Chapter 1

INTRODUCTION TO ELECTRICITY

OUTLINE

- Basic Atomic Theory
- Conductors, Insulators, and Semiconductors
- Basic Circuit Operation Principles
- Symbols and Schematic Diagrams
- Conductor Wire Specifications
- Electrical Quantities and Units of Measure
- Resistor Theory of Operation
- Circuit Configurations

OBJECTIVES

Given various electronic devices, symbols, and diagrams, you will be able to accomplish the following objectives:

- Identify various elements of atomic theory.
- Identify basic schematic symbols and electrical components.
- Identify various electrical units such as voltage, current, resistance, and power.
- Identify series, parallel, and series-parallel circuit configurations.
- Describe the relationship between the size and length of a conductor as it relates to the resistance of a conductor.

Basic Atomic Theory

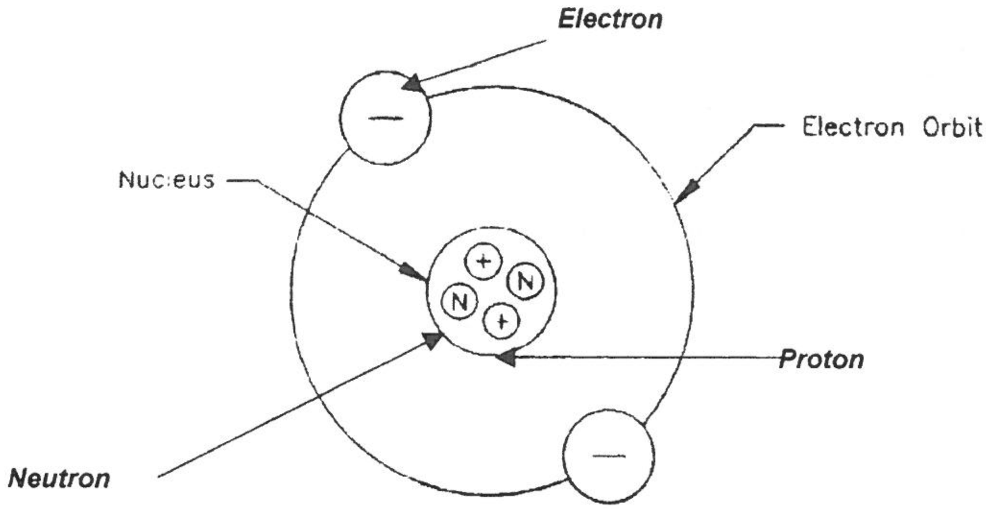


Figure 1-1

The Electron

- Electrons orbit outside and around the center or the nucleus of an atom.

- All electrons have a negative electrical charge.

- An orbit is the path of an electron around an atomic nucleus. Orbits are also called shells. The valence orbit, or the orbit that is farthest away from the nucleus is the main interest in electronics.

- Electrons contained in the valence orbit are called valence electrons.

- Valence electrons are important because they are the ones that enter into chemical or electrical combinations with other atoms. When an atom contains eight valence electrons it is considered stable and is least likely to be influenced to leave the valence orbit of the parent atom.

The Proton

- The proton is contained inside the nucleus of the atom and therefore has no orbit.

- The proton has a positive electrical charge. Because protons and electrons are charged particles, they form an electric field of force within the atom. These charges are always pulling and pushing one another, and this action produces energy in the form of movement.

The Nucleus

- The center of the atom is called the nucleus.

- It is constructed of protons and *neutrons* (*neutrons* are uncharged particles that are permanent parts of the nucleus. Their mass is nearly equal to that of the proton).

- Because there is no negative charge inside the nucleus to cancel out the positive charge of the proton, the nucleus has an overall positive potential.

The Law of Electrical Charges

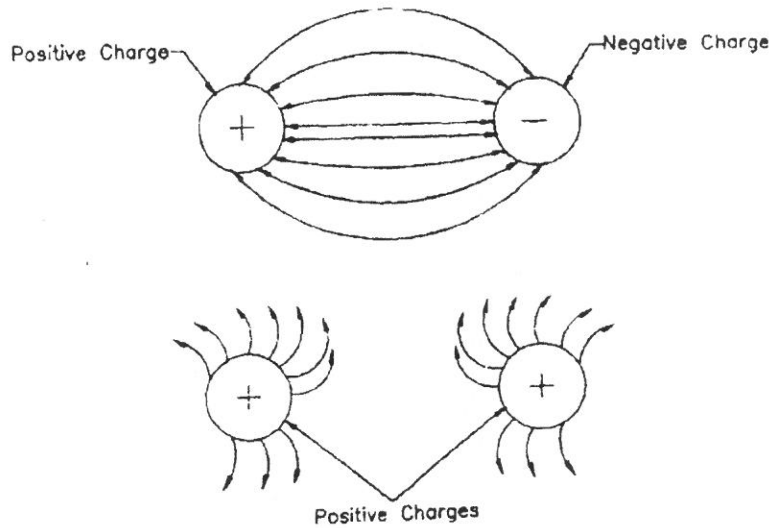


Figure 1-2

- Particles with like charges repel each other.

- Particles with unlike charges attract each other.

Electrostatic Fields

- An electrostatic field is a force that exists between any two charged bodies or objects.

- The electrical charge of an electron is equal but opposite to the positive charge of a proton. The charges on an electron and a proton are called electrostatic charges.

- The lines of force associated with each particle produce electrostatic fields.

- The charged particles interact through the electrostatic fields to attract or repel one another. If two objects have the same charge, the generated force is <u>repulsion</u>. If the two objects have unlike charges the generated force is <u>attraction</u>.

Activity 1

Basic Atomic Theory

Determine whether the following statements are true or false.

1. Electrons are much heavier in weight than protons. ________
2. Protons orbit outside and around the center of the atom. ________
3. The nucleus of an atom has an overall neutral charge. ________
4. An electron has a negative charge. ________
5. Neutrons are located inside of the nucleus. ________
6. Particles with like charges attract each other. ________
7. An electrostatic field is a force that exists between any two charged bodies or objects. ________

Conductors, Insulators, and Semiconductors

Conductors

- Regarding the way they conduct electricity, all elements fall into one of three categories: conductors, insulators, and semiconductors.

- Conductors have less than four electrons in their valence shell and they offer very little opposition to current flow.

- Conductors form the fundamental paths for electronic circuits.

- Copper, aluminum, and silver are the most common examples of conductors, however, copper is the most widely applied.

- Aluminum is less expensive than copper however it is difficult to solder and tends to corrode quickly when brought into contact with other metals.

- Silver is the best conductor of the three because it has the least resistance to current however it is very costly. Gold is also a very good conductor.

Insulators

- Insulators are materials that offer high resistance to current flow. They have five or more valence electrons.

- Insulators are poor conductors and are mainly used to block or prevent the transfer of electricity or heat.

- Practically all insulators used in electronics are compounds (combinations of two or more different kinds of atoms). Common examples are rubber, plastic, glass, and ceramic.

Semiconductors

- Semiconductors are materials whose electrical characteristics fall between those of conductors and insulators. They are neither good conductors nor insulators. Semiconductors have four valence electrons.

- Silicon and germanium are two examples of semiconductor materials.

- Semiconductors are used extensively to make transistors, diodes, and integrated circuits.

- All semiconductors have a negative coefficient of resistance.

Activity 2

Conductors, Insulators, Semiconductors

Answer the following questions.

1. Conductors are materials that offer __________ (high or low) resistance to current flow.

2. Insulators are materials that ____________ (aid or oppose) current flow.

3. Semiconductors contain ______________ valence electrons.

4. Identify the materials with their associated category (Conductor, Insulators, Semiconductors)

    a. Rubber ____________

    b. Copper ____________

    c. Glass ______________

    d. Silicon _____________

    e. Silver ______________

    f. Germanium ____________

5. The outermost shell of an atom is called the ____________ shell.

Basic Circuit Operating Principles

Requirements for Current Flow

Current, which is defined as the movement of electrons, does not automatically flow as soon as a device is turned on. There are three basic requirements that must be met in order for current to flow through a circuit.

- There must be a source of electromotive force (voltage), such as a battery.

- There must be conductor material to provide a travel path for the electrons. Copper wire is a good example.

- There must be "continuity." Continuity is defined as a completed or closed path for current flow. The conductor must not be broken, and all connections must be good.

Requirements for a Practical Circuit

All circuits contain three basic items:

- Power supply (battery)
- Load device (resistance)
- Conductor (wire)

However, to make the circuit more practical and controllable, more items must be added. Some of these items are listed below.

- Protective device (fuse/circuit breaker)
- Control device (switch)
- Measurement device (meter)

Of course, simply having these components does not make a circuit. These components must be connected for continuity. Figure 1-3 contains a description and schematic for each circuit component.

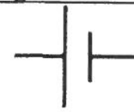
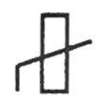
Circuit Components	Schematic Diagram
Power Source – A Power source provides the electromotive force needed to push current through a circuit.	 **Battery**
Conductors – Conductors are used to connect components and provide a path for current to flow.	 **Crossed Wires**
Load Device – Load Devices control the amount of current flow in a circuit.	 **Resistor**
Control Device – Often a switch, Control Devices permit or prohibit current flow.	 **Switch**
Protection Device – Protection Devices interrupt current in case of circuit malfunction.	 **Fuse**
Metal Oxide Varistors (MOV) – MOVs are widely used to protect electronic equipment from line transients.	
Meters – Meters are devices used to measure electrical quantities.	 **Voltmeter**

Figure 1-3

Schematic Diagrams

Schematic diagrams are a "shorthand" method of depicting an electronic circuit.

- Schematic diagrams have several functions. They are used to make electronic circuits smaller, to save time, for standardization, and to show component connectivity with a circuit. Figure 1-4 is an example of a schematic diagram.

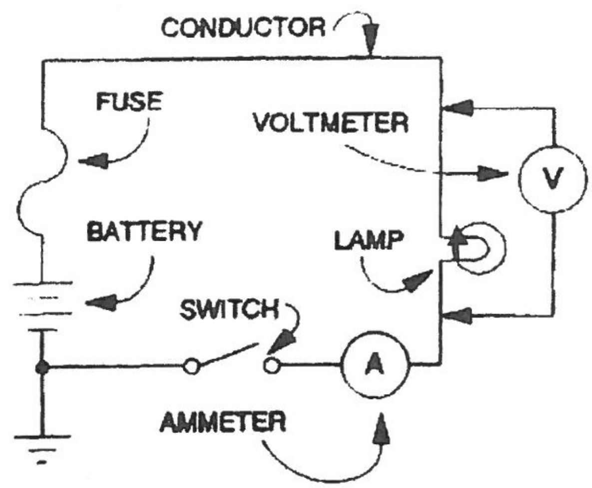


Figure 1-4

- Many schematics show circuit components that are "labeled." Labeling is used in electronics to identify one fuse from another or one switch from another, etc. Labeling normally begins at F1, S1, etc., from the left side of a schematic drawing to the right.

Other circuit components

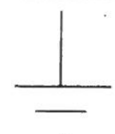
Circuit Components	Schematic Diagram
Circuit Breakers – Circuit Breakers, like fuses, are protection devices that protect circuits against excessive current flow caused by malfunctions or electrical surges.	
Lamps – Lamps are used to provide a visual indication of current flow.	 **Lamp**
Ground – Ground represents a common electrical reference point from which voltages are measured.	 **Earth Ground**

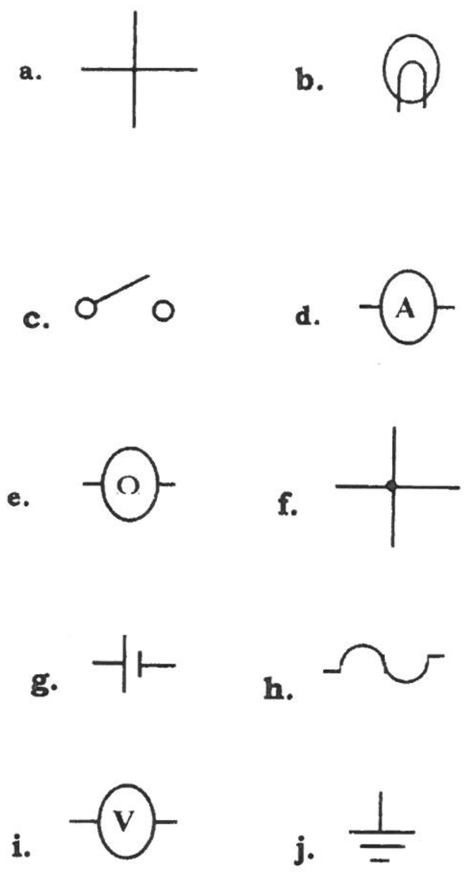
Figure 1-5

Activity 3

Schematic Diagrams

Match the circuit component name description with the symbols below. Write the letter associated with each symbol on the line beside the number.

1. ____________ Battery
2. ____________ Fuse
3. ____________ Connected Wires
4. ____________ Switch
5. ____________ Wires not connected
6. ____________ Lamp
7. ____________ Ground
8. ____________ Ammeter
9. ____________ Ohmmeter
10. ____________ Voltmeter



Conductor Wire Specifications

Gage Specifications

- A gage number specifies the size of a round conductor wire.

- Each gage number represents a different diameter of wire.

- The diameter of a wire is specified in mils, and one mil is equal to .001 in.

- Electric wire is measured with the American wire gage (AWG). This standard is the same as the Brown and Sharpe gage used by machinists.

- The smaller the gage number of the wire, the larger the diameter of the wire.

- The width of the slot leading to the hole in the gage indicates the gage size. The hole is designed to be larger than the wire to allow the wire to move freely through the slot.

Cross-sectional Area

- The cross-sectional area of a conductor is specified in circular mils (cmil or CM).

- One circular mil is the area of a circle with a diameter of 1 mil. The cross-sectional area of a conductor is equal to the diameter in mils squared.

- The amount of current a copper wire can safely carry depends on the cross-sectional area of the wire and how much heat the wire can dissipate before the insulation is damaged and the metal is affected.

Insulation

- The insulation used on electric wires and cables is rated as to its effectiveness in resisting voltage breakdown, harsh environments, flammability and heat.

- The maximum temperature rating represents the maximum continuous temperature that the insulation should be exposed to.

- The voltage ratings for both cables and wires are dependent upon both the type of insulation and the thickness of the insulation. For insulated wire, the voltage rating represents the maximum voltage that the insulation can withstand continuously.

- Insulating materials are also rated as to their relative resistance to damage by various materials and environments such as acid, abrasion, flame, heat and cold.

Wire Gage Chart

Gage (AWG)	Diameter (Inches)	Resistance (Ohms/1000 ft.)
0	.3249	.09827
1	.2893	.1239
2	.2576	.1563
3	.2294	.1970
4	.2043	.2485
5	.1819	.3133
6	.1620	.3951
7	.1443	.4982
8	.1285	.6282
9	.1144	.7921
10	.1019	.9989
11	.09074	1.260
12	.08081	1.588
13	.07196	2.003
14	.06408	2.525
15	.05707	3.184
16	.05082	4.016
17	.04526	5.064
18	.04030	6.385
19	.03589	8.051
20	.03196	10.15
21	.02846	12.80
22	.02535	16.14
23	.02257	20.36
24	.02010	25.67
25	.01790	32.37
26	.01594	40.81
27	.01420	51.47
28	.01264	64.90
29	.01126	81.83
30	.01003	103.2

Figure 1-6

Activity 4

Conductor Wire Specifications

Match the term on the left with appropriate description on the right.

Terms	Description
______Maximum temperature	a. Specifies the size of a round conductor wire.
______Cross-sectional area in circular mils	b. The area of a circle with a diameter of 1 mil
______Gage Number	c. The highest temperature rating to which insulation can be exposed.
______Circular Mil	d. Equal to the diameter of a conductor in mils.

Figure 1-7

Complete the statements below.

1. The larger the gage number of the wire, the (smaller/larger)____________ the diameter of the wire.

2. The diameter of a wire is specified in ______________.

3. The ______________ leading to the hole indicates the gage size.

4. Electrical wire is measured with a/an _________________.

5. The __________________ ratings are dependent upon the type of insulation and the thickness of the insulation.

Electrical Quantities and Units of Measure

Before learning any more about electronics, it is necessary for certain terms and measurements to be understood. Figure 1-8 is a list of standard electrical quantities and units of measure that form the foundation for all future lessons.

Term	Definition	Unit of Measure	Symbol	Comments
Charge	The electrical property possessed by electrons and protons. It is mathematically expressed as 6.25×10^{18}	Coulomb (C)	Q	The Coulomb is used to define other base units such as current and voltage.
Current	The movement of charged particles.	Ampere (A)	I	Current flow requires a voltage source (EMF) and circuit continuity.
Voltage	The force or electrical energy necessary to move charged particles from one place to another. Also known as electromotive force (EMF), difference of potential or potential.	Volt (V)	V*	Common voltage sources include batteries, power supplies, and electric generators.
Resistance	The opposition a material offers to current flow.	Ohm (Ω)	R	Resistors used in DC circuits control, divide voltages, and convert electrical energy to other useful forms. May be fixed, adjustable, variable or tapped.
Work	A force moving through a distance. A related term Energy is the ability or capacity to do work. Energy is required to do work.	Joule (J)	(W)	Although the unit of measure for work or energy is the joule the symbol for either work or energy is W.
Power	The rate at which work is done.	Watt (W)	(P)	Power applications include home, auto, and industry.

Figure 1-8

*Older manuals use the letter "E" as the symbol for Voltage, however, the letter "V" is more commonly used in manuals today. Both symbols are used interchangeably.

Activity 5

Electrical Quantities and Units of Measure

Answer the following questions.

1. What unit of measure does 6.25×10^{18} represent?

   a. Coulomb
   b. Ampere
   c. Joule
   d. Volt

2. The rate at which work is done is called ____________.

   a. Resistance
   b. Current
   c. Voltage
   d. Power

3. The symbol for current is ____________.

   a. A
   b. C
   c. I
   d. J

4. ____________ is the force necessary to move electrons from one place to another.

   a. Resistance
   b. Current
   c. Voltage
   d. Power

5. The unit of measure for resistance is the joule.

   a. True
   b. False

Resistor Theory of Operation

Resistance

- Resistance is defined as the opposition a material offers to current. All materials offer some amount of resistance to current. The symbol for resistance is R. Resistors are semiconductor material.

- The unit of measure is for resistance is the ohm. The symbol used as an abbreviation for the ohm is the Greek letter omega (Ω).

- There are various types of resistors. The most common types are fixed, variable, and adjustable.

Schematic Symbols

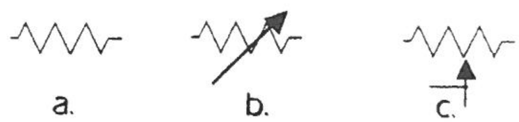


Figure 1-9

- Figure 1-9a is the symbol for a fixed resistor. These resistors have a non-variable value and are generally carbon or wire-wound resistors type resistors.

- Figure 1-9b and 1-9c represent two of the symbols for variable resistors. Rheostats and potentiometers (pots) are two of the most common types of variable resistors.

Factors Affecting Resistance

- The resistance of a wire is dependent on four factors:

    - The type of material used to construct it (carbon, silver, iron, etc.)

    - Length (The longer the wire, the more resistance it offers)

    - Cross-sectional area of the conductor (height x width)

    - The temperature

- The amount of resistance of an object is directly proportional to its length, and inversely proportional to its cross-sectional area.

- The resistance of most materials increases as the temperature increases. However, with materials such as carbon, the resistance decreases as the temperature increases.

- The change in resistance as temperature changes is called a temperature coefficient of resistance. A negative coefficient exists when the resistance of a material decreases with an increase in temperature. (Carbon) A positive temperature of coefficient occurs when the resistance of a material increases as the temperature increases. (Copper)

Activity 6

Resistor Theory Of Operation

Answer the following questions.

1. The four factors that affect the resistance of a wire are ______________________________.

2. The most common types of resistors are ______________________________.

3. The symbol for resistance is __________.

   a. V
   b. R
   c. I
   d. P

4. The larger the resistor, the (more/less)____________ power it can dissipate.

5. The diagram shown below represents a ______________ resistor.

   a. Fixed
   b. Variable
   c. Adjustable

6. A negative temperature coefficient occurs when the resistance of a material increases as the temperature of a material increases.

   a. True
   b. False

7. Carbon has a negative temperature coefficient of resistance.

   a. True
   b. False

Circuit Configurations

Series Circuit

- The most basic circuit is the Series Circuit. If a resistor (R1) is substituted for the lamp as shown on the right, the circuit still works the same. Resistors will be discussed later in this unit.

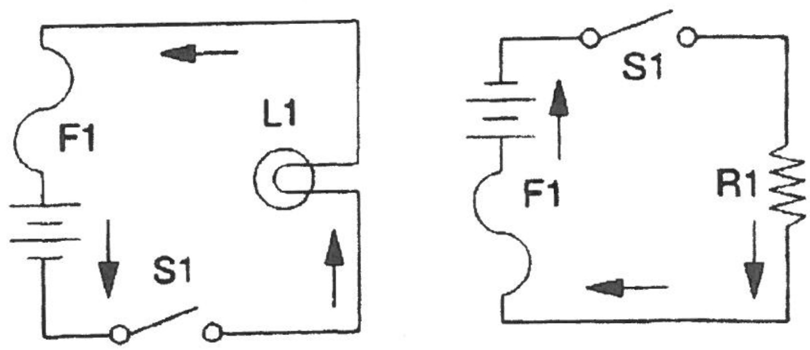


Figure 1-10

Circuit Characteristics

- Components are connected end-to-end. Circuit components are connected one after the other to complete the path from one terminal of the battery to the other.

- There is only one path for current flow. Current (electron) flow is always from negative battery terminal to positive battery terminal. Current flows through each component before returning to the positive terminal of the battery.

- Current is the same at all points through the circuit. Since the same current flows through each component, current is the same value at all points.

- Voltage varies across the circuit. The voltage drop will vary depending on the resistance value.

Parallel Circuits

It is often necessary to connect electrical devices so that the entire source of voltage is across each device. A circuit having more than one path for current flow is called a parallel circuit.

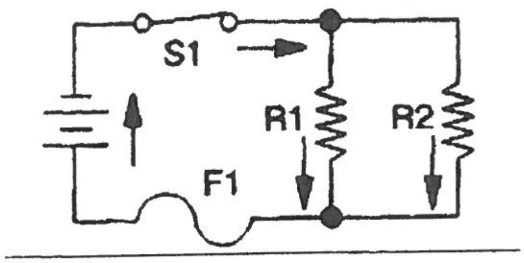


Figure 1-11

Circuit Characteristics

- More than one current path exists. Each current path is called a branch. Total current is found by adding the individual current paths.

- Each branch is independent of all other branches. The current and power in one branch are not dependent on the current, resistance or power in any other branch.

- Voltage is the same across each branch. The same voltage appears across each branch of a parallel circuit because each branch is connected across the source voltage.

Series-Parallel

A series-parallel circuit is simply a group of parallel resistances connected in series with other resistances. Current will flow throughout all available paths.

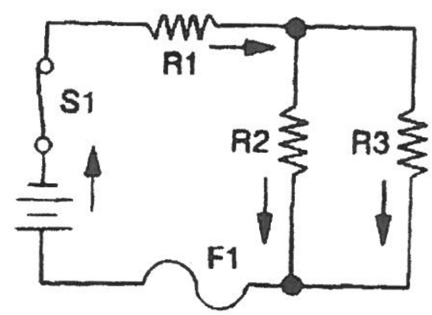


Figure 1-12

Circuit Characteristics

➔ Current Path. The current flows from the negative battery terminal and through R1. Current is then split between R2 and R3 parallel resistors. The amount of current that flows through each of the parallel branches is determined by the value of the parallel resistances R2 and R3. It is combined again and flows through Fuse F1 to the positive terminal of the battery.

The purpose of this chapter is to provide a general understanding of the subject areas addressed. For more information on the topics covered in this unit, refer to the reference books and other study materials listed in the Study Guide for the Basic Electricity Test.

Summary

1. *Most complete electric circuits contain six parts: A power source, a conductor, a load device, a control device, a protection device, and an insulator.*
2. *There are three requirements for current flow: EMF (difference of potential), conductor wire, and continuity or a completed path for current to flow.*
3. *Schematic diagrams show connection of components in a circuit, they provide standardization of components, and they save time.*
4. *There are three basic circuit configurations. There are series, parallel and series-parallel circuits.*
5. *A series circuit has only one path for current to flow.*
6. *Parallel circuits have more than one path for current to flow. Voltage is the same across each branch.*
7. *In a series-parallel circuit, total current runs through the series components and divides according to the parallel resistances.*
8. *Current is the movement of charged particles. The symbol is I, the unit of measure is the Ampere, and the abbreviation is A.*
9. *Voltage is the force required to move electrons from one place to another. The symbol is V and the unit of measure is the Volt.*
10. *Resistance is the opposition a material offers to current flow. The unit of measure is the Ohm and the symbol is Ω.*
11. *Power is the rate of using energy or doing work. The symbol for power is P and the unit of measure is the Watt.*
12. *There are four factors affecting resistance. They are the type of material used, length, cross-sectional area, and temperature.*

Chapter 1 Self Test

Answer the following questions.

1. An electrical force is required for the flow of electrons through a conductor, this force is called

    a. continuity.

    b. current.

    c. voltage.

    d. ampere.

2. The unit of measurement for current flow is the

    a. amp.

    b. ohm.

    c. volt.

    d. electron.

3. A difference of potential which causes current to flow is called

    a. ampere force.

    b. current force.

    c. continuity force.

    d. electromotive force.

4. The movement of charged particles through a conductor is called

   a. difference of potential.

   b. electromotive force.

   c. current.

   d. Voltage.

5. The unit of measure for electromotive force is the

   a. amp.

   b. ohm.

   c. volt.

   d. electron.

6. The standard symbol for current is

   a. A.

   b. I.

   c. R.

   d. V.

7. Resistance is

   a. the amount of power dissipated.

   b. the opposition to current flow.

   c. the opposition to electromotive force.

   d. the amount of voltage required to move electrons.

8. The Watt measures

   a. power.

   b. intensity.

   c. resistance.

   d. conductance.

9. Power is

   a. the rate of EMF.

   b. the rate of doing work.

   c. the rate of electron flow.

   d. the rate of unbalanced atom flow.

Using the figure below, match the lettered components with their purpose for questions 10-16.

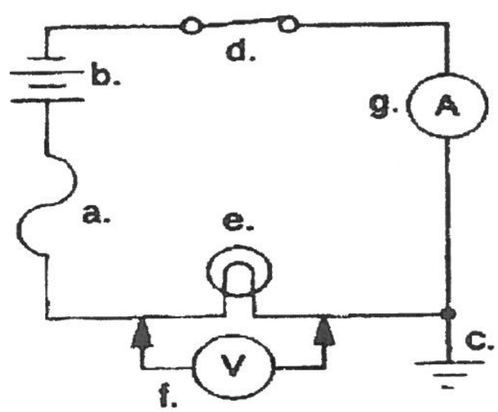


Figure 1-13

10. ______ This component protects the circuit against excessive current.

11. ______ A source of electromotive force.

12. ______ Turns the power ON and OFF.

13. ______ Will light when power is applied to the circuit.

14. ______ Used to measure current.

15. ______ Used to measure voltage.

16. ______ Provides a common reference point.

17. The symbol below represents a

a. fuse.

b. lamp.

c. battery.

d. resistor.

18. The relative resistance to damage rating for insulation on electric wires refers to ______________________________________.

19. The symbol below represent a

a. fuse.

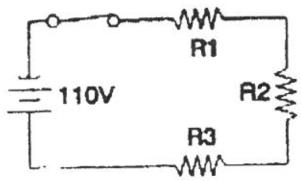
b. switch.

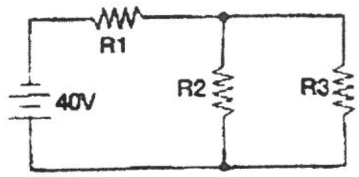
c. battery.

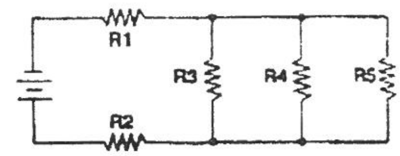
d. resistor.

20. In the figures below, list the resistors through which total current flows.

a. ________ b. ________ c. ________







Chapter 1-Activities-Answer Key

Activity 1

1. F
2. F
3. F
4. T
5. T
6. F
7. T

Activity 2

1. Low
2. Oppose
3. Four
4. a. Insulator
   b. Conductor
   c. Insulator
   d. Semiconductor
   e. Conductor
   f. Semiconductor

5. Valence

Activity 3

1. g
2. h
3. f
4. c
5. a
6. b
7. j
8. d
9. e
10. i

Activity 4

Matching

c
d
a
b

1. Smaller
2. Mils
3. Width of Slot
4. AWG
5. Voltage

Activity 5

1. a
2. d
3. c
4. c
5. b

Activity 6

1. Material, length, cross-sectional area, temperature
2. Fixed, variable, adjustable
3. b
4. more
5. fixed
6. b
7. a

Chapter 1-Self Test- Answer Key

1. c
2. a
3. d
4. c
5. c
6. b
7. b
8. a
9. b
10. a
11. b
12. d
13. e
14. g
15. f
16. c
17. a
18. voltage rating, temperature rating, or other environmental rating
19. c
20. a. R1,R2,R3 b.R1 c. R1,R2