# AMATEUR RADIO LESSONS

For
Those who wish to become HAMs
But have little knowledge of the theory needed.

These Lessons are designed to be used as Home Study and not to be shown by projector in a class situation. That would not be very effective as most slides contain far too much material and type too small for an audience.

But used by students independently, they can supplement material studied in class. They may not present the topics in the same order as the class instructor, and may include topics not usually included by instructors.

They may treat topics with a different approach and in different order than is usually done, but having taught basic electronics at the post high School level for over 15 years, and instructed students in High School Amateur Radio Clubs to get their licence, I have some experience in ways to make difficult topics such as sidebands, suppressed carrier, etc easy and obvious to the learner.

They are not an abbreviated course designed to rush a student to the exam through rote memorization, or recognition without understanding. How long it takes to complete them depends on the student.

They emphasize understanding, not memorization.

Author

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# VE6JMC

## Teaching Experience

Grades 5 to 8 --------------------- 3 years
Grades 9 to 12 -------------------- 3 years
Grades 10 to 12----------------- 15 years

Northern Alberta Institute of Technology
Electronics Engineering Tech -- 5 Yrs
Westerra Institute of Technology
Computer Engineering Tech---- 5 yrs
Northern Alberta Institute of Technology
Computer Engineering Tech---- 5 yrs

## Certificates

RCA Institute – Television
RCA Institute – Colour Television
RCA Institute – Electronics Engineering
Saskatchewan Journeyman Cert – TV rep
Alberta Journeyman Certificate – TV rep
Saskatchewan Teaching Certificates
Alberta Permanent Teaching Certificates
RCAF – Air Radio Officer Diploma (Wings)

**Related Experience**: McCaslin Radio & TV Ltd.– 5 years Orthon Computers Ltd – 5 yrs
Rybet Electronics Research & Development Ltd. -2 years

# NOTICES

This Lesson was first published 10 July 2012
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## Copyright information

# DISCLAIMER

**FOR DISCLAIMER INFORMATION**
**SEE**
**LESSON 1**

# LESSON NUMBER 2

# BASIC RADIO RECEIVER THEORY

# ELECTRO-MAGNETIC WAVES

# LET'S GET STARTED
# BY
# REVIEWING SOME BASICS
# ABOUT RADIO RECEIVERS
# AND
# HAM RADIO JARGON

# Electrical Currents

Electrical Currents come in a number of different forms, such as AC, as Square Wave, Complex, etc. and DC, as Pulse.etc.

## Let's start with DC

**DC or Direct Current** always flows in just one direction. A **Battery** produces DC in a conductor. Long before they understood what electric current was they gave names to the poles of the battery.

One connection on the battery was named the **anode** and the other the **cathode.**

**T**he anode was called the **+** or the **positive terminal** or **pole.**

The cathode was called the – or the **negative terminal or pole.**

Before science knew what was flowing in an electric current or in what direction, they arbitrarily decided that whatever it was, was flowing from anode to cathode, or +ve to -ve.

When they discovered that it was free electrons flowing from cathode to anode (-ve to +ve) they decided not to change text books because it made no difference to the electrical trade which direction, and was not worth the cost to make the change.

When vacuum tubes were used, to explain as to how they worked, the flow had to be electron flow, -ve to +ve. So people in electronics corrected their text books.

**Thus most
Electricians
still use the old direction
while
Electronics Technicians
use the correct one.**

**Their incorrect flow was renamed
Traditional or Conventional Flow
And the correct flow was named
Electron Flow**

# Then Bardeen and others at Bell Labs Discovered SEMI-CONDUCTOR TRANSISTORS

Although the flow of electrical current through a transistor
is by the motion of electrons
they are not free electrons but ones bound in the atom.

Instead a flowing freely as they do in a copper conductor
they move by jumping from one atom to another one that is missing an electron.

Then either that electron or another one jumps to a hole in
completely different atom.

It is better with semi-conductors to think of the current as the empty holes moving atom to atom than electrons moving to fill in empty holes.

## That means
## now there are three ways of talking about electrical current flow.

1. Traditional flow      from positive to negative in a conductor
2. Electron Flow      from negative to positive in a conductor
3. Hole Flow    from positive to negative in a semi-conductor

## WHAT FACTS DO I NEED TO REMEMBER?

1. An electric current in wire conductor is actually a flow of free electrons ( those not bound in atoms). The more free electrons in a material (conductor) the easier for them to flow. If there are none there is no flow.

2. There are two ways to describe electrical flow. Electricians usually use the conventional flow, i.e. from positive to negative. Electronic technicians normally use the electron flow, i.e negative to positive.

3. It does not really matter which you use unless you use vacuum tube circuits in which case electron flow is needed. Whatever way you choose stay consistent, as some laws are mirror images in different directions

4. When dealing with semi-conductor circuits, it is usually easier to think in terms of hole flow. (+ to -)

## Words in approximate order found in Lesson 1

AC
DC
Battery
Positive Terminal
Negative Terminal
Cathode
Anode
Tube
Valve
Traditional flow
Conventional flow
Electron flow
Semi-conductor
Free electrons
Bound electrons
Holes
HAM

Amateur Radio
Conductor
Sine wave
Hole flow

Square wave
Saw Tooth wave
Complex wave

# START LESSON 2

**Lesson 1 I mentioned that any wave shape can be made by mixing DC with sine waves. There could be a number of sine waves in the mix. For some wave shapes it would need an infinite number of sine waves. We can *approximate* most wave shapes with only a few sine waves, but we cover that later. For now all we need to know is that all we need is DC and AC Sine waves to create any shape of wave.**

**There are things that a student is required to know to pass the exam.**

**There are things that help one understand what is required for the exam.**

**There are things that help students to remember what is taught.**

**There are things that are nice to know but are not required.**

**There are things that challenge thought but are not required.**

**These Lessons will try to do all these things.**

**Lets start with something simple!**

# A BOX

**Words are fine to explain something, but often a picture is worth a thousand words!**

When we don't have a picture then a drawing will have to do, and might even be better because it gets rid of any extra detail and emphasizes what is wanted.

In Electronics we can explain many things just by drawing a **schematic** of it.

But often that includes more detail than we need.

So we draw boxes and name the box by putting a word inside.

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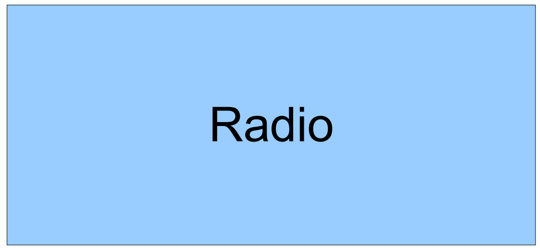
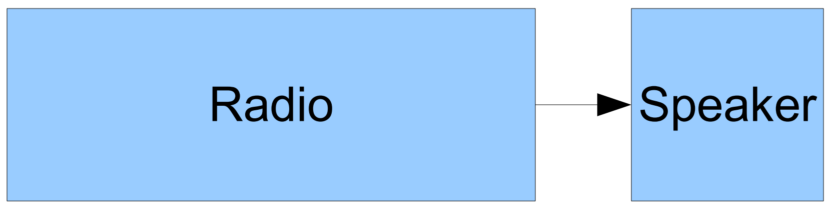
# Here is a **box diagram** of a Radio.

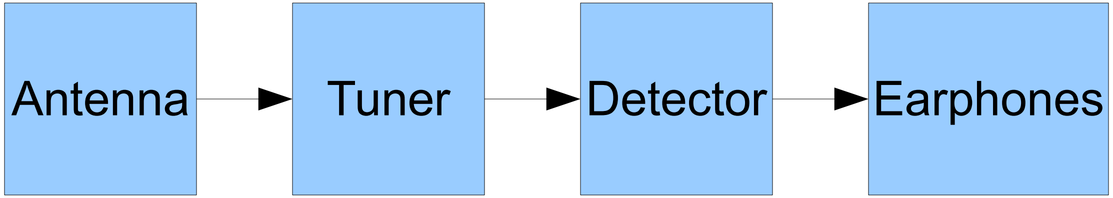



Well that didn't help me much so I will add more information in more boxes.




Now we see that a **signal** is going from the radio into a loud speaker
And we know it comes from the radio to the speaker because of the arrow.

## This is a block diagram of a very simple radio receiver




A block diagram may contain parts that are not inside the radio itself if that is self evident. Everyone knows that earphones are separate, and with such a simple radio as this an outdoor antenna is also separate.

So the tuner and detector are the sections actually inside the radio.

The names are picked to try and demonstrate the function of the parts that are in each box.

Often it is obvious what each box does just from the name, as in the antenna and ear phone boxes. One can make a good <u>guess</u> what the tuner does (although not <u>how</u> it does it), but the function of a detector may or may not be known.

# Boxes can hold passive circuits or active circuits

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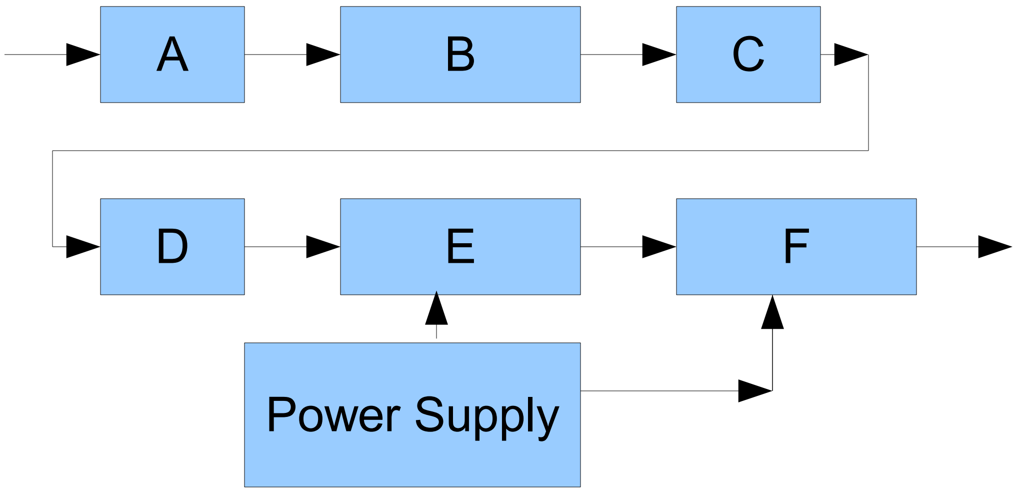
A signal is message travelling from one electronic component to another. To show signals going between boxes we use an arrow. If signals pass both ways we can either use an arrow with a head on both ends as ◄——► or two arrows one above the other.

——►
◄——

Usually it is better to use the one line with two heads. Just a note. A Arrows showing signals are never on a slant. They are either vertical or horizontal. As much as possible we have the signal going from the left to the right, and top to bottom, just like regular printing on a page. When you get to the right edge it is alright to have the end arrow to go back to the left side as below to another box.




Boxes A, B, C, and D contain only passive circuits because they have no arrow coming from the power supply.

Boxes E and F have at least one active circuit inside. (They may also include passive circuits)

If it is difficult to draw an arrow from one box to the next, the arrow coming out has a small circle (with a number in it) on the end rather than an arrow head. An arrow then starts with a small circle (with the same number in it) that points into the next box.

# PASSIVE CIRCUITS

Passive circuits have signals passing through them. They may make changes to the incoming signal and pass it out changed.

But the power of the signal out can never be greater than what went in.

Since there is always a loss of power in the form of heat in any device , the output signal power will be less!

Power is Volts times Amps, so if the device increases the voltage of the signal it must also decrease the current (Amps) to make the same power in the signal minus the loss.

The block diagram of the simple radio shown earlier is passive. The antenna changes the electromagnetic wave to an electrical signal. The power in the wire is no greater than in the wave that it caught. Since all the blocks are passive, the power in the earphones is less because of the loss.

## ACTIVE CIRCUITS

Before talking about active circuits, I want you to picture men from the fire department trying to put out a fire.

Often it takes three or four men to hold the high pressure hose. There is so much power in the water coming out one man cannot hold it. Nor can he use his hand over the end of the hose to stop the water. Yet it is easy to stop the flow. One man can do it easily! *How?*

He turns off the valve! It took a very low power to control a much greater power.

Now imagine a water motor turning the valve. A low power stream of water is controlling a high power stream. This looks like a small stream of water went into the valve and came out as a powerful stream. The small power stream was not converted to a powerful stream but just used to control it.

The small stream was not changed into a huge stream Rather the small stream controlled the large stream by means a a device called a valve!

The valve had two inputs: a steady powerful stream coming from the pump in the fire truck, and a small stream to control it.

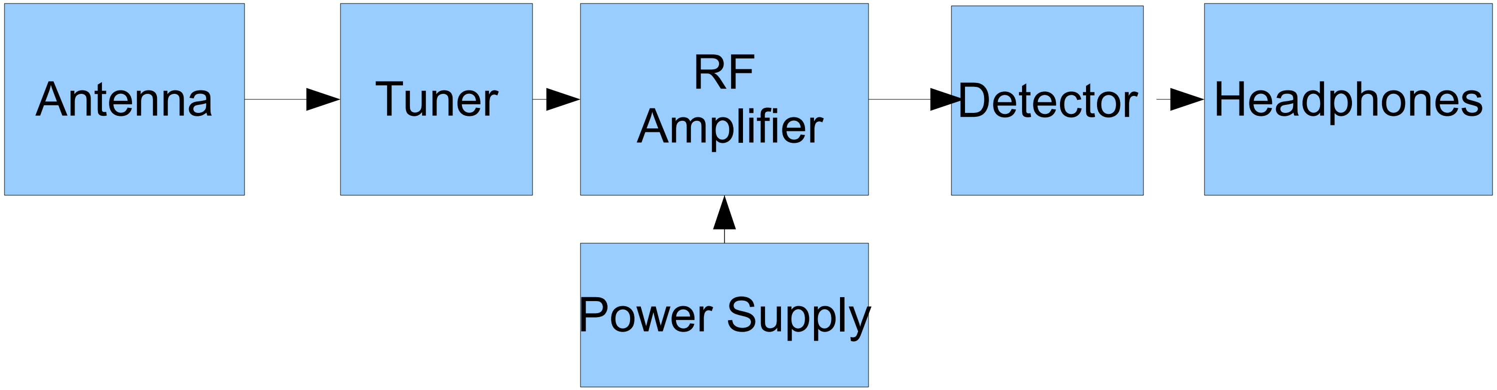
An active circuit is one that takes a low power signal to control a steady high power source by means of a device that acts like a valve.

Unfortunately we call this active circuit an amplifier as though it changed the weak signal to be a stronger one.

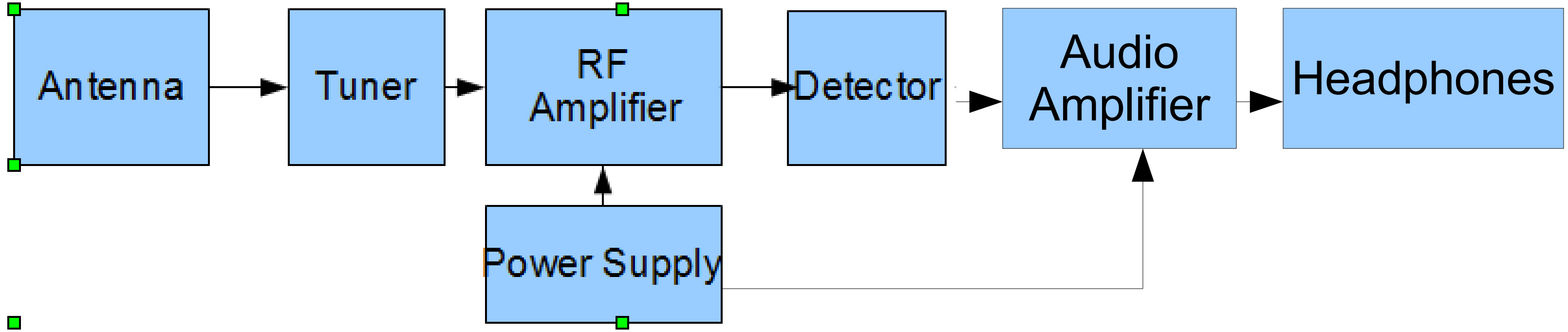
Another way to think of it is a cowboy controlling the actions of his horse by the bit in its mouth. The weak cowboy was able to control the powerful horse through a device called a bridle The cowboy was not magically changed into a horse. Both remained separate. They got their power from separate sources, Hay for the horse and steak for the cowboy

It was the invention of the radio (vacuum) tube that enabled active circuits to be built.  It was because they worked like a valve that the British called them valves rather tubes! The name Valve relates to their function, while our name tube just relates to what they look like.

**We can use an active circuit to make our passive radio better.**




The antenna takes a weak signal (Radio Wave) and sends it to the tuner as a electrical signal. The tuner acts like a filter to separate the wanted radio signal from all the others. The Radio Frequency Amplifier causes the steady powerful current from the power supply to vary like the input signal. The detector extracts the audio information from the carrier and passes that to the headphones,




With this radio we have added an amplifier for the audio so it's louder. The Radio Frequency Amplifier was used to increase the power of the Radio signal. The Audio amplifier increased the volume in the headphones

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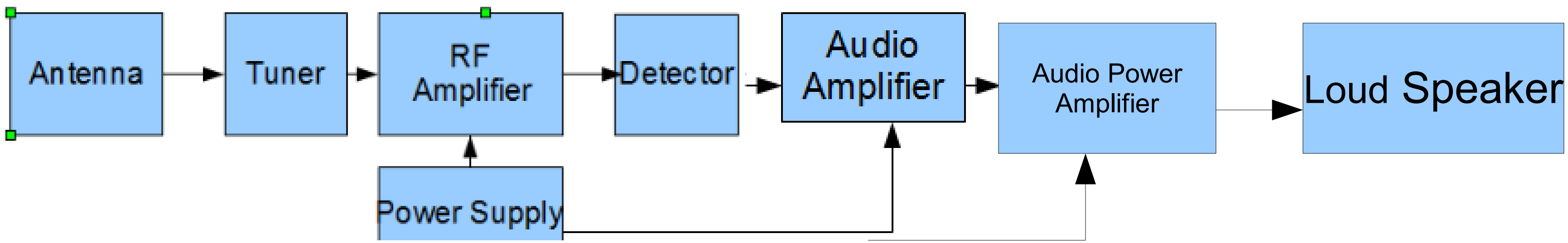



The loud speaker needs more power than headphones so we add another amplifier with enough power to do the job.

# TIRED OF LOOKING AT BLOCKS?

Well then lets do something else. We can add more blocks to our radio at another lesson.

The blocks you have seen so far show the way radios were actually built in the past. They started with the first block diagram and then as technology improved blocks were added.

At that time the power supply block just contained batteries because DC power was required from the Power Supply. It wasn't until later that they changed household AC to DC.

We have not talked about what is in each block. That will come later when we talk about schematic diagrams.

Do you have to memorize these block diagrams? NO WAY!!!!

If you understand **why** the blocks are needed then you can create the diagrams yourself, but if you can't then just do this and future lesson again and again, until you can.

# ELECTROMAGNETIC WAVES

Just from the name we can tell they have something to do with electricity and with magnetism and something to do with waves.

From our experience with water waves we know the wave is moving out from the source. That means the water is moving out, right? WRONG! Try throwing the rock where you have placed a cork in the water. It is not carried out by the wave created but just bobs up and down. The wave moves out but the water just bobs up and down at right angles to the waves 'motion'. Sound waves moves the air back and forth in the direction as the wave. But the air does not travel with the wave, just back and forth, so they are called longitudinal waves.

I know you are going to say that you have been on the beach and maybe did some surfing, and that you know the water is moving as the waves come in. The problem here is the word wave is used incorrectly in 'ocean waves'. What you are observing is tides. As the moon passes over the ocean gravity pulls up the water in the middle of the ocean. This water came from the beaches leaving dry land. When the moon is no longer over the ocean it rushes back to the beaches. So of course the water is moving! What we call waves on the shore is the in rushing water stumbling on the ground below causing breakers.. True waves on the water are caused primarily by winds.

*(Note this is a case of not telling the 'whole story" about tides to simplify what all is happening. I talked about this in the disclaimer. So don't Email me the correction, we don't need it here!)*

# LIGHT WAVES

At first scientists didn't have a clue as to what Light was. They thought it must be very tiny particles bouncing off things hitting your eyes. So they tried using Newtonian Physics to explain light with only limited success.

Then Young performed his famous two slit experiment that proved beyond any doubt that light was a wave. But  all the waves they were familiar with required something to wave (like water or air). But light could pass through a vacuum! And light from the stars travelled through the vacuum of space .What was waving?

Obviously there must be something in the vacuum that was waving.  When scientists can't figure something out they just give it a name, and then they can talk about it as if they understand it. They called this unknown substance aether, and the waves ethereal waves.

The search was on! Everyone wanted to be the first to discover aether. Then an experiment using earth on opposite sides of its orbit as a Michelson Morley Interferometer proved  that if aether existed it was moving along with the earth in its orbit. That meant all the aether in the galaxy was moving as though attached to the earth.

Of course it was absurd to think that the earth controlled all the aether in the Universe, even between all the stars therefore it does not exist! So they solved their problem by declaring that light waves do not need anything to wave. Some say that fields exists and light waves are disturbances in the field.

## SO WHAT IS IN EMPTY SPACE?

The Big Bang Theory says that in the beginning nothing existed, not even space. Then a point of infinite energy suddenly appeared from nowhere and started to expand creating space as well as matter and even time as it expanded . So that means there is an edge to empty space! Space itself is getting larger as it expands. If that is the case what exists beyond its edges?

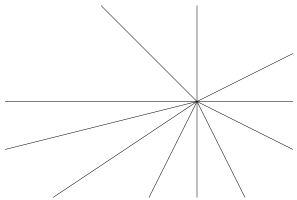
In these lessons we will go along with the field theory that it is electromagnetic **fields** that are waving, but unfortunately we can't really explain what a field is. The best explanation is that it is a 'little bit of magic' that lets something in space have an effect on something in another part of space with no physical connection between them. For example a permanent magnet has an attraction to metals, pulling them towards it. How? We don't know so we call it a magnetic field. The Sun pulls on the earth and that is called a gravitational field.

The earth has a gravitational field around it. This field extends in all directions right out to infinity. What does this field do? It tries to pull everything out there including distant stars into the earth. *How does it do that?* We don't know, but we can measure the pull. Some other fields include electrical fields, magnetic fields, football fields (just kidding).

What kind of properties do fields have? One is it has no structure. It extends out  in all direction  from the object creating it.  Its 'density' decreases by the square of the distance from the source. So although it extends to infinity, it does not have much effect when the distance is large.

A field can support waves. If it is a magnetic field it can have **magnetic waves**, if an electric field **electric waves**, gravitational field gravitation waves, etc. <u>The field itself does not travel</u>, but the waves in it do.  Just like the waves  in a water wave travel but the water itself just moves up and down. Notice that the motion of the water is at **right angles to the wave travel.**

With a magnetic wave, the vibration (or whatever is happening with the field) is happening at right angles to the magnetic waves motion just like in a water wave. If the wave is travelling horizontally then the field can be thought of as moving sideways to the wave motion, vertically to the wave motion, or any angle between these.



In this drawing think of the wave motion as straight out of the paper at the centre point. Thus all the lines are right angles to the wave's travel, and represent the direction of field 'vibration' or 'waving'.

Unlike a water wave that is just waving on a flat surface, these waves are going in all directions from the source, like gravity waves going out from the spherical earth, in all directions Think of it being an infinite number of waves all travelling in straight lines out of the earth, (or as one wave swinging around in all directions). For this wave to travel in all directions the field must exist in all directions. We know the field does not travel with the wave, and the wave "vibrates" the field at 90 degrees to the waves direction of travel. Thus there will be vibration in all direction at right angles to all the waves radiating from the centre point.

This is hard to picture in three dimensions, This is can be thought of as vibrating spheres around the centre point.To visualize it better if we can cut the sphere in half and look at the cut side, it looks like a series of rings around the centre point. We thus say the polarization of the waves are of circular polarization,

This is normal polarization for any electromagnetic wave created by a small source (i.e. Point source) Light usually is of this type, and has circular polarization. Radio waves, on the other hand, are usually generated from a long wire antenna. This causes them all to be polarized in one way: horizontal polarized from a horizontal wire or vertical polarized from a vertical wire.

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It was proved that a light wave is a magnetic wave. It was also proved to be an electrical wave. *How could this be possible? Was it just different ways at looking at the same thing?* It was found that for every **law about an electric current flow** there was an identical law about a moving magnetic flow!  There was always a dual.  The dual of an electric motor is an electric generator. The motor takes an electric current to produce a magnetic current which causes the shaft to turn. In a generator we turn the shaft to cause the magnet to produce an electrical current,so perhaps it is just two different ways of describing the same thing. In fact the only time we see magnetic effects without accompanying electrical effects, or electric effects without  magnetic effects is when no changes are taking place.

**Thus Static** electricity has no magnetic effects only electrical.  **Permanent** Magnets have no electrical effects, only magnetic.  **Static and permanent** are just different ways of saying the same thing. Static means not changing and permanent means not changing.  As soon as there is a change in either one of these a change in the other appears.

So if we have an electrical wave (waves are constantly changing) there is always a magnetic wave along with it.

Since a magnetic wave always accompanies an electric wave it is easier to talk about them as though they are just one wave with two different sets of properties,

So we call the pair together an electromagnetic  wave and treat it as one wave that has two sets of properties: magnetic and electric. Or we can talk about them separately keeping in mind the other is always present too.

Its like having two very active twins who are always together except when asleep. They are not exactly alike because one is female and the other male. They sleep in separate rooms (static) and are not together, but as soon as one wakes up ( moving) the other wakes up too and they stay active  together (move together) till bed time (become static and separate again)).

In the same way we can have a permanent magnet (asleep) separate from static electricity (asleep) but as soon as one of them becomes active (wakes up and moves) they both are active  together. You can talk about them by just saying ”the twins are doing this or that”, or by using their individual names. You can talk about an electromagnetic wave (the twins), or separately as the “magnetic wave” or the “electric wave”.

Light is an example of an electromagnetic wave. A wave travels in straight lines away from the source by making 'vibrations' in the electromagnetic field. Any 'motion' of the field is periodic and at right angles to the flow of the wave. In light it is normal for “vibration” of the field to take place in space in all angles that are right angles to the wave motion, and is thus polarized in all directions or called circular polarization. If the source of the wave is a point in space the wave travels like an expanding sphere with the point as its source.

Radio waves, x -rays, micro waves, heat waves, ultra-violet rays, etc. are all electromagnetic waves travelling in the electromagnetic field (whatever that is).

Sound waves are not, (nor are water waves), electromagnetic waves.

There are many different named light waves such as a red wave, a green wave, a violet wave etc. There are many different radio waves such as CHED, CJCA, CHAB, CHAT, KSL, etc. (Many waves are given names to make it easier to talk about them.) Some are grouped under one name, such as Light, Radio, Short Wave, Heat, micro wave. etc. We call a group of waves a **BAND.** Bands are sometimes broken into sub bands such as Broadcast Band, Short Wave Band, 40 meter Band, Long Wave Band, etc. (More Jargon!) *Do you have to know this?* The answer is YES and NO. If you are asking if it will be on the exam the answer is probably NO, but the exam may use the word 'band' in a question so it will be a big help if you know what the word means!

**What is the difference between different Electromagnetic waves?**

The difference is their frequency. We will not discuss frequency at this point but leave it to the Sine Wave topic. You probably already know enough about it for this Lesson. Waves of different frequencies may act on their surroundings in different ways. Xrays affect things differently than Light waves!

**Before we go any further be sure you understand we are talking about waves here, not electrical current travelling down wire. Electromagnetic Waves travel out from a source through air, some materials, and through the vacuum of space.**

**They are not like electricity flying through the air (We call that sparks).**

**They have different characteristics than electric currents. (*When was the last time you got an electric shock from light shining on you?)***

***If they are strong enough some can harm you, such as X-Rays,or micro waves, or ultraviolet light for example.***

Now back to the question: “What's the difference?”

# Frequency

**Frequency used to be measured in cycles per second. But It was officially changed to be Hertz. What's the difference between a cycle per second and a Hertz? - Absolutely nothing! Why was it changed to Hertz? - To honour a researcher who discovered much about electromagnetic waves in the Radio Bands.**

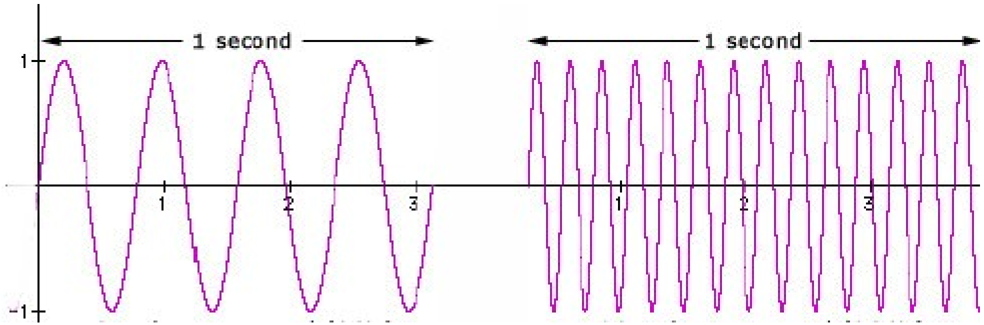
**In the Light Band, Red has the lowest visible frequency, while violet has the highest. Included in the light band is a frequency sub band lower than Red called Infrared. (Infra means below in Latin) and higher than violet called Ultraviolet. (Ultra means above.) Infrared is the name of a sub-band of the light band. There are a number of different infrared frequency. The same applies to Ultraviolet sub bands. The red to violet is a sub-band called visible light**

**INFRA RED I RED ORANGE YELLOW GREEN BLUE VIOLET ULTRAVIOLET**

**VISIBLE LIGHT**
**LIGHT**

# ELECTROMAGNETIC WAVES ARE IN THE FORM OF SINE WAVES

**We previously mentioned that any EM wave can be treated as a number of sine waves**

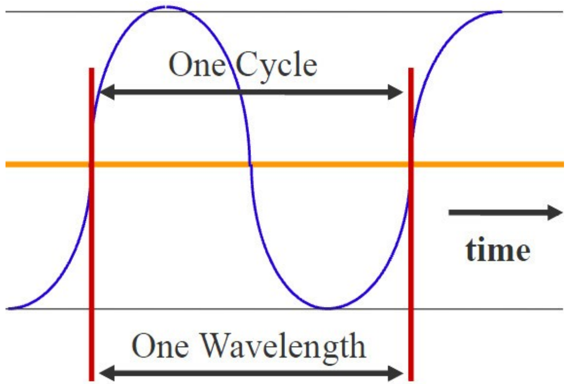



Here are graphs of sine waves of different frequencies

Frequency was measured in cycles per second.

For Radio Signals now we use the term Hertz

One Hertz is the same as one cycle per second




Since all electromagnetic wave travel at the speed of light, lower frequencies must be spread out more than higher frequencies, as shown in the diagrams on the previous page. So one cycle of any electromagnetic wave will have a specific length in space depending on its frequency. of the wave.

This means we can describe the wave using two different measurements. One is frequency in Hertz (cycles per second). The other is the length of one cycle in space (we usually use metres as the length unit).

You can change from one method to the other by the formula: Wave length is equal to the speed of light divided by the frequency of the wave. We use the speed of light measured in metres per second.

# DIMENSIONAL ANALYSIS

## OPTIONAL TOPIC

Do you have trouble memorizing formulas Like I do? Do we need to divide or multiply by the speed of light, and if its division which should be on top and which on the bottom?

Well there is a method of checking. Just remember what an equation means. It means that whatever is on the left side must equal that on the right. Not just the numeric values but also their dimensions! If the left side is a length then the right side must also be a length. i,e. length = length

So in this equation the left side is a length such as meters so the right side must end up also being just a length.

The speed of light is so many meters per second. So its dimension are a length divided by a time. (l/t) (l stands for length and t stands for time). Frequency is just a number divided by time. (#/t) where the # represents a number that is not a dimension. In order to have only length (l) on the right we have to get rid of both of the the times (t). Since t/t is a # ( they cancel each other out). Since t multiplied by t would give t squared and not cancel each other, the formula must use division and not multiplication. But what should be on top and what should be on the bottom? So if we put the frequency on top and speed of light on the bottom to do the division we end up with 'per meters or 1/l. But the left side is l not 1/l so the formula must be the speed of light divided by the frequency for the dimensions on both sides to be equal!

In the last frame we used # to stand for some numeric value we don't know. We were only making sure the dimensions balanced not the numeric values. From algebra we know the numeric value of each side must be equal.

If you use meters on one side don't use feet on the other side unless you know a value for # that converts feet to meters. The formula will still work if you supply the right #. Unless you are trying to convert from one measuring system to another make sure you use the same measuring system on both sides

Even when you are using the same system, I suggest you use the same magnitude or size of unit on both sides. (meters on both or kilometres on both.) Again you can use different size as long as you add the correct value for # to convert to the same size of measurement. Some equations always require a # no matter what units you are using. For instance all equations dealing with circles require a # of about 3.14 to them. When a certain size constant appears in equations often, we give them special names and symbols. In the above example we call it pi and give it a special symbol in equations.

In most equations not using a special # such as pi, they use the letter 'k' in the formula and call it a constant. In almost every equation with a 'k', its value has been determined by experiment and not by theory. For example: diameter equals 2 times the radius or D=2r. Or D=kr where the k has been determined to be 2, and both D and r are a length.

Since almost all waves are either sine waves or a number of different sine waves acting together, and  sine waves are related to circular effects, and since calculations of circles have the pi constant as part of them, in HAM radio many things we want to calculate has a pi in the formula.

Will there be questions on dimensional analysis on the HAM exam?
NO! This has only been included to help you understand a simple way to create a formula you can't quite remember.  Since I hate memorizing formulas, I tend to use dimensional analysis whenever I need one (like on an exam). I personally find it easier than rote memorization. If like me you find it easier then use it, if not then forget it and just memorize those formulas.

There are other constants used often in science other than pi. A couple of examples are Boltzmann's constant, and Avogadro's Number, etc.

The speed of light acts almost like a constant, but is not a true constant because it has has dimensions and constant's have no dimension.,. However because it is tied closely to electromagnetic wave theory it occurs almost as often as we run into pi. It would be wise to memorize its value. We also always give it the same symbol in all equations using it : C  like in $E=MC^2$

## SINE WAVES

We can talk about electromagnetic waves by talking about their frequency, or we can talk about the same wave by talking about its wavelength.

So which do we use?

BOTH

It depends on why we are talking about the wave.

For example if we are talking about the length of the best antenna for a given radio wave, it is easier to use the wave length of the wave.

If we want to tune in a certain station we use the frequency rather than wave length.

If we want to talk about a certain band of frequencies we use the approximate wave length of the band, such as the 40 metre band.

## THE DIFFERENCE BETWEEN AN AC ELECTRIC CURRENT IN A CONDUCTOR AND AN ELECTROMAGNETIC WAVE

**The electric current in a conductor is a flow of free electrons in the wire.**

**The motion of electrons in a wire cause an electric field around it.**

**DC or the electrons all flowing constantly in one direction create a constant field**

**An AC electron flow varies as a sine wave, (or a combination of sine waves if it is a complex flow).**

**That means the electron flow keeps changing direction. The number of times it does this in one second is called its frequency.**

**At low frequencies this periodic change does not cause any ripples in the field.**

This repeats over and over again. If it is the household electricity it repeats this every 60th of a second. (60 Hertz) This means that the electrons flowing in the wires in your house were already there when you turned on the switch, They just bounce back and forth sixty times a second in the wire..

The more electrons that are moving (the higher the current) the stronger the magnetic field is.

If the frequency of the AC is increased to a certain value called the critical frequency the disturbance of the magnetic field becomes so great that waves are produced in it, which travel out at the speed of light. As we mentioned before the moving magnetic wave is accompanied by an electrical wave. The combination is called an electromagnetic wave. Remember it is not the field that moves out, but only the wave imposed on the field that moves.

Electromagnetic waves are produced at all frequencies greater than the critical frequency.

This is the method that all 'radio' waves are created.

Light is an electromagnetic wave that is created by many other methods, than electrons flowing in a wire, which we will not discus. Light can be created at a very small point, and travel out in all directions. Also the light will be circular polarized. (The waves vibrating in all directions that are at right angles to the direction the wave travels.)

Radio waves are not created at a point but along a current carrying wire, so they are not circular polarizes but are polarized with horizontal polarization if the wire is horizontal, and vertical polarized if the wire is vertical.

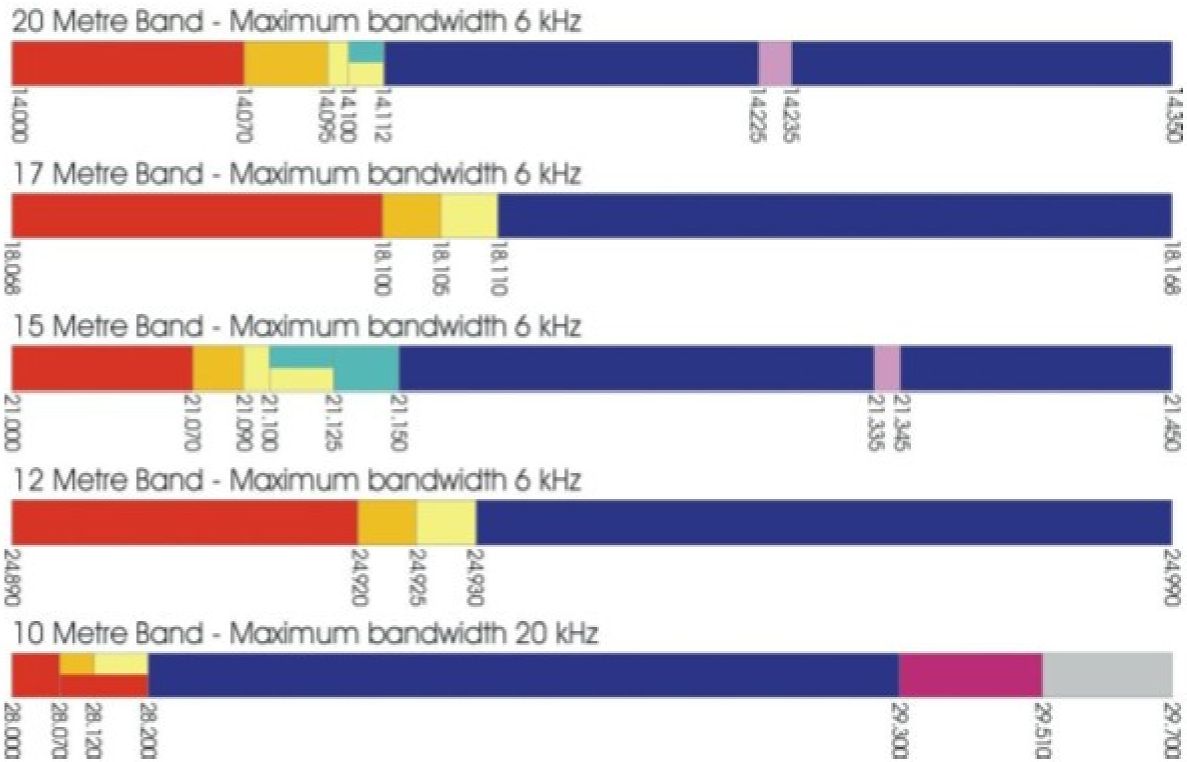
Is this important to know? YES! If we compare this to light, we can produce polarized light by passing it through a Polaroid filter that only lets one polarization through and blocks all others. If you try to see the light through another Polaroid filter you can only see it if that filter has the same polarization as the first one.

The same applies to radio waves, The receiving antenna of the receiver must have the same polarization as the transmitting antenna if we want to be able to pick them up. There are ways to pick up both horizontal and vertical polarized signals. A square loop will work. More about this when we have a lesson on antennas.

It

# RADIO FREQUENCY BANDS

This is a graph of some of the frequencies available for HAMs to use. The colours indicate what types of transmissions may be made in sub-bands of each of the HAM bands. The numbers under the Bands indicate the frequencies of the edges of the sub-bands.



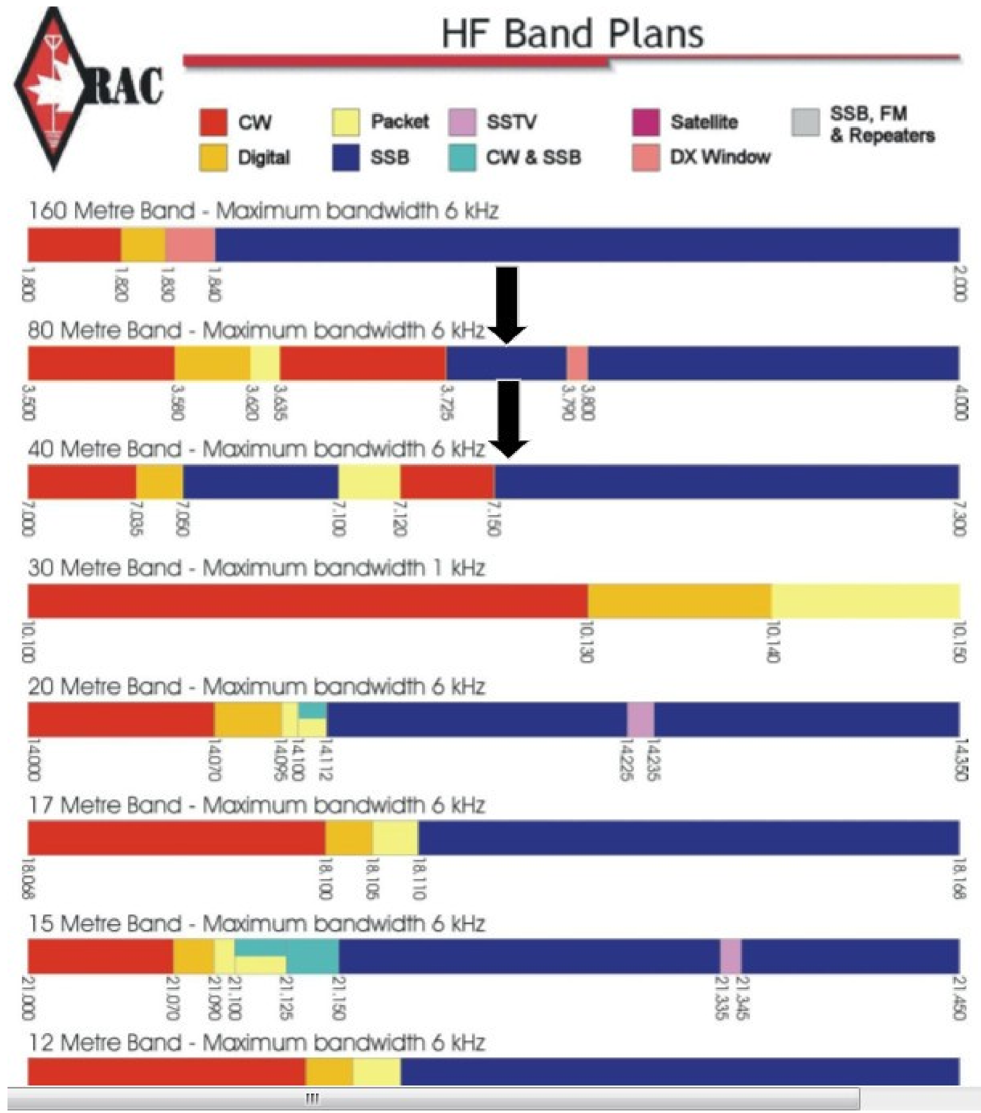
It may surprise you to find out that with all the different frequencies available for radio signals that there is a shortage of unused frequencies.

The governments of countries around the world meet together to decide what frequencies can be used for what purposes and by whom.

Here are more bands set aside for HAMs to use.

At the top is the colour code,for frequency sub-bands.

Where there are overlaps shown both may use those frequencies.



# WHAT SHOULD YOU HAVE LEARNED IN THIS LESSON?

Box diagrams make it easier to understand complex circuits.

Names in the boxes signify the purpose of the box.

Box diagrams can be memorized but if you understand what is happening you should be able to draw them without memorization. You will have questions on the exam that can be answered by a box diagram.

Arrows show direction of AC signal flow and DC power supply flow.

Passive Circuits do not add any power to the signal, in fact there will be some loss.

Active circuits use a weak power signal to <u>control</u> a large power to make it an image of the original.

Some of the active devices are:  vacuum tubes (called valves in England), transistors, FETs etc..

Boxes containing active circuits will always have both a signal arrow pointing in, a power supply arrow going in and a signal arrow going out.  Passive circuits have no arrow from the power supply going in but only signal arrows going in and out.

Power is equal to volts times amps. (More about this in a later lesson).

Electromagnetic waves do not require a medium in which to move like sound and water waves do. They require a field which is not well understood what it is.

A field extends out to an infinite distance.

Field strength diminishes by by the inverse of the square of the distance away from its source.

The electromagnetic wave is like a ripple in the field.

The ripple  in the field is at right angles to the direction the wave travels.

Light is an electromagnetic wave of very high frequency.

Light is often generated at a small area or point so the waves have circular polarization, meaning waves of every polarization extend out from the source, each one at right angles to the direction the light travels.

Radio waves are given off from a wire conductor and are polarized parallel to the conductor. Thus they are vertical or horizontal polarized.

Antennas can only pick up signals that are polarized the same as the antenna. vertical or horizontal. A box or loop antenna can pick up either.

Radio waves can only leave a conductor if the AC current in it is above the critical frequency.

Radio waves are like two waves combined. A magnetic wave and an electrical wave. They are at right angles to each other. When we talk about the polarization of a radio waves we are talking about the electrical wave, not the magnetic one (which has opposite polarization).

Any shape of an AC current, or an electromagnetic wave, can be thought of as a number of sine waves along with a DC component. We thus need to understand sine waves.

Sine waves are directly associated with anything that has a circular motion.

Sine wave shaped currents are not electromagnet waves, but an actual flow of electrons in a conductor.

A sine wave shaped current in a conductor, if above the critical frequency, will cause an electromagnetic wave of a sine wave shape.

Electromagnetic waves travel at the speed of light, no matter what their frequency. This means the frequency must be related to the wave length. So we can talk about the wave by frequency or by its wavelength. Although they measure different things about the wave, either defines the wave.

Static electricity in a conductor has electrons that are moving only at random so there is no current flow. It does not create electromagnetic waves. It does not display any magnetic fields, only an electrical field. Permanent magnets have a magnetic field, but do not have an electrical field associated with them. They cannot send out electromagnetic waves.

The spectrum of electromagnetic waves have different properties depending on their frequency (or wavelength). Different names are applied to waves with similar properties. Examples are X rays, Visible light and Radio Waves.

Different physical devices are used to detect these different frequencies. For example our eyes detect visible light and transform them into nerve signals which are sent to the brain, Radio receivers turn Radio waves into audio waves.
(This is one of those simplifications that are not quite true.)

Just because something is given a name by scientists does not mean they know what it is or how it works. It just enables them to talk about it and give it certain properties to explain the unknown. Fields are example of this.

Often two different explanation can be given to explain something. For instance light can be treated as particles or as a wave to explain it. Sometimes one theory for light works better, and other times the other theory works better.

In order to make it easier to talk about electromagnetic waves that have similar properties, we divide them up into bands of frequencies, and give each band a name. A band may be divided into sub-bands. E.g. The 40 metre band of the Radio Frequency band

# JARGON USED IN LESSON 2

Box diagrams
Circuit diagrams
Schematic diagrams
Loud Speaker
Earphone
Antenna
Tuner
Detector
Passive Circuits
Active Circuits
Power Supply
Electronic component
Signals
Volts
Amps
Watts
Tubes
Valves
Amplifier
Radio frequency amplifier
Audio frequency amplifier

Input
Output
Carrier
Electromagnetic wave
Field
Electric field
Magnetic field
Space
Matter
Time
Polarization
Circular polarization
Horizontal polarization
Vertical polarization
Current electricity
Static electricity
Permanent magnet
Bands
Sub-bands
Conductor
Frequency

Wave length
Sine wave

# LOOKING FORWARD TO LESSON 3

- SCHEMATIC DIAGRAMS
- EMF
- CURRENT
- POWER
- OHMS LAW
- POWER LAW
- RESISTANCE
- SERIES RESISTANCE
- PARALLEL RESISTANCE
- ELECTRIC CELLS
- ELECTRIC CELLS IN SERIES
- ELECTRIC CELLS IN PARALLEL
- BATTERIES
- SCHEMATIC DIAGRAM SYMBOLS
- LEFT TO RIGHT, TOP TO BOTTOM RULE
- AC PEAK VALUE
- AC RMS VALUE
- AC PEAK TO PEAK VALUE

# OPTIONAL
# EXTRA READING

**Not required BUT**
**It may help to understand what is to follow in future lessons.**

**NOT REQUIRED FOR THE EXAM**

# DUALITY

**Nature seems to like duality, and it appears over and over again.**

**OPPOSITES**

**Opposites are things that have opposite characteristics**

**Proven Examples:**

electrons – positrons
Positive charges – Negative charges
North pole – South pole (on magnets)
Expansion – Contraction
Matter – Anti-matter

**Examples of things that should have a dual from what we know, but the dual has never been found yet:**

Gravity – Anti gravity
Forward time – Reverse time

There are some things that always have a dual way of looking at them. These are usually things that are hard to explain but are very important. Let's talk about them:

**Electricity and Magnetism.**

For every electrical law we have there is a magnetic law that is the same.

Every time we have flowing electricity we have a magnetic field produced around the conductor.

Every time we have a moving magnetic field electricity will be produced in a conductor.

When electricity is 'radiated' it carries along with it radiated magnetism. In fact we call it an electromagnetic radiation.

## Matter and Energy:

At one time they were considered to be two different things. Then Einstein came out with his famous law $E=MC^2$ which showed they were just different ways of describing the same thing. The atomic bomb showed we were able change the matter form to the Energy form. The Big Bang Theory is based on the energy form being turned into the matter form.

## Light:

At one time light was thought of as some kind of particles given off by objects flying into our eyes. Then Young with his famous 2 slit experiment proved it had to be a wave. Not long after that Einstein and others proved it had to be particles. Who was right? Years of experiments has not resolved the issue.

Science has two different ways of getting around the problem:

1. Light can change from one to the other, depending on the experiment being done with it.

2, Light is a particle of waves, or a wave of particles. We give a particle of waves a name. We call it a photon. No one can explain what a particle of ways really means. Its similar to saying an object is here and there at the same time.

# NAMING THINGS WHEN WE DON'T KNOW WHAT IT IS.

When scientists don't understand what something is they have a habit of just giving it a name, then it looks like they know what they are talking about. We read about photons all the time, and act as if we know what it is, when all it is is a compromise between the wave group and the particle group. It probably does not even exist. But because it has a name we can throw the word around just as though we do.

The medical profession do this all the time. When they determine there is something that is causing a disease that they haven't got a clue it is, they give it a name. Usually the name is the name of the person who discovered the disease with syndrome added to the end. So if I discovered a new disease but didn't know what the cause was it would be called mccaslin syndrome. So if you came down with that disease the doctor would say you have mccaslin syndrome and you would go away happy because the doctor knows what is wrong. Really all he said to you is "You have a disease that has the symptoms you described that we don't know how to treat other than ease the pain"

**Naming things enable scientists to talk about things they do not understand.**

# THEORIES

Since we will be studying many theories it might be good to understand what a theory is.

Man has always wanted to figure out how the world worked. He did this by observing everything around him and tried to make sense of it all. On many things he could only guess at the cause. That's what a theory is – a best guess at the cause of things we observe.

Remember that word – guess. That's all, just a guess.  Lets's look at a few theories.

1. OBSERVATIONS:
   I am sitting in my room when a baseball come flying through the window.
   I heard an aircraft over head.
   I heard the boy next door playing outside.

   THEORY:
   1. His ball jumped off the ground and flew itself through the window.
   2. He hit the ball with his bat, it flew in the air, bounced off the plane and went through the window.

3. His mother threw the ball at him and it missed and went through the Window.

4. He hit the ball with the bat and it went through the window.

So we see a number of theories that can explain what we observed ... a ball through the window. How do we choose the right one? We are never sure we have the right one! We only can pick the most probable one.

Number 1 – We can reject this one because it includes something we have NEVER experienced before.

Number 2
Number 2 – We can reject this one because it is too complicated. Ocam's Razor says the correct theory is usually the simplest.

Number 3 – This one includes something we did not observe and should have for it to be Right so we reject it

Number 4 - Of all the theories this is the best. It fits Ocam's Razor and the observations.

**This does make it correct, it must stand the test of time. It cannot be a theory that says all balls coming through a window have been hit by a boy with his bat. If we find**

Even one case where a girl hit the ball, our theory that boys hit all the balls going through windows has to be thrown out! Or we could patch our theory to say child instead of boy. We may have to patch it again if an adult hits it to say person rather than child. It would need patching again.

Some of our theories in common use today are so patched that Ocam's Razor says they are probably wrong!

For example our atomic theory of atoms was chosen over many others because it was so simple - contained only 3 particles, electron proton and neutron, or only 2 (duality again) if we say the neutron is a proton joined together. Has it stood the test of time? Well it has now been patched so often that it requires hundreds of different particle.

I remember in about 1970 when I was studying Nuclear Physics at UBC. The subject was about the latest particles discovered at that time and their properties. One had been found that had to have a revolutionary property that it actual was going back in time! Had the opposite of forward time duality at last been discovered? Since it has never been publicizes I guess they managed to patch the atomic theory so the properties so that particle didn't have to include reverse time travel. Since that time new 'atom smashers' have discovered many new particles.

There are other theories. One is the wave theory. Instead of particles it uses it's dual – waves. Another requires a 11 dimensional space (not our thee, or four if we include time as a dimension) And space has to be in strings all tangled together. The string theory of space is starting to disappear because it predicts an infinite number of possibilities for space

# End of Lesson 2

# Radio Receivers