AMATEUR RADIO LESSONS

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

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

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SEE
LESSON 1

LESSON NUMBER 3

BASIC RADIO RECEIVER THEORY

BASICS

START LESSON 3

LET'S GET STARTED BY REVIEWING SOME BASICS ABOUT WAVES AND HAM RADIO JARGON LEARNED IN LESSON 2

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

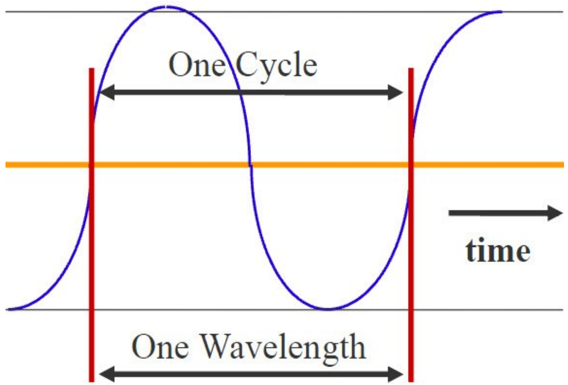
A BOX

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.

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 output signal can never have greater power than the input signal.

Active circuits use a low power signal to modify a steady high power source by means of components that act like a valve. The high power source is called the power supply.

With a magnetic wave, the vibration (or whatever is happening in the field) is happening at right angles to the magnetic waves motion. The same applies to an electrical wave,



Wave length is equal to the speed of light divided by the frequency of the wave.

If we are talking about antennas for a given frequency of radio wave, it is easier to use the wavelength of the wave rather than the frequency.

If we want to tune in a certain radio station we use the frequency rather than wavelength.

If we want to talk about a certain band of frequencies we use the approximate wavelength of the band, such as the 40 metre band, rather the two end frequencies

The receiver's antenna must have the same polarization as the transmitter’s antenna.

Electromagnetic waves do not require a medium in which to move like sound and water waves do. They require a field (which we don't understood just what it is).

The ripple created in the field is at right angles to the direction the wave is travelling

Any shape of an AC current, or an electromagnetic wave, can be treated as a number of sine waves along with a DC component. It sometimes needs an infinite number of waves to create the exact form of the desired wave. In real life relatively few waves will create a very close approximation.

A sine wave shaped current in a conductor, if above the critical frequency, will cause an electromagnetic wave to travel away from the wire.

Electromagnetic waves travel at the speed of light.

The Electromagnetic waves of different frequency have different characteristics.

Jargon used in Lesson 3.

Schematic Diagram
Schematic Symbol
Electric ground
Insulator
Transformer
Coil
Step-down transformer
Step-up transformer
Resistor
Capacitor
Condenser
Semi-conductor
Tuned circuit
Resonant circuit
Parallel tuned circuit
Q factor
Filter
Tuner
Selectivity
Audio frequency
Short circuit
Bypass capacitor

Low pass filter
EMF
Electromotive Force
Potential difference
Volt
Cell
Battery
Series
Parallel
Dry cell
Voltage
Current
Amp
Ohm's Law
Power
Power Law
watt

Topics Covered in Lesson Three

Schematic Diagrams
EMF
Current
Power
Ohm"s Law
Electric Cells
Electric cells in series
Electric Cells in parallel
Batteries
Schematic symbols
Left to right, top to bottom rule

Coming in Lesson Four

Resistance
Series Resistance
Parallel Resistance
Alternating Current
Peak Value
RMS Value
Peak to Peak value

Heterodyne
Carrier
Side Bands
Single Sideband
Suppressed Carrier
Super Heterodyne

LOOKING FORWARD TO LESSON 3

Topics to be discussed

SCHEMATIC DIAGRAMS

EMF

CURRENT

POWER

OHMS LAW

POWER LAW

ELECTRIC CELLS

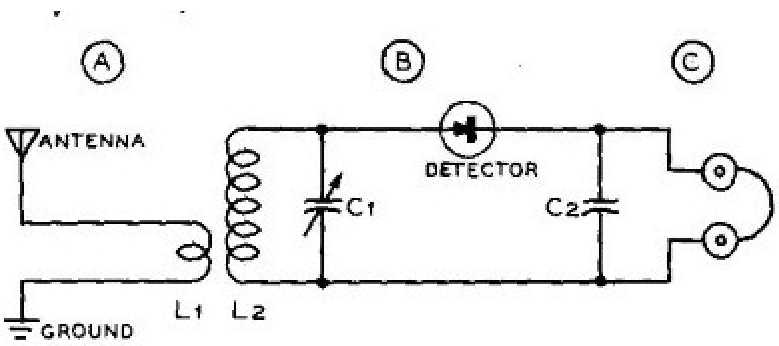
ELECTRIC CELLS IN SERIES

ELECTRIC CELLS IN PARALLEL

BATTERIES

SCHEMATIC DIAGRAM SYMBOLS

LEFT TO RIGHT, TOP TO BOTTOM RULE

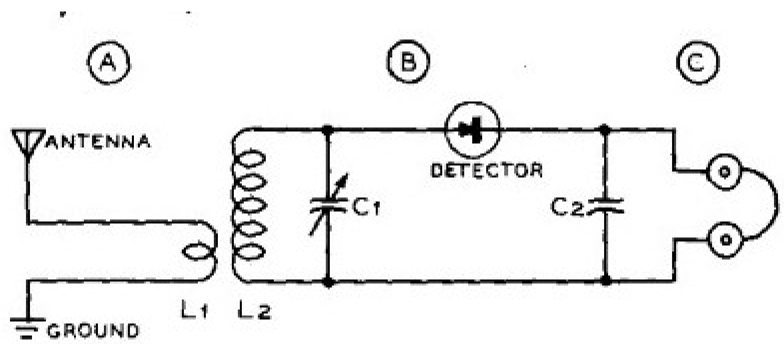


Here we have a schematic diagram of the simplest radio receiver that was shown as a Box Diagram in Lesson 2.

The schematic diagram shows representations of all the components found in a box diagram, plus any other component not inside the box diagram. Schematic diagrams follow the same left to right and top to bottom rules as box diagrams follow.

Standard symbols for each component are used in these diagrams..

Each symbol has a name consisting of a letter followed by numbers that are used in sequence for the same type of component. For example C1 and C2.

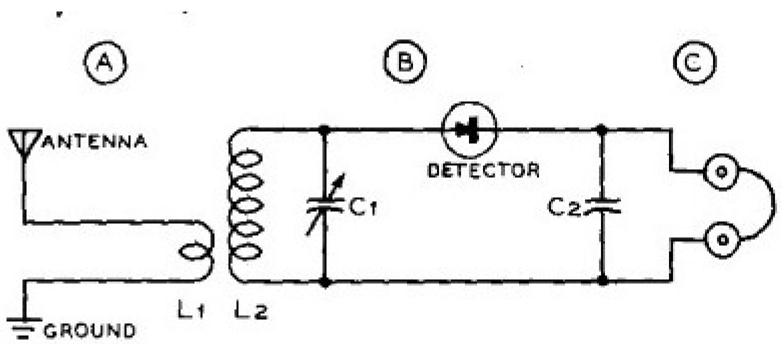


Arrows are not used to show the direction of signal flow, it is assumed to be from left to right as though reading sentences in a book, starting at the top. So in this diagram the signal starts at the antenna and follows the line through the coil L1 and then to ground.

Lets talk about what a ground represents: Sometimes it is a 10 foot long metal pole driven into the ground, or a copper water pipe in the house that comes out of the ground.

Sometimes it is just the metal case that contains the electronic device, and sometimes it is a large flat plate on the ground.

Or it could be through the ground lead (the long semi-round pin) on the electrical wall plugs. Some people use the term 'Earth' instead of 'Ground' when the connection is made directly to the ground outside.

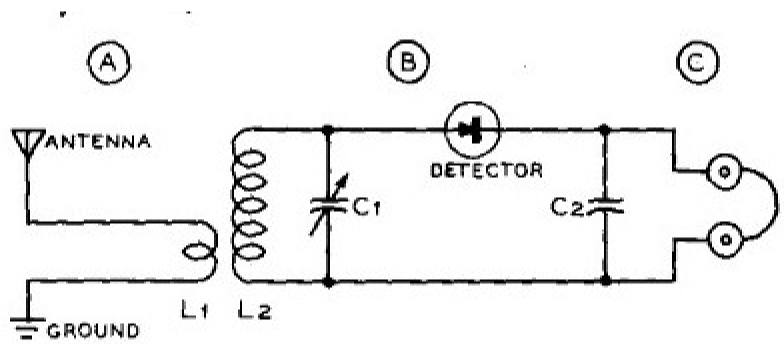


The symbol for a coil of wire that only has a few turns of wire wound on an insulator (or just the air) is shown at L1.

A coil that has many turns is shown at L2. (Coils are always named on schematics by the letter L followed by consecutive numbers.)

When two coils are shown close together as in this diagram it is called a transformer. If L1 has fewer turns than L2 it is called a step up transformer. If L1 has more turns it is called a step down transformer. A transformer can be named by the letter T followed by a number, or as two coils as shown above.

A transformer is a passive device. That means the signal going through suffers a small loss of power when it passes through. The power loss is in the form of heat.

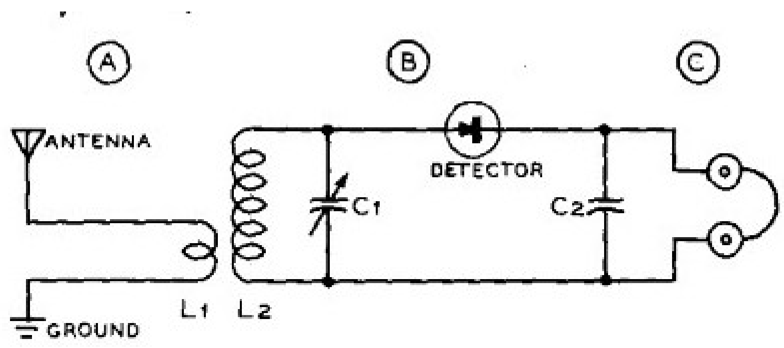


As stated the power loss is in the form of heat. The loss is mainly caused by the resistance of the wire used to make the coil. A perfect coil would have no resistance so the power loss would be extremely small. Resistance is a property of a conductor that opposes electron flow.

The turns of the wire must be insulated from one another. If bare wire is used, space is left between the turns so the air between the turns acts as the insulator, or the wire can be coated with varnish to insulate them. Then it doesn't matter if the turns touch one another.

Often the wire is wrapped with cotton or silk or coated with plastic. The signal is passed through the transformer by means of a magnetic field rather than by an electron flow.

We will talk more about coils, transformers and resistors later.



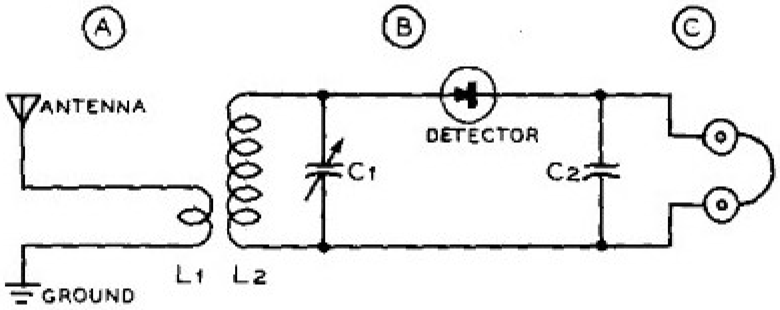
The component marked as C1 is a capacitor. More about capacitors later.

Although the letter C has been designated to stand for the speed of light in the algebraic equations used in electronics, a "C" is also used to name a capacitor in schematic diagrams and will always be followed by a number such as C1.

In the schematic above, if you look closely at the capacitor symbol, you will notice the bottom line of the capacitor is very slightly curved. Sometimes it is drawn as a straight line the same as the top line. The arrow through the capacitor symbol indicates that the value of the capacitor may be varied by the user.

Sometimes instead of putting an arrow through the capacitor to show it can be adjusted, an arrow head is put on the right hand end of the curved line. This indicates which plates move.

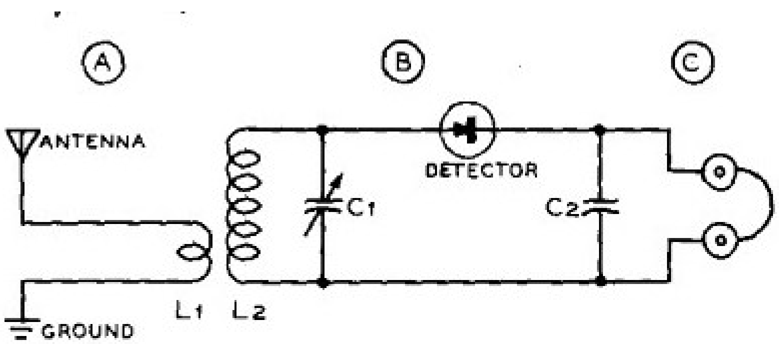
In the past a capacitor was called a condenser. The standard today is to call it a capacitor.



You will notice the connection lines coming from the capacitor are connected to the lines coming from the coil with a small black dot at the junction. The black dot means there is an actual electrical connection there.

Sometimes in complex schematics lines must be drawn across other lines where no connection is made at the crossing. In the past a little curved jump was put there instead of a dot. Now it is the practice to just let the drawn lines cross. If no black dot is placed there it means there is no connection.

You will notice there is no arrow through C2. This means it has a fixed value that cannot be changed.

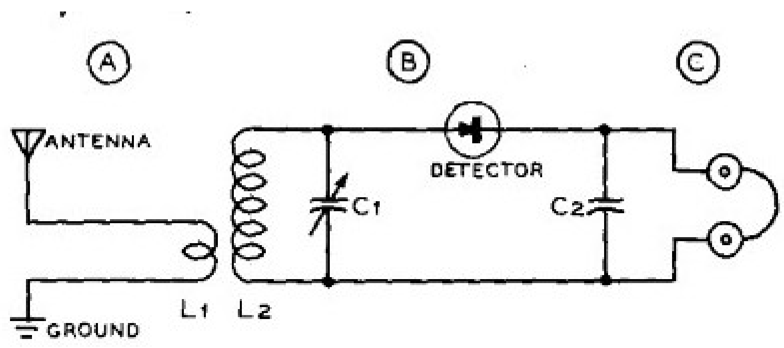


There is a non-standard symbol at B in this schematic. It is standard to put a circle around a component when it comes in a glass or metal container with a vacuum inside. These components were almost always vacuum tubes.

The detector in this schematic is not in a vacuum tube, so by today's standards should **not** be shown with a circle around it.

Capacitors like coils are passive devices. (They do not increase the power in a circuit.)

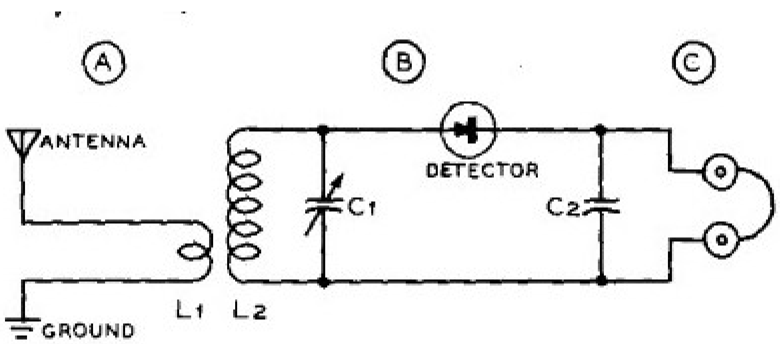
The detector in this circuit is a semi-conductor device called a diode made out of a crystal material. How it works will be explained in another lesson.



The symbol shown here for headphones is also non-standard. The standard symbol does not have those two little circle inside the larger ones. The larger circles represent the part of earphones that go over your ears, and the large arc on the right represent the band that goes over your head

Older electronics books will often have non-standardized symbols, such as we find here before they became standardized, but they are usually close enough that you should have no difficulty to know what they represent.

You will often come across a coil and a capacitor joined together as above. Together they form a type of tuned circuit or resonant circuit. Connected as shown it is called a parallel tuned circuit.



When L2 and C1 are connected like this they make a resonant filter. They only allow a very narrow band of frequencies to be passed on to the detector. This combination has a **Q factor.** The higher the Q factor the narrower the band that can pass. We will talk about Q in a later lesson. All you need to know and remember at this point is that “the 'Q' of a circuit represents its **'QUALITY',** or how well it works.

Here the purpose of the 'filter' is to filter out all unwanted radio station frequencies and only let the desired one to pass on to the detector. So we use the capacitor C1 to tune in the station we want. Hence this part of the radio is the **tuner** we showed in the box diagrams in lesson 2.

The 'quality' of L2 (the lower its resistance) and quality of C1 will determine the Q factor of the circuit. The higher the Q the better we can be sure that only one radio station will get through to the earphones. This is called receiver selectivity.

The detector separates the audio frequencies from the carrier that were added at the radio transmitter and passes all on to the earphones.

But before they get there they come to C2. Which is a very simple filter all by itself. It causes the carrier frequency to be short circuited to ground so it can't get to the earphones. The lower audio frequencies are not shorted out and so go on to the earphones. Thus C2 by itself acts like a low pass filter, in that it only allows very low frequencies to pass by.

This capacitor is ofter called a bypass capacitor when used this way.

We find band pass filters, low pass filters, and high pass filters, being used all over in radios. Sometimes they are given other names because of what they are filtering. So far we have seen a band pass filter used to tune stations so we called it a 'Tuner', and we saw a low pass filter being used to by-pass all the high frequencies from the earphones, hence called a bypass capacitor.

ELECTROMOTIVE FORCE

All the circuits we have looked at so far are passive in that they pass on a signal that they modified. The modified desired signal comes out with less power than the one entering had. The loss is in the form of heat.

With the simple radio we have been looking at, an electromagnetic wave crosses the antenna and transfers power to it. By the time the sound wave enters our ears there is far less power than in the wave hitting the antenna.

Unless you are very close to the transmitting station it will be only a few milliwatts of power, so its not going to be very loud!.

What causes electrons to flow in a wire conductor? Lets examine how a DC current is made to flow by looking at an analogy first. Later we will examine how AC currents are produced.

Think of a long hallway in a school that has a lot of old desks scattered around. In the empty spaces between the desks students are wandering around, but going nowhere. There is no room for any more guys, as all the spaces are filled. There is a door at each end of the hall that are closed. There is a pop machine outside one of the doors in a cubical with room for only 1 person.

The door is opened and someone yells free pop so everyone tries to the pop machine. One gets to it, but cannot get back in the hall because his way is blocked by others trying to get a pop, but there is no room. So no one can move.

If there is a door at the other end of the cubicle, as soon as a student gets his pop he is pushed out that door, but if there is no place for him to go he just stands at the door and does not go out so there can be no flow of students.

But if we have a circular hallway, so that door is the same door that enters the other end of the hall, he can get back in because as when he left everyone had moved down by one person towards the pop machine.

The flow of students would continue on forever as long as the pop held out. The guys would never stop heading for more pop because as we all know you can never fill a teen age boy!

The desks in the hall prevented them from running to the door because the desks in the way slowed them down. Without the desks they would have all run so fast that they would hit the door and pop machine in a big pile up that would destroy it.

Now think of the guys as electrons, the hall as a wire, the desks as molecules in the wire and the pop machine as a battery.

The battery attracts an electron out of the wire to go into the battery where it obtains energy, The electron is moved on out when the ends of the wire are connected in a circle so it can get in line again to get back to the battery for another jolt of energy. The scattered molecules act as a resistance so the electrons cannot move too fast and pile up and cause damage.

However the guys rushing through the hall had to push the desks around a lot to get more pop. In doing so they loose the energy they got from the last can of pop they drank and that energy went into moving the desks and created heat,

In a like manner the electron met with a resistance to their motion through the wire by bumping into the molecules. Thus the energy they obtained in the battery was used up in the form of heat.

Lets make the comparison more extensive.

To get a current flow in a wire we need to have electrons flowing in it. To get a flow we need something to attract the electrons. That is the positive pole of a battery

While in the battery the electron gets kicked out onto the negative pole. If there is nowhere for the electrons to go (open circuit) there is no flow. If the negative pole is connected to the positive pole creating a closed circuit and if the wire has no resistance to the flow (like no desks in the hall) there will be such a rush of electrons that the battery will certainly heat up and might even explode, or the wire heat up so much it melts, creating an open circuit. To prevent this we make sure that the wire that has a resistance to the flow. The energy picked up by the electron in the battery will be dissipated in the resistance as heat.

Just as a wide hall will let a greater number of students flow in a given time, a bigger diameter of wire will allow more current to flow. Just as a longer hall with desks in it will cause more resistance to the flow of students, longer resistance wire will also cause less current.
If the pop machine runs out of pop the students quit going for it and if the battery runs out of all its energy, the electric current stops.

If the pop machine gives out 2 cans instead of 1, the students will run faster to get a bigger jolt.
If the electromotive force of the battery is higher, the electron flow will also be greater.

ELECTROMOTIVE FORCE

In our example the pop machine provided the force to move the guys.
In an electrical circuit a battery provides the force to move the electrons. That is why we call this force an

ELECTROMOTIVE FORCE

The battery works by using a chemical reaction that causes extra electrons to move to the cathode post of the battery.

At the same time this leaves a shortage of electrons at the positive post.

This causes a potential difference between the posts that can be measured with a meter.
For most battery cells, the potential difference is about one to three volts depending on the metals used in the cell.

A dry cell has about 1.47 volts and the lead acid cell (car battery) has 2.0 volts.

The unit used to measure EMF is called the volt after Volta, a scientist who studied batteries.

Then how come my car battery is 12 volts?

Your car **battery** consists of six **cells** connected
In **series**

A **dry cell** (like those used in flash lights) is often called a battery in error.
A true battery always has a number of cells connected in series
Like the **car battery.**

When cells are connected in series their voltages are added together
So for the car battery

There are 6 two volt cells in series,
2+2+2+2+2+2=12.

For a 9 volt battery 1.5 + 1.5 + 1.5 + 1.5 + 1.5 + 1.5 = 9

Electromotive Force is too long to say or write so it is usually shortened to

EMF

Or sometimes just **voltage**

The symbol used in equations for EMF or Voltage is the letter E and not V.

The word battery used when cells are joined together comes originally from the military.

When a number of artillery guns were used together it was called a battery of guns because they were used together to batter down the enemy forces.
So cells used together in series took on the name battery.

Cells can also be joined in parallel.
Both cathodes are joined and both anodes are joined together

Only cells with the same voltage should be joined in this manner!

The voltage of cells connected in this way is the same as the EMF of each cell.

CURRENT

Just like the amount of water flowing down a river per second is called the current, the number of electrons flowing through a wire per second is called the current.

Since it takes an exceedingly large number of electrons to provide any power we don't use one electron per second as the unit for current.
If we did that Ohm's law would have a huge constant in the formula.
The unit picked was so that Ohms Law would not need a constant included to make it work.

This unit is called the **ampere** after a scientist of that name. Nobody ever calls it ampere however, but a shorter version of **amp.**

OHM'S LAW

Since the force causing electrons to flow is EMF

The greater (larger) the EMF is, the more electrons that will flow per second.

The less (smaller) the resistance to the flow is, the more that will flow per second.

OHM'S LAW

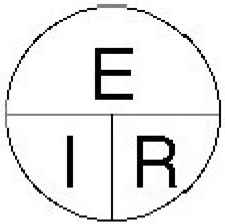
THE FORMULA THAT SHOWS THIS RELATIONSHIP IS KNOWN AS OHM'S LAW

The symbol used for Current in Ohm's Law is I (for intensity)
And the symbol used for Resistance is R.

E=IR

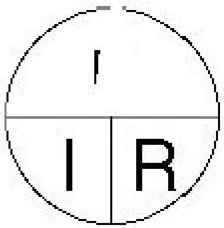
I=E/R OR R=E/I

Where E is measured in volts, I measured in amps, and R measured in Ohms



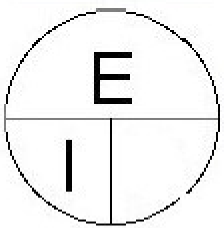
Here is an easy way to remember how to find the desired formulae for Ohm's Law.

Just draw this figure, (from your memory) **So memorize it !**

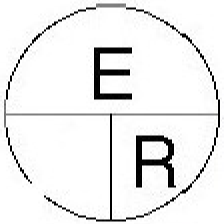


Put your thumb over the one you want to find, in this case E.

You see I and R side by side so that means they are multiplied to give you the value of E



With your thumb over the R you see E over the I which means you divide the E by the I to give the value of R



Here you see that to find the value of I you need to divide E by the value R.

POWER & POWER LAW

The amount of power available from a river depends upon two things:

1. the force of the flow of water in the river

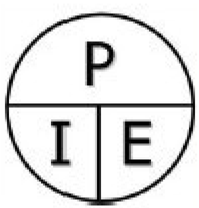
2: The size of the river, (i.e. The amount of water flowing per second.)

The same applies to electricity.

1. The force pushing the electrons is called EMF or voltage.

2. The amount (number) of electrons flowing per second (the current in amps).

The unit of measurement for the power is the Watt after James Watt who worked with steam power.



P is the symbol for power, Use the same trick you used for Ohm's Law using the symbol to the left. P in watts E in volts and I in Amps

OPTIONAL EXTRA READING

Provided to challenge you to think.

NOT REQUIRED FOR THE EXAM

The earliest battery (actually a cell) discovered comes from ancient Egypt.
It consisted of a clay cup and two metal bars fixed on opposite edges, with the top sealed with pitch, with the bars poked through the pitch. This is very similar to the first cells made in modern times. What use they made for such a cell back then is not known.

The first cells used in more recent times consisted of two different metals such as zinc and copper bars placed in an electrolyte filled jar, held in place with a pitch insulator top. The electrolyte used can be salt water, or lemon juice, etc.

One of the improvements made later was to make the jar out of zinc with a rod made of carbon suspended in the centre by pitch. Since the electrolyte tends to evaporate or worse yet, to leak out, it was mixed with a filler to produce a paste, to create what was called a **dry cell**. If left in a flashlight the paste eat holes through the zinc container/negative pole releasing electrolyte to damage the flashlight (or radio, etc). To prevent this Mallory placed it all inside a steal container to produce the first **leak-proof dry cel**l!

Today cells may use an **alkali** instead of acid as electrolyte, or use a **mercury amalgam** as one of the metals for the pole.

Rechargeable cells are made so if you pass an electric current through it in the opposite direction it will plate the metal back onto the pole that the acid ate away in producing electricity. This allows a cell or battery to last much, much longer.

Fuel Cells

Fuel cells use oxygen in place metal as the cathode. Cells wear out because the cathode is eaten away by the electrolyte to produce the electrical current. Rechargeable cells plate the metal back by using a reverse current flow through the cell. This repair is never makes it as good as it was before and after a number of recharges electrolyte escapes.

In an **air cell** the oxygen in the air is used as the cathode and is replaced as fast as it is used up. Since air is not pure oxygen it is not as efficient as a metal and it is very difficult to make an electrical connection to oxygen, so the cell is very complicated and expensive to manufacture. The material that holds the oxygen becomes contaminated in time and the cell ceases to function when the oxygen can no longer be replaced from the air.

Other methods can be used to supply the oxygen rather than using air. Oxygen is part of the molecular structure of the material making up the cathode and when it is removed the cell can replace the material providing it is a liquid or gas, and the old material can be removed. Such materials as natural gas, alcohol etc. are used**. T**his cell is called a fuel cell as it is somewhat similar to burning a fuel to produce electricity directly instead of heat. Impurities again mean the fuel cell finally fails.

In the early 50's about 100 homes in Calgary were equipped with natural gas fuel cells to produce all the electricity the home needed at a much lower cost than purchasing conventional electricity. Maintenance costs along with the fact DC electricity is hard to use, made it impractical for home use, and the fuel cells were removed after a few years.

Jargon used in Lesson 3.

Schematic Diagram
Schematic Symbol
Electric ground
Insulator
Transformer
Coil
Step-down transformer
Step-up transformer
Resistor
Capacitor
Condenser
Semi-conductor
Tuned circuit
Resonant circuit
Parallel tuned circuit
Q factor
Filter
Tuner
Selectivity
Audio frequency
Short circuit
Bypass capacitor

Low pass filter
EMF
Electromotive Force
Potential difference
Volt
Cell
Battery
Series
Parallel
Dry cell
Voltage
Current
Amp
Ohm's Law
Power
Power Law
watt

Topics Covered in Lesson Three

Schematic Diagrams
EMF
Current
Power and Power Law
Ohm"s Law
Electric Cells
Electric cells in series
Electric Cells in parallel
Batteries
Schematic symbols
Left to right, top to bottom rule

Coming in Lesson Four

Resistance
Series Resistance
Parallel Resistance
Alternating Current
Peak Value
RMS Value
Peak to Peak value

Heterodyne
Carrier
Side Bands
Single Sideband
Suppressed Carrier
Super Heterodyne

End of Lesson 3

Radio Receivers