Amateur Radio Technician Class License Study Guide

lesson 1

Element 5: Electrical Principles

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Question pool sections: T5

Corresponding pages of Gordon West book:
55, 57, 135, 137, 140-142, 149-151, 153, 160-164

Element 5: Electrical Principles

Basic electronics: Our discussion of electronics begins with something very basic, the electron. The atomic theory, defined by chemists and physicist, says that all matter is composed of atoms. These atoms consist of a dense nucleus, surrounded by a cloud of orbiting electrons. In some materials, these electrons are held very tightly by the nucleus and are difficult to knock loose. In other materials, the outer electrons are not held as tightly by the nucleus, and are much easier to move. Materials with tightly held electrons do not conduct electricity very well, and are known as insulators*. Some examples of good insulators include glass,* air (dry), plastic, and porcelain. In contrast, materials with loosely held electrons readily conduct electricity, thus are known as conductors. *Metals are generally good conductors of electricity as they have many free* (loosely held) *electrons..*

In order *to make electrons flow in a conductor, some sort of force must be applied*. This force is called "electromotive force", is also *known by the electrical term **voltage***. You can think of voltage as the pressure that forces the electrons to move along. The basic unit of electromotive force (EMF) is the volt. EMF, also known as electrical potential, is abbreviated as "**E**" in equations*.*

*The flow of electrons in an electrical circuit is known as **current**.* The more electrons flowing through a conductor, the higher the current. Think of current as the flow created in response to pressure (voltage) applied. *Electrical **current** is measured in **amperes***, most often called "amps". In equations, current is abbreviated as "**I**".

Not all conductors are equal. Some of the better conductors, such as gold, silver, and copper, require less "pressure" or EMF to produce a given flow of electrons or current, than in a poorer conductor, such as graphite. The property of a material which resists the flow of electrons is known as electrical resistance*.* Good conductors have low resistance, poor conductors have higher resistance, and insulators have very high resistance. The basic *units of electrical **resistance** are known as **ohms***. Resistance is abbreviated as "**R**" in equations*.*

Current that flows in only one direction is known as "direct current" or DC*.* This is the type of current that batteries deliver and that operates most mobile amateur equipment*.*

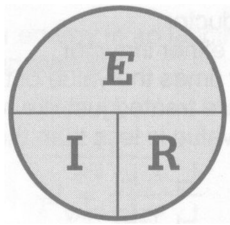
The power in your home, however, is most likely *"alternating current",* or AC, which is *current that alternates between positive and negative directions. The number of times per second that an alternating current makes a complete cycle is known as the **frequency**.* The basic *unit of **frequency** is the **Hertz**. The opposition to AC current flow* in a circuit (similar to resistance in a DC circuit*) is known as **impedance**.* The basic *unit of **impedance** is the **ohm**,* same as resistance.

Radio signals are also a type of alternating current, but at much higher frequencies than household current. Radio waves are a form of electromagnetic energy. *The abbreviation **"RF"** refers to radio frequency energy of all types.*

Resistance opposes the flow of all types of current, direct, alternating or RF. The current (flow) in an electrical circuit decreases as the voltage (pressure) decreases or as the resistance increases. *This relationship, which can be written as I (current) = E (voltage)/R (resistance), is known as **"Ohm's law"**.* This equation shows that the current will increase if the voltage is increased, or if the resistance is decreased. Ohm's law may be stated 3 ways:

- *Voltage “E” equals current “I” multiplied by resistance “R” (E = I X R)*
- *Current “I” equals voltage “E” divided by resistance “R” (I = E/R)*
- *Resistance “R” equals voltage “E” divided by current “I” (R = E /I)*

Just as the relationship was restated above, the formula for ohm’s law can be rearranged to solve for any of the three quantities, if the other two are known. An easy tool for using Ohm’s law to find the unknown quantity is the “magic wheel” shown below. To use this, simply cover the unknown quantity, and use the resulting formula to solve for it.

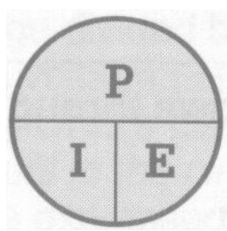


Where E = EMF in volts, I = currents in amperes, and R = resistance in ohms.

Let’s try some examples:

- *R = 2 ohms and I = 0.5 amps, E = ? volts   Cover E, then I x R = 1 volts*
- *E = 120 volts and R = 80 ohms, I = ? amps   Cover I, then E / R = 1.5 amps*
- *I= 3 amps and E = 90 volts and, R = ? ohms   Cover R, then E / I = 30 ohms*

*The term that describes the rate at which electrical energy is being used is **power**.* The basic *unit of **electrical power** is the **watt**.* Watts are easily calculated in DC circuits. The power “P” in watts is equal to the current “I“ in amps, times the EMF “E” in volts, or *P = I x E*. This relationship can also be expressed using a “power circle”, as shown below:



Let’s try some examples:

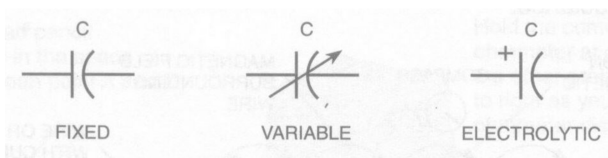
- *E = 13.8 volts and I = 10 amps, P = ? watts   Cover P, then I x E = 138 watts*
- *E = 12 volts and I = 2.5 amps, P = ? watts   Cover P, then I x E = 30 watts*
- *E = 12 volts and P = 120 watts, I = ? amps   Cover I, then P / E = 10 amps*

Changes in power levels are expressed in decibels or dB. Each +3 dB change represents a doubling of power, while a -3 dB change reflects a halving of power. *So going from 5 to 10 watts (10/5 = 2 X) equals a 3 dB increase in power. Decreasing power from 12 watts to 3 watts is a -6 dB change* (12/2 = 6 watts = -3 dB, 6/2 = 3 watts = -3 dB, so -3 dB + -3 dB = -6 dB). *Increasing power from 20 watts to 200 watts equals at 10 dB increase.*

A component called a resistor is used to add resistance to an electrical circuit. Since resistance in an electrical circuit opposes the flow of electrons, resistors may be used to control the amount of current that flows for a particular applied voltage. The symbols below represent a resistor in a schematic diagram.

variable fixed

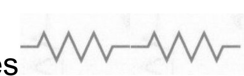
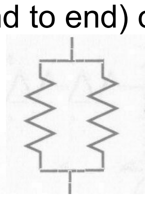
Two other common electrical components are known as “***capacitors***” and “***inductors***”. Both of these devices have the ability to store electrical energy, but each stores it in a different manner. *Inductors,* which are basically coiled wire*, store energy in a “magnetic field”. The basic unit of inductance is the “**henry**”. Capacitors,* which consist of metal plates separated by a thin layer of insulating *material, store energy in an “electric field”. The basic unit of capacitance is the “**farad**”.*



capacitors

inductors

Any of these components may be included in an electrical circuit. In that circuit, they may be connected in series (end to end) or in parallel (side by side).

series   parallel

In series circuits, the DC current is the same through all of the components (what goes in one end equals what comes out of the other end). *In parallel circuits, the voltage is the same across all components.*

Many times the actual value of a component or unit of measure is several times greater, or only a small fraction of the base unit. This is why prefixes are often used to indicate a multiplier. Here are some common prefixes:

pico	=	*1 trillionth*	*multiplier* 10^{-12}
micro	=	*1 millionth*	*multiplier* 10^{-6}
milli	=	*1 thousandth*	*multiplier* 10^{-3}
kilo	=	*thousand*	*multiplier* 10^{3}
mega	=	*million*	*multiplier* 10^{6}

So, a 1.5 A = 1500 mA; 1,500,000 Hz = 1.500 kHz = 1.5 MHz; 500 mW = 0.5 W and 3000 milliamps = 3 amps. 28,450 kilo Hertz (kHz) is the same as 28.450 mega Hertz (MHz), or 1000 kHz per MHz.

The difference between the exponents of unit multipliers may be used to determine decimal placement. Start with the exponent of the original multiplier, then subtract the exponent of the multiplier you wish to convert to. If the result is a positive number, the decimal will move to the right. If the result is a negative number, the decimal will move to the left.

To convert 3.525 MHz (10^6) to kHz (10^3) 6-3 = 3 move decimal right 3 places (3525 kHz)

To convert 500 milliwatts (10^{-3}) to watts (10^0) -3-0 = *-3* move decimal *left* 3 places (0.5 watts)