Lesson 2: How Radio Works

Preparation for Amateur Radio Technician Class Exam

Topics

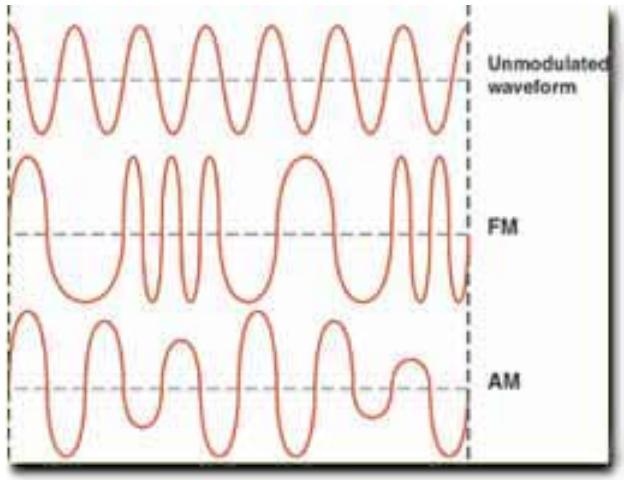
- How radios work
- Current
- Frequency & Wavelength
- Radio Frequencies
- Quick review of Metric
- Electricity
- Conductors & Insulators
- Resistance
- Series & Parallel Circuits
- Exam Questions for this section

Reading

- Chapter 2 – 2.1-2.4
- Chapter 7 – 7.1-7.11

How Radios Work (not on the test)

- NASA gave an example of using a radio to talk to the Mars Rovers:
  - Data or pictures are collected by the Rover and sent to its computer as data packets
  - The computer converts the data packets to binary code and sends it to a transponder
  - The transponder turns the binary code into radio signals and sends them to Earth through its antenna



http://spaceplace.nasa.gov/en/kids/st5xband/st5xband.shtml

How Radios Work (not on the test)

- A big antenna on Earth collects the radio signals into a receiver
- The receiver converts the radio signal back to binary code and sends it to a computer on Earth
- The computer converts the binary code back to data packets
- The computer can display the data packets as numbers or pictures
- The process is reversed when controllers on Earth send commands to the Rover

http://spaceplace.nasa.gov/en/kids/st5xband/st5xband.shtml

How Radios Work

- This section starts to look at the electrical theory and components that make that process work

Current

- Radios work using electricity
- Electricity is measured in Amperes (A)
  - Usually called Amps
- Electricity comes to us in two different types
  - Direct current (DC)
  - Alternating current (AC)

Current

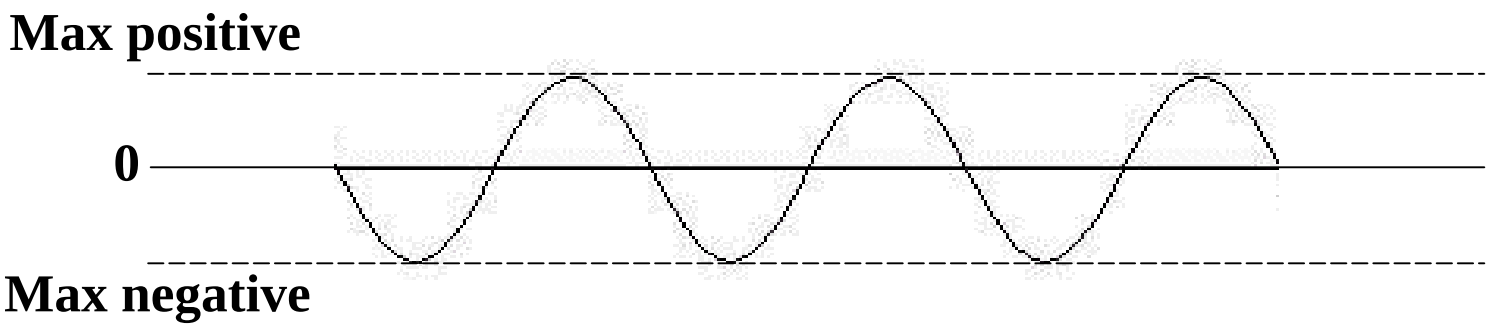
- Direct current (DC)
  - Electric current flows in one direction (like a river flowing downstream
  - Example sources of DC are batteries and solar panels

Current

- Alternating current (AC)
  - Electric current alternates direction (like an ocean wave going back and forth, or water sloshing in a bucket)
  - An example source of household current is AC

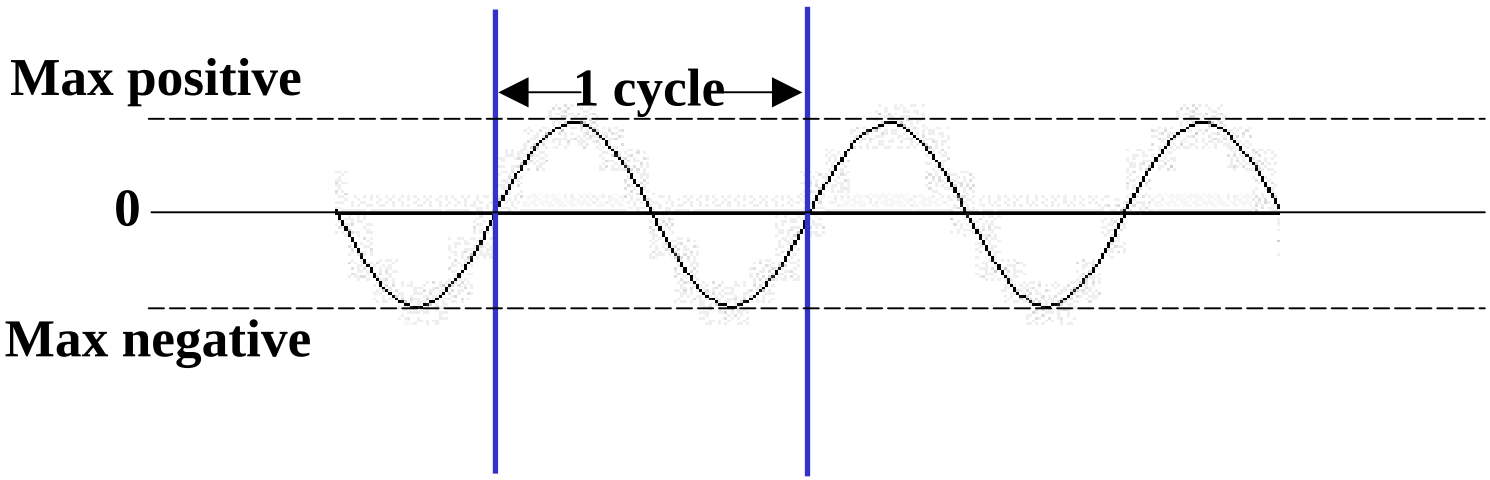
Current

- AC is typically shown as a sine wave
  - The negative part of the sine wave is one direction of current, the positive part of the sine wave is the other direction of current



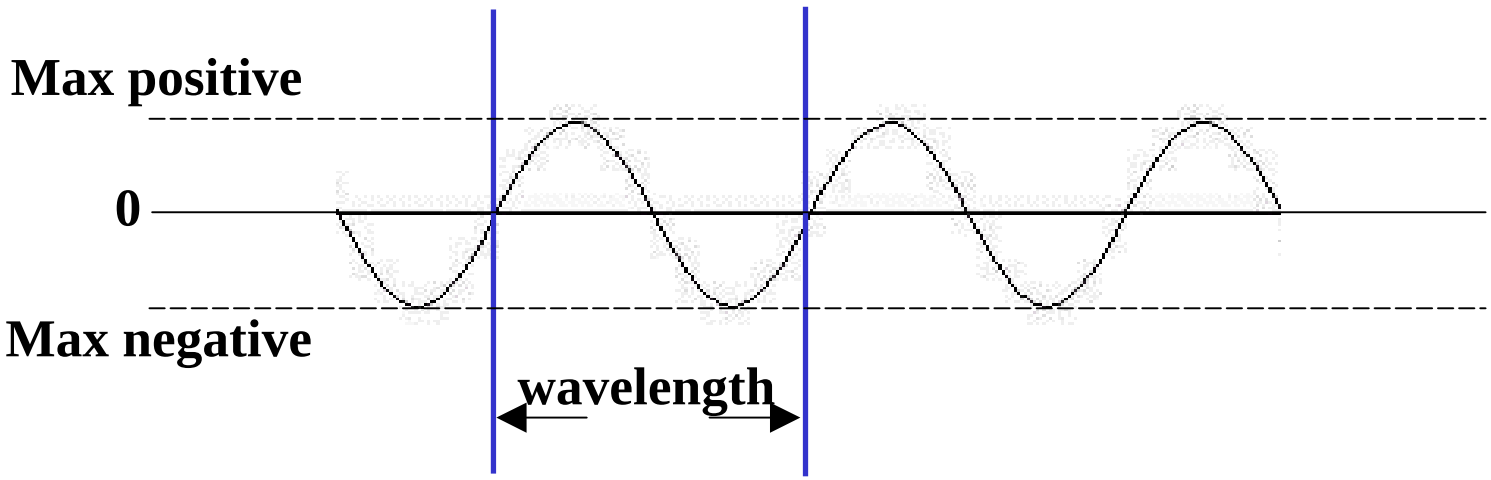
Current

- A Cycle is a round trip of AC
  - Starting at zero, up through the positive, down to zero, then continuing down through the negative, then back to zero again

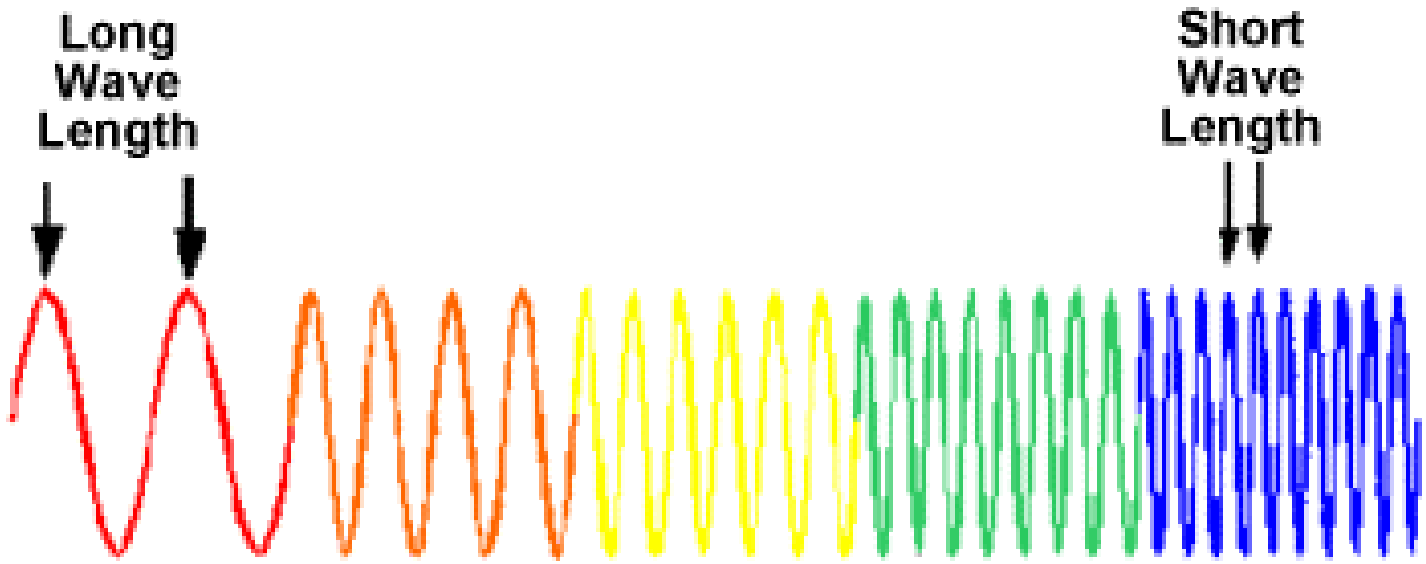


Wavelength

- Wavelength is the distance electricity travels in one cycle



Wavelength

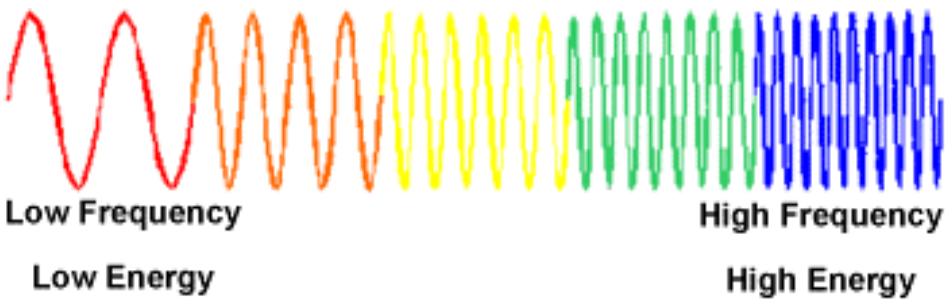


Frequency & Wavelength

- Frequency is the number of cycles in one second
- Frequency is measured in Hertz (Hz)
  - One cycle per second is 1 Hz
  - One thousand cycles per second is 1 kHz (kilohertz)
  - One million cycles per second is 1 MHz (megahertz)
  - 3,725,000 cycles in one second is 3,725,000 Hz or 3725 kilohertz (kHz)

Frequency & Wavelength

- The higher the frequency, the more cycles you have in one second
  - Therefore the shorter the wavelength

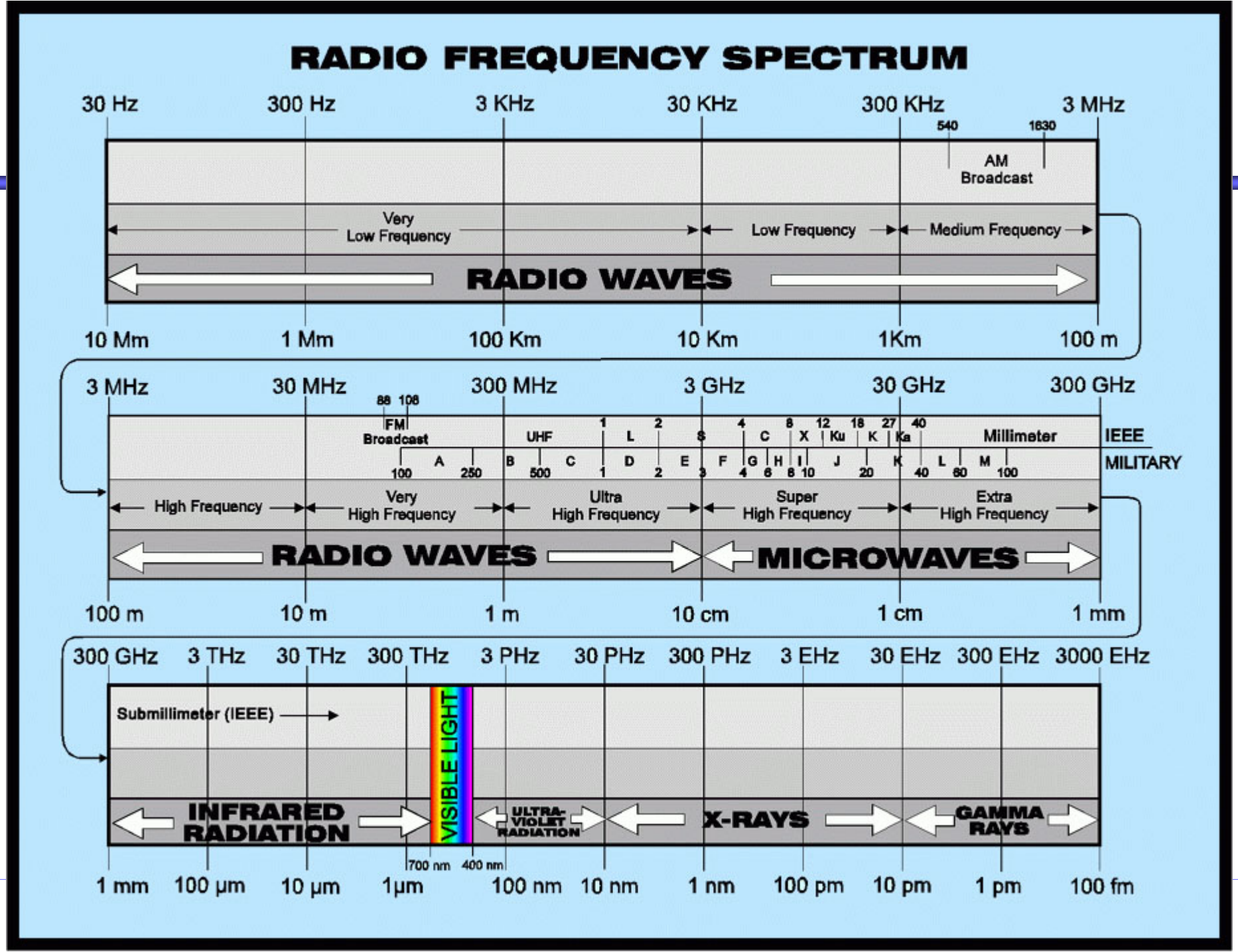


(NOTE: Frequency refers to number of crests of waves of same wavelength that pass by a point in one second.)

In this picture, each color represents one second.

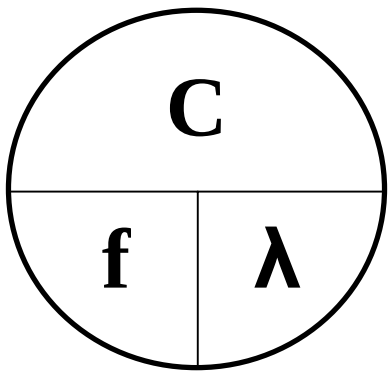
Radio Frequencies

- Audio Frequencies (AF) are electromagnetic oscillations or cycles that repeat 20 to 20,000 times per second
  - Frequency is 20 Hz to 20 KHz
  - This is the range that humans can hear
- Radio Frequency Waves (RF) are electromagnetic oscillations or cycles that repeat more than 20,000 times per second
  - Frequency is 20,000 Hz or 20 kHz
  - The lowest end of RF is 20,000 Hz, which is the highest frequency a human can hear
  - Example: 7125 kHz is a radio frequency


RADIO FREQUENCY SPECTRUM
30 Hz
300 Hz
3 KHz
30 KHz
300 KHz
3 MHz
540
1630
AM Broadcast
Very Low Frequency
Low Frequency
Medium Frequency
RADIO WAVES
10 Mm
1 Mm
100 Km
10 Km
1Km
100 m
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz
88 108
FM Broadcast
UHF
L
S
C
X
Ku
K
Ka
Millimeter
IEEE
MILITARY
A
B
C
D
E
F
G
H
I
J
K
L
M
High Frequency
Very High Frequency
Ultra High Frequency
Super High Frequency
Extra High Frequency
RADIO WAVES
MICROWAVES
100 m
10 m
1 m
10 cm
1 cm
1 mm
300 GHz
3 THz
30 THz
300 THz
3 PHz
30 PHz
300 PHz
3 EHz
30 EHz
300 EHz
3000 EHz
Submillimeter (IEEE)
INFRARED RADIATION
VISIBLE LIGHT
ULTRA-VIOLET RADIATION
X-RAYS
GAMMA RAYS
700 nm
400 nm
1 mm
100 µm
10 µm
1µm
100 nm
10 nm
1 nm
100 pm
10 pm
1 pm
100 fm

Radio Frequencies

- All electromagnetic waves travel through space (vacuum) at the speed of light
  - 300,000,000 meters per second
  - 3.00×10^8 m/s
- Frequency and wavelength are related by this formula:
  - Speed of light (m/s) = frequency (Hz) X wavelength (m)
  - $C = f \lambda$



Frequency Bands

- There is a large range of radio frequencies
  - To make it easier to talk about, we divide the RF frequencies into bands
- Ham radio is mostly concerned with these bands:
  - High Frequency (HF) = 3 MHz and 30MHz
  - Very High Frequency (VHF) = 30 MHz and 300 MHz
  - Ultra High Frequency (UHF) = 300 MHz and 3000 MHz (or 3 GHz)
- A popular ham band is:
  - 2 meter = VHF = 144 –148 MHz
  - You can identify a radio wave by frequency (144-148 MHz), wavelength (2 meter) or band (VHF)

Quick review of metric

- Giga = 1,000,000,000 = 10^{9}
- Mega = 1,000,000 = 10^{6}
- Kilo = 1,000 = 10^{3}
- Deca = 10
- Deci = 1/10 = 10^{-1}
- Centi = 1/100 = 10^{-2}
- Milli = 1/1,000 = 10^{-3}
- Micro = 1/1,000,000 = 10^{-6}
- Pico = 1/ 1,000,000,000,000 = 10^{-12}

Quick Review of Metric

- Examples:
  - 3000-milliampere current = 3 amperes
  - 1000 hz = 1 kHz
  - 3.525 MHz = 3525 kHz
  - 1,000,000 picofarads = 1 microfarad
  - 500 milliwatts = 0.5 watts

Quick Review of Metric

- When going from a smaller unit of measure to a larger unit of measure, divide
  - 12 apples = ? Dozen – divide by 12 to get 1 dozen
- When going from a larger unit of measure to a smaller unit of measure, multiply
  - 1 dozen apples = ? Apples – multiply by 12 to get 12 apples

Electricity

- We learned that electricity is measured by current, which is the flow of electrons
  - Current is measured in amps
  - Amps are measured with an ammeter or amp meter
- Current or Amps in electricity is analogous to current in a river

Electricity

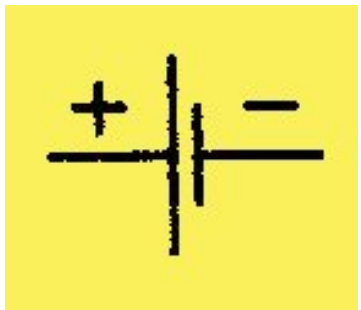
- It takes force to make the electrons move
- This is called the Electromotive force
  - It is measured in volts (V)
  - Volts are measured with a voltmeter
- Force or Volts in electricity is analogous to a waterfall
  - The height of the waterfall determines the force that the water hits the bottom
  - The volts in electricity determine the force pushing the current

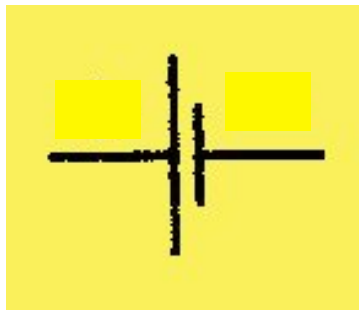
Electricity

- Batteries are one form of power supply that we can use to make the electrons move
- Large batteries are really a group of small batteries put together
  - The small batteries are called cells, so a large battery is a group of cells
- Different kinds of cells produce different amounts of power (volts)
  - A lead-acid cell in a car battery produces about 2 volts of power
  - A 6 cell car battery produces about 12 volts of power

Electricity

- We can diagram electrical circuits using symbols
- A single cell battery, such as a small hearing aid or watch battery, has this symbol on an electrical diagram:





Conductors & Insulators

- Conductance refers to how easily electricity moves through a substance
- Most metals are good conductors
  - Gold, Silver, Copper, Aluminum
  - That is why electrical wires are made of metal

Conductors & Insulators

- Insulation refers to how poorly electricity moves through a substance
- Insulators cover electrical wire to keep the electricity in the wire and not in the walls of your house!
- Stone, wood, and plastics are good insulators (but poor conductors)
  - Mica, glass, rubber, plastic, wood

Resistance

- Resistance refers to blocking (resisting) the flow of electricity
  - Insulators have good resistance
  - Conductors have poor resistance
- There are devices called resistors that are used in electrical circuits to limit or control the amount of current that flows through the circuit (either AC or DC current)

Resistance

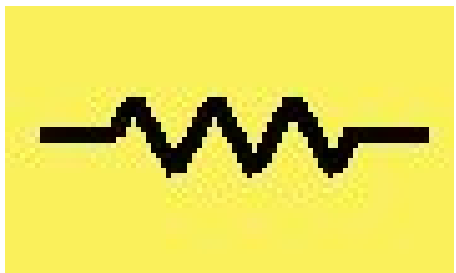
- Resistors come in different values
- Each value controls some amount of the flow of current for a particular voltage
- Resistance is measured in Ohms
  - We will discuss this later under Ohm's Law

Resistance

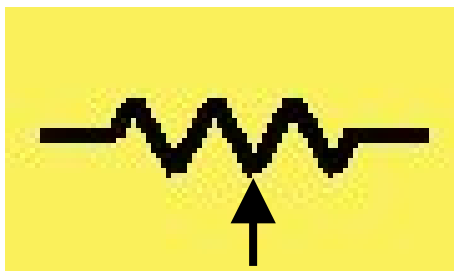
- Some resistors have only one value
  - These are fixed resistors
  - This is the most common kind of resistor
- Others have the ability to vary their value
  - These are called variable resistors or potentiometers (pots)

Resistance

- Since a resistor is a part of an electrical circuit, we can diagram it. Here is a fixed and 2 versions of variable resistors:



Fixed



Variable resistors or pots

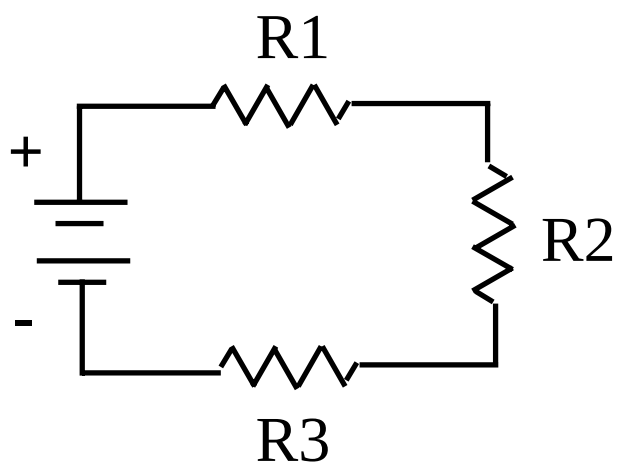
Series and Parallel Circuits

- Now that we have batteries and resistors, we can draw very simple electrical diagrams
- There are two main categories of circuits
  - Series
  - Parallel

Series & Parallel Circuits

- Series – the parts are connected in a line and the current flows through each part in turn
- In a series circuit, add all the resistor values together, as if it were one large resister, rather than several smaller ones
- Total resistance is the sum of the values of the resistors:

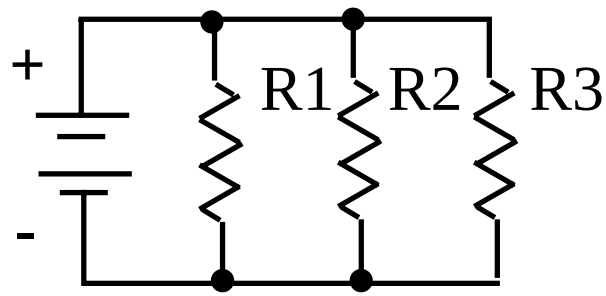
$$R_{total} = R1 + R2 + R3$$



Series & Parallel Circuits

- Parallel – the parts are connected so that current flows through all the parts at the same time
- This reduces the effect of each individual resistor, so the combination appears to have a smaller value
- Total resistance is one over the sum of the inverse of the values of the resistors:

$$R_{total} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$



Exam Questions

- The following slides contain questions from the exam pool that are covered in this section of the notes

T2A01

- T2A01 What happens to a signal's wavelength as its frequency increases?
  - A. It gets shorter
  - B. It gets longer
  - C. It stays the same
  - D. It disappears

T2A03

- T2A03 What does 60 hertz (Hz) mean?
  - A. 6000 cycles per second
  - B. 60 cycles per second
  - C. 6000 meters per second
  - D. 60 meters per second

T2A04

- T2A04 What is the name for the distance an AC signal travels during one complete cycle?
  - A. Wave speed
  - B. Waveform
  - C. Wavelength
  - D. Wave spread

T2A06

- T2A06 What is a radio frequency wave?
  - A. Wave disturbances that take place at less than 10 times per second
  - B. Electromagnetic oscillations or cycles that repeat between 20 and 20,000 times per second
  - C. Electromagnetic oscillations or cycles that repeat more than 20,000 times per second
  - D. None of these answers are correct

T2A07

- T2A07 What is an audio-frequency signal?
  - A. Wave disturbances that cannot be heard by the human ear
  - B. Electromagnetic oscillations or cycles that repeat between 20 and 20,000 times per second
  - C. Electromagnetic oscillations or cycles that repeat more than 20,000 times per second
  - D. Electric energy that is generated at the front end of an AM or FM radio receiver

T2A08

- T2A08 In what radio-frequency range do amateur 2-meter communications take place?
  - A. UHF, Ultra High Frequency range
  - B. MF, Medium Frequency range
  - C. HF, High Frequency range
  - D. VHF, Very High Frequency range

T2A09

- T2A09 Which of the following choices is often used to identify a particular radio wave?
  - A. The frequency or the wavelength of the wave
  - B. The length of the magnetic curve of wave
  - C. The time it takes for the wave to travel a certain distance
  - D. The free-spare impedance of the wave

T2A10

- T2A10 How is a radio frequency wave identified?
  - A. By its wavelength, the length of a single radio cycle from peak to peak
  - B. By its corresponding frequency
  - C. By the appropriate radio band in which it is transmitted or received
  - D. All of these choices are correct

T2A11

- T2A11 How fast does a radio wave travel through space (in a vacuum)?
  - A. At the speed of light
  - B. At the speed of sound
  - C. Its speed is inversely proportional to its wavelength
  - D. Its speed increases as the frequency increases

T2A12

- T2A12 What is the standard unit of frequency measurement?
  - A. A megacycle
  - B. A hertz
  - C. One thousand cycles per second
  - D. EMF, electromagnetic force

T2A14

- T2A14 How is the wavelength of a radio wave related to its frequency?
  - A. Wavelength gets longer as frequency increases
  - B. Wavelength gets shorter as frequency increases
  - C. There is no relationship between wavelength and frequency
  - D. The frequency depends on the velocity of the radio wave, but the wavelength depends on the bandwidth of the signal

T2A15

- T2A15 What term means the number of times per second that an alternating current flows back and forth?
  - A. Pulse rate
  - B. Speed
  - C. Wavelength
  - D. Frequency

T2A16

- T2A16 What is the basic unit of frequency?
  - A. The hertz
  - B. The watt
  - C. The ampere
  - D. The ohm

T7A01

- T7A01 What is the name for the flow of electrons in an electric circuit?
  - A. Voltage
  - B. Resistance
  - C. Capacitance
  - D. Current

T7A02

- T7A02 What is the name of a current that flows only in one direction?
  - A. An alternating current
  - B. A direct current
  - C. A normal current
  - D. A smooth current

T7A03

- T7A03 What is the name of a current that flows back and forth, first in one direction, then in the opposite direction?
  - A. An alternating current
  - B. A direct current
  - C. A rough current
  - D. A steady state current

T7A05

- T7A05 What is the basic unit of electric current?
  - A. The volt
  - B. The watt
  - C. The ampere
  - D. The ohm

T7A06

- T7A06 How much voltage does an automobile battery usually supply?
  - A. About 12 volts
  - B. About 30 volts
  - C. About 120 volts
  - D. About 240 volts

T7A07

- T7A07 What limits the current that flows through a circuit for a particular applied DC voltage?
  - A. Reliance
  - B. Reactance
  - C. Saturation
  - D. Resistance

T7A08

- T7A08 What is the basic unit of resistance?
  - A. The volt
  - B. The watt
  - C. The ampere
  - D. The ohm

T7A17

- T7A17 If an ammeter marked in amperes is used to measure a 3000-milliampere current, what reading would it show?
  - A. 0.003 amperes
  - B. 0.3 amperes
  - C. 3 amperes
  - D. 3,000,000 amperes

T7A18

- T7A18 How many hertz are in a kilohertz?
  - A. 10
  - B. 100
  - C. 1000
  - D. 1,000,000

T7A19

- T7A19 If a dial marked in megahertz shows a reading of 3.525 MHz, what would it show if it were marked in kilohertz?
  - A. 0.003525 kHz
  - B. 35.25 kHz
  - C. 3525 kHz
  - D. 3,525,000 kHz

T7A20

- T7A20 How many microfarads is 1,000,000 picofarads?
  - A. 0.001 microfarads
  - B. 1 microfarad
  - C. 1000 microfarads
  - D. 1,000,000,000 microfarads

T7A21

- T7A21 If you have a hand-held transceiver with an output of 500 milliwatts, how many watts would this be?
  - A. 0.02
  - B. 0.5
  - C. 5
  - D. 50

T7B05

- T7B05 Most humans can hear sounds in what frequency range?
  - A. 0 - 20 Hz
  - B. 20 - 20,000 Hz
  - C. 200 - 200,000 Hz
  - D. 10,000 - 30,000 Hz

T7B06

- T7B06 Why do we call electrical signals in the frequency range of 20 Hz to 20,000 Hz audio frequencies?
  - A. Because the human ear cannot sense anything in this range
  - B. Because the human ear can sense sounds in this range
  - C. Because this range is too low for radio energy
  - D. Because the human ear can sense radio waves in this range

T7B07

- T7B07 What is the lowest frequency of electrical energy that is usually known as a radio frequency?
  - A. 20 Hz
  - B. 2,000 Hz
  - C. 20,000 Hz
  - D. 1,000,000 Hz

T7B08

- T7B08 Electrical energy at a frequency of 7125 kHz is in what frequency range?
  - A. Audio
  - B. Radio
  - C. Hyper
  - D. Super-high

T7B09

- T7B09 If a radio wave makes 3,725,000 cycles in one second, what does this mean?
  - A. The radio wave's voltage is 3725 kilovolts
  - B. The radio wave's wavelength is 3725 kilometers
  - C. The radio wave's frequency is 3725 kilohertz
  - D. The radio wave's speed is 3725 kilometers per second

T7C01

- T7C01 Which of the following lists include three good electrical conductors?
  - A. Copper, gold, mica
  - B. Gold, silver, wood
  - C. Gold, silver, aluminum
  - D. Copper, aluminum, paper

T7C02

- T7C02 What is one reason resistors are used in electronic circuits?
  - A. To block the flow of direct current while allowing alternating current to pass
  - B. To block the flow of alternating current while allowing direct current to pass
  - C. To increase the voltage of the circuit
  - D. To control the amount of current that flows for a particular applied voltage

T7C03

- T7C03 If two resistors are connected in series, what is their total resistance?
  - A. The difference between the individual resistor values
  - B. Always less than the value of either resistor
  - C. The product of the individual resistor values
  - D. The sum of the individual resistor values

T7C11

- T7C11 Which symbol of Figure T7-1 represents a fixed resistor?
  - A. Symbol 1
  - B. Symbol 2
  - C. Symbol 3
  - D. Symbol 5

T7C12

- T7C12 In Figure T7-1, which symbol represents a variable resistor or potentiometer?
  - A. Symbol 1
  - B. Symbol 2
  - C. Symbol 3
  - D. Symbol 12

T7C13

- T7C13 In Figure T7-1, which symbol represents a single-cell battery?
  - A. Symbol 1
  - B. Symbol 6
  - C. Symbol 12
  - D. Symbol 13