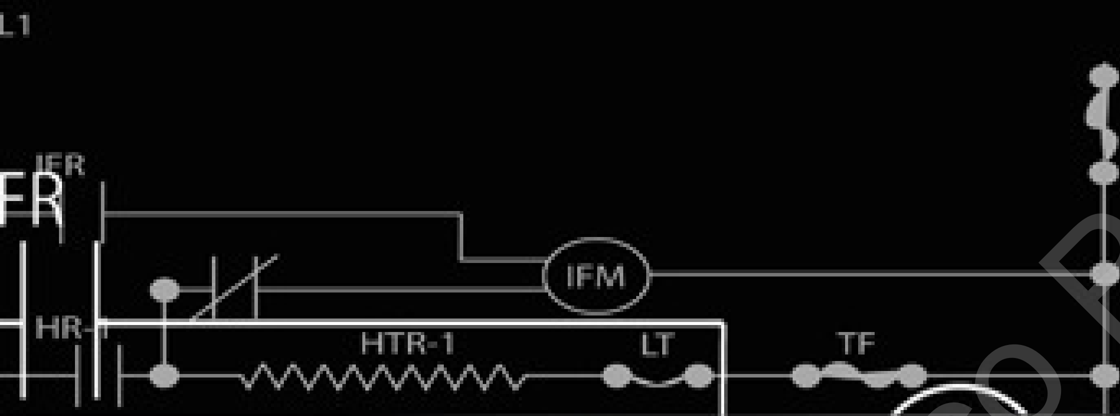
Electrical Theory & Application for HVACR



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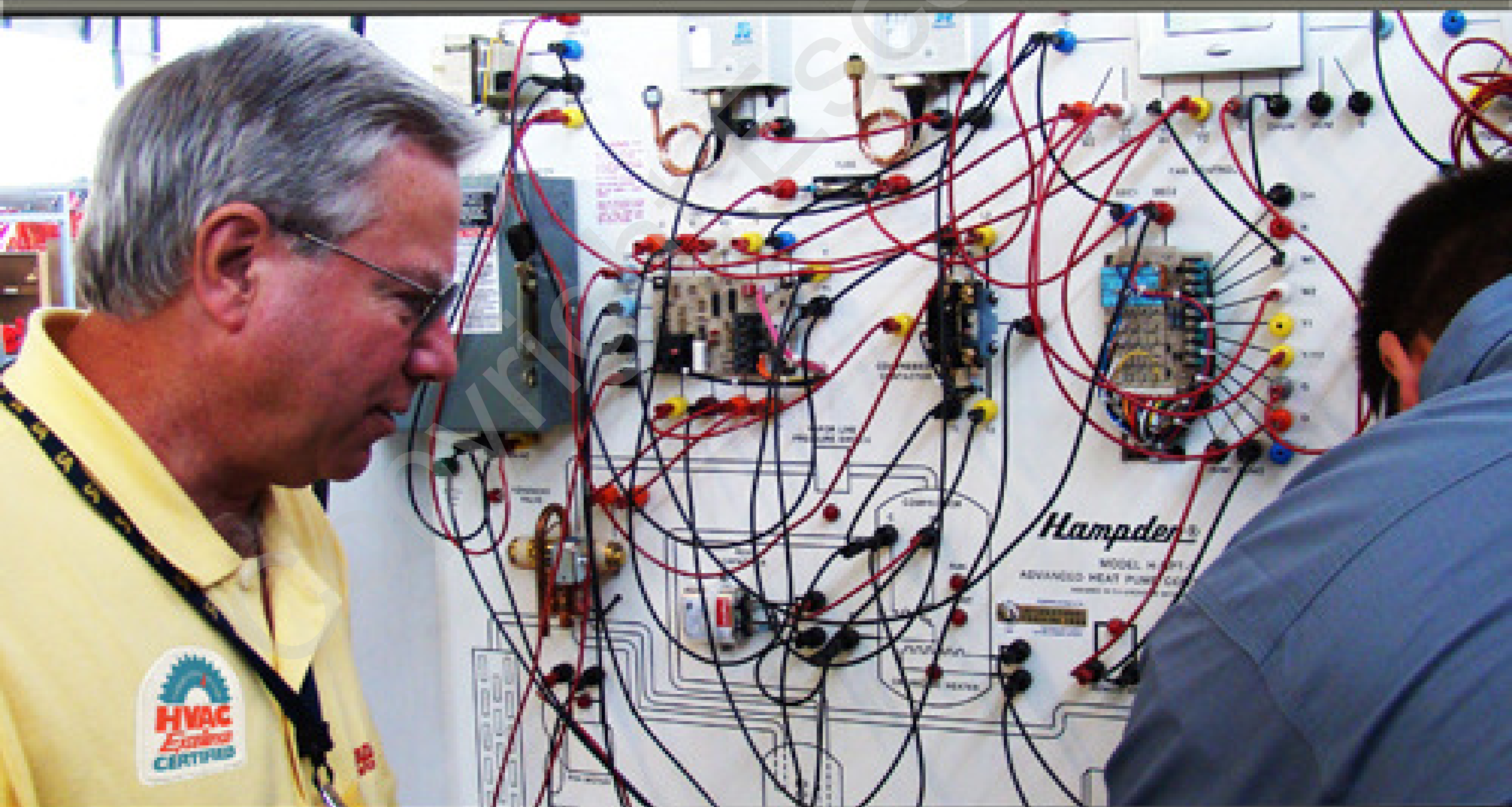
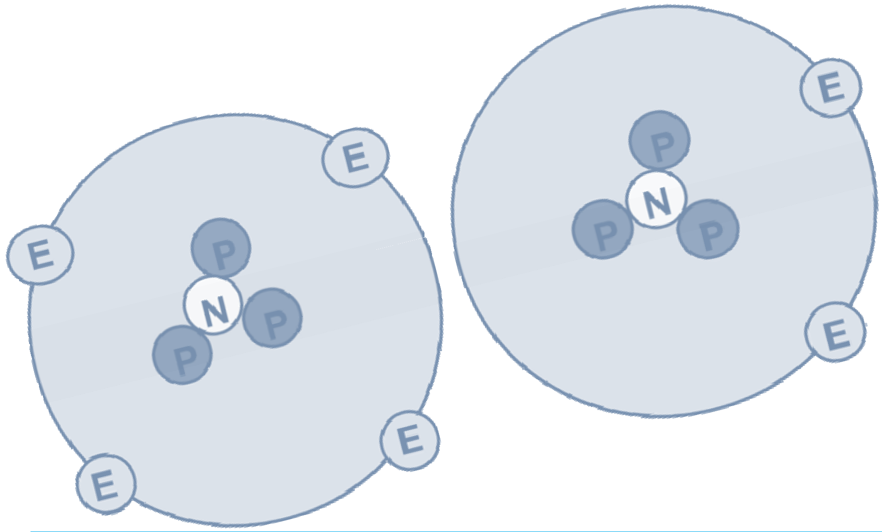


TX

OFM-Outdoor Fan Motor
TH-1-1st Stage Heat
TH-2-2nd Stage Heat
TC-Cooling

CR-Compressor Contactor
IFR-Indoor Fan Relay
IFM-Indoor Fan Motor
DFR-Defrost Relay



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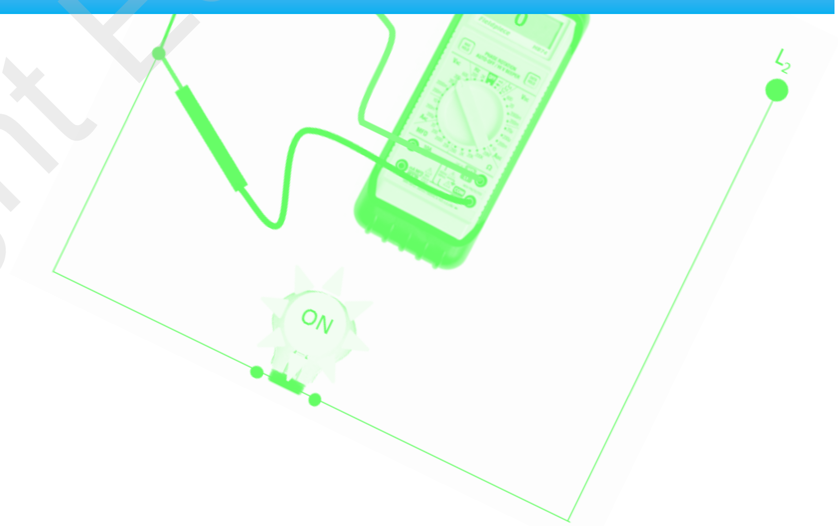

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Table of Contents

Chapter 1: What Is Electricity?

OBJECTIVES:

- Understand atomic structure and theory
- Identify various electrical terms and laws
- Measure voltage, current, and resistance, and calculate impedance
- Recognize electrical symbols
- Gain knowledge of electrical theory and practical uses

1 What Is Electricity?

Electricity is a form of energy. Electrical energy is the movement of electrons through a conductor. Other forms of energy include heat, light, chemical (battery), atomic (power plant), and mechanical (motor). Energy cannot be created or destroyed, but it can be converted from one form to another. For example, heat is used to produce electricity, which can be used to produce light. Electrical appliances are designed to convert electrical energy to another form of energy, thereby performing useful work. Some devices produce heat and others produce motion or light.

ATOMS/ELECTRONS

All matter is made of atoms. Atoms are made up of particles called protons, neutrons, and electrons. Protons and neutrons are located at the center, or nucleus, of the atom. Electrons travel in orbits around the nucleus. Protons have a positive charge, electrons have a negative charge, and neutrons have no charge and therefore no effect on the electrical characteristics of the matter. Electrical energy is released when electrons move from one atom to another; electrons can be forced to pass from one atom to another. Atoms try to maintain equal numbers between positive (+) and negative (-) charges (protons vs. electrons). An atom that loses an electron becomes positively charged (+) due to the excess proton. An atom that gains an extra electron becomes negatively charged (-).

The Law of Electric Charges states that like charges repel and opposite charges attract. Excess electrons are attracted to atoms lacking electrons. To perform useful work, a constant and steady movement of electrons must be produced.

POTENTIAL DIFFERENCE

An imbalance of electrons is called a potential difference. A potential difference describes a situation where excess electrons have accumulated, and are waiting for an opportunity to reconnect with atoms that lack electrons. Electrons travel from negative (-) to positive (+) atoms.

There are a variety of methods used to create a potential difference (electromotive force) between two points: friction (static electricity), chemical (battery), thermoelectric (heat), photoelectric (light), and magnetic (generator or alternator).

The presence of a potential difference is sometimes called electromotive force (EMF), which is further abbreviated to "E."

VOLTS

The potential difference (EMF) between two points can be very high or very low. The unit of measurement used to indicate the strength of the EMF is the Volt.

Some typical voltages include: 1.5 Volts for a flashlight cell, 12 Volts for auto batteries, 24 Volts for controls, 120 Volts for homes, and 240 Volts for commercial systems. Voltage can vary from a microvolt (millionths of a Volt) to megavolts (millions of Volts).

The terms potential, electromotive force (EMF), and voltage mean the same thing and can be used interchangeably. Most people refer to EMF as Volts. Remember, electromotive force is NOT electricity. It is the driving force that causes electrons to move from one atom to another.

MEASURING VOLTS

Voltmeters are used to measure the potential difference between two specific points and are available in analog or digital types. Digital meters are much easier to read because they display the voltage directly while analog meters move a pointer across a scale in proportion to the voltage of the circuit and can be easily misread.

All voltage testers, regardless of type, have two probes and the meter indicates potential difference between the two probes. Voltmeters are often used to check electrical power supply. Correct placement of the probes and interpretation of the readings is critical for proper troubleshooting of electrical problems.

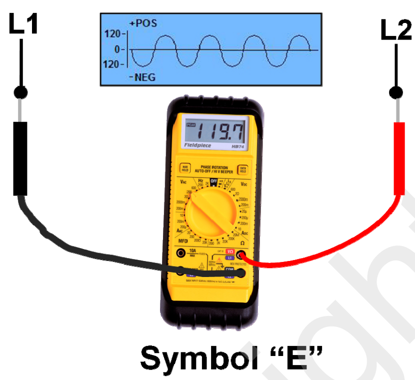


Fig. 1-1 (a): Digital Voltmeter

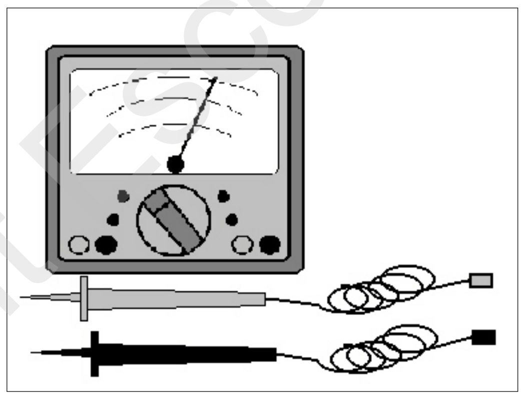


Fig. 1-1 (b): Analog Voltmeter

Electrical appliances are energy-consuming and conversion devices (called loads) and they are designed for connection between a potential difference. A specific voltage must be applied to force electron movement through the device. When testing supply voltage, a maximum variation of plus or minus five percent is generally acceptable. Connecting wires supply the necessary electrons and complete the circuit or pathway for electron flow. When the proper voltage is connected to a load, the load should operate. If the device is supplied the proper voltage and does not operate, it is defective. A voltage tester can quickly reveal this problem.

A voltage tester reads zero when no potential difference exists between the two probes, but will also read zero if voltage and polarity are the same at both probe locations. Additional voltage tests are required to determine whether or not voltage is present.

Never touch an electrical wire because a zero voltage reading was obtained – you may be reading the same potential (no difference) between the probes!

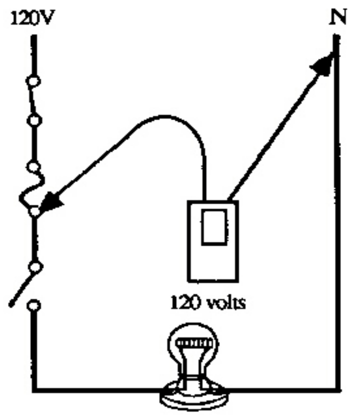


Fig. 1-2 (a)

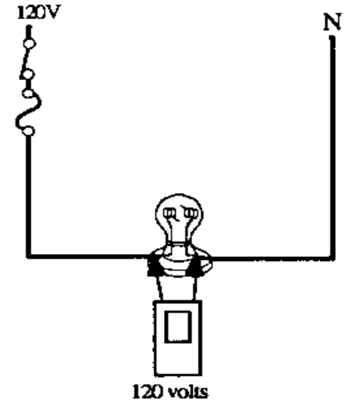


Fig. 1-2 (b)

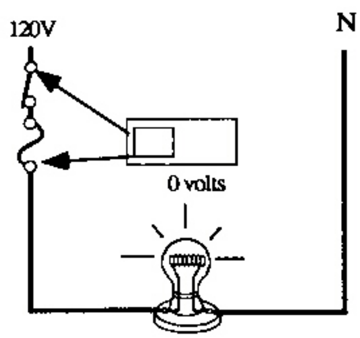


Fig. 1-2 (c)

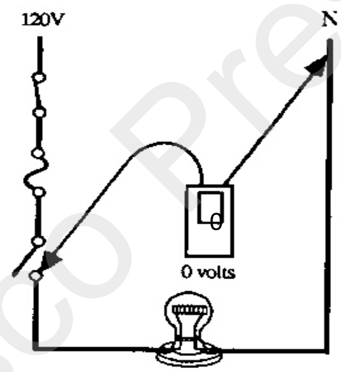


Fig. 1-2 (d)

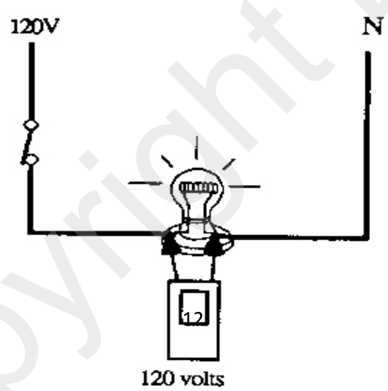


Fig. 1-2 (e)

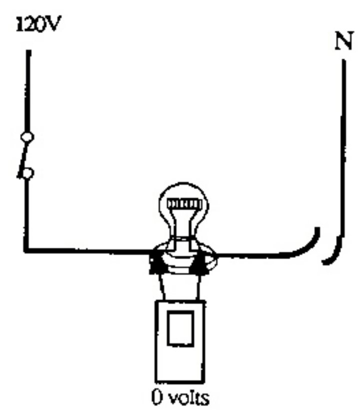


Fig. 1-2 (f)

HOW ELECTRONS FLOW THROUGH A CONDUCTOR

Voltage is the force that causes electrons to move, but electrons cannot move unless they have a place to go. Electrical circuits (electrical pathways) are composed of copper or aluminum wires and devices or loads that are designed to control the flow of electrons (current). Power plants produce EMFs, NOT electrons. The electrons are already inside the wires. The EMF produced by the power plant forces free electrons inside the conductor to travel to the next atom within the conductor, much like a domino effect. This electron movement from one atom to another occurs throughout the length of the conductor. The conductors provide the necessary free electrons and provide the proper pathway for electron movement. In a DC circuit (direct current), the electrons travel in one direction only. In an AC circuit (alternating current), the electrons are constantly changing directions. In the United States, power is transmitted at 60 hertz. This means the change from negative to positive occurs 60 times per second.

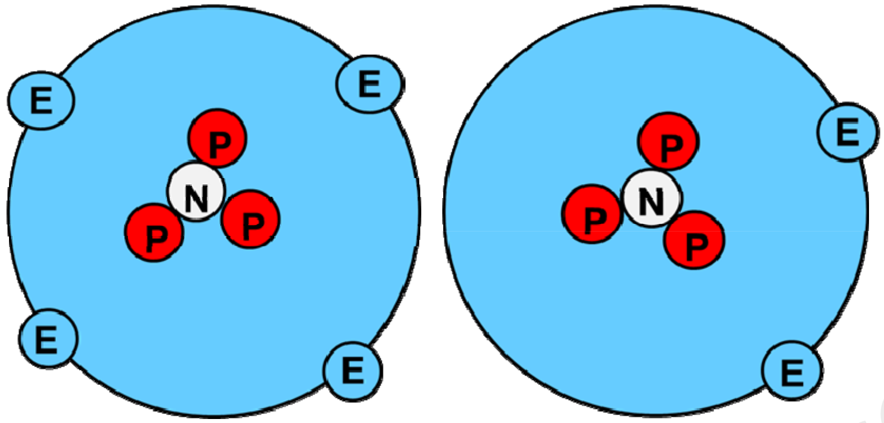


Fig. 1-3: The negative atom has 4 electrons and the positive atom has 2 electrons.

Electricity is often compared to the flow of water. However, water valves and electrical switches operate differently. Water flows when a valve is opened. Electricity flows when a switch is closed; electrons cannot flow through an open switch or a broken wire. Any opening in the circuit (pathway) is much like a drawbridge.

Switches are used in electrical circuits to act as these "drawbridges" for stopping and starting the flow of electrons.

AMPERAGE

The words *ampere, amperage, amps*, and *current* are frequently used to describe the quantity and intensity of electrons moving through a conductor. Amperage determines how much electricity will be converted to another form of energy. Thus, electrical loads are "energy conversion devices." These energy conversion devices (toasters, light bulbs, motors, etc.) are used to perform useful work.

An ammeter is used to measure the quantity and intensity of electrons flowing inside a wire, or through a load. The letter "I" (for "intensity") is often used to indicate amperage flow. When current flows through a conductor, a magnetic field is created. The clamp-on ammeter is most commonly used on AC circuits and is designed to read the intensity of flow in ONE wire. The magnetic fields will cancel each other out and the ammeter will indicate a reading of zero when clamped around the two wires feeding a load device. If the same wire is coiled through the jaws of the ammeter, the reading will increase by the multiple of each wrap of the coil. With an amperage reading of 20, and the wire coiled 5 times, the actual amperage for the circuit will be 4. Figure 1-4 illustrates a typical clamp-on ammeter. These are available in analog type (needle pointer) or digital readout.

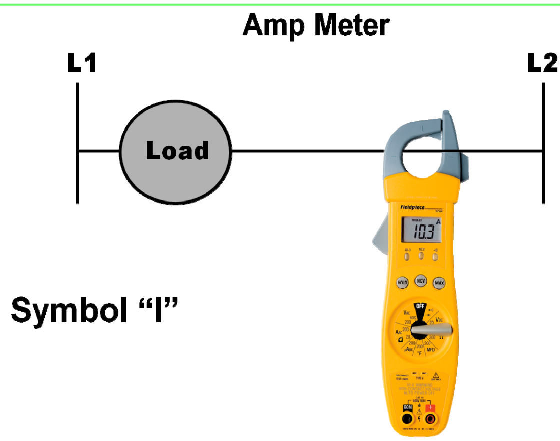


Fig 1-4: The inductive ammeter reads intensity of magnetic field around the wire and converts it to an amperage reading.

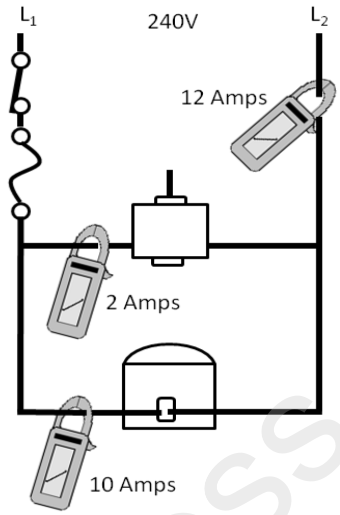


Fig 1-5: Total amperes for a circuit is the sum of the branch circuits.

RESISTANCE

Resistance refers to anything offering opposition to the flow of electrons. It is the resistance that causes energy conversion. Electron flow is energy in motion and must be controlled. The resistance is one factor that controls the amount of electron flow, and thus regulates the rate at which the useful work is performed. A circuit without resistance to control the electron flow is considered shorted.

There are several types of resistance that will be discussed later in this chapter. However, a basic understanding of Ohm's Law is necessary before that discussion.

Fig. 1-6

OHM'S LAW

Ohm's law, discovered by George S. Ohm, defines the exact relationship between voltage (E), amperage (I), and resistance (R). Ohm's Law is used for troubleshooting purposes and designing electrical devices and circuits. The capital letter "R" is often used to indicate resistance. Another symbol for resistance is the Greek letter Ω (omega).

Ohm's Law is best remembered as a pie, as shown in Figure 1-7. To use the pie chart, cover the item to be determined and follow the instructions as indicated by the horizontal or vertical lines. For example, to discover E, you must multiply I by R. To discover I, divide R by E.

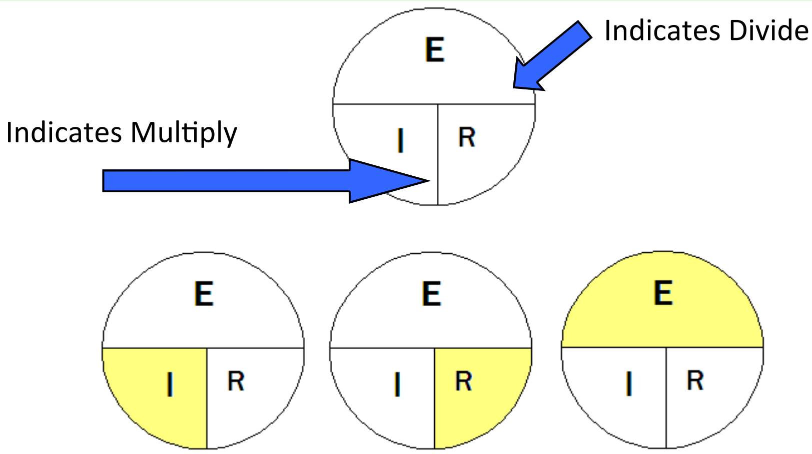


Fig. 1-7: Cover the unknown item and follow the instructions indicated by the horizontal or vertical lines.

RESISTANCE AND REACTANCE

There are three important types of resistance to electron flow: pure resistance, inductive reactance, and capacitive reactance.

PURE RESISTANCE

Pure resistance is opposition that remains constant. Pure resistance can be directly measured with an ohm meter and will only change with temperature. Toasters and electric heaters are examples of loads that have close to pure resistance. (Ohms Law: With a fixed resistance, higher voltage increases amperage and lower voltage decreases amperage.)

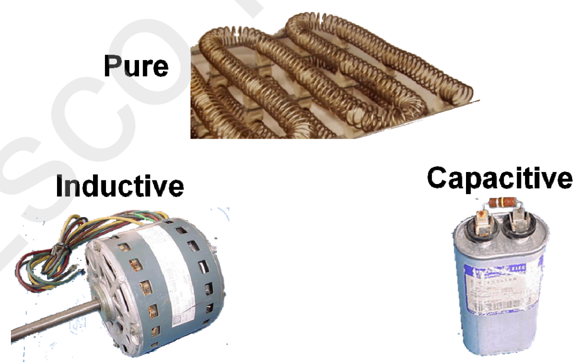


Fig. 1-8: Types of Resistance

INDUCTIVE REACTANCE

When a conductor is wound into a coil, the magnetic lines of force overlap and reinforce each other inducing a counter-EMF or opposing voltage. The counter-EMF is the source of opposition to current flow. A constant direct current has a zero rate-of-change and sees an inductor as a short circuit (it is typically made from a material with a low resistivity). An alternating current has a time-averaged rate -of-change proportional to frequency; this causes the increase in inductive reactance with frequency. The formula for inductive reactance is:

XL = 2 x E(3.14) x (f) frequency x (L) Inductance (Henries)

The inductive coil has a low measured resistance until it is energized and increases in resistance during operation, due to reactance. Transformers, solenoid coils, and motor windings are examples of components that produce inductive reactance. These devices produce a magnetic field and voltage of their own in direct opposition to the supply voltage. This counter-EMF acts as additional resistance, created only when the device is operating. Counter-EMF decreases current flow after start -up and during operation of the device. (Ohms Law: increased resistance decreases amperage, and lower resistance increases amperage.)

CAPACITIVE REACTANCE

A capacitor is a device that stores electrical energy for later use. A capacitor is composed of two conductive plates with an insulating (dielectric) material between them. In an A/C circuit, the capacitor continuously charges and discharges, creating an opposition to current flow or a type of resistance referred to as capacitive reactance.

IMPEDANCE

Impedance is the total opposition to alternating current flow. "Z" is the symbol for impedance.

MEASURING RESISTANCE

Ohmmeters are used to check resistance. Ohmmeters are very sensitive and measure resistance in Ohms. They measure electron movement calibrated to a voltage supplied by the meter's battery.

When using an ohmmeter, supply voltage must be turned off and disconnected from the device being tested. When devices are wired in parallel, a conductor should be removed from the device being measured in order to prevent a feedback circuit.

Failure to disconnect the device from the circuit can cause bodily harm to the technician and/or severe damage to the ohmmeter and can result in false readings caused by electron flow through another circuit.

Resistance readings also reveal specific situations such as continuity, an open circuit, or a short circuit.

Continuity describes a complete path for electron flow and is indicated by zero resistance. Continuity indicates no broken wires, open switches or blown fuses.

An open circuit describes an open switch, blown fuse, broken wire, etc. Electrons cannot flow in an open circuit. The ohmmeter reveals an open circuit by unlimited resistance (infinity) or extremely high resistance (megaohms).

A short circuit is a complete circuit (continuity) where none should exist. There is very little or no resistance in a short circuit. The ohmmeter detects a short circuit by indicating zero resistance between two points that should read extremely high resistance or infinity.

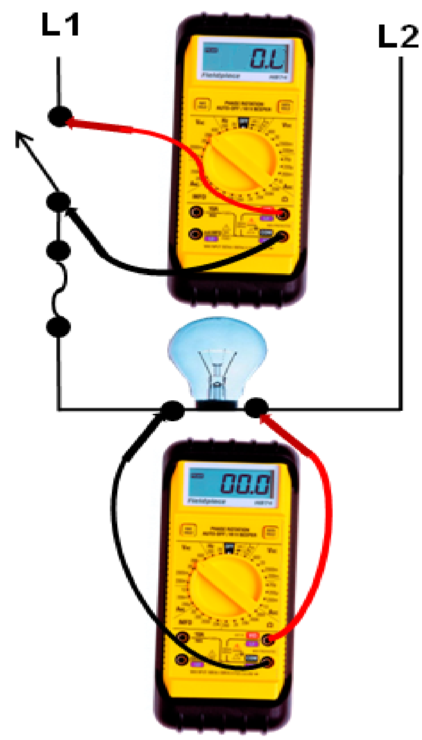


Fig. 1-9: The top ohmmeter indicates an open circuit. The bottom meter shows a shorted circuit.

WATTAGE

James Watt (1763-1819) discovered the method we use for measuring electrical power. Electrical power is the rate at which electricity is used to perform useful work. This work is measured in units called watts.

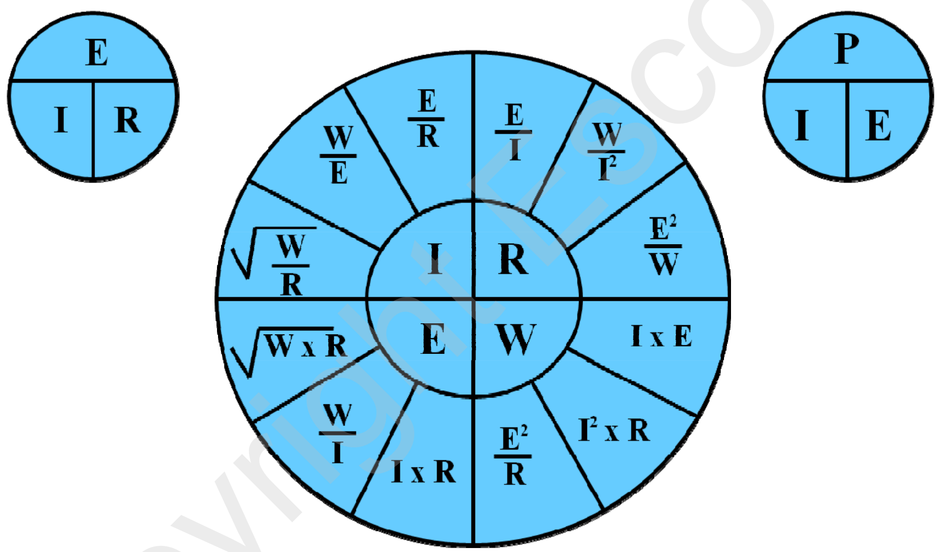
Watts are calculated by multiplying amperage x voltage:

W = I x E

(746 watts = 1 horsepower)

A wattmeter is normally located at the power entry to a building and measures the number of kilowatts (1000 watts = 1 kilowatt) consumed.

Figure 1-9 is a wheel showing the formulas for calculating volts, amperes, resistance, and power. It is a combination of the Ohm's Law circle and the Power Law circle. If any two factors are known, the others can be calculated.



I = intensity (amperes)

R = resistance (ohms)

E = electromotive force (voltage)

W = watts (power)

P = power (watts)

Fig. 1-10

Name ________________________________ Date ______________________

Solve For Ohm's Law and Power Laws.

1. Find voltage if resistance is 20Ω and current is 6 Amps.

2. Find current if voltage is 240 and resistance is 60Ω.

3. Find resistance if voltage is 24 and current is 3 amps.

4. Find power if current is 10 amps and voltage is 120.

5. Find power if current is 5 amps and resistance is 5Ω.

6. Find voltage if power is 1000 watts and current is 8 amps.

7. Find resistance if power is 960 watts and voltage is 12.

8. Find current if power is 500 and voltage 50.

9. Find power if resistance is 24Ω and current is 10 amps.

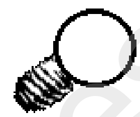
10. Find power is voltage is 200 and resistance is 400Ω.

Name ________________________________   Date ______________________

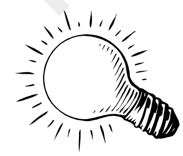
Use an ohmmeter to measure the resistance of an incandescent light bulb (hot and cold), a heating element, relay coil and contacts (NO and NC), and fan motor. Record measurements.

NOTE: Disconnect and remove all items to be tested from any live circuit.
Never use an Ohmmeter with voltage.

1. **Incandescent lamp, cold:** ________________________

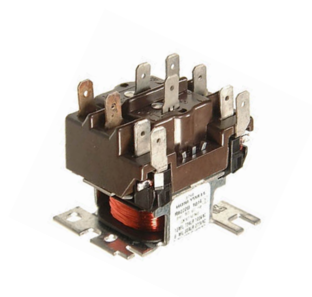


2. **Incandescent lamp, hot:** ___________________________



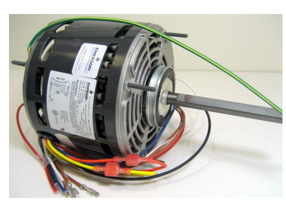
3. **Heating element:** ___________________________

4. **Relay coil:** ___________________________



5. **Contacts:** ___________________________

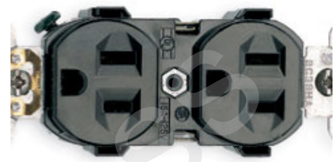
6. **Fan Motor:** ___________________________



Name ________________________________ Date ______________________

Use a volt meter and measures the voltage of a 120v receptacle, 240v receptacle, and 24v side of a transformer. Record measurements.

1. 120V Receptacle



2. 240V Receptacle

3. 240V Disconnect

4. 24V Transformer

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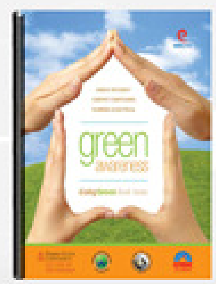

This Training Power Point will Prepare you for the Heat Load Analyst certification exam. It is essential to properly determine the heating & cooling load of a structure, ensuring optimal system performance.

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