SUBCOURSE
OD0611

EDITION
B

PRINCIPLES OF AUTOMOTIVE ELECTRICITY

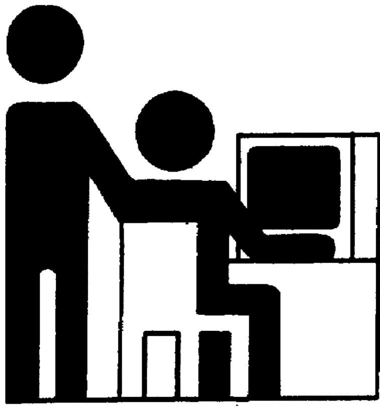
AIPD

READINESS / PROFESSIONALISM

THRU GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM



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PRINCIPLES OF AUTOMOTIVE ELECTRICITY

Subcourse Number OD 0611

EDITION B

United States Army Combined Arms Support Command
Fort Lee, VA 23801-1809

4 Credit Hours

EDITION DATE: October 1991

SUBCOURSE OVERVIEW

This subcourse is designed to teach you the relationship of voltage, current, resistance and series and parallel circuits of military vehicle electrical systems. Practice exercises are provided prior to the examination.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time the subcourse was prepared. In your own work situation, always refer to the latest publications.

The words "he", "him", and "men", when used in this publication, represents both the masculine and feminine genders unless otherwise stated.

TERMINAL LEARNING OBJECTIVE

TASK: Identify electrical flow in circuits and maintenance of vehicle storage batteries.

CONDITIONS: Given this subcourse with illustrated electrical circuits, information on battery maintenance, technical publication extracts, explaining electricity.

STANDARDS: You must identify the electrical flow in circuits and maintenance of vehicle storage batteries in accordance with information provided within this subcourse and applicable publications.

PLEASE NOTE

Proponency for this subcourse has changed
From Armor (AR) to Ordnance (OD).

TABLE OF CONTENTS

TM 9-8000 with Change 1, Principles of Automotive Vehicles, dated 25 Oct 85.

Use the above publication extract to take this subcourse. At the time this subcourse was written, this was the current publication. Always refer to the most current publication in a working environment.

ELECTRICAL CIRCUITS

MQS Manual Tasks: None

OVERVIEW

TASK DESCRIPTION:

In this lesson, you will learn the definition of electrical terms and identify symbols and circuits used in the vehicle's electrical systems.

LEARNING OBJECTIVE:

ACTIONS: Identify electrical flow circuits.

CONDITIONS: Given this subcourse with illustrated electrical circuits, technical publication extract explaining electricity.

STANDARDS: You must specify the amount of voltage, amperage, or resistance in a particular circuit. You must also specify if the circuit is in series or parallel.

REFERENCES: The material contained in this lesson was derived from the following publications:

TM 9-8000
FM 11-60
FM 11-61
TM 9-6140-200-14

INTRODUCTION

Electricity has been used for decades and scientists have been experimenting with it longer. We know that everything that exists consists of particles called molecules. Molecules are further divided into a material called atoms. Atoms consist of some arrangement of protons, electrons, and neutrons. The proton is a positive charged particle; the electron is a negative charged particle; and the neutron is not charged. Molecules are a very basic necessity in the composition of all materials with the exception of hydrogen. Neutrons and protons will always be located in the center of an atom. The electrons will always be located in the outer shells of the atom. There are two types of electrons. They are the bound electron and the free electron. The free electrons are the electrons which will be found in the outermost shell, or orbit of the atom and can be moved readily from their orbit. The innermost shells of the atom contain electrons that are not easily freed and are referred to as bound electrons.

LESSON CONTENT

1. There are many terms and symbols that are particular to the study of electricity. As a maintenance supervisor, an understanding of electrical terns and an ability to interpret schematic wiring diagrams, electrical drawings, and symbols will enable you to properly supervise maintenance personnel in diagnosing and locating electrical problems.

a. Electrical Terms.

(1) AC - Alternating current, or current that reverses its direction at regular intervals.

(2) Ammeter - An electric meter that measures current.

(3) Battery - A device consisting of two or more cells for converting chemical energy into electrical energy.

(4) Circuit - A closed path or combination of paths through which passage of the medium, electric current, air, and liquid, is possible.

(5) Circuit Breaker - In electrical circuits, a mechanism designed to break or open the circuit when certain conditions exist; especially the device in automotive circuits that opens the circuit between the generator and battery to prevent overcharging of the battery. One of the three units comprising a generator regulator.

(6) Conductor - A material through which electricity will flow readily.

(7) Core - An iron mass, generally the central portion of a coil, electromagnet or armature around which wire is coiled.

(8) DC - Direct current or current that flows only in one direction.

(9) Electricity - A form of energy that involves the movement of electrons from one place to another or the gathering of electrons in one area.

(10) Electromagnet - A temporary magnet constructed by winding a number of turns of insulated wire into a coil or around an iron core.

(11) Electron - A negative particle that is a basic constituent of matter and electricity.

(12) Flux - Lines of magnetic force moving through a -magnetic field.

(13) Ground - Connection of an electrical unit to the engine/frame to return the current to its source.

(14) Induction - The action or process of producing voltage by the relative motion of a magnetic field and a conductor.

(15) Insulation - A substance that stops movement of electricity (electrical insulation) or heat (heat insulation).

(16) Magnet - Any body that has the ability to attract iron.

(17) Magnetic Field - The space around a magnet that the magnetic lines of force permeate.

(18) Magnetic Pole - Focus of magnetic lines of force entering or emanating from a magnet.

(19) Magnetism - The property exhibited by certain substances and produced by electron, electric current, and/or motion which results in the attraction of iron.

(20) Negative - A term designating the point of lower potential when the potential difference between two points is considered.

(21) Ohm - A unit of measure of electrical resistance.

(22) Parallel Circuit - The electrical circuit formed when two or more electrical devices have like terminals connected together, positive to positive or negative to negative, so that each may operate independently of the other.

(23) Positive - A term designating the point of higher potential when the potential difference between two points is considered.

(24) Potential - A characteristic of a point in an electric field or circuit indicated by the work necessary to bring a unit positive charge from infinity; the degree of electrification as compared to some standard. For example: the earth.

(25) Relay - In the electrical system, a device that opens or closes a second circuit in response to voltage or amperage changes in a controlling circuit.

(26) Resistance - The opposition offered by a substance or body to the passage through it of an electric current.

(27) Series Circuit - The electrical circuit formed when two or more electrical devices have unlike terminals connected together, positive to negative, so that the same current must flow through all.

(28) Volts - A unit of potential, potential difference, or electrical pressure.

b. Electrical Symbols. As a maintenance supervisor, you must be able to interpret schematic wiring diagram. To read these diagram, you must know the meaning of the symbols used. Examples of same electrical symbols are illustrated in Figure 1-1.

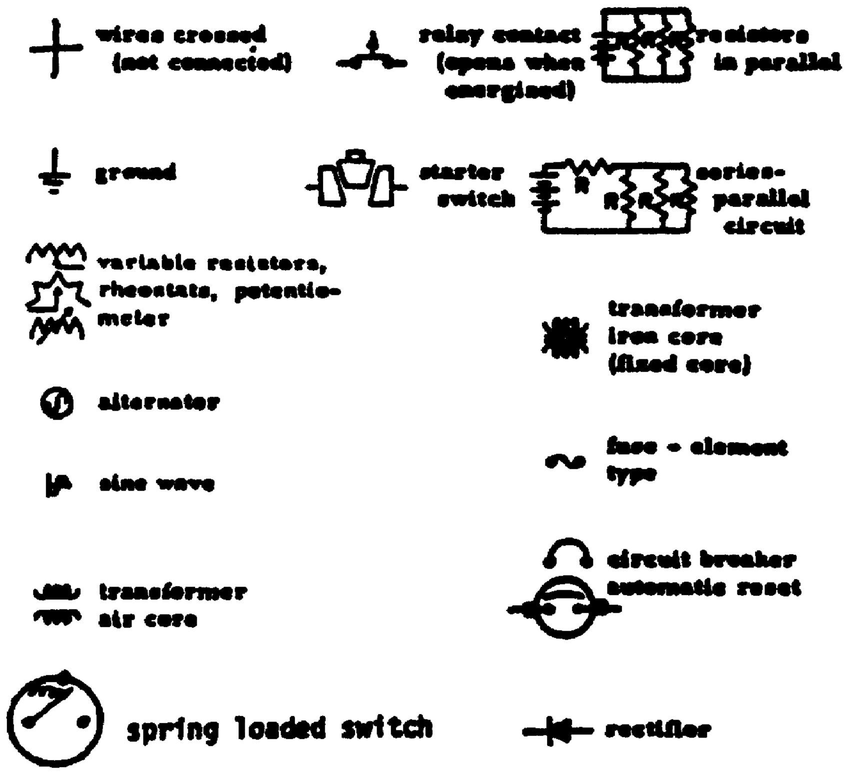


Figure 1-1. Electrical Symbols (page 1 of 2).

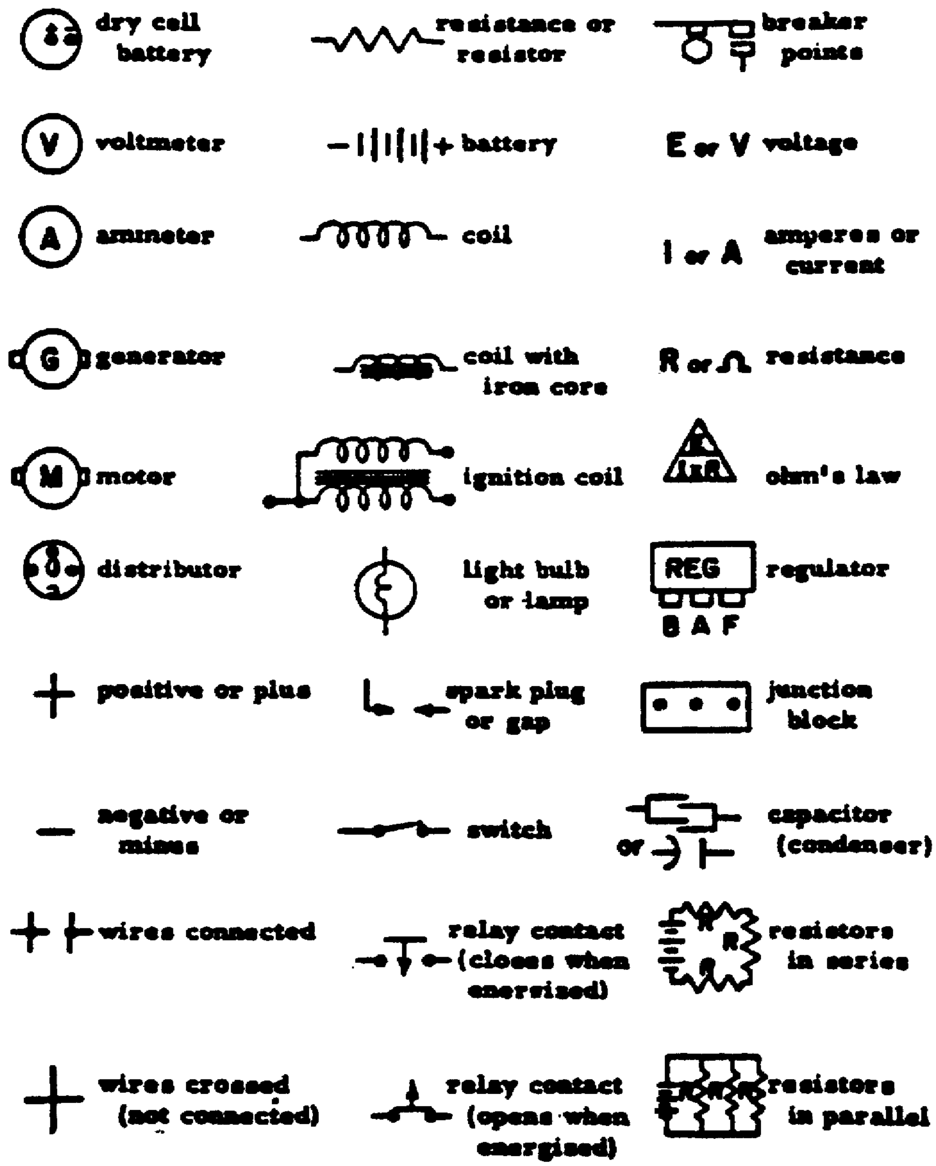


Figure 1-1. Electrical Symbols (page 2 of 2).

2. While the study of electricity may seem complicated, it can be broken down into three elements: voltage, current, and resistance.

a. Voltage. Electrons are caused to flow by a difference in electron balance in a circuit; that is, when there are more electrons in one part of a circuit than in another, the electrons move from the area where they are concentrated to the area where they are lacking. This difference is called potential difference or voltage. Methods of producing voltage include friction (static electricity), chemical reaction (battery), and magnetic induction (generator).

b. Current. Current flow or electron flow is measured in amperes. While it is normally considered that one ampere is a rather small current of electricity, it is actually a tremendous flow of electrons. More than six billion electrons a second are required to make up one ampere. Personnel in the maintenance field are concerned with two types of current, alternating current (AC) and direct current (DC).

(1) Alternating current - While alternating current is acceptable for house or commercial use, it is not acceptable for automotive use. As its name implies, AC alternates back and forth in direction of flow at timed intervals and therefore cannot be stored in a storage battery.

(2) Direct current - DC is used in automotive systems because circuits can be controlled so the current will readily flow to the component where it is needed and return to its source (storage battery) through a frame return circuit.

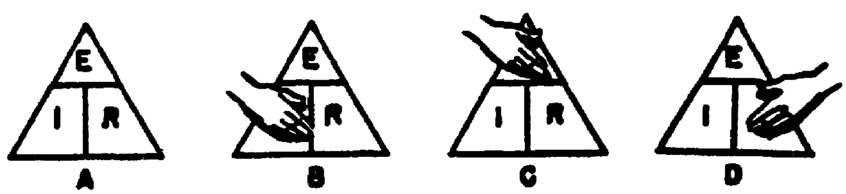
c. Resistance. Resistance is defined as the opposition to current flow. Even though a copper wire will conduct electricity with ease, it still offers resistance to electron flow. This resistance is caused by the energy necessary to break the outer shell electrons free, and the collisions between the atoms of the conductor and the free electrons. It takes force (or voltage) to overcome resistance encountered by the flowing electrons. This resistance is expressed in units called ohms. The resistance of a conductor varies with its length, cross-section area, composition, and temperature.

d. Generators. Generators are a major component of automotive systems as they supply the electrical power to operate all electrical systems of automotive vehicles. Some of the functions of generators are to supply electrical current to the lighting system, the ignition system, heater motor, instruments, and radios. There are two types of generators in use today. They are the alternator or AC generator, and the direct current or DC generator.

(1) Alternating current. The AC generator produces alternating current which is unacceptable for automotive systems. The alternator rust have a rectifier installed to convert AC to DC to satisfy the needs of the storage battery. In the alternator, the magnetic field is rotated and voltage is produced in the stationary coils. One advantage of the AC generator is that it will produce current at low speeds which make it the more acceptable component.

(2) Direct current. The DC generator, as its name implies, produces DC current, but must be run at a much higher speed than the AC generator. The DC generator works much the same way as the AC generator, but the magnetic field is stationary and coils of wire, called an armature, are rotated in the magnetic field. A magnetic switch, brushes, and a commutator are provided.

3. Ohm's Law states that the voltage impressed on a circuit is equal to the sum of the product of current measured in ohms. One ohm is the resistance of a circuit element that permits a steady current of one ampere to flow when a steady force of one volt is applied to the current. An easy way to remember Ohm's Law is to think of a triangle with E at the top and I and R in the lower angles (Figure 1-2).



E = Volts, I = Current in Amperes, R = Resistance in Ohms

Figure 1-2. Ohm's Law Triangle.

The mathematical formula is written in one of the following three ways:

a. E = I x R. The voltage in a circuit equals the current multiplied by the resistance. An example of Ohm's Law in relation to voltage is an electric heater which has a known resistance of 20 ohms. The same heater requires a current flow of 6 amperes for proper operation.

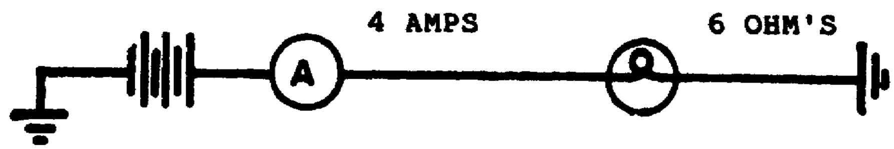


Figure 1-3. Determine Voltage.

b. I = E/R. The current equals the voltage divided by the resistance. An example of Ohm's Law in relation to current is an electric horn that requires a pressure of 12 volts and offers 3 ohms of resistance to the flow of current.

Figure 1-4. Determine Current.

c. R = E/I. The resistance of the circuit equals the voltage divided by the current. An example of Ohm's Law in relation to the resistance is an electric iron that operates from a 120 volt input and requires a current flow of 5 amperes.

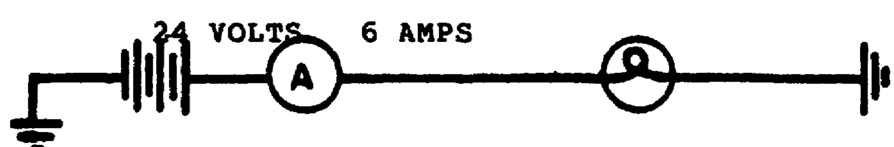


Figure 1-5. Determine Resistance.

4. A very basic circuit consists of a power source, a unit to be operated, and a wire to connect the two together.

a. Series Circuits.

(1) Laws of series circuits.

(a) A series circuit has only one path for current to flow.

(b) Amperage remains the same in all parts of a series circuit.

(c) When resistance is added in series, the total resistance increases and current decreases.

(d) The sum of all different voltage drops is equal to the applied voltage.

(2) Figure 1-6 shows a series circuit consisting of one or more units connected in series (negative to positive) to form a single path for current to flow. Most every one is familiar with the old type of Christmas tree lights where all of the bulbs go out when any one of the bulbs burn out. These lights are connected in series (negative to positive). A break anywhere in the circuit will cause all of the lights to go out.

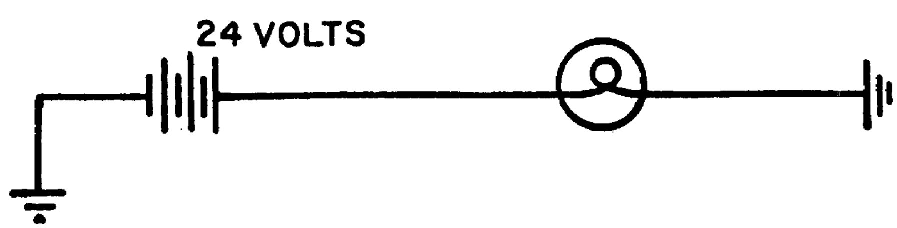


Figure 1-6. Series Circuits.

b. Parallel Circuits.

(1) Laws of parallel circuits.

(a) A parallel circuit has two or more paths for current to flow.

(b) Applied voltage is the same to each branch of the circuit.

(c) When resistance is added in parallel, the total or effective resistance decreases.

(d) The sum of the amperage in each branch is equal to the total amperage.

(e) The total or effective resistance will always be less than the lowest resistance.

(2) Figure 1-7 demonstrates how the voltage source is applied equally to each of the electrical components in a parallel circuit and how the parallel circuit has two or more paths for current to flow. Opening or closing the circuit of any branch does not affect the other circuits.

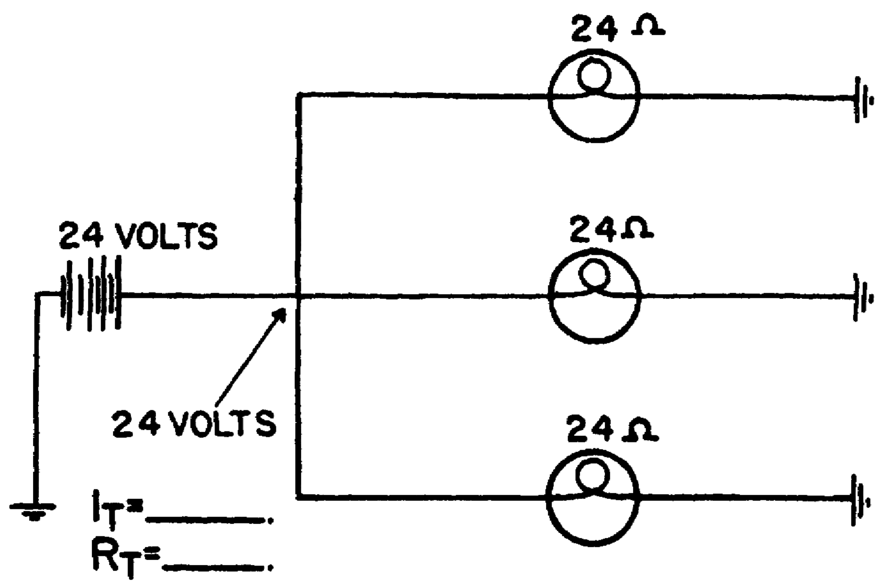


Figure 1-7. Parallel Circuits.

LESSON ONE

Practice Exercise

The following items will test your grasp of the materials covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study that part of the lesson which contains the portion involved.

<u>Situation</u>. You have been tasked to supervise maintenance personnel in the testing, repair, and replacement of electrical systems/components. To become proficient in that area, you have decided to increase your knowledge in the area of automotive electricity.

1. What are the three elements of electricity?

    A. Short, Voltage, and watt.
    B. Current, voltage, and open circuit.
    C. Resistance, amperage, and electron.
    D. Voltage, current, and resistance.

2. An ohm is

    A. a unit of measure of electrical resistance.
    B. a unit of measure of electrical potential.
    C. a material which electricity will flow through.
    D. the force that causes current to flow.

3. What is a circuit breaker?

    A. A device for turning lights on or off.
    B. One of the three units comprising a generator regulator.
    C. A warning device for instrument control.
    D. A turn signal control device.

4. What is measured with an ammeter?

    A. Pressure.
    B. Resistance.
    C. Current.
    D. Potential.

5. What is one advantage of an alternator?

A. It does not need a rectifier.
B. It produces direct current.
C. It delivers more current at lower speeds.
D. It is gear-driven.

6. If one component burns out in a series circuit,

A. the rest of the circuit will continue to operate.
B. the entire circuit is inoperative.
C. one third of the circuit is inoperative.
D. two thirds of the circuit is inoperative.

7. What is alternating current?

A. Current that restricts voltage.
B. Current that flows in only direction.
c. current that flows back and forth in direction.
D. Current with high amperage.

8. What is the current in a flashlight that requires 3 volts of pressure and has 1 ohm of resistance?

A. 1 ampere.
B. 3 amperes.
C. 2 amperes.
D. 6 amperes.

9. What is the resistance of a blower motor in a heater that operates on a 24 volt circuit and requires 3 amperes of current?

A. 12 ohms.
B. 10 ohms.
C. 8 ohms.
D. 6 ohms.

10. What is the voltage in a car headlight that has a known resistance of 3 ohms and requires 4 amperes of current?

A. 6 volts.
B. 9 volts.
C. 12 volts.
D. 15 volts.

11. What is the current in a stereo speaker that requires 120 volts of pressure and has 8 ohms of resistance?

A. 10 amperes.
B. 15 amperes.
C. 20 amperes.
D. 25 amperes.

12. What is the resistance of a vehicle headlight that operates on a 24 volt circuit and requires 1.8 amperes of current?

A. 2.5 ohms.
B. 5.3 ohms.
C. 9.6 ohms.
D. 13.3 ohms.

13. What is the voltage of an electric windshield wiper motor with a known resistance of 6 ohms and requirement of 4 amperes of current for proper operation?

A. 6 volts.
B. 12 volts.
C. 18 volts.
D. 24 volts.

14. What constitutes a parallel circuit?

A. Two or more components connected together positive to positive.
B. Two or more components that depend upon each other for proper operation.
C. Two or more paths for current to flow.
D. Two or more resisters to control current flow.

LESSON ONE

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item Correct Answer and Feedback.

1. D. Voltage, current, and resistance.

Voltage is the forage or pressure that causes current to flow in a wire, and resistance is the opposition to current movement. (Page 7, para 2).

2. A. Unit of measure of electrical resistance.

An ohm is the amount of resistance that must be overcome for current to move in an electrical circuit. (Page 4, para 1.a. (21)).

3. B. One of three units comprising a generator regulator.

In electrical circuits, a mechanism designed to break or open the circuit when certain conditions exist. (Page 3, para 1.a. (5)).

4. C. Current.

The ammeter is designed specifically for measuring current flow in an electrical circuit. (Page 3, para 1.a.(2)).

5. C. It delivers more current at lower speeds.

When current is induced into the alternator, it will start charging. The DC generator does not produce current until it reaches high speed. Therefore, the alternator is the preferred component. (Page 7, paras d. and d.(1)).

6. B. The entire circuit is inoperative.

A series circuit only has one path for current to flow. Any component in that circuit that burns out causes the entire circuit to be inoperative because it now has an open circuit. (Page 10, para 4.a.(2)).

7. C. Current that flows back and forth in direction.

As its name implies, alternating current will flow back and forth in direction of flow at timed intervals. (Page 7, para 2.b.(1)).

8. B. 3 amperes.

Ohm's Law allows you to determine the amount of amperage or current in a circuit by equation I = E/R or 3 ohms. (Page 9, para b.).

9. C. 8 ohms.

Ohm's Law allows you to determine the amount of resistance in a circuit by equation R = E/I or 8 ohms. (Page 9, para c.).

10. C. 12 volts.

Ohm's Law allows you to determine the amount of voltage in a circuit by equation E = I x R or 12 volts. (Page 9, para a.).

11. B. 15 amperes.

Ohm's Law allows you to determine the amount of amperage in a circuit by equation I = E/R = 15 amperes. (Page 9, para b.).

12. D. 13.3 ohms.

Ohm's Law allows you to determine the amount of resistance in a circuit by equation R = E/I. (Page 9, para c.).

13. D. 24 volts.

Ohm's law allows you to determine the amount of voltage in a circuit by equation E = I x R or 24 volts. (Page 9, para a.).

14. C. Two or more paths for current to flow.

A parallel circuit consists of two or more resister units (electrically operated components in separate branches). [Page 11, para b.(2)].

LESSON TWO

BATTERY MAINTENANCE

MQS Manual Tasks: none

OVERVIEW

TASK DESCRIPTION.

In this lesson you will learn the procedures for inspection and maintenance of Lead Acid Storage Batteries.

LEARNING OBJECTIVE:

ACTIONS: Inspect storage batteries.

CONDITIONS: Given situations describing storage battery conditions.

STANDARDS: You must identify all faults and determine battery serviceability. Describe the inspection procedures for each situation.

REFERENCES: TM 9-6140-200-14.

INTRODUCTION

Lead acid storage batteries are used in automotive application to supply electricity to vehicle components as required and act as a voltage stabilizer in vehicle electrical systems.

LESSON CONTENT

1. Inspection and maintenance of lead acid storage batteries is an important part of ensuring that your vehicles will be able to perform their mission. Without proper maintenance, lead acid batteries can fail and then you are without equipment at a critical time.

a. Description of Vehicle Storage Batteries. The lead acid storage battery is an electro-chemical device for storing energy in the chemical form. When this energy is needed to operate an electrical component in the system, it is released as electricity. Storage batteries perform four functions in automotive application.

(1) They supply electrical energy for vehicle engine starts.

(2) They supply short term overload demands in excess of generator electrical output.

(3) They supply limited or emergency power when the generator is not operating.

(4) They act as a voltage stabilizer in the vehicle electrical system.

b. Safety Precautions. Certain safety precautions must be observed when you are working around storage batteries.

(1) While removing or installing vehicle batteries, remove the ground cable (negative side of the battery) first and connect it last to eliminate arcing.

(2) Avoid open flames and arcing of cables near the battery. One small spark can cause the battery to explode.

(3) Avoid contact with sulfuric acid; it can cause severe burns. Keep a strong solution of soda and water available, as a precaution if contact occurs. If soda solution is not available, flush the area of contact with clear water.

(4) Ventilate the battery room well at all times to avoid explosions due to the presence of hydrogen gas which is produced by storage batteries.

(5) While working with batteries, wear chemical protective splash goggles (goggles with no vent holes which prevent splashed acid or chemicals from entering the eyes), rubber gloves, and a rubber gown while filling batteries with electrolyte.

c. Battery Construction. The lead acid battery consists of a number of cells connected together. Each cell will produce approximately two volts; the number of cells needed will depend upon the voltage desired. For example, one 12-volt battery will have six cells.

(1) A cell consists of a compartment made of hard rubber, plastic, or other bituminous material into which the cell element is placed. The cell element consists of two types of lead plates, known as positive and negative plates. These plates (Figure 2-1) are insulated from each other by suitable separators (usually made of plastic, rubber, or glass) and submerged in a sulfuric acid solution (electrolyte).

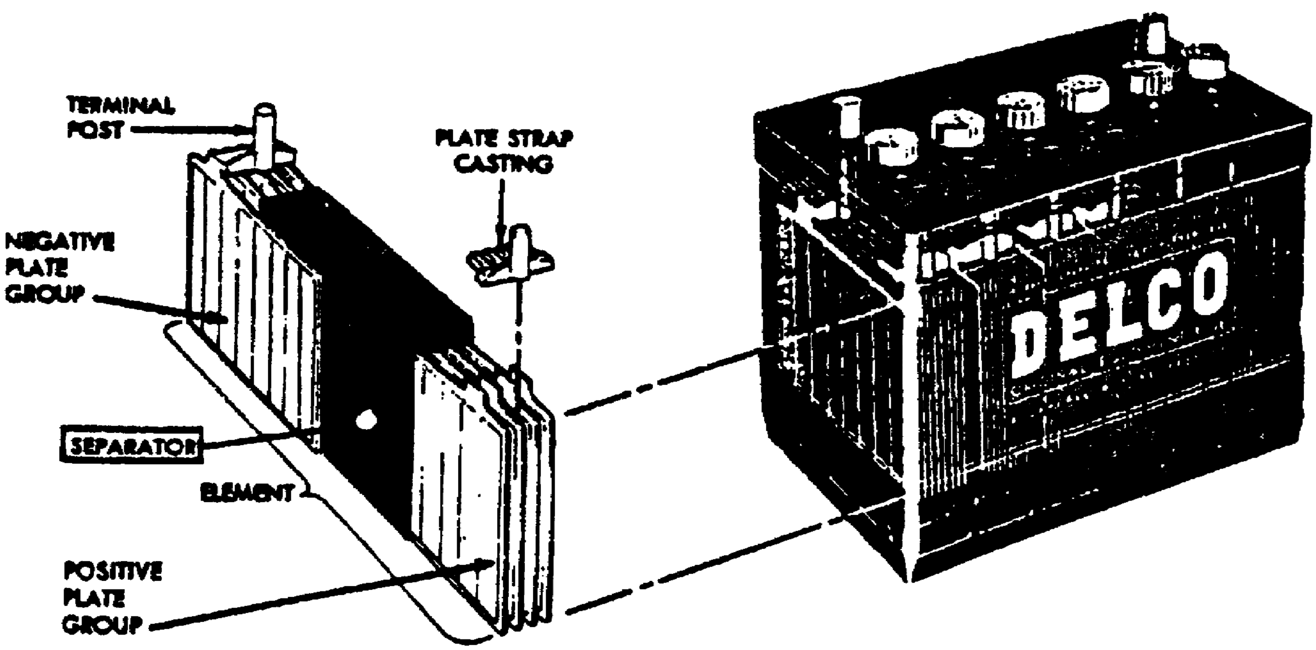


Figure 2-1. Negative and Positive Plate Group With Separators.

(2) Battery cells are filled with a solution of sulfuric acid and water, known as electrolyte. This solution contains approximately one-part of acid, by volume, three-parts water. The strength of the electrolyte is measured in terms of specific gravity. Specific gravity is the ratio of weight of a given volume of electrolyte to an equal volume of pure water. The specific gravity of pure water is 1.000. Sulfuric acid has a specific gravity of 1.830. A mixture of sulfuric acid and water will vary in strength from 1.000 to 1.830. Normally, electrolyte (water and acid mixture) will have a strength of 1.280 when the battery is fully charged. As a storage battery discharges, the sulfuric acid is depleted and the electrolyte is converted into water. This action provides a guide in determining the state of discharge of the lead acid cell. If the specific gravity reading is below 1.225, the battery is in a low state of charge. Testing and recharging of a lead-acid battery will be covered later in the subcourse.

CAUTION

Sometimes, pure sulfuric acid will be issued. This acid must be mixed with water to produce the desired specific gravity. When mixing electrolyte, always pour the acid into the water. NEVER pour water into the acid.

d. Battery Classification. Storage batteries are classified according to their rate of discharge and ampere-hour capacity. Most batteries are rated according to a 20-hour rate of discharge. If a fully charged battery is completely discharged during a 20-hour period, it is discharged at the 20-hour rate. At the end of the discharge time, the average voltage must be 1.75 volts or higher. If a battery can deliver 20 amperes continuously for 20 hours, the battery has a rating 20 X 20, or 400 ampere-hours. The batteries used in military vehicles are the 6TN battery with a capacity of 45 ampere-hours. When more capacity is required than can be supplied by one battery, additional batteries can be connected in parallel to increase total capacity. If two 100-amp, 12 volt batteries were connected in parallel, they would have a combined capacity of 200-amps. The total voltage would remain the same (12 volts).

e. Maintenance of Storage Batteries.

(1) Visually inspect the battery to determine if maintenance or repairs are required.

(a) Inspect the battery case for holes or cracks. If a hole or large crack is evident, turn in the battery to intermediate support maintenance.

(b) Inspect the battery for loose posts. If slight pressure causes the post to move, turn the battery in to intermediate support maintenance.

(c) Inspect posts, clamps, and battery holddowns for corrosion. The posts and terminals should be cleaned and coated lightly with grease. Turn in to maintenance if:

- A post is out-of-round to the extent that it prevents full contact between the post and a new clamp.

NOTE. Post and clamps are tapered for a tighter fit. Also, the positive post is larger in diameter than the negative post.

- The post is less than 5/8 inch high. This condition would prevent full contact between the post and a good clamp.

(2) Inspect filler caps. Check to see that the caps are not damaged or broken and that the gasket is present. Some filler caps have a built-in gasket made of the same material as the cap. The gasket is tapered from the outside edge toward the center of the cap to provide a tight seal with the case. Make sure the vent holes in the caps (Figure 2-2) are open to permit escape of gases. Replace all caps that are defective.

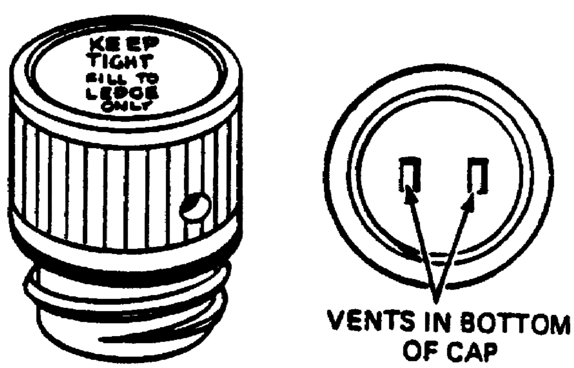


Figure 2-2. Vent Cap (Plug).

(3) Check the electrolyte level of each cell. At a minimum, the electrolyte level should cover the cell plates (Figure 2-3). When adding water to batteries, the electrolyte level should be brought up to the bottom of the split ring.

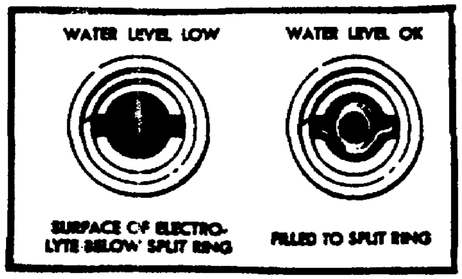


Figure 2-3. Visual Level Fill.

(4) Charge the batteries. Connect the battery to the charger, following the equipment manufacturer's recommendations. Observe the polarity of the battery (connections are made positive to positive and negative to negative). Specific charging rates will vary, depending on the battery (eight to ten amperes for 6TN and four to five amperes for 2HN batteries). Leave the battery caps on and at one hour intervals, check the specific gravity of each cell. The temperature should not exceed 130 degrees during the charging. If the temperature is too high, reduce the charging rate. Do not overcharge the batteries. Overcharged batteries will be damaged internally, shortening their life. Overcharging is indicated by excessive use of water. Overcharging can be avoided by removing the battery from the charger when specific gravity reading remains the same for three successive hourly tests. Add water to the battery during charging, if it is needed.

CAUTION

During charging, batteries give off highly explosive hydrogen gas. The charging area must be well ventilated and every precaution must be taken to prevent sparks that could cause an explosion.

(5) Measure specific gravity. Use the optical battery/antifreeze tester "duo-check" (Figure 2-4), when measuring the specific gravity of a battery. This tester is quick, accurate, and reliable. There is no guesswork or arithmetic involved and the tester will automatically adjust for temperature.

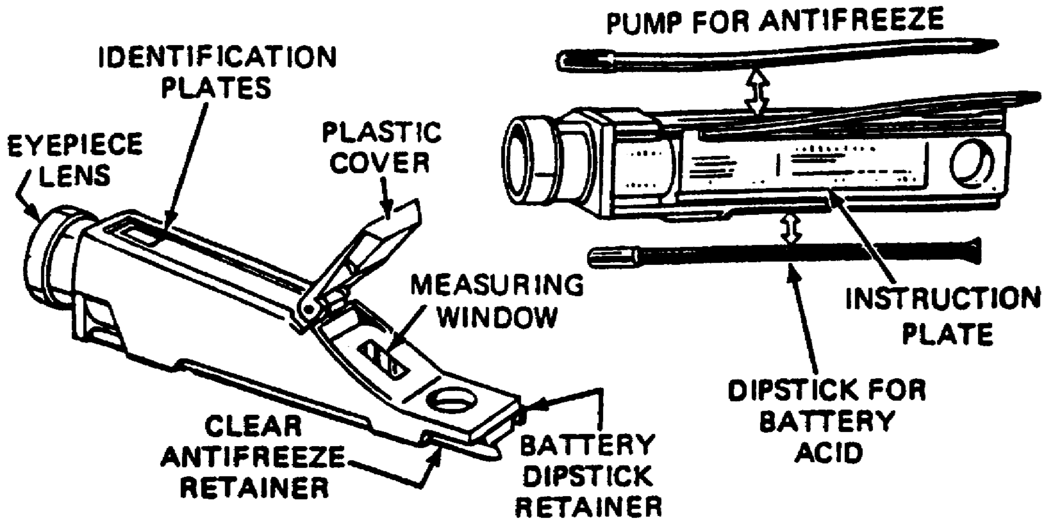


Figure 2-4. Optical/Antifreeze Tester (Duo-deck).

(a) Before using the duo-check tester, clean and dry the plastic cover and measuring window. Wipe each piece clean with a soft cloth (Figure 2-5). Clean the eyepiece lens. Clean water can be used to clean any dirty areas if it is needed.

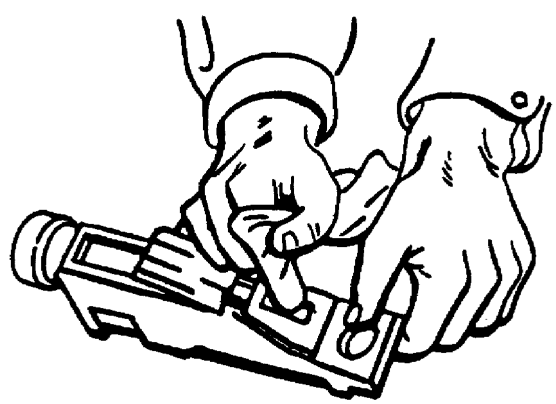


Figure 2-5. Cleaning the Tester.

(b) Swing the plastic cover down until it rests against the measuring window. Using the black dipstick, place a few drops of electrolyte onto the exposed portion of the measuring window (Figure 2-6).

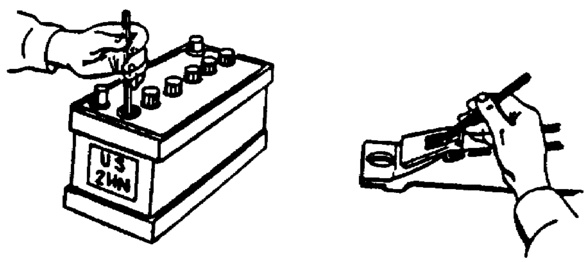


Figure 2-6. Electrolyte Sample.

(c) Point the tester toward a bright light source. When looking through the eyepiece lens, you will see a rectangle with two calibrated scales. The battery charge readings will appear on the left scale; antifreeze readings on the right scale. The electrolyte sample will divide the rectangle with an area of light and an area of shadow. Read the scale where they meet (Figure 2-7).

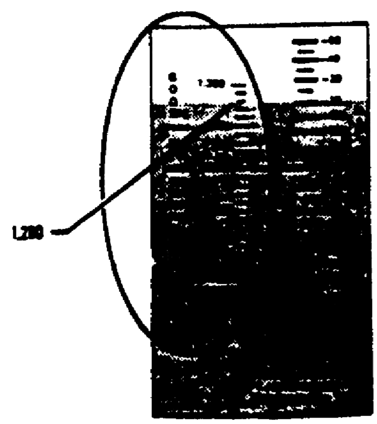


Figure 2-7. Battery State of Charge.

(d) Always perform a separate test for each battery cell. Test the battery before adding water to the cells.

f. <u>Control and Protective Devices</u>. Electricity, when properly controlled, is of vital importance to the operation of equipment. When it is not properly controlled, it can become very dangerous and destructive. Such devices as fuses, circuit breakers, and switches are connected into circuits to control electrical force.

(1) The simplest protective device is a fuse. All fuses are rated according to the amount of current that is safely carried by the fuse element at a rated voltage. The most important fuse characteristic is its current-versus-time or "blowing" ability. Current-versus-time indicates how quickly an overloaded fuse will blow: fast, medium, and delayed. Fast may range from five microseconds through 1/2 second; medium, 1/2 to five seconds; and delayed, five to 25 seconds. When a fuse blows, it should be replaced with another of the same rated voltage and current capacity, including the same current-versus-time characteristic. Normally, when the circuit is overloaded, or a fault develops, the fuse element melts and opens the circuit it is protecting.

(2) A circuit breaker is designed to break the circuit and stop the current flow when the current exceeds a predetermined value. It is commonly used in place of a fuse and may sometimes eliminate the need for a switch. A circuit breaker differs from a fuse in that it "trips" to break the circuit, and it may be reset, while the fuse melts and must be replaced. Some circuit breakers must be reset by hand, while others reset themselves automatically. When the circuit breaker is reset, if the overload condition still exists, the circuit breaker will trip again to prevent damage to the circuit.

(3) A switch may be described as a device used in an electrical circuit for making, breaking, or changing connections under conditions for which the switch is rated. Switches are rated in amperes and volts; the rating refers to the maximum voltage and current of the circuit in which the switch is to be used. Because it is placed in series, all the circuit current will pass through the switch. Switch contacts should be opened and closed quickly to minimize arcing; therefore, switches normally utilize a snap action.

LESSON TWO

Practice Exercise

The following items will test your grasp of the materials covered in this lesson. There is only one correct answer for each its. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study that part of the lesson which contains the portion involved.

1. When removing the battery cables, the ______________ cable should be removed first.

A. positive.
B. ground.
C. center.
D. outside.

2. Battery cells are filled with a solution of ____________________________ and ________________________ which is known as electrolyte.

A. water and sulfuric acid.
B. electrolyte and water.
C. distilled water and soda.
D. nitric acid and sulfur.

3. The ______________ is used to test the specific gravity of a battery state of charge.

A. voltmeter.
B. hydrometer.
C. ammeter.
D. duo-check.

4. A ________________ is defined as a device used in an electrical circuit for making, breaking, or changing connections.

A. circuit breaker.
B. switch.
C. fuse.
D. rheostat.

5. When adding water to batteries, the electrolyte level in the cells of a battery should be ______________________________ .

A. to the top of the filler hole.
B. just covering the top of the plates.
C. up to the bottom of the split ring.
D. halfway between the plates and the vent.

6. Battery vent caps should be _________________________ .

A. inspected for damaged or missing gaskets.
B. painted red for identification.
C. checked for cleanliness and serviceability.
D. installed snugly to prevent spillage of electrolyte.

7. When testing battery state of charge, you test _________ .

A. the center cells.
B. before adding water.
C. after adding water.
D. any one cell.

8. When mixing electrolyte, you should ____________________ .

A. pour water into the acid.
B. pour water and acid together.
C. pour acid into the water.
D. pour acid and water alternately.

9. The number of cells in a battery is determined by the _____________________________ .

A. voltage that is desired.
B. amperage that is required.
C. space designated for the battery.
D. components the battery supports.

10. The simplest protective device in an electrical system is the _________________________ .

A. switch.
B. circuit breaker.
C. fuse.
D. relay.

LESSON TWO

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item		Correct Answer and Feedback
1.	B.	When removing the battery cables, the ground cable (negative side) should be removed first. (Page 20, para b. (1)).
2.	A.	Battery cells are filled with a solution of water and sulfuric acid which is known as electrolytes. (Page 22, para (2)).
3.	D.	The duo-check is used to test the battery state of charge. (Page 25, para (5).
4.	B.	A switch is defined as a device used in an electrical circuit for making, breaking, or changing connections. [Page 27, para (3)].
5.	C.	Electrolyte level in the cells of a battery should be up to the bottom of the split ring. [Page 24, para (3)].
6.	A.	Battery vent caps should be inspected for damage or missing gaskets. [Page 23, para (2)].
7.	B.	Test the battery before adding water to the cells. [Page 26, para (d)].
8.	C.	When mixing electrolyte, you should pour acid into the water. (Page 22, CAUTION).
9.	A.	The number of cells in a battery is determined by the voltage that is desired. (Page 21, para c.).
10.	C.	The simplest protective device in an electrical system is a fuse. [Page 27, para (1)].