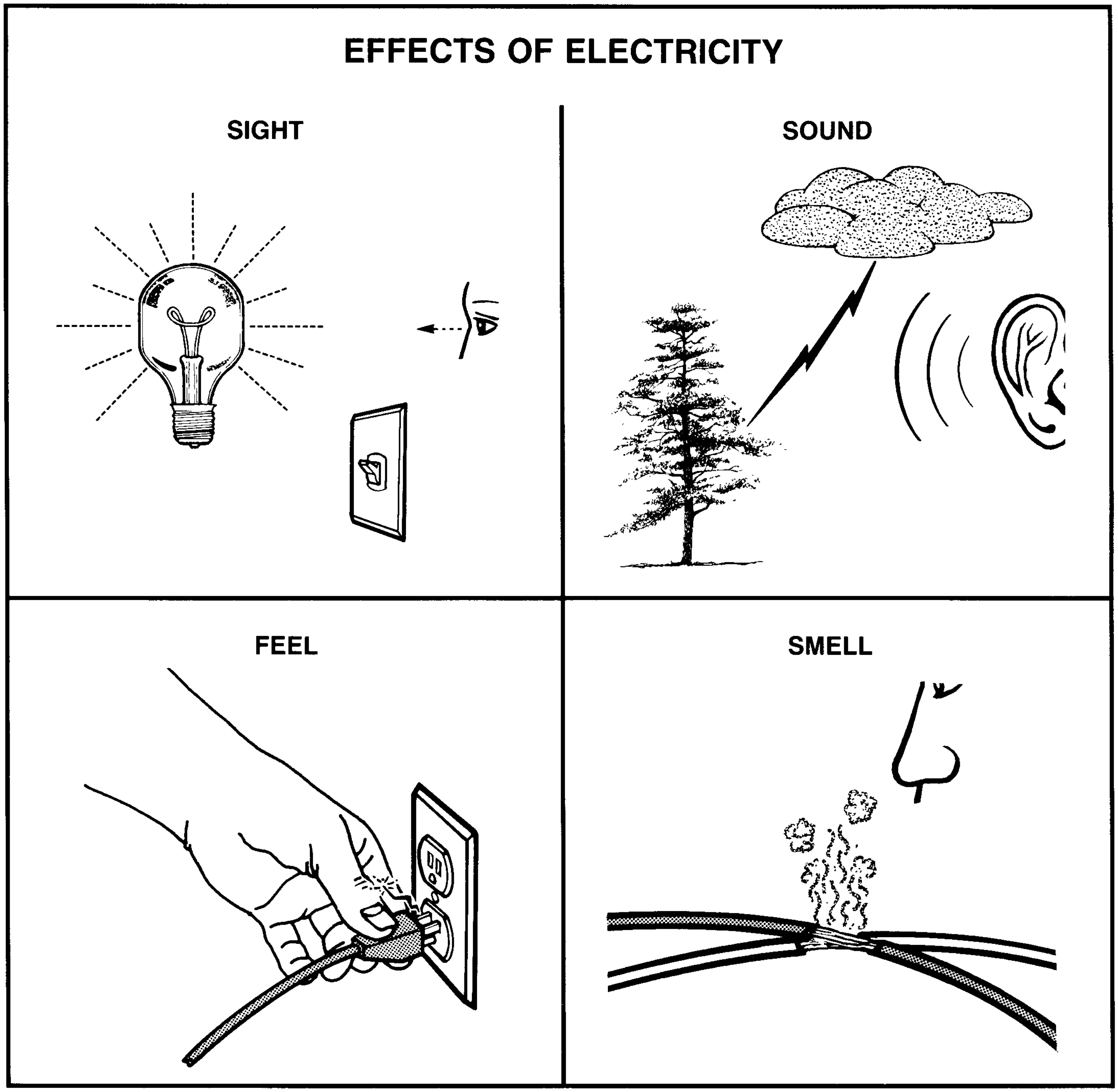
General

Electricity is a form of energy called electrical energy. It is sometimes called an "unseen" force because the energy itself cannot be seen, heard, touched, or smelled.

However, the effects of electricity can be seen ... a lamp gives off light; a motor turns; a cigarette lighter gets red hot; a buzzer makes noise.

The effects of electricity can also be heard, felt, and smelled. A loud crack of lightning is easily heard, while a fuse "blowing" may sound like a soft "pop" or "snap." With electricity flowing through them, some insulated wires may feel "warm" and bare wires may produce a "tingling" or, worse, quite a "shock." And, of course, the odor of burned wire insulation is easily smelled.



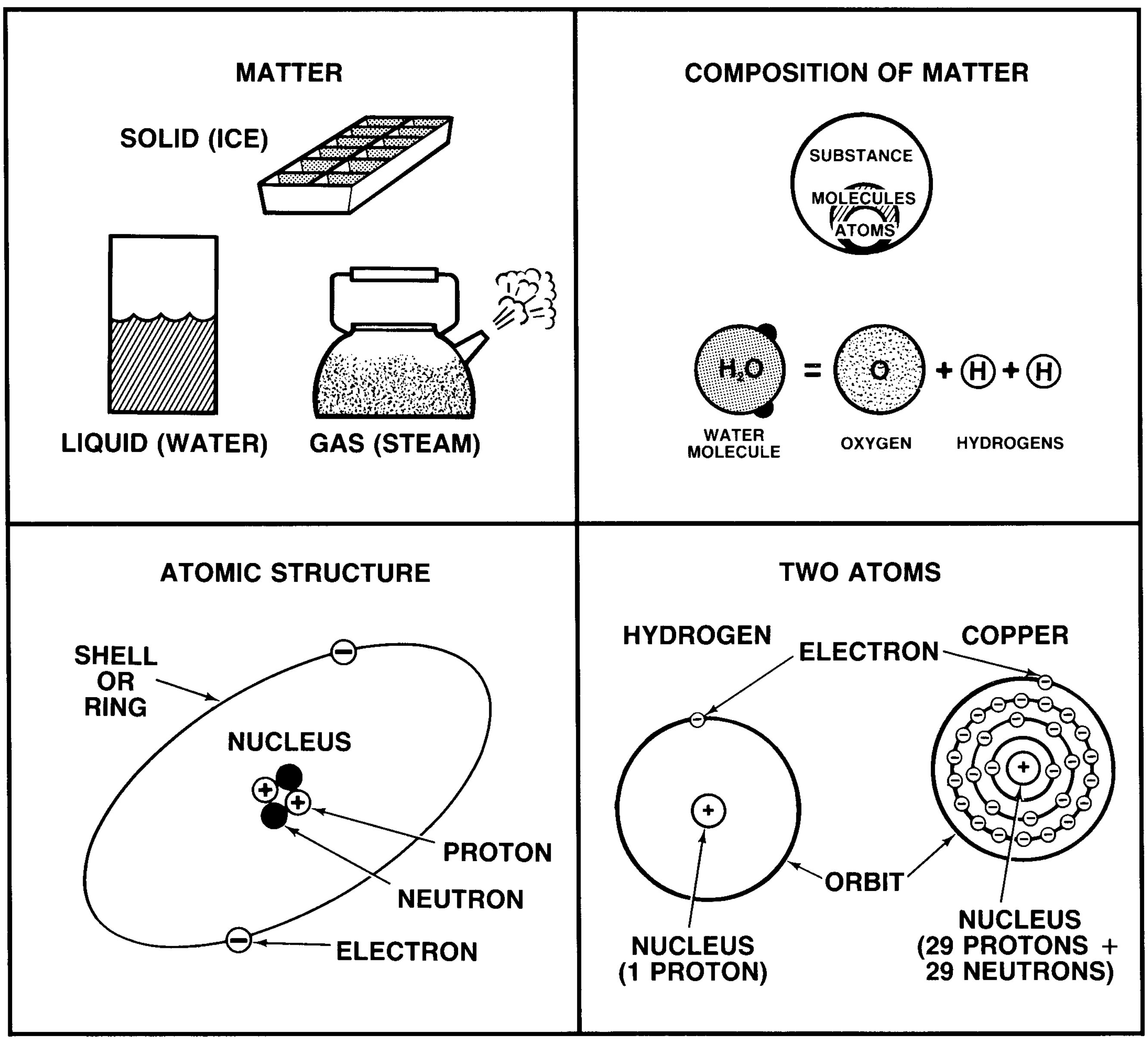
Electron Theory

Electron theory helps to explain electricity. The basic building block for matter, anything that has mass and occupies space, is the atom. All matter - solid, liquid, or gas - is made up of molecules, or atoms joined together. These atoms are the smallest particles into which an element or substance can be divided without losing its properties. There are only about 100 different atoms that make up everything in our world. The features that make one atom different from another also determine its electrical properties.

ATOMIC STRUCTURE

An atom is like a tiny solar system. The center is called the nucleus, made up of tiny particles called protons and neutrons. The nucleus is surrounded by clouds of other tiny particles called electrons. The electrons rotate about the nucleus in fixed paths called shells or rings.

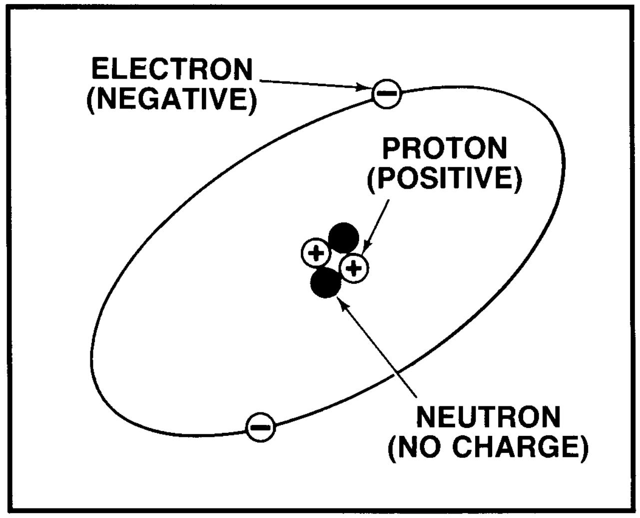
Hydrogen has the simplest atom with one proton in the nucleus and one electron rotating around it. Copper is more complex with 29 electrons in four different rings rotating around a nucleus that has 29 protons and 29 neutrons. Other elements have different atomic structures.



ATOMS AND ELECTRICAL CHARGES

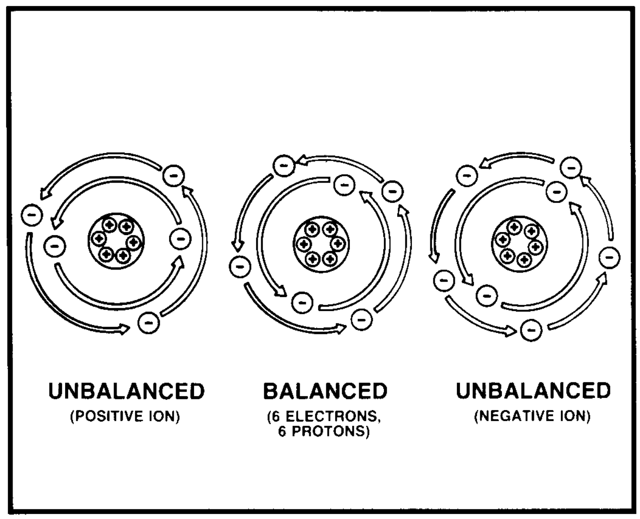
Each atomic particle has an electrical charge. Electrons have a negative (-) charge. Protons have a positive charge. Neutrons have no charge; they are neutral.

In a **balanced atom**, the number of electrons equals the number of protons. The balance of the opposing negative and positive charges holds the atom together. Like charges repel, unlike charges attract. The positive protons hold the electrons in orbit. **Centrifugal force** prevents the electrons from moving inward. And, the neutrons cancel the repelling force between protons to hold the atom's core together.



POSITIVE AND NEGATIVE IONS

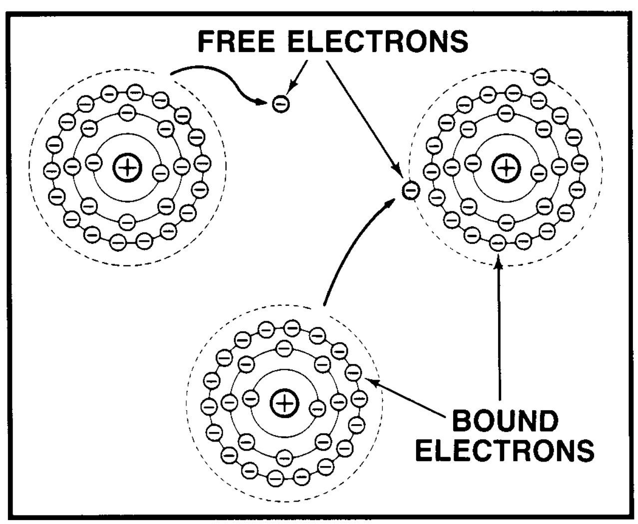
If an atom gains electrons, it becomes a **negative ion**. If an atom loses electrons, it becomes a **positive ion**. Positive ions attract electrons from neighboring atoms to become balanced. This causes electron flow.

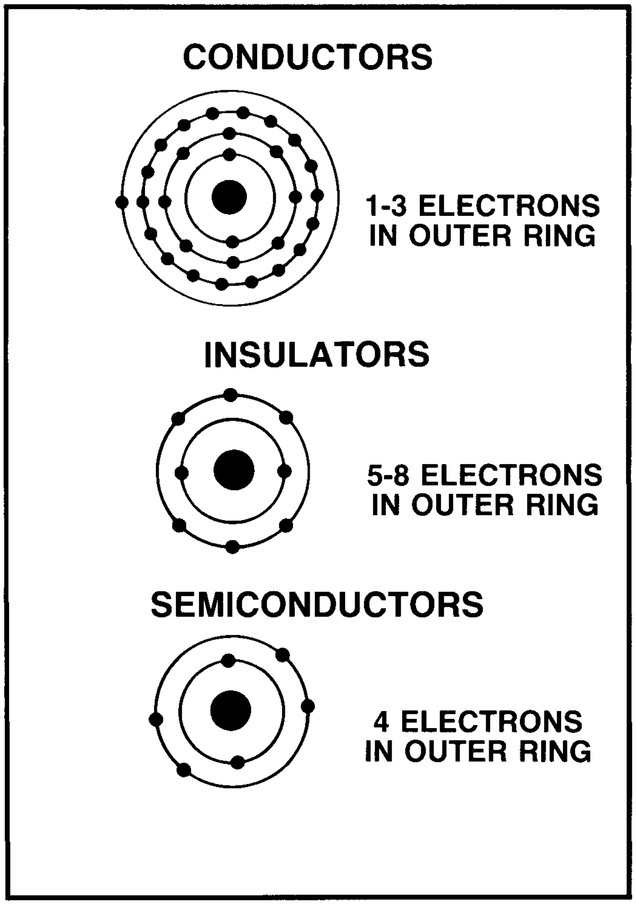


ELECTRON FLOW

The number of electrons in the outer orbit (**valence** shell or ring) determines the atom's ability to conduct electricity. Electrons in the inner rings are closer to the core, strongly attracted to the protons, and are called **bound electrons**. Electrons in the outer ring are further away from the core, less strongly attracted to the protons, and are called **free electrons**.

Electrons can be freed by forces such as friction, heat, light, pressure, chemical action, or magnetic action. These freed electrons move away from the **electromotive force**, or EMF ("electron moving force"), from one atom to the next. A stream of free electrons forms an electrical **current**.





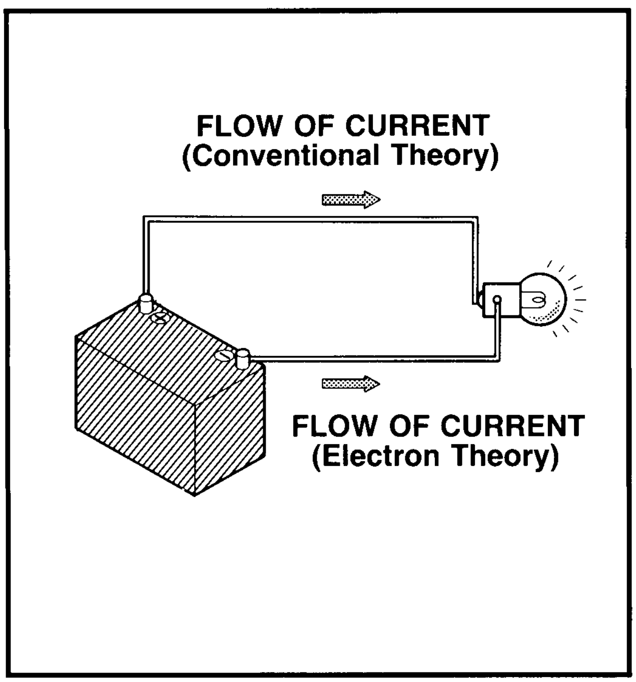
CONDUCTORS, INSULATORS, SEMICONDUCTORS

The electrical properties of various materials are determined by the number of electrons in the outer ring of their atoms.

- **CONDUCTORS** - Materials with 1 to 3 electrons in the atom's outer ring make good conductors. The electrons are held loosely, there's room for more, and a low EMF will cause a flow of free electrons.

- **INSULATORS** - Materials with 5 to 8 electrons in the atom's outer ring are insulators. The electrons are held tightly, the ring's fairly full, and a very high EMF is needed to cause any electron flow at all. Such materials include glass, rubber, and certain plastics.

- **SEMICONDUCTORS** - Materials with exactly 4 electrons in the atom's outer ring are called semiconductors. They are neither good conductors, nor good insulators. Such materials include carbon, germanium, and silicon.



CURRENT FLOW THEORIES

Two theories describe current flow. The **conventional theory**, commonly used for automotive systems, says current flows from (+) to (-) ... excess electrons flow from an area of high potential to one of low potential (-). The **electron theory**, commonly used for electronics, says current flows from (-) to (+) ... excess electrons cause an area of negative potential (-) and flow toward an area lacking electrons, an area of positive potential (+), to balance the charges.

While the direction of current flow makes a difference in the operation of some devices, such as diodes, the direction makes no difference to the three measurable units of electricity: voltage, current, and resistance.

Terms Of Electricity

Electricity cannot be weighed on a scale or measured into a container. But, certain electrical "actions" can be measured.

These actions or "terms" are used to describe electricity; **voltage, current, resistance,** and **power**.

Voltage is pressure

Current is flow.

Resistance opposes flow.

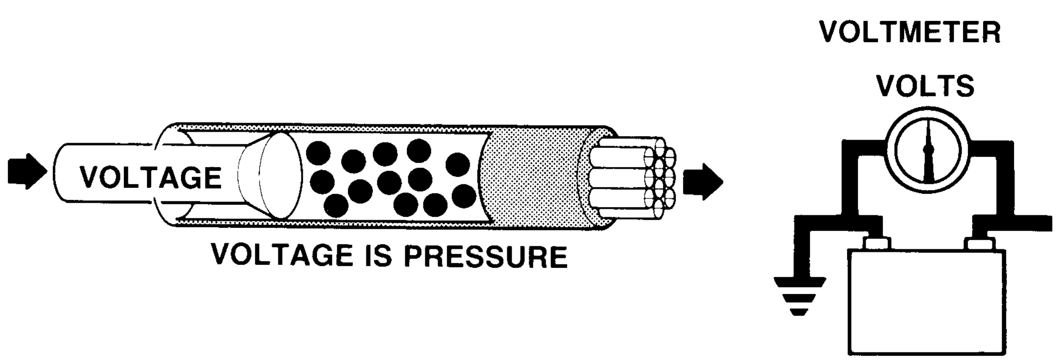
Power is the amount of work performed. It depends on the amount of pressure and the volume of flow.

VOLTAGE

Voltage is electrical pressure, a **potential force** or difference in electrical charge between two points. It can push electrical current through a wire, but not through its insulation.

Voltage is measured in **volts**. One volt can push a certain amount of current, two volts twice as much, and so on. A **voltmeter** measures the difference in electrical pressure between two points in volts. A **voltmeter** is used in parallel.

Voltage	Basic Unit	Units for Very Small Amounts		Units for Very Large Amounts	
Symbol	V	μV	mV	kV	MV
Pronounced As	Volt	Micro-volt	Milli-volt	Kilo-volt	Mega-volt
Multiplier	1	0.000001	0.001	1,000	1,000,000

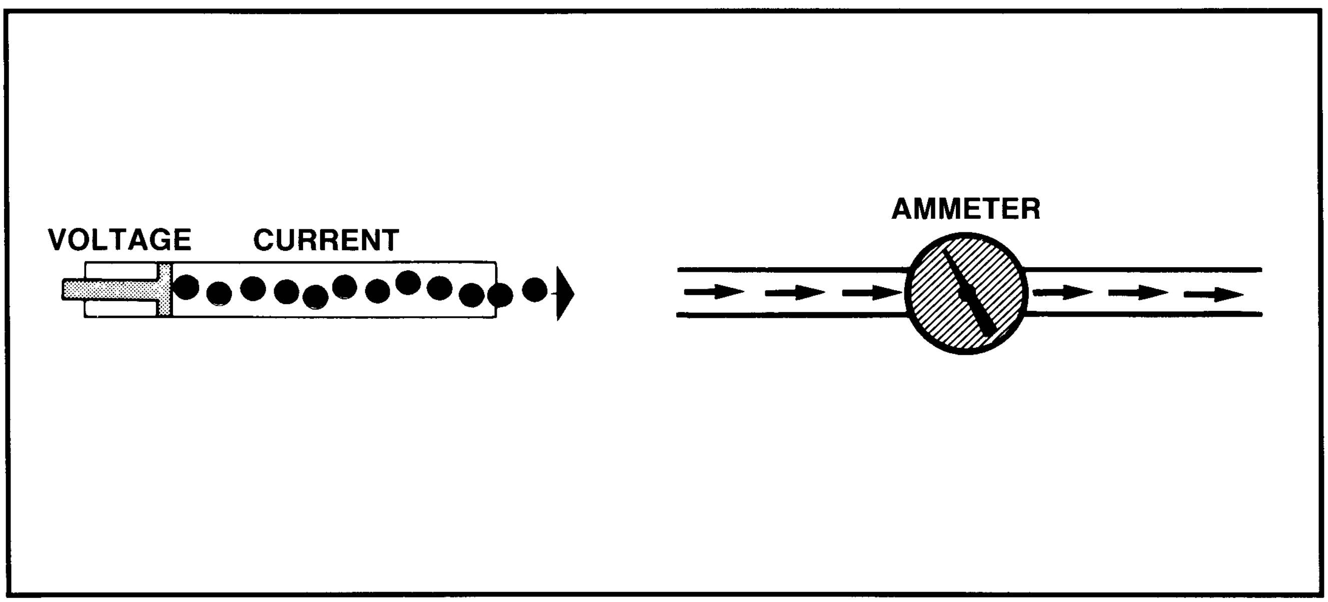


CURRENT

Current is electrical flow moving through a wire. Current flows in a wire pushed by voltage.

Current is measured in amperes, or amps, for short. An ammeter measures current flow in amps. It is inserted into the path of current flow, or in series, in a circuit.

Current	Basic Unit	Units for Very Small Amounts		Units for Very Large Amounts	
Symbol	A	µA	mA	kA	MA
Pronounced As	Ampere (Amp)	Micro-ampere	Milli-ampere	Kilo-ampere	Mega-ampere
Multiplier	1	0.000001	0.001	1,000	1,000,000

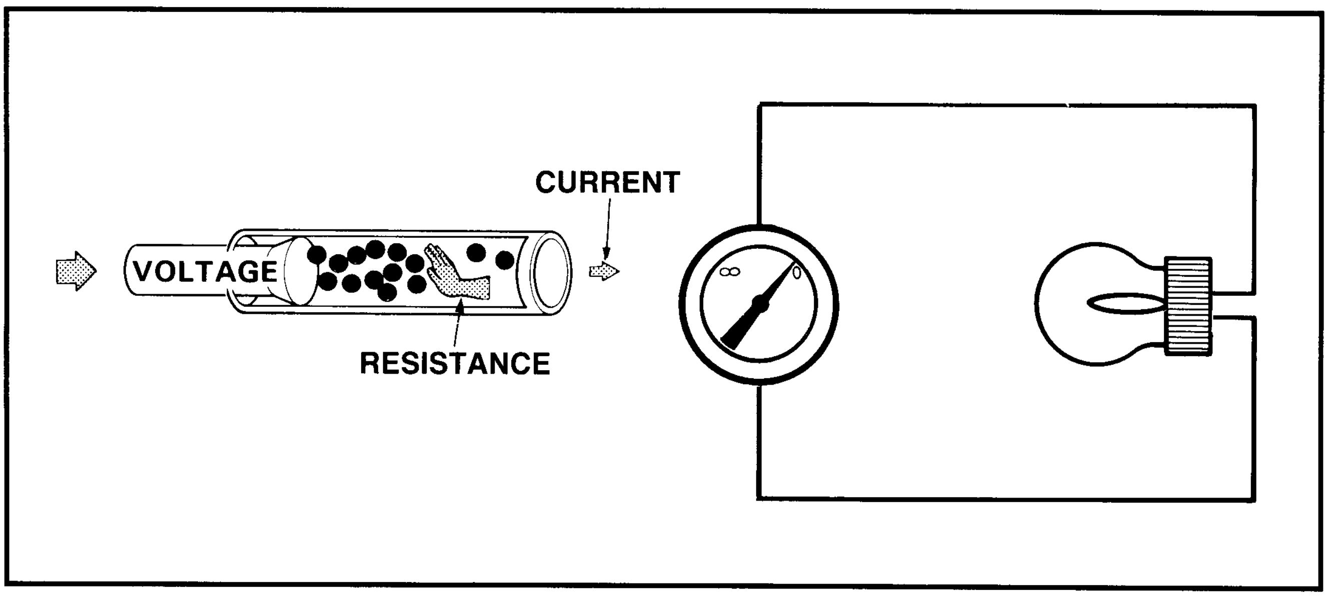


RESISTANCE

Resistance opposes current flow. It is like electrical "friction." This resistance slows the flow of current. Every electrical component or circuit has resistance. And, this resistance changes electrical energy into another form of energy - heat, light, motion.

Resistance is measured in ohms. A special meter, called an **ohmmeter**, can measure the resistance of a device in ohms when no current is flowing.

Resistance	Basic Unit	Units for Very Small Amounts		Units for Very Large Amounts	
Symbol	Ω	μΩ	mΩ	kΩ	MΩ
Pronounced As	Ohm	Micro-ohm	Milli-ohm	Kilo-ohm	Mega-ohm
Multiplier	1	0.000001	0.001	1,000	1,000,000



Factors Affecting Resistance

Five factors determine the resistance of conductors. These factors are length of the conductor, diameter, temperature, physical condition and conductor material. The filament of a lamp, the windings of a motor or coil, and the bimetal elements in sensors are conductors. So, these factors apply to circuit wiring as well as working devices or loads.

LENGTH

Electrons in motion are constantly colliding as voltage pushes them through a conductor. If two wires are the same material and diameter, the longer wire will have more resistance than the shorter wire. Wire resistance is often listed in ohms per foot (e.g., spark plug cables at 5Ω per foot). Length must be considered when replacing wires.

DIAMETER

Large conductors allow more current flow with less voltage. If two wires are the same material and length, the thinner wire will have more resistance than the thicker wire. Wire resistance tables list ohms per foot for wires of various thicknesses (e.g., size or gauge ... 1, 2, 3 are thicker with less resistance and more current capacity; 18, 20, 22 are thinner with more resistance and less current capacity). Replacement wires and splices must be the proper size for the circuit current.

TEMPERATURE

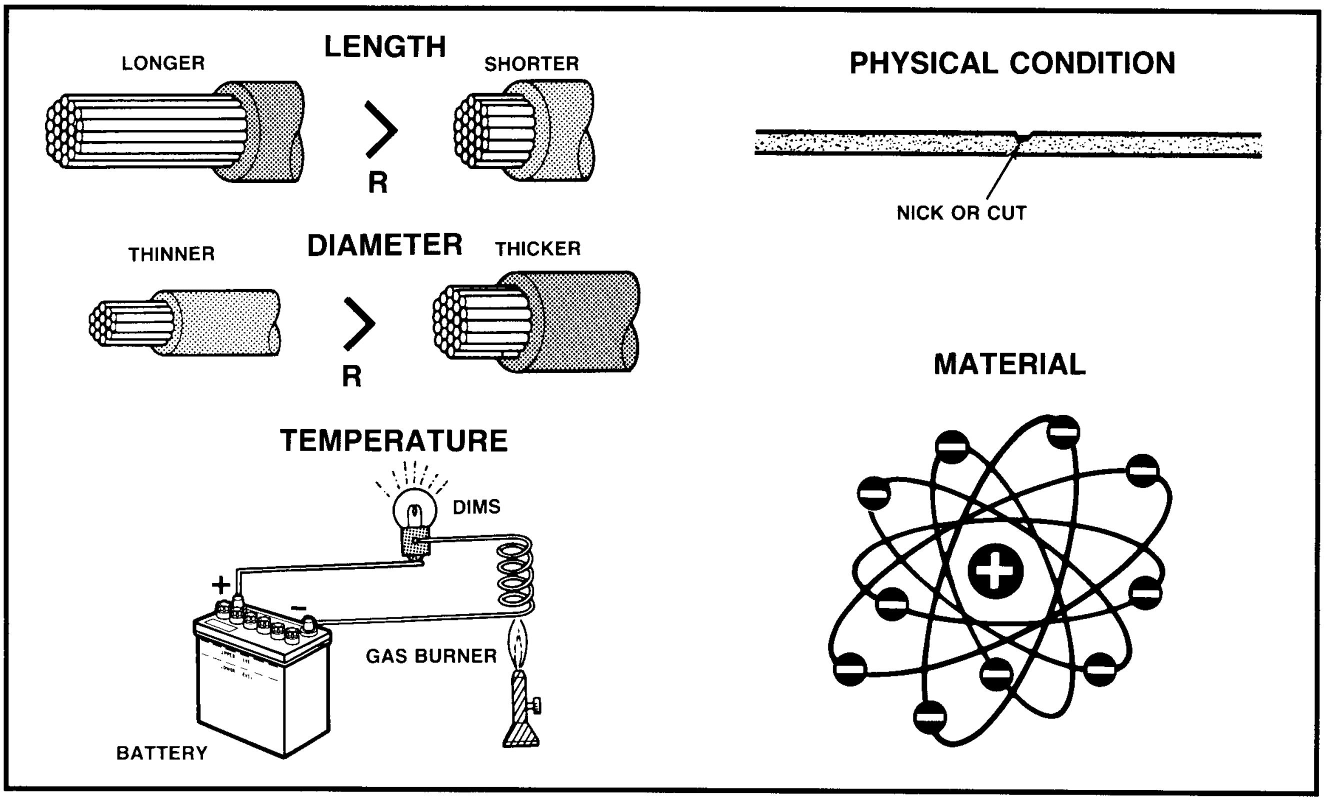
In most conductors, resistance increases as the wire temperature increases. Electrons move faster, but not necessarily in the right direction. Most insulators have less resistance at higher temperatures. Semiconductor devices called thermistors have negative temperature coefficients (NTC) resistance decreases as temperature increases. Toyota's EFI coolant temperature sensor has an NTC thermistor. Other devices use PTC thermistors.

PHYSICAL CONDITION

Partially cut or nicked wire will act like smaller wire with high resistance in the damaged area. A kink in the wire, poor splices, and loose or corroded connections also increase resistance. Take care not to damage wires during testing or stripping insulation.

MATERIAL

Materials with many free electrons are good conductors with low resistance to current flow. Materials with many bound electrons are poor conductors (insulators) with high resistance to current flow. Copper, aluminum, gold, and silver have low resistance; rubber, glass, paper, ceramics, plastics, and air have high resistance.



Voltage, Current, And Resistance In Circuits

A simple relationship exists between voltage, current, and resistance in electrical circuits. Understanding this relationship is important for fast, accurate electrical problem diagnosis and repair.

OHM'S LAW

Ohm's Law says: The current in a circuit is directly proportional to the applied voltage and inversely proportional to the amount of resistance.

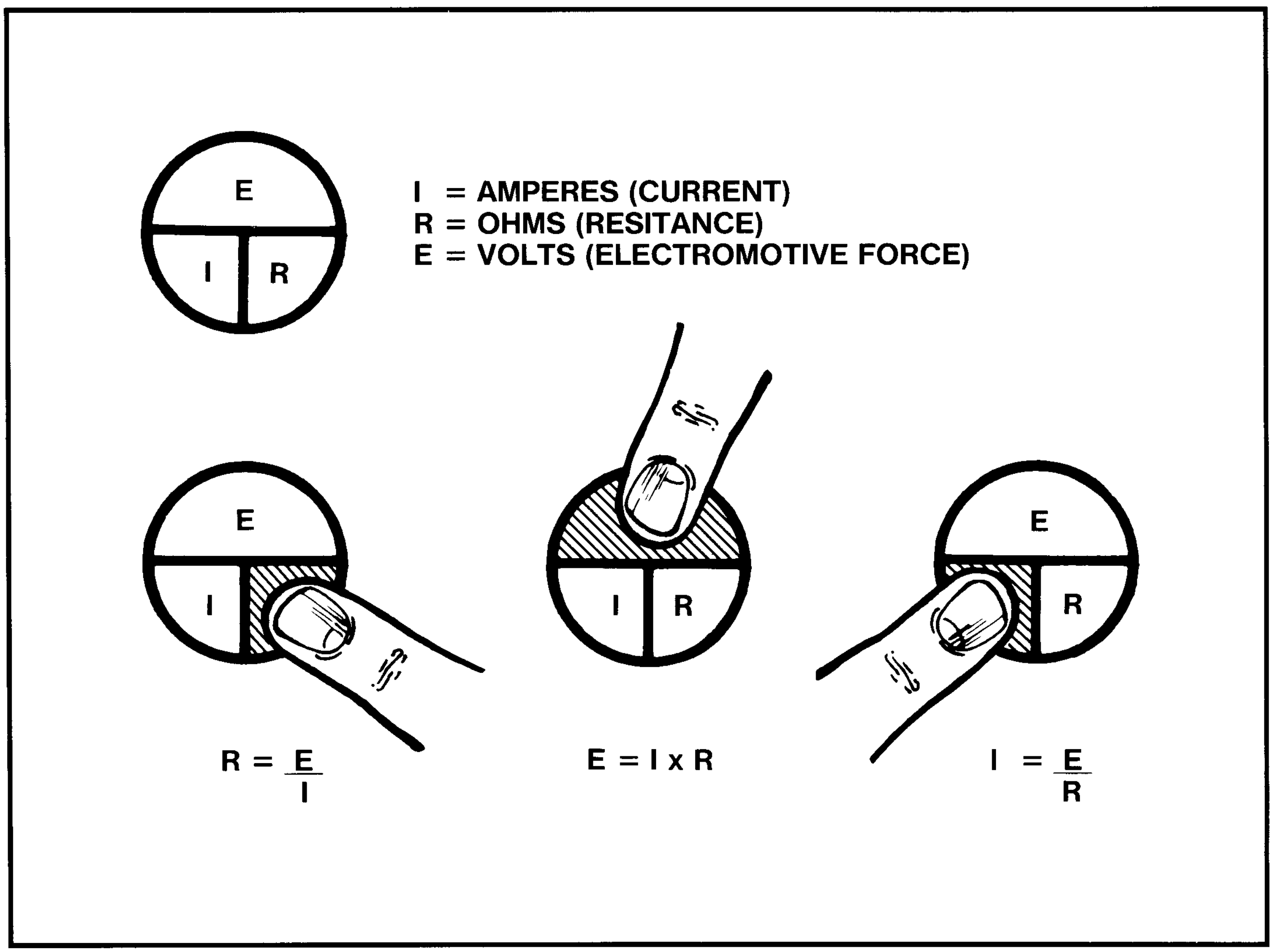
This means that if the voltage goes up, the current flow will go up, and vice versa. Also, as the resistance goes up, the current goes down, and vice versa.

Ohm's Law can be put to good use in electrical troubleshooting. But, calculating precise values for voltage, current, and resistance is not always practical ... nor, really needed. A more practical, less time-consuming use of Ohm's Law would be to simply apply the concepts involved:

SOURCE VOLTAGE is not affected by either current or resistance. It is either too low, normal, or too high. If it is too low, current will be low. If it is normal, current will be high if resistance is low or current will be low if resistance is high. If voltage is too high, current will be high.

CURRENT is affected by either voltage or resistance. If the voltage is high or the resistance is low, current will be high. If the voltage is low or the resistance is high, current will be low.

RESISTANCE is not affected by either voltage or current. It is either too low, okay, or too high. If resistance is too low, current will be high at any voltage. If resistance is too high, current will be low if voltage is okay.



ELECTRIC POWER AND WORK

Voltage and current are not measurements of electric power and work. Power, in watts, is a measure of electrical energy ... power (P) equals current in amps (1) times voltage in volts (E), P = I x E. Work, in wattseconds or watt-hours, is a measure of the energy used in a period of time ... work equals power in wafts (W) times time in seconds (s) or hours (h), W = P x time. Electrical energy performs work when it is changed into thermal (heat) energy, radiant (light) energy, audio (sound) energy, mechanical (motive) energy, and chemical energy. It can be measured with a waft-hour meter.

Power	**Basic Unit**	**Units for Very Small Values**	**Units for Very Large Values**	
Symbol	W	mW	kW	MW
Pronounced As	Watt	Milliwatt	Kilowatt	Megawatt
Multiplier	1	0.001	1,000	1,000,000

Actions Of Current

Current flow has the following effects; motion, light or heat generation, chemical reaction, and electromagnetism.

HEAT GENERATION

When current flows through a lamp filament, defroster grid, or cigarette lighter, heat is generated by changing electrical energy to thermal energy. Fuses melt from the heat generated when too much current flows.

CHEMICAL REACTION

In a simple battery, a chemical reaction between two different metals and a mixture of acid and water causes a potential energy, or voltage. When the battery is connected to an external load, current will flow. The current will continue flowing until the two metals become similar and the mixture becomes mostly water.

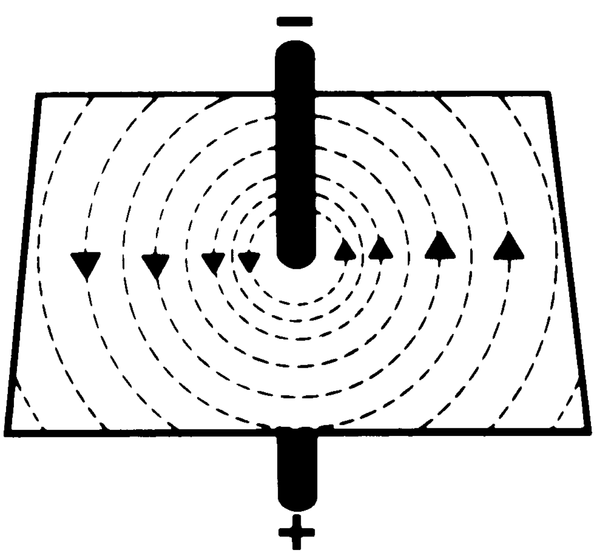
When current is sent into the battery by an alternator or a battery charger, however, the reaction is reversed. This is a chemical reaction caused by current flow. The current causes an electrochemical reaction that restores the metals and the acid-water mixture.

ELECTROMAGNETISM

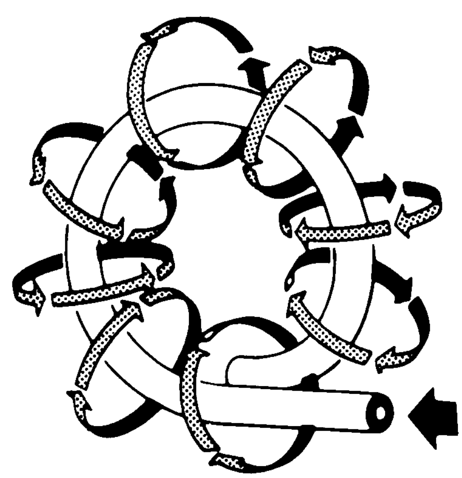
Electricity and magnetism are closely related. Magnetism can be used to produce electricity. And, electricity can be used to produce magnetism.

All conductors carrying current create a magnetic field. The magnetic field strength is changed by changing current ... stronger (more current), weaker (less current).

With a straight conductor, the magnetic field surrounds it as a series of circular lines of force. With a looped (coil) conductor, the lines of force can be concentrated to make a very strong field. The field strength can be increased by increasing the current, the number of coil turns, or both. A strong electromagnet can be made by placing an iron core inside a coil. Electromagnetism is used in many ways.



DIRECTION OF CURRENT FLOW



DIRECTION OF CURRENT FLOW

Types Of Electricity

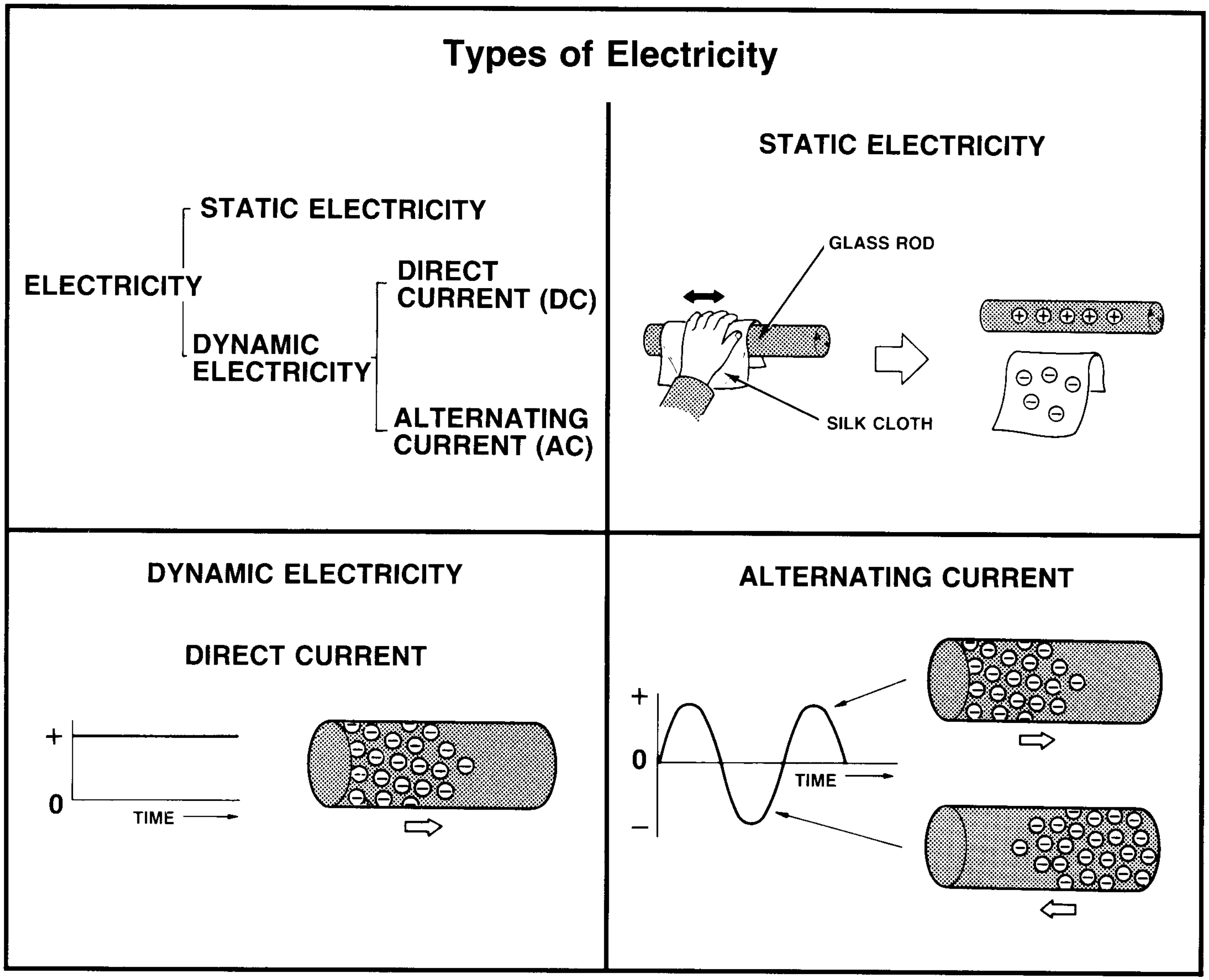
There are two types of electricity: static and dynamic. Dynamic electricity can be either direct current (DC) or alternating current (AC).

STATIC ELECTRICITY

When two non conductors - such as a silk cloth and glass rod - are rubbed together, some electrons are freed. Both materials become electrically charged. One is lacking electrons and is positively charged. The other has extra electrons and is negatively charged. These charges remain on the surface of the material and do not move unless the two materials touch or are connected by a conductor. Since there is no electron flow, this is called static electricity.

DYNAMIC ELECTRICITY

When electrons are freed from their atoms and flow in a material, this is called dynamic electricity. If the free electrons flow in one direction, the electricity is called direct current (DC). This is the type of current produced by the vehicle's battery. If the free electrons change direction from positive to negative and back repeatedly with time, the electricity is called alternating current (AC). This is the type of current produced by the vehicle's alternator. It is changed to DC for powering the vehicle's electrical system and for charging the battery.



ASSIGNMENT ***NAME:***_______________________________

1. Describe the atomic structure of an atom and name all it’s components.
2. Explain how an ION differs from an atom.
3. Explain the difference between “bound” and “free” electrons.
4 Explain the function of the “Valence ring”
5. Define the following items: Conductors, Insulators, and Semiconductors.
6. Describe the two theories of electron flow.
7. Define in detail “voltage” and how is it measured.
8. Define in detail “current” and how is it measured.
9. Define in detail “resistance” and how is it measured.
10. Explain the relationship between current and resistance.
11. List and describe the various factors that effect resistance.
12. Explain what ohms law is and how it can be used.
13. Describe the effects of “current flow” through a conductor.
14. Describe in detail the two general categories of “electricity”.
15. Describe the two types of “dynamic electricity”.