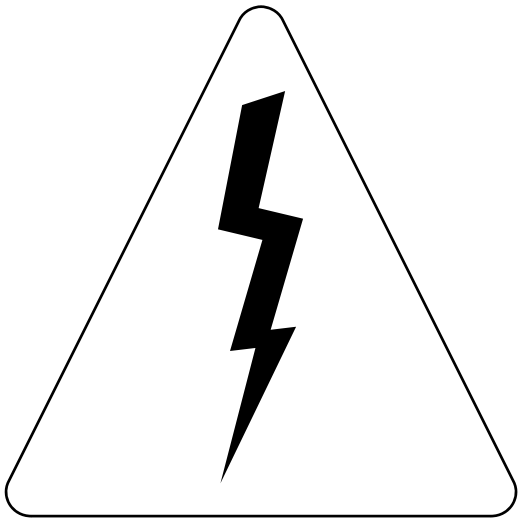
EF1

Student Learning Guide

Electrical Fundamentals



Automotive Electrical Course

KIA

SERVICE TRAINING

Each year there is an increased use of electronics in the automobile. With the emphasis put on fast and accurate diagnosis it is important for the technician to understand what electricity is and how it works.

LEARNING OBJECTIVES

After successfully completing this module, you should be able to:

- Explain what electricity is and how it works
- Define voltage, amperage, resistance and watts
- Define magnetism, inductance, capacitance and impedance

EF1-1

MODULE DIRECTIONS

Carefully read this material. Study each illustration as you read the material. Feel free to ask questions any time something is not clear. Be sure to answer the questions in the spaces provided as you perform the activities.

THINGS YOU WILL NEED

- The materials in this module
- The electrical project board
- A digital multimeter

- First recorded in 600 BC
- Some materials when rubbed together will attract other materials
- 18th century discovery found that like charges repel and opposite charges attract

EF1-2

- Benjamin Franklin proves that lightning is a form of electricity - mid 1800's
- Electrical current is thought to flow from positive to negative (Conventional Current Flow)
- The electron is discovered in 1897

EF1-3

- A form of energy where electrons move from one atom to another
- Exists when a voltage source creates a current flow by pushing electrons with enough force to overcome the resistance of the circuit
- Voltage, current and resistance are the three basic elements of a circuit
- Invisible, but effects can be seen

EF1-4

DISCOVERY OF ELECTRICITY

The first recording of electricity was around 600 BC. It was found that by rubbing certain substances they would attract lighter objects to them. Later in the 18th century it was discovered that there were two kinds of forces, or charges, caused by rubbing certain materials. It was found that like charges would repel and opposite charges would attract.

THE FAMOUS KITE EXPERIMENT

In the mid 1800's Benjamin Franklin proved that lightning was a form of electricity. He flew a kite into a thunderstorm and found that sparks jumped to the ground from a metal key attached to the wet string.

An assumption was made that there was current coming down the string from a high level of energy to a lower level. The high level of energy was called **positive** and the low level of energy was called **negative**. The assumption that electrical current flowed from positive to negative was accepted until 1897 when the discovery of the electron proved that it was actually the electrons, or negative particles of electricity, that move through a circuit.

WHAT IS ELECTRICITY?

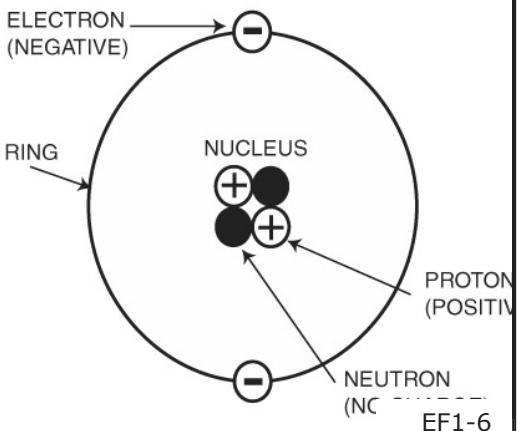
Electricity is a form of energy where electrons move from one atom to another. The movement of these electrons can be explained by the **Electron Theory**. Electricity exists when a voltage source creates a current flow by pushing electrons with enough force to overcome the resistance of the circuit. Voltage, current and resistance are the three basic elements of a circuit. Electricity itself is invisible but its effects can be seen in the forms of light, heat, noise and motion. Examples: We can see the light that a lamp gives off. We can see a motor turn. We can hear the buzzer's sound and we can feel the heat from an electric heater element.

- All matter is made up of atoms
- Each atom has a nucleus surrounded by orbiting electrons
- The outer orbiting electrons can move to neighboring atoms when the atom becomes unbalanced
- The movement of electrons from atom to atom is electricity

EF1-5

ELECTRON THEORY

The Electron Theory states that all matter (solid, liquid or gas) is made up of atoms joined together. Each atom is made up of a nucleus and electrons. The electrons orbit around the nucleus. The outer orbiting electrons can move from one atom to another when the number of electrons in the atom become unbalanced. This movement of electrons is known as electricity.



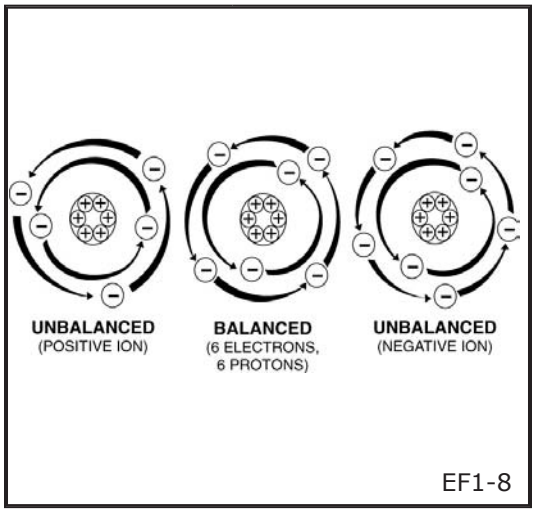
EF1-6

THE ATOM

The atom is like a tiny solar system. The atom has a nucleus at its center which is made up of protons and neutrons. The protons are positively charged. The neutrons have no electrical charge but are of the same weight as the protons. Orbiting at a very high rate of speed around the nucleus are negatively charged electrons. When the number of electrons equals the number of protons the atom is balanced. These electrons weigh about 1/1845 as much as a proton. Energy within the atom causes the electrons to spin around the nucleus in rings or shells. As they spin, centrifugal force pulls the electrons away from the nucleus but an electrostatic force within the nucleus balances the centrifugal force and keeps the electrons at a specific distance from the nucleus. When more energy is added to the atom, such as heat, the electrostatic force within the nucleus decreases and the centrifugal force of the electrons increases. The electrons then move further away from the nucleus until the two forces become equal again.

- Protons have a positive charge
- Neutrons have no charge
- Negatively charged electrons orbit the nucleus
- Combination of electrostatic force and centrifugal force keep the electrons in orbit
- The distance between the electrons and the nucleus is increased when more energy is added to the atom

EF1-7



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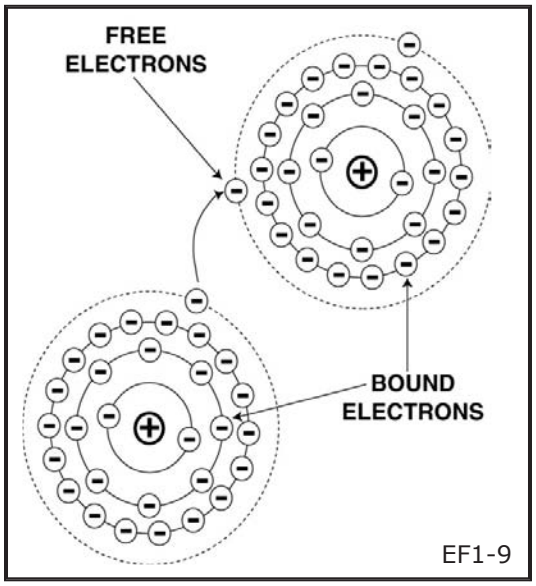

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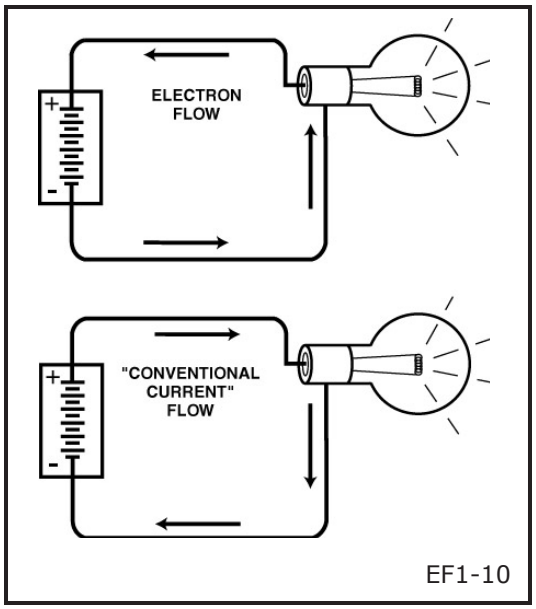

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IONS

An electrical force outside the atom can attract electrons from the outer ring and leave the atom in an unbalanced condition. An unbalanced atom is called an ion. When an atom gains an electron and has more electrons than protons it is a negative ion. When an atom loses an electron and has more protons than electrons it is a positive ion and will attract an electron from a nearby balanced atom. The electrons are constantly moving within a material from one atom to another. This causes electron flow.

ELECTRON FLOW

The electrons in the outer ring are not as strongly attracted to the protons as the inner rings of electrons. The inner electrons are called **bound electrons** and the outer electrons are called **free electrons**. When a force such as heat, pressure, friction, light, chemical action or magnetic action is applied to the material, the free electrons can move from one atom to the next. Electrical current can be formed by a stream of these free electrons along a conductor.

DIRECTION OF FLOW

There are two ways that we can consider the flow of electrical current. The **electron flow** which is from negative to positive and the flow of **conventional current** which, while actually a myth, flows from positive to negative. It is easier to think in terms of conventional current flow since most electrical drawings and semiconductor symbols are marked with arrows indicating the conventional current flow. It is also easier to use the conventional current flow because we can relate the flow of electricity to the rules of hydraulics in that there is a pressure, flow and opposition.

Quantity

- Basic unit is the coulomb
- One coulomb = 6.28 x 10^{18} electrons
- Symbol for quantity is Q

Flow

- Basic unit is the ampere
- The flow of one coulomb past a given point in one second
- Normally called current
- Symbol for current is I (Intensity)

Pressure

- Basic unit is the volt
- Amount of pressure required to force one ampere of flow through one ohm of resistance.
- Symbol for voltage is E (Electromotive force)

Opposition

- Basic unit is the ohm
- The resistance that opposes current flow
- Changes electrical energy into another form of energy eg: heat, light or motion
- The symbol for resistance is R

Power

- Basic unit is the watt
- The amount of electrical power used when one amp of current flows under a pressure of one volt
- The end result of electricity
- The symbol for power is P

EF1-11 thru EF1-16

MEASUREMENT OF ELECTRICITY

Quantity
The electron is such a small particle of electricity that a very large quantity are required to have a measurable unit. The basic unit of electrical quantity is the **coulomb**. A coulomb is equal to 6.28 billion, billion electrons (6.28 x 10^{18}). The symbol for quantity is **Q**.

Flow
When one coulomb flows past a given point in one second, there is a flow of one **ampere**, or one amp. It will be the same whether we think of electron flow or conventional current. This flow is normally called current and its symbol is **I** for intensity.

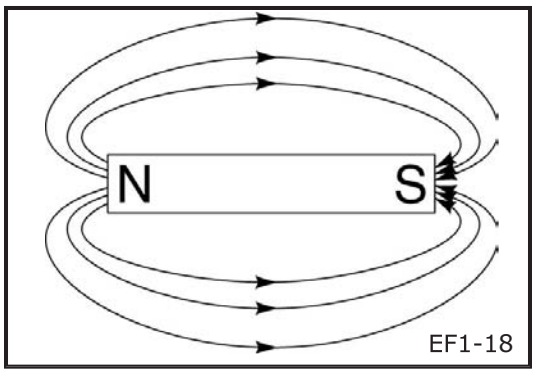
Pressure
The **volt** is the standard unit of electrical pressure and is the amount of pressure required to force one ampere of flow through one ohm of resistance. The symbol for voltage (electrical pressure) is **E** for electromotive force.

Opposition
Every electrical circuit or component has resistance. Resistance is what opposes current flow. It is this resistance that changes the electrical energy into another form of energy such as heat, light or motion. There are five factors that affect the resistance of a conductor - the conductor's type of material, length, diameter, temperature and physical condition. The standard unit of resistance is the **ohm**. One ohm is the resistance through which a pressure of one volt can force a flow of one ampere. The symbol for resistance is **R**.

Power
The end result of electricity is power. The **watt** is the unit of electrical power. One watt is the amount of power used when one amp of current flows under a pressure of one volt. The symbol for power is **P**.

- Magnetism is an invisible force
- Causes certain metals to repel or attract
- Magnets have a field/flux that loops from the N pole to the S pole
- Like poles repel and unlike poles attract

EF1-17



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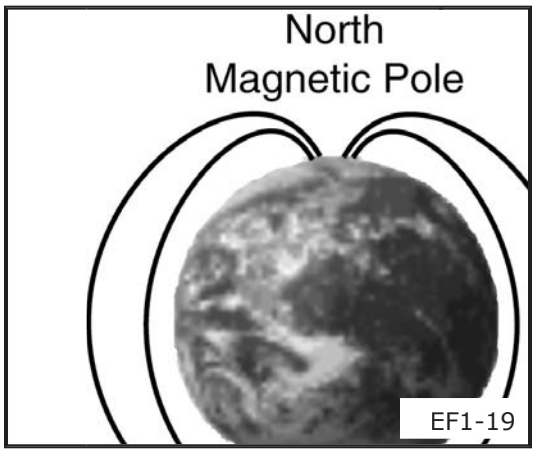

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MAGNETISM / ELECTROMAGNETISM

Magnetism

Like electricity, you cannot see magnetism, but you can feel its effects. It is an invisible force that acts on certain types of metals, such as iron and steel, causing them to pull together or push away from each other.

There is a definite area around every magnet where the magnet force exerts its power. This power is called the magnetic field or flux. The further away from the magnet, the weaker the field. The magnetic force always completes a loop that leaves one end of the magnet (North-seeking) and re-enters the other end (South-seeking). These ends of the magnet are the magnetic poles and are the two strongest areas of the field. Because the magnet is polarized, unlike poles attract and like poles repel.

The earth itself is an extremely large magnet with its magnetic lines of flux extending 50,000 miles from its surface. If a bar magnet is suspended by a string the earth's magnetic field will cause the magnet to orient itself in a north-south direction. We are able to use this phenomenon to make a compass.

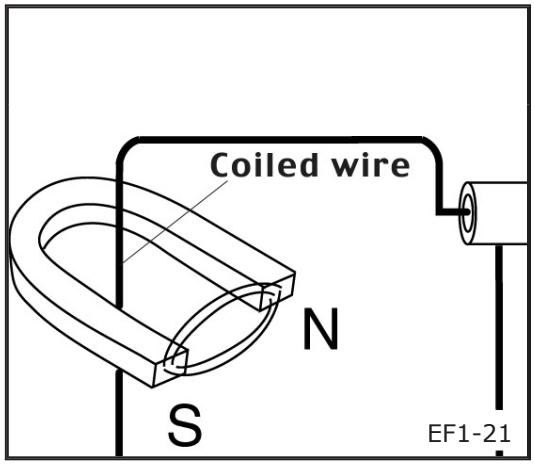
- A weak magnetic field with no polarity surrounds a conductor with current flowing through it
- If the conductor is coiled the field becomes stronger and now has a north and south pole
- The coil's magnetic field is directly proportional to the current and the number of turns on the coil
- An iron rod down the middle of the coil strengthens the magnetic field

EF1-20

Electromagnetism

In the early 1800s, the relationship between magnetism and electricity was discovered when it was found that the needle of a magnetic compass was deflected when it was placed near a current carrying conductor.

This deflection was caused by an invisible magnetic field that surrounds the conductor when an electrical current flows through it. This magnetic field is relatively weak and has no polarity. But if the wire is wound into a coil the field becomes stronger and has a definite north and south pole. The strength of the coil's magnetic field is directly proportional to the current and the number of turns on the coil. It was soon discovered that the magnetic field could be made even stronger by placing an iron rod down the middle of the coil.



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INDUCTANCE

Just as electric currents can produce magnetic fields, so too can magnets produce electric currents. If a magnet is moved near a coil of wire a current is generated in the wire. A current can also be generated if the coil of wire is moved near the magnet. The magnetic lines of flux passing through the conductor forces the electrons to flow through the conductor. The amount of electricity generated depends on the rate at which the lines of flux are cut. The rate can be increased by increasing the number of lines of flux by making the magnet stronger, or by moving the conductor through the lines of flux faster. This principle is used in the alternator to recharge the battery and provide the vehicle with the electricity it needs to operate.

- Capacitance is the storage of an electrical charge
- Capacitors consist of two parallel conductors separated by a dielectric
- When DC is applied to the capacitor the dielectric stores the charge until a path is provided for the current to flow
- Capacitors block the flow of DC
- Capacitors seem to pass AC; the current constantly rises and falls so the capacitor is constantly being charged or discharged

EF1-22

CAPACITANCE

Conductors are able to pass electrical current because the electrons within their atoms are loosely held in orbit. Insulators block the flow of current because their electrons are held tightly within the atom. In certain types of insulators called dielectrics the electrons can be pulled into a distorted orbit. This permits a voltage to exist across the dielectric or you could say the storage of an electrical charge. Some materials used as dielectrics are: waxed paper, glass, mica, oil and air.

Capacitors are made up of two parallel conducting plates separated by a dielectric. When a DC voltage is applied to the terminals of the capacitor the build up of electrons on the negative plate distorts the orbits of the dielectric's electrons in the direction of the positive plate causing the capacitor to become charged. If the voltage source is removed the charge still remains. If a path for the current is provided outside the capacitor the current will then flow from the capacitor discharging it. Capacitors block the flow of direct current since current only flows during the charging or discharging of the capacitor. Capacitors don't pass alternating current but they act like they do. Because the current is constantly rising and falling the capacitor is always either being charged or discharged.

FEEDBACK

SELF-TEST

This self-test will enable you to measure the knowledge that you have gained about Fundamentals of Electricity. Circle the one best answer that completes the statement or answers the question.

1. Electricity is an invisible form of energy where electrons move from one atom to another.

   a. True

   b. False

2. Which of the following is a factor that would affect the resistance of a conductor?

   a. The type of material the conductor is made of.

   b. The length of the conductor.

   c. The physical condition of the conductor.

   d. All of the above.

3. What is the relationship between magnetism and electricity?

   a. Magnetism is required to make electricity.

   b. A magnetic field surrounds a conductor with current flowing through it.

   c. A magnet requires electrical current flow.

   d. A magnet has the same atomic structure as copper, making it a good conductor.

4. Inductance is the generation of electrical current by rubbing two conductors against each other.

   a. True

   b. False