In contrast, the basic physical operating principles of heating and cooling systems have been understood and employed for a very long time. Since humans first used fire to warm a cave or ice to keep their food from spoiling, they've relied on the comfort-control concepts and techniques we still use today.

The Importance of the Field

Your chosen path of learning is in an increasingly important field. In the past, cooling dwellings and humidifying and cleaning the interior air we breathe was considered a luxury. Today these comforts aren't only expected, but are also considered by most as necessary to maintaining our health and well-being. Imagine hospitals and nursing homes without HVAC systems, or homes and supermarkets without refrigerators and freezers, and you'll quickly realize how these one-time luxuries have become necessities of life.

Licensing and Certification

In this first reading assignment you'll learn about employment opportunities available in the broad field known as heating, ventilation, air-conditioning, and refrigeration (HVAC/R). It's a profession that, depending on the regulations where you're employed, often requires licensing. Keep in mind, these requirements vary greatly between states and cities or counties within those states. For example, you might be required to serve as an apprentice to a licensed technician or to enroll in a specific school or program. If you're not already employed in the HVACR field, it's very important that you research licensing requirements in your area now, so you can be prepared to work in the field as soon as possible.

One way to prove your competency in the trade is through certification. The EPA (Environmental Protection Agency) requires by law that HVACR technicians be certified in the safe handling of the refrigerants used in cooling systems. This training program prepares you to successfully complete the certifying examination. Most technicians are also certified through one of the many professional organizations, such as HVAC Excellence or NATE (North American Technician Excellence). This first lesson explains the different specialty areas of expertise, which are part of the NATE certification process. Professional organizations are also great sources for information about current technology, and have excellent educational programs to maintain and improve your diagnostic skills.

What Is a Professional Technician?

Being a professional technician means more than just being licensed or certified. As you'll learn in this assignment, it's also important to act and dress professionally. A proper appearance sends a message that you take your job seriously, and your customers will feel confident in your abilities. Professional behavior includes recognizing the importance of your position and acting accordingly in the workplace. HVAC systems often directly affect a dwelling's air quality. Since many of the materials you're handling can be hazardous, safe work practices protect by both your own and your clients' health.

Although often overlooked, good communication skills are an essential trait of a competent technician. Naturally, having good diagnostic skills and working in a safe and efficient manner are very important. However having extensive knowledge about a particular system or component is of little value if you can't explain to your customer what to purchase, why you're replacing a part, or how to operate a control. Clear and reasonable explanations go a long way towards avoiding conflicts and maintaining a high level of customer satisfaction.

The Road to Success

The career field you've chosen is respected for its long history, for its positive effects on our health, and for its degree of technical knowledge. Don't be overwhelmed by the amount or technically challenging nature of the material in the textbook. If you simply take each lesson step-by-step, and make sure you understand the concepts discussed before moving on to the next lesson, you'll gain the skills necessary to be a successful HVAC/R technician.

After you've read pages 1–19 in the textbook *Fundamentals of HVAC/R* carefully and completed the "Review Questions" on pages 9, 10, 18, and 19, check your answers against those provided in the back of this study guide. When you're sure you completely understand the material from Assignment 1, move on to Assignment 2.

ASSIGNMENT 2

Read this introduction to Assignment 2. Then read Unit 3, "Safety," on pages 20–32 in the textbook, *Fundamentals of HVAC/R.*

This assignment covers the general safety practices you should follow when working on refrigeration equipment. The topics covered include both personal safety and safety procedures you should follow when handling pressurized refrigerant vessels.

If you follow proper procedures, working on refrigeration equipment can be very safe. However, there are still dangers of which you should be aware. Following all safety procedures and wearing proper safety equipment is the best way to prevent injury.

General Safety Practices

You, as a heating, ventilation, and air-conditioning technician, will come into contact with many hazardous situations and materials each workday. There are dangers present from pressurized liquids and gases, electrical energy, heat, cold, chemicals, rotating machinery, and heavy objects. You must be familiar with the general safety practices and procedures in this assignment. Remember, the decisions you make will affect not only you, but those around you. No matter what or where the job is, be sure to always answer the following questions:

- Where are the emergency exits?
- How do you get out of the building in case of an emergency?
- Where's the first-aid station?
- Where's the eye wash station?
- Where are the first-aid kits located?
- What are the emergency telephone numbers?
- Are there any site-specific safety requirements or restrictions?

When working with refrigeration tools and equipment, you should always

- Read and follow the manufacturer's instructions
- Wear safety glasses and/or goggles as the situation warrants
- Wear the proper protective equipment
- Be sure not to exceed the limitation of a tool or piece of equipment
- Be a professional
- Be sure not to take unnecessary risks

Safety Practices to Follow When You're Working with Tools, Machinery, and Harmful Substances

Injuries that occur when using hand or power tools are almost always avoidable. Read and follow the user's manual supplied with a power tool. It explains how to safely and properly use the equipment. When working around moving machinery, ensure that you remain cautious. Even small motors develop enough power to cause serious injury. *Never* try to stop a piece of machinery, no matter how small, while it's coasting to a stop. Keep loose clothing away from moving machinery. Remove all jewelry before performing any work. Use the proper tool for the job. Keep all tools in proper working condition. Wear a safety harness that's properly secured when working at heights. When moving heavy objects, prevent injuries by using the safest method possible.

Refrigerants are heavier than air. In an enclosed area, they can displace the oxygen you breathe, causing you to become unconscious. You may not recognize the symptoms before it's too late. Ensure that there's adequate ventilation and that ventilation equipment is operating properly before you start a job.

Always handle and use chemicals in strict compliance with the manufacturer's directions. Read all the instructions before you use any chemical. Know what to do in case of a spill or accident before the need arises.

Wearing proper protective clothing, using tools properly, knowing the safety hazards of a job, and knowing how to alleviate dangerous situations are key safety practices. Remember to always be alert to identify safety hazards and ensure that they're immediately corrected.

Safety Practices to Follow When You're Working with Heat

The use of heat, including welding torches, around refrigeration equipment demands your attention and respect. Torches can supply a high concentration of heat to a very small area.

Ensure that a protective heat barrier is placed in back of the work area when necessary to prevent unwanted combustion or damage to surrounding equipment. *Never* apply a concentrated heat source to a sealed pipe or tubing. Always keep a fire extinguisher nearby when using a torch or other source of high heat.

Safety Practices to Follow When You're Working with Electrical Power

Let's turn our attention to electrical shocks and burn hazards. Since it will be necessary at times to troubleshoot with power applied, you must understand the proper procedures to work near live circuits. During power-on testing, never allow your body to contact any portion of the circuit. Know the voltage of the circuit you're testing before you proceed.

When working on or around an electrical circuit, there's always the potential of electrical shock. An electrical shock occurs when your body becomes part of the circuit. Depending on the amount of energy, the effect of an electrical shock will vary from surprise to death by electrocution. *Never* let your body become part of a live electrical circuit. All power tools should carry three-prong (grounded) plugs to prevent accidental electrocution. If possible, connect power tools to outlets that have a *ground fault circuit interrupter (GFCI)* circuit. The GFCI is designed to sense very small electrical leaks. If an electrical leak is detected, the GFCI opens the circuit. *Never* wear jewelry while working on live electrical circuits. Always be careful when using metal hand tools around live power. When you're required to work off the floor, use a nonconductive ladder.

Safety Practices to Follow When You're Working with Refrigeration Cylinders

Every day, you'll come in contact with refrigeration pressure cylinders and piping. As you'll soon learn, a gas applies pressure equally in all directions. A large cylinder with 1500 $in.^3$ of R-22, at an ambient temperature of 110°F (not uncommon on a hot summer day), has an internal pressure of 339,000 lbs, or 169.5 tons. This internal pressure is well within the limitation of the cylinder as long as it's protected from damage and handled properly. All cylinders have a safety valve and fusible plug that will vent the gas if the cylinder gets too hot. All cylinders used to transport refrigerant should be Department of Transportation (DOT) approved. You should remember a few key points:

- Store and transport refrigeration cylinders in a vertical position only.
- *Never* use an open flame to heat a refrigeration cylinder.
- If heating a tank is necessary, place it in a container of warm water that doesn't exceed 90°F.

Continuing with R-22 as the example, when taking pressure readings, remember that it boils at –41°F when released into the atmosphere. Coming in contact with the refrigerant will quickly cause frostbite. Always keep liquid refrigerant off your skin and out of your eyes by wearing the appropriate safety equipment and protective eye goggles. Oxygen and nitrogen tanks pose an even greater danger and must be handled with extreme care.

Safety Note: *Never* attempt to stop a refrigerant leak with your hand.

Safety Note: *Never* use oxygen as a pressure source. If oxygen comes in contact with any oil or oil residue, an explosion will result.

Safety Note: Whenever possible, electrical power should be disconnected at the distribution or entrance panel, locked out, and tagged in an approved manner. The Occupational Safety and Health Administration (OSHA) has specific requirements for power-down and lock-out activities.

After you've read pages 20–32 in the textbook *Fundamentals of HVAC/R* carefully and completed the "Review Questions" on page 32, check your answers against those provided in the back of this study guide. When you're sure you completely understand the material from Assignment 2, move on to Assignment 3.

ASSIGNMENT 3

Read this introduction to Assignment 3. Then, study Unit 4, "Properties of Matter," on pages 33–42, and Unit 5, "Types of Energy and Their Properties," on pages 43–57 in the textbook, *Fundamentals of HVAC/R.*

In this assignment, you'll learn about matter, mass, density, specific gravity, and specific volume. You'll learn about the three states in which matter exists (solid, liquid, and gas), what happens when matter changes from one state to another, and how pressure and temperature determines which one or more states are present at a time. Since cooling systems rely on matter (the refrigerant) changing state with the transfer of energy (another concept introduced in this assignment), these concepts play an important part in the rest of your studies. Be sure you understand them well.

Composition of Matter

Matter is a substance made up of atoms that has weight and occupies space. *Mass* is a measure of the amount of material that matter contains and causes it to have weight in a gravitational field. The gravitational field of the Earth determines the weight of matter. Matter has three states—solid, liquid, or gas. The state in which matter exists depends on the heat content of the matter and the pressure exerted on the matter.

Since all matter is composed of *atoms,* it's useful for you to understand what makes up an atom. Each atom has a specific structure. The structure of an atom includes individual components including *protons, neutrons,* and *electrons.* By varying the number of these individual components within an atom, different elements (such as oxygen, copper, or gold) result. One or more different types of atoms combine to form *molecules.* A molecule is the smallest particle that behaves in the same way as the whole object it makes up. For instance, copper and other metallic elements combine to make molecules of the copper alloy found in flexible tubing. When exposed to high temperatures, physical loads, or chemicals, each of these molecules would behave the same way as the piece of copper tubing.

Alloy is just a term that describes metals made from a mixture of different elements; therefore, most metals we use are actually alloys.

States of Matter

Matter exists in one of three states, *solid, liquid,* or *gas.* The state of matter at any given instant in time depends on the space between its molecules. This space, and the relative motion of one molecule compared to the next, varies based on the temperature and pressure at which the matter exists. HVAC/R systems function by transferring energy to or from bodies of matter. It's important to understand the relative amount of energy transfer required to change the temperature of a quantity of matter compared to the much greater amount needed to change state.

Properties of Matter

Density of matter expresses its mass-to-weight relationship. Since the density of wood is less than that of water, wood floats on water. *Specific gravity* allows you to compare the density of one material against another. The specific gravity of any matter is based on the density of water, while *specific volume* is the volume that one pound of substance occupies.

Just as different types of matter have different densities, they also change from one state to another at defined temperature and pressure levels. The points (specific temperature and pressure) at which a type of matter changes state are commonly referred to as its *freezing* and *boiling points.* Remember that these changes in state aren't defined solely by temperature level. Each point is defined by both temperature and pressure. This means, for instance, that by changing the pressure of a substance, a system can dramatically alter the temperature at which the substance boils.

Energy Performs Work

As you've already learned, matter has weight and takes up space. While energy has no weight and takes up no space, it acts on matter to do work. This assignment introduces the different types of energy and differentiates between energy, work, and power. It then explains the relationship between energy sources, the conversion of one energy type to another, and methods for measuring energy levels.

It's easy to understand how energy acts on matter to do work if you think of an energy source, such as you, pushing on a box. As soon as the box begins to slide, work is being performed. That's because *work* is done when energy is transferred to an object. For mechanical work to result, a force is applied to an object that then moves through a distance. The most commonly encountered measurement of energy transfer isn't work, however. Instead, you'll more often encounter measurements of the rate at which work is done. This rate is known as *power,* and is most often expressed as *horsepower (hp).* As you'll soon learn, energy has the capacity to do much more than just mechanical work. Perhaps most important to the heating and cooling systems you'll service, energy performs work when it changes the temperature or state of matter.

Energy is either in the process of doing work or is stored, ready to perform work when released. *Kinetic energy* is energy in motion, in the process of performing work. Meanwhile, energy that's capable of doing work once released is known as *potential energy.*

Forms of Energy

Beyond classifying an energy source as either kinetic or potential, it's sometimes useful to recognize the form in which energy is provided. As you'll soon learn, work is done in heating and air-conditioning systems when energy supplied in one form is converted to another form. For instance, a photovoltaic cell mounted to a home's roof converts *radiant energy* (a form of energy typically obtained from the sun's light) to electrical energy. The home's baseboard electric heater may then convert this electrical energy into heat energy to warm a room.

Conversion of Energy Sources

Our daily lives depend on the use of various energy sources. Some of these sources, identified as *renewable,* aren't reduced as we use them. Solar energy, which is harvested in various ways from the sun's heat energy, is an example of a renewable energy source. Meanwhile, the supply of coal, a *nonrenewable* energy source, is very large but continues to decline each time a power plant burns a trainload of it. Whether a process depends on a renewable or nonrenewable energy source, the systems you'll encounter as an air-conditioning technician require the conversion of one form of energy to another.

Energy isn't created or destroyed, but converted into another form. This conversion may involve a single step, such as a burning a campfire converting chemical energy to heat energy, which then heats nearby air. Multistep conversions are more common, such as an automobile consuming a fossil fuel through the engine's combustion process (which converts chemical energy to heat energy). The engine and drive-train then converts the heat energy that results form the combustion process into mechanical energy to move the automobile.

Measuring Energy

Energy is usually purchased in units. For instance, natural gas is sold by the cubic foot over a specific time period, coal is sold by the ton, and propane is sold by the gallon. Since the energy (heat) content of each material is known, the total amount of heat purchased can be calculated. Energy is purchased as power. *Power* is the rate at which work is done. *Work* is expressed as the force required to move an object a specified distance.

As previously stated, power is the rate of doing work. Power can be expressed as *horsepower (hp).* One horsepower equals 33,000 ft-lb/min. Stated another way, one horsepower can move 33,000 lbs to a height of one foot in one minute. Electrical power is measured in *watts (w).* To produce one unit of horsepower, 746 watts of electricity must be consumed. One kilowatt (1000 watts) equals 3413 Btu per hour. *British thermal unit (Btu)* represents the amount of heat an object contains. One Btu is the amount of heat required to raise the temperature of one pound of water one degree.

After you've read pages 33–57 in the textbook *Fundamentals of HVAC/R* carefully and completed the "Review Questions" on pages 42 and 57, check your answers against those provided in the back of this study guide. When you're sure you completely understand the material from Assignment 3, move on to Assignment 4.

ASSIGNMENT 4

Read this introduction to Assignment 4. Then, study Unit 6, "Temperature Measurement and Conversion," on pages 58–67 and Unit 7, "Thermodynamics—The Study of Heat," on pages 68–78 in the textbook, *Fundamentals of HVAC/R.*

Throughout your career, one of the measurements you'll most often encounter is temperature. It's important that you understand what the term really means. First, keep in mind that temperature and heat aren't the same. While temperature, or heat intensity, indicates the degree of warmth in an object, it doesn't indicate the amount of heat contained within that object. *Temperature* measures the speed of motion of one atom. *Heat* indicates the total thermal energy contained within a group of atoms (combining to make up the mass of the object). As an example, compare one copper penny with one pound of solid copper. If the penny is heated to 500°F and the pound of copper is heated to 100°F, the penny has a higher temperature but the pound of copper, having greater mass than the penny, contains more heat.

How Temperature Is Measured

Thermometers are used to measure temperature. The *United States customary measurement system* (abbreviated *USCS* units and sometimes referred to as *English units*) uses the *Fahrenheit scale,* while the metric system uses the *Celsius scale.* While you know that water freezes at 32°F (0°C) and boils at 212°F (100°C), it's important to understand that these temperatures are based on a specific set of criteria. If any of the criteria aren't met, the freezing and boiling temperatures of water are affected. Temperatures encountered in the refrigeration industry are often based on *absolute temperature scales.* There are two absolute temperature scales. The *Rankine scale* is used for USCS absolute measurement; the *Kelvin scale* is used for metric absolute measurement.

Fahrenheit and Celsius Temperature Readings

In the United States, most temperature readings are specified using the Fahrenheit scale. But it's important to know how to convert from Fahrenheit to Celsius. In this assignment you'll encounter various formulas for converting between these scales as well as their corresponding absolute temperature scales. You should work at memorizing the conversion formulas, as you'll rely on them in the future.

Laws of Thermodynamics

Heating and cooling systems are governed by heat-transfer principles. As an HVAC technician, you won't be expected to have an extensive knowledge of the laws of physics. However, you'll need a fundamental understanding of the relationship between temperature and pressure, how to measure their changes, and the basic physical principles that describe how heat flows. This group of principles, known as *thermodynamics,* is the subject of this assignment.

You've already learned that heat is a form of energy, resulting from the conversion of a different energy form. This conversion is the basis of the *first law of thermodynamics,* which states that energy can't be created or destroyed. You've also learned that heat results from the movement of molecules, and always flows from warm matter to colder matter as the moving atoms transfer their energy. In order for this heat energy to travel from one body to another, common sense tells you there must be a difference in their temperatures. The presence of a temperature difference is the basis of the *second law of thermodynamics.*

Heat Transfer

The travel or transfer of heat can occur in three different ways, all of which you've regularly experienced. *Radiation* heat transfer is carried out by waves, such as the heat from the sun's light waves. Feeling the effects of wearing a dark shirt on a bright sunny day is a simple example of radiation.

The transfer of heat between substances in contact (or within a substance) is called *conduction.* When the spoon you place in your coffee cup becomes warm, it's the result of conduction. *Convection* is the form of heat transfer responsible for heating the air just above the coffee cup (something you may have experienced if you've ever warmed your hands outside, over a hot cup of coffee). Convection, or *convective heat transfer,* occurs only through liquids or gases.

Change of State–Sensible and Latent

The heat-transfer examples you've just considered didn't result in a change of state. More specifically, the solid spoon didn't melt into a liquid, nor did the coffee boil (producing steam, which is a gas). The type of heat transfer that simply raises the temperature of an object is known as *sensible heat,* and can be measured. As you can imagine, it takes much more heat energy to melt the spoon or boil the coffee than is required to just increase their temperatures. The term *latent heat* describes the heat required to cause a change of state. While heat energy is added and the change of state takes place, the temperature of the substance doesn't change. This assignment explains how to measure and calculate the energy required to change state.

Terminology

As you've seen from experience, changes of state (such as an ice cube melting into a small puddle of water) don't happen instantaneously. It's a process with events that occur at different points along the way. This assignment introduces descriptive terms such as *saturated, superheating,* and *subcooling,* which you'll encounter regularly throughout your career as an HVAC/R technician. By taking measurements of the temperature and pressure at which these events occur, and comparing the measured values to expected values, you can troubleshoot the operation of system components. Your understanding of heat transfer, temperature, and change of state, presented in this part of your textbook, forms the basis of your future studies.

After you've carefully read pages 58–78 in the textbook, *Fundamentals of HVAC/R,* complete the "Review Questions" on pages 67 and 78. Check your answers with those provided at the back of this study guide. When you're sure that you understand the material from Assignment 4, move on to Assignment 5.

ASSIGNMENT 5

Read this introduction to Assignment 5. Then, study Unit 8, "Pressure and Vacuum," on pages 79–90 in the textbook, *Fundamentals of HVAC/R.*

You should now understand the basics of heat theory, including the laws of thermodynamics, how to measure the transfer of heat energy, and concepts related to the change of state. A refrigerant's ability to easily change state from a liquid to a gas is an essential part of the refrigeration process. Measuring the gas pressure at different locations in the refrigeration cycle is an essential part of evaluating the system's performance. In this assignment you'll study the basic characteristics of pressure, then you'll learn to identify and use pressure-measuring equipment, and the laws of physics relating to gases.

Pressure Produces Force

The temperature/pressure relationship has been mentioned several times in your course. What is pressure, and how does it act? *Pressure* is simply the force applied to a surface by the pressurized substance (such as air or refrigerant) compared to the physical size of the area over which it's applied. The way pressure acts depends on the nature of the pressurized substance. For example, due to the force of gravity solids and liquids exert pressure downwards, and gases exert pressure in all directions. You witness these forces every time you weigh yourself, drain the water from your bathtub, or blow up a balloon.

Types of Pressure

Many of the terms used in this lesson may already be familiar to you. Atmospheric pressure is simply the pressure of the air around you. *Atmospheric pressure* results simply from the weight of the air. Local atmospheric pressure is usually measured, then compared to what the pressure would be at sea level. The higher the elevation above sea level, the lower the atmospheric pressure. Simply put, locations located higher above sea level have less air above them to press down. This lesser amount of air means the weight of air is lower, which translates to less pressure.

Atmospheric pressure is also affected by the conditions around it, such as temperature and humidity. For example, the higher the temperature, the more the gases in the atmosphere expand. There will be fewer molecules in a given volume of gas so the volume's weight (and resulting pressure) drops. Humidity affects atmospheric pressure in a way that may not seem as familiar to you. On humid days, more water molecules are held in the air, replacing some of the air molecules (mostly nitrogen and oxygen). Since water molecules are lighter than the nitrogen or oxygen molecules they replace, the air is actually lighter (and exerts less pressure) when high humidity is present. The current atmospheric pressure is commonly called *barometric pressure* after its measuring instrument, the *barometer.* The condition that often exists in refrigeration systems, known as a *vacuum,* occurs whenever pressures are at a level below atmospheric pressure.

Gas Laws

Several laws dictate how gases behave. You learned earlier that gas exerts pressure in all directions, which is the basis of Pascal's law. *Pascal's law* explains why soap bubbles tend to be round, since the force of pressure is equally dispersed in a container (the bubble) in a uniform manner. Other gas laws you'll learn about in this assignment describe the relationships between pressure and volume, volume and temperature, and pressure and temperature. The *ideal gas law,* which explains the behavior of all gases according to a mathematical equation, will also be part of your studies, along with various other calculations relating to gas properties.

Measurements

To work with pressurized gases, you'll need to understand of the units of measurement that describe them. For instance, you just learned about the effect of atmospheric pressure, but also need to know how it's measured. *Psia* commonly describes the number of pounds per square inch that results from atmospheric pressure. Since gages are used extensively as measuring devices by HVAC/R technicians, you'll also become very familiar with *psig* (pounds per square inch gage), which refers to the actual pressure read at a gage. Psig indicates the pressure level above or below atmospheric pressure. As you continue through the textbook, you'll become familiar with many different types of gages, how they're installed, and how to interpret their readings.

As you can see, there are numerous theories, calculations, measuring devices, and units of measurement that you'll rely on during this assignment and your future studies. It isn't realistic to memorize all of the formulas and theories you'll encounter. It's important however to understand the concepts they're based on and the terminology used. Those you use frequently will become second nature as you continue with your training and on-the-job experience.

After you've read pages 79–90 in the textbook *Fundamentals of HVAC/R* carefully and completed the "Review Questions" on page 90, check your answers against those provided in the back of this study guide. When you're sure you completely understand the material from Assignment 5, complete the Lesson 1 Examination.