CHAPTER

Basic Theories

2

Classroom Manual Objectives

Upon completion and review of this chapter, you should be able to:

- Explain the theories and laws of electricity.
- Describe the difference between insulators, conductors, and semiconductors.
- Define voltage, current, and resistance.
- Define and use Ohm's law correctly.
- Explain the difference between AC and DC currents.
- Define and illustrate series, parallel and series-parallel circuits and the electrical laws that govern them.
- Explain the theory of electromagnetism.
- Explain the principles of induction.

Classroom Manual Overview

This chapter covers the basic theories of electricity. It discusses how voltage, current, and resistance works as a unit to be what we consider electrical flow. It covers Ohm's and Watt's laws, giving the student information needed to understand electricity and how to test it. This background and basic knowledge helps the student understand how electricity works and assists in troubleshooting problems identified in later chapters. It discusses the basic fundamentals of structure of matter and develops into a discussion of series, parallel, and series-parallel circuits. It covers the basic structure of conductors and insulators, and the theories of magnetism and magnetic fields.

Reading Assignments

Classroom Manual, pages 17-47

Terms to Know

Alternating current (AC)
Ampere
Atom
Balanced
Balanced atom
Capacitor
Circuit
Closed circuit
Conductor
Conventional theory
Continuity
Current
Cycle
Direct current (DC)
Electromagnetic interference (EMI)
Electromagnetism
Electromotive force (EMF)
Electron theory
Electrons
Equivalent series load
Ground
Induction
Insulator
Ion
Kirchhoff’s voltage law
Kirchhoff’s current law
Magnetic flux density
Mutual induction
Neutrons
Nucleus
Ohms
Ohm's law
Open circuit
Parallel circuit
Permeability
Photovoltaics (PV)
Power
Protons
Reluctance
Resistance
Right-hand rule
Saturation Static electricity
Self-induction
Semiconductors
Series circuit
Series-parallel circuit
Shell
Valance ring
Voltage
Voltage drop
Watts

Lecture Outline and Notes

I. Objectives

A. Review the chapter's objectives.

II. Introduction

Discuss how the understanding of the principles and laws of electrical circuits can make diagnosing the electrical system a much easier task. With this knowledge the technician does not need to guess or "shotgun" the customer's problem. Also, explain that since electromagnetism and induction are related fields of study, these principles will be discussed in this chapter.

III. Basics of Electron Flow

A. Atomic Structure

Discuss the make up of all matter. Bring the discussion around to electrical components, electrons, protons, and neutrons.

1. Electrons
   Electrons are negatively charged components of the atom. Describe how electron flow is the basics of electricity.
2. Protons
   Protons are positively charged components of the atom and the center the electrons move around.
3. Neutrons
   Neutrons are neutral charged parts of the structure of the atom. Explain how these and the protons are the stable parts of the atom.
4. Balance
   Within the natural order of things, everything attempts to stay balanced. Discuss how there are equal electrons for protons.

5. Neutral
   If the electrons and protons are in balance, the atom is called neutral.
6. Positive Ion
   If an atom has lost an electron, it is called a positive ion.
7. Negative Ion
   If an atom has gained an electron, it is called a negative ion.
   Note: An assortment of different colored marbles can be used to "build" some atoms. Use the red marbles to represent the electrons, the black marbles to represent the protons, and so on.

B. Conductors and Insulators

Conductors and insulators are materials that will or will not support electrical flow because of their atomic structure.

1. Conductors
   Discuss the materials that have three or less electrons in the outer ring (valence ring).
2. Insulators
   Discuss materials that have five or more electrons in their outer ring (valence ring).
   Note: List the different materials on the blackboard and discuss how they are constructed. Show how some materials allow electrons to flow more easily because of the atomic structure.
3. Semiconductors
   Semiconductors are materials that have four electrons in the outer ring (valence ring). They are man made. Talk about doping of materials to make these.

IV. Electricity Defined

Ask the students to define or describe electricity in their own words. Put descriptions on the board in brief words. Use this as a starting point to define electricity.

It is good to bring the discussion around to the fact that the human body runs on electrical charges. Discuss how muscles operate, and so on. Discuss how the heart beats with electrical pulses, how easy it is to become overcome with electricity, and how it can harm you.

A. Electromotive Force

Use the term and discuss how it is the pressure that causes the electrons to move from one point to another.

Note: A set of dominos can be used to effectively illustrate the concept of electron and "hole" flow.

B. Voltage

Define the terms that are used interchangeably in describing voltage: electromotive force (emf), potential, and pressure. Voltage is measured in volts with a voltmeter.

C. Current

Current is the measurement of the flow of electrons. Intensity is the reason the letter "I" is used to indicate amperage flow. Current is measured in amps with an ammeter. Discuss the need for the two types of current. Ask if AC can be used in vehicles and why we need DC.

1. Electron theory
   The electron theory explains the movement of electrons from negative to positive. This is the most accurate depiction of current flow since it describes the actual flow of electrons. Understanding this theory is required in order to understand semiconductor devices.
2. Conventional theory
   This is the oldest theory stating that flow is from positive to negative. All test equipment is set up this way. Ask the students if it matters which theory they use.

D. Resistance
Resistance is the part of electricity that slows down the flow. It can be referred to as load, work, or counter-electromotive force. It consumes some energy as it passes through it, usually in the form of heat. Resistance is measured in ohms (Q) with an ohmmeter.

E. Voltage Drop
Voltage drop is the voltage converted to heat or some other form of energy as it goes through a resistance. Discuss how normal load devices convert electrical energy and voltage is dropped. Discuss the effects that unwanted resistances would have on a circuit.
Note: Real-life examples of voltage drop such as corroded connectors, melted switches, and so on, will assist the student in visualizing its adverse effects.

V. Electrical Laws

Electrical behavior is governed by well defined laws. The most common and useful are Ohm's and Watt's laws.

A. Ohm's Law
This is the law that governs the flow of electricity. Explain how it simplifies the understanding of the relationships between voltage, amperage, and resistance.
Note: Write the symbols that can be used to indicate the law, the triangle, a circle or the "T" symbol on the blackboard. Spend time making sure everyone understands its use.
Simple quote: It takes one volt to push one unit of current through one ohm of resistance.

B. Watt's Law
The electrical law that indicates a unit of work. The formula
is: Volts x Ampere (current) = Watts
For example, a bulb that consumed 5 amps in a 12 volt circuit would use 60 watts of power (5 x 12 = 60)

VI. Types of Current

A. Direct Current
Defined as a given voltage moving in one direction only.

B. Alternating Current
Voltage moves from positive to negative at a frequency that can vary. Quiz the students concerning alternating voltage. Sample questions include:
Is AC voltage ever used on the automobile? Can a storage battery be charged with AC voltage?

VII. Electrical Circuits

A. Series Circuit
A series circuit is one in which the loads are connected together such that current must flow through one to get to another.

B. Parallel Circuit
Parallel circuits allow current to flow through two or more loads at the same time along two or more paths.

C. Series-Parallel Circuit
A series-parallel circuit is a circuit that allows the current to pass through more than one path, as well as through a single load, before or after the parallel loads.

D. Applying Ohm's Law
This portion of the chapter provides the student with an opportunity to study Ohm's law more thoroughly. This section discusses the application of Ohm's law to automotive circuits and how resistances and opens affect the circuits.

E. Kirchhoff's Current law
This law states that if more current entered a point than left the point than a charge would develop at that point.

F. Kirchhoff's Voltage law
This law states that the sum of the voltage drops equal the total voltage of the circuit.

XIII. Magnetism Principles

Explain how this is used in many parts of the vehicle so it is very important to know how it works. Talk about starter motors, relays, ignition coils, and generators.

A. Magnets
Explain permanent magnets and what makes them permanent.

B. Magnetic Flux
Discuss the lines of force around a magnetic pole.

C. Permeability
Define and discuss the ability of materials to take on a charge to make a magnet.

D. Reluctance
Discuss the materials that resist the passage of flux lines.

E. Electromagnetism
Discuss how electricity flowing through a conductor will have a magnetic field around it, and discuss how from that, an electromagnet can be constructed.

IX. Theory of Induction

A. Induction
Discuss how the movement of a magnetic field across another conductor causes the electrons to become agitated and want to flow.
Note: Induction can be demonstrated by connecting a DVOM (in the low AC millivolt range) to a piece of wire that is moved rapidly back and forth through the magnetic field of a magnet. Alternately, the voltage output of a distributor pick-up coil is developed through induction and can also easily be measured.

B. Saturation
In the case of saturation, the magnetic field is as big as it will get. The magnetic field is resisting any further growth.

C. Mutual Induction
Discuss how the rapid making and breaking of a circuit causes the ignition coil to mutually induce into the other set of windings.

D. Electromagnetism Interference
Discuss the interference that can cause problems when a magnetic circuit is switched off. Example: the noise in a radio of a vehicle with the older point-type ignitions or the whine in a radio from an AC generator. Discuss problems in computerized vehicles. Describe how a clamping diode can reduce voltage spikes.

E. Discuss photovoltaics.

X. EMI Suppression

Discuss the cause of electromagnetic induction and its effect on computer controlled systems. Also discuss static electricity. Include in your discussion methods used to suppress EMI.

XI. Summary

Review the material covered, emphasizing the main points and key words.

Chapter 2 Classroom Manual Answers to Review Questions

CLASSROOM MANUAL, PAGES 48-59

Short Answer Essays

1.
   1) Voltage - the electrical pressure that causes electrons to move through a circuit.
   2) Current - the rate of electron flow. Amperage is the amount of electrons passing any given point in the circuit in one second.
   3) Resistance - opposition to current flow.
2. Ohm's Law defines the relationship between current, voltage, and resistance. It is the basic law of electricity and states that the amount of current in an electric circuit is inversely proportional to the resistance of the circuit, and is directly proportional to the voltage in the circuit. Ohm's Law is a mathematical formula that shows how current, voltage, and resistance work together to produce electricity. If any two electrical values are known, the third can be found.
3. Series Circuit - provides a single path for current flow from the electrical source through all the circuit's components, and back to the source.
   Parallel Circuit - provides two or more paths for electricity to flow.
   Series-Parallel Circuits - a combination of the series and parallel circuits.
4. Whenever an electrical current flows through a conductor, a magnetic field is formed around the conductor. The number of lines of force, and the strength of the magnetic field produced, increases in direct proportion to increases in current flow. This magnetic field has true north and south poles. Looping the wire doubles the flux density where the wire is running parallel to itself. As more loops are added, the fields from each loop will join and increase the flux density. To make the magnetic field even stronger, an iron core can be placed in the center of the coil. The strength of an electromagnetic coil is affected by the following factors:
   1) The amount of current flowing through the wire.
   2) The number of conductors.
   3) The size, length, and type of core material.
   4) The angle at which the lines of force are cut.
5. Induction is the magnetic process of producing a current flow in a wire without any actual contact to the wire. Magnetic induction occurs when a conductor is moved through the magnetic lines of force. A difference of potential is set up between the ends of the conductor and a voltage is induced. This voltage exists only when the magnetic field or the conductor is in motion. The induced voltage can be increased by either increasing the speed in which the magnetic lines of force cut the conductor, or by increasing the number of conductors that are cut.
6. Electricity is the movement of electrons from atom to another. If there is an excess amount of positive charges (protons) placed on one end of a conductor, one of the positive ions will pull the outer electron away from the atom on the other end. For the electrons to move in the same direction, there must be an electromotive force (EMF) applied. When electrons in the atoms of a conductor are affected by the EMF, an unbalance condition will occur in the atom between the negative charges of the electrons and the positive charges of the nucleus. The EMF attempts to push the electron from its orbit. If an electron is freed from its orbit, the atom acquires a positive charge because it now has one more protons than electrons. This action will cause one of the atoms to be slightly positively charged. The unbalanced atom attempts to return to its balanced

state so it will attract electrons from the orbit of other balanced atoms. This starts a chain reaction as one atom captures an electron and another releases an electron.

7. Direct Current - current flow that is in the same direction and remains constant on or off.
   Alternating Current - circuit, voltage and current does not remain constant. AC current changes directions from positive to negative. The voltage in an AC circuit starts at zero and rises to a positive value, then it falls back to zero and goes to a negative value, then it returns to zero.
8. Insulator - not capable of supporting the flow of electricity. If the atom does not shed its electrons easily, the substance is a good insulator.
   Conductor - capable of supporting the flow of electricity through it. If an atom sheds electrons easily, it is a good conductor.
   Semiconductors - neither conductors nor insulators.
9. Voltage drop is the loss of energy (voltage) as the current flow passes through a resistance such as a load or corrosion.
10. Wattage is a measure of the rate of total electrical work being performed.

Fill-in-the-Blanks

1. Electrons, protons, neutrons (in order)
2. Conductor, insulator (in order)
3. Electromotive force (EMF) or voltage
4. Conventional theory or hole theory
5. Opposition (resistance), ohms (in order)
6. Resistance
7. Total (sum) voltage drop, equal (in order)
8. Sum
9. Voltage
10. Current

Multiple Choice

1. D
2. B
3. B
4. D
5. A
6. B
7. C
8. C
9. A
10. D