ADVANCED

Lesson 5

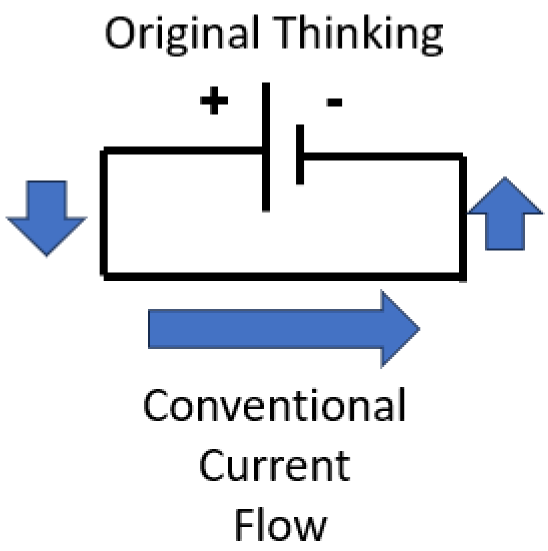
MAGNETISIM AND ALTERNATING CURRENT

ACMA Syllabus February 2024 Chapters 1.4 , 1.6 and 2.4

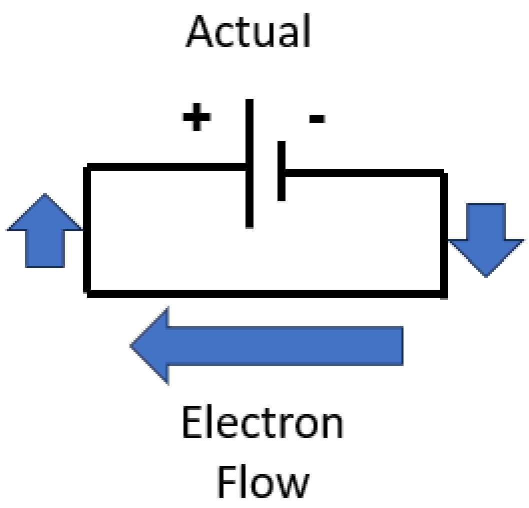
Contents

Conventional Current Flow and Electron flow.

Benjamin Franklin (1706 – 1790) proposed that static electricity is an “electric fluid” that moved from a positive (+) source to a negative (**---)** source. This thinking, called “Conventional Current Flow”, persisted and was the basis for many future experiments in magnetism and electricity.



In 1897, JJ Thomson was experimenting and discovered that the electrons, orbiting the atom, moved from a negative source to a positive. Electron flow is important in understanding components such as valves, transistors and diodes.



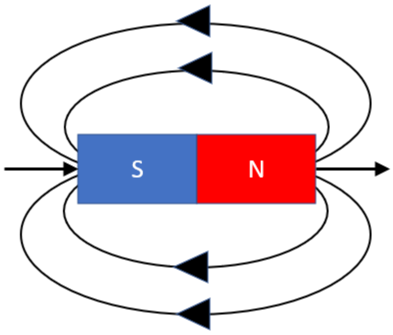
This is important to understand both concepts as many electrical theories were developed before the movement of electrons was understood.

The first place you will strike Conventional Current Flow in Ampere’s and Fleming’s Laws.

Magnets

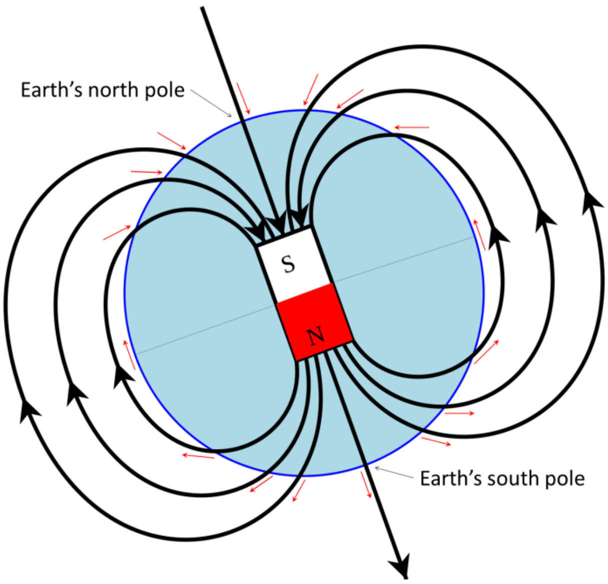
Magnetism is an invisible force or field that causes objects to attract or repel one another.

A magnet is an object holding an invisible field that can attract ferromagnetic materials. Magnets have North and south poles. Opposite poles attract and like poles repel.



The magnetic field emanates from the North to the South pole.

Magnetic compasses work because the Earth is a magnet. A compass indicates to magnetic North which is really the earth's south pole. Opposites attract.



Flux density, B, is a measurement of the density of magnetic field lines.

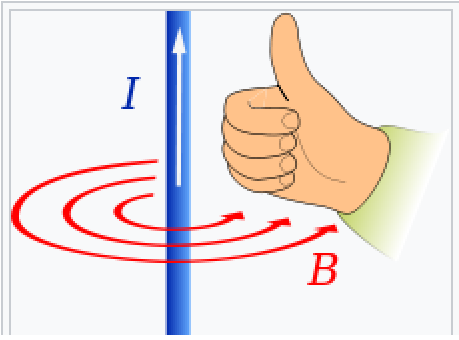
Magnetic flux is a measurement of the total number of magnetic field lines passing through a given area.

Induced Magnetism

A magnetic field is induced in a wire when a current passes through the wire. The direction of the magnetic flux is determined by **Ampere's Right Hand Rule**.

Wrap your right hand round the wire with the thumb pointing in the direction of the conventional current flow, the fingers represent the magnetic flux direction.

NOTE – Conventional current flow so the thumb is pointing to the negative terminal.

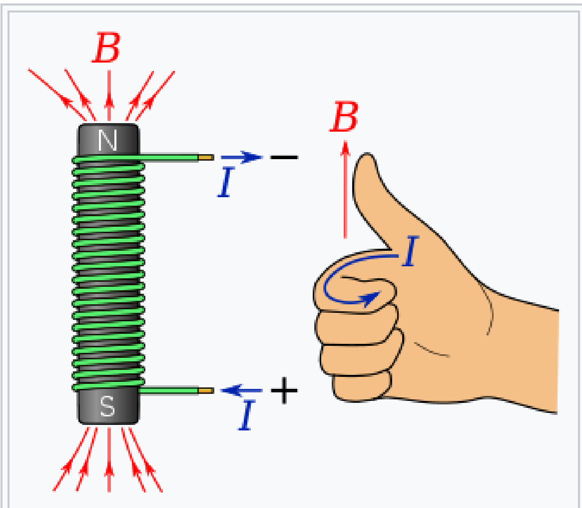


Wikipedia

NOTE – Conventional current flow so the thumb is pointing to the negative terminal.

Ampere's second Right Hand Rule also refers to the magnetic field generated when a current is passed through a solenoid.

Wrap your right hand round the solenoid with your fingers pointing in the direction of the conventional current flow and the thumb points in the direction of the North pole.



Wikipedia

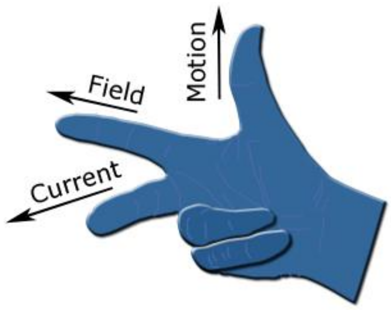
NOTE – Conventional current flow so the wrapped fingers point so current flows positive to negative.

Induced Current

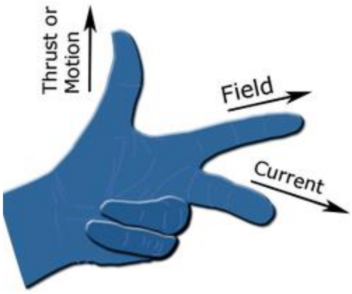
Electricity is generated by moving a conductor through a magnetic field. As the conductor passes through a magnetic field, electrons will move along the conductor in one direction. Reverse the field and current flows in the opposite direction.

Fleming's right-hand rule (for generators) shows the direction of induced current (conventional current flow) when a conductor attached to a circuit moves in a magnetic field. (Right to generate)

NOTE – Conventional current flow so the current finger is pointing to the negative terminal.



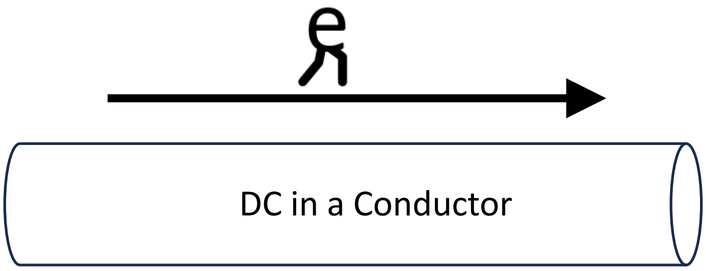
Fleming's left-hand rule (for electric motors) is a simple way of indicating the direction of motion of a conductor (conventional current flow) in a magnetic field. (Left to motor)



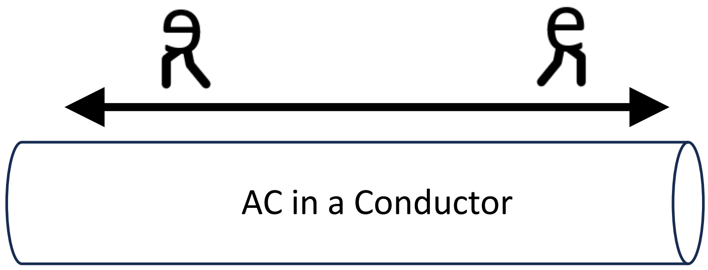
NOTE – Conventional current flow so the current finger is pointing to the negative terminal.

Alternating Current

Up till now we dealt with Direct Current (DC) where the electrons only moved in one direction.

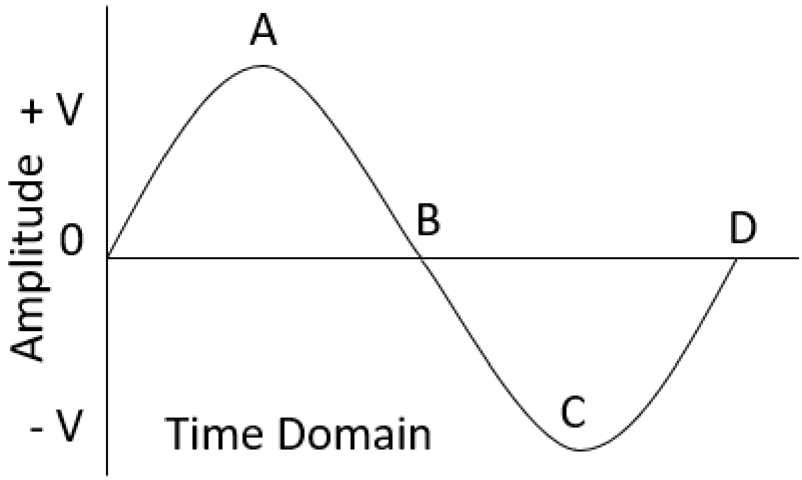


Alternating current (AC) is where the directional flow of electrons, in a conductor, switch back and forth at regular intervals or cycles.



This flow over time is shown as a sinusoidal wave. The number of cycles back and forth is termed the frequency (f) and is measured in Hertz (Hz).

Sinusoidal (Sine) Wave



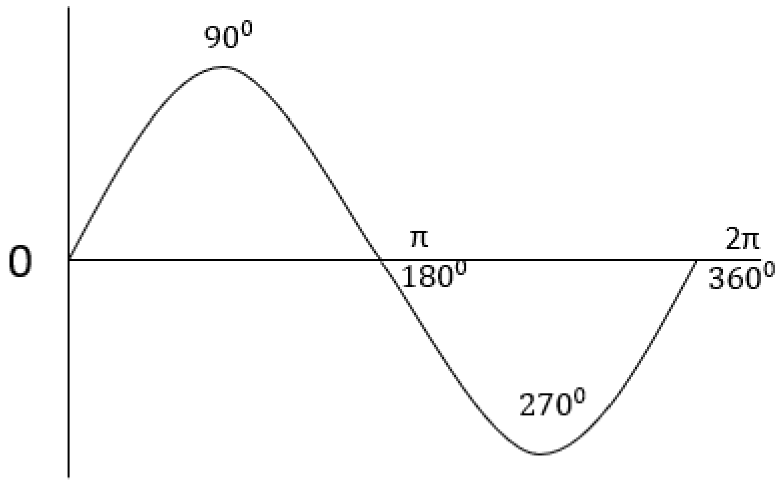
In AC, the electrons move positively from 0 with the maximum positive voltage reached at point A. Between point A and B, the electrons slow and come to a halt at point B.

Between point B and C, the electrons are flowing in the negative direction and reach a maximum negative voltage at point C. Between point C and D, the electrons slow and stop at point D.

Between point 0 and point D is **one cycle** which is repeated over and over for alternating current.

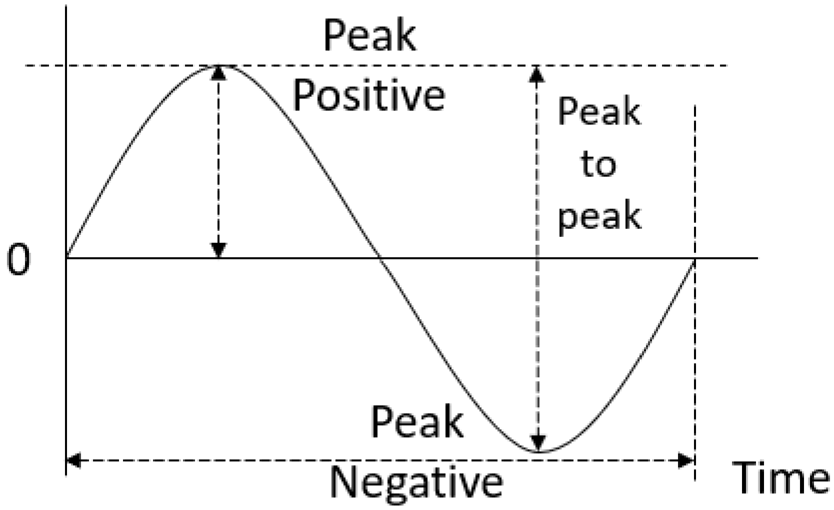
Angles

The shape of the sine wave is derived from a moving circle so the wave can be related in degrees to a circle.



- The maximum positive voltage is at the 90-degree point.
- The point where the electrons change direction is the 180-degree point.
- The maximum negative voltage is at the 270-degree point.
- The cycle starts again at the 360 degree or 0-degree point.

Voltages



The **peak value** is the highest voltage value reached in either direction.

Peak to peak value is the measurement between the positive peak and the negative peak.

Time per cycle also called the "**Period".**

Examples: If the peak positive and negative value is +50v and - 50v the peak-to-peak value is 100v.

If the peak-to-peak value is 200v then the peak positive value is +100v and the peak negative value is -100v.

RMS

As the AC is constantly changing in value, the voltage that would produce the same work or heating value to a DC voltage can be found and is called the Root Mean Squared (RMS) value. The RMS value is the 45-degree point in the cycle.

RMS = 0.707 x Peak value

or

Peak value = RMS / 0.707

Note: AC voltages and currents are normally quoted in RMS values unless stated otherwise. Using a **multimeter** to read the mains voltage, the reading the meter gives is the RMS value. In Australia the mains voltage is measured as **RMS 230v**. The peak voltage is **325v**.

Examples: The peak voltage is 325 v AC. What is the RMS value?

RMS = 0.707 x Peak voltage

RMS = 0.707 x 325

RMS = 230 v

The RMS value is 230v. What is the peak voltage?

Peak voltage = RMS / 0.707

Peak voltage = 230 / 0.707

Peak voltage = 325v

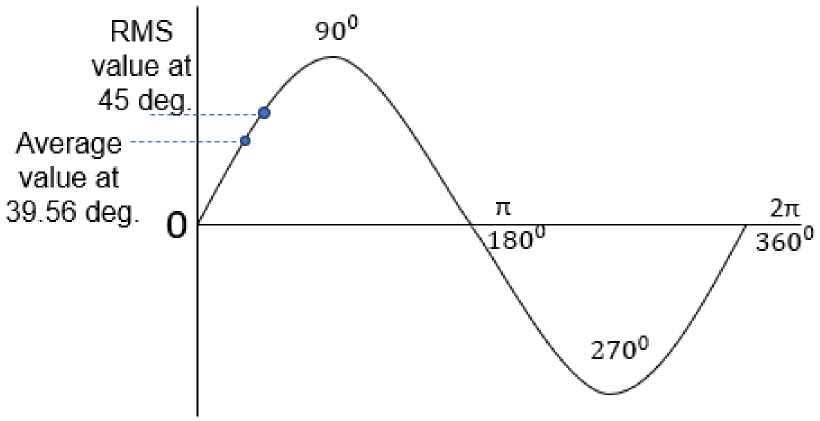
Average valve

The average value of sine wave over one complete cycle is zero as the two halves cancel each other. The average value is taken over half a cycle and is 0.637 times the peak value. The angle for the average value is 39.56847907 degrees.

Average value = 0.637 x Peak value.

Example: 10V peak sine wave. What is the average value?

10 x 0.637 = 6.37 V



Instantaneous value

The voltage or Instantaneous value at any point along the wave, regarding the angle, can be calculated by the formula below.

$$E_{int} = E_{Peak}\ x\ Sine\ (\theta)$$

Example: What is the instantaneous voltage at 30^0 if the peak voltage is 339v.

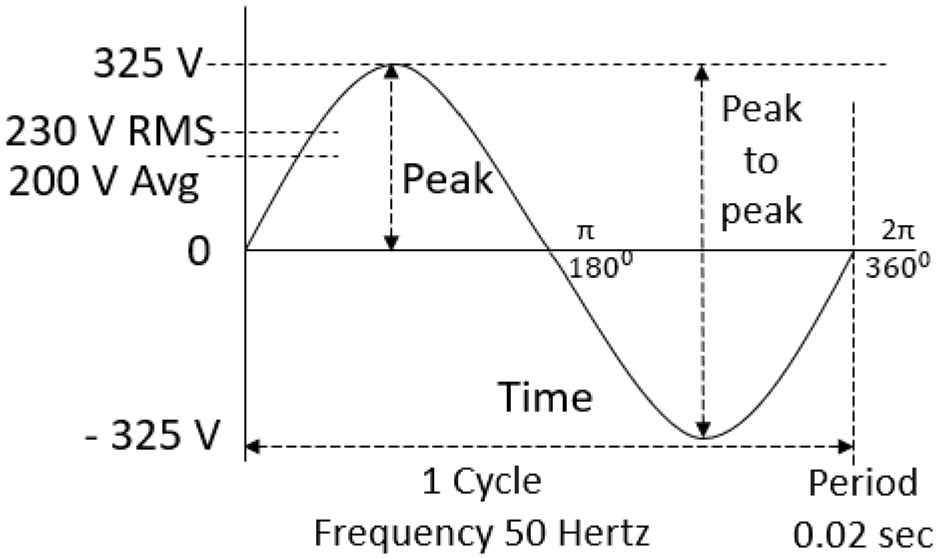
E int = 339 x Sine (30)

E int = 339 x 0.5

168 V

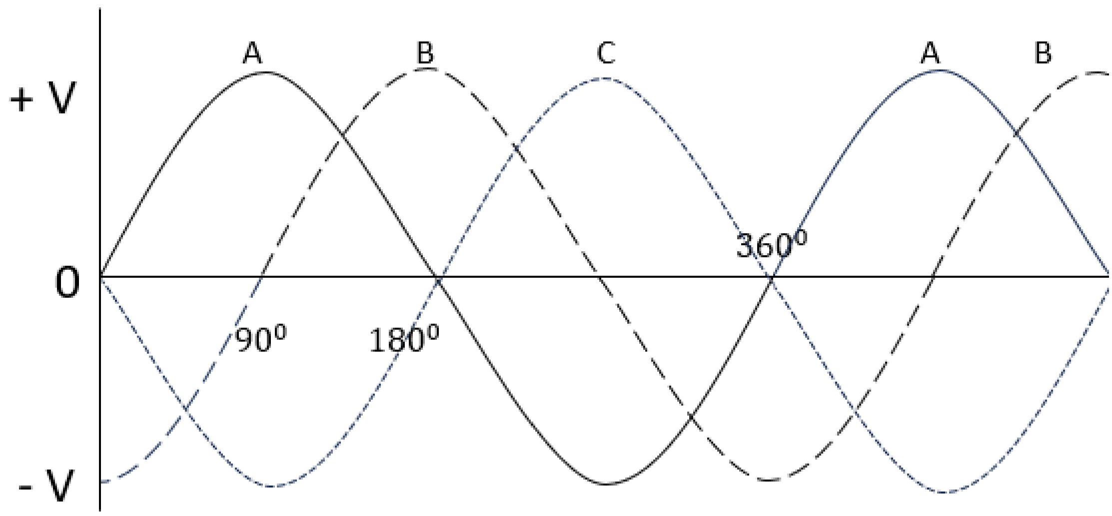
Australian Mains Power

Below is the wave form of the Australian mains power. This figure demonstrates all the points covered so far.



Phase

We know the sine wave can be related to a 360-degree circle Starting at 0^0 and moving right. The cycle has a positive peak at $90^{0,}$ passes through 0 again at 180^0, a negative peak at 270^0 and returns to 0 at 360^0. If we change the starting point for a cycle, we can get a phase shift. In the figure below, we have three waves 90 degrees apart. This phase difference between two sine waves can be measured.



Wave B is 90^0 out of phase with wave A. B and C are 90^0 out of phase. A and C are 180^0 out of phase. Wave A and C will cancel each other out as A is going positive, B is going negative.

A practical example is three phase power. This is a common power supply for heavy load electric machines. Each wave is 120^0 apart and they are the same amplitude and frequency. See Figure 4 from Wikipedia.

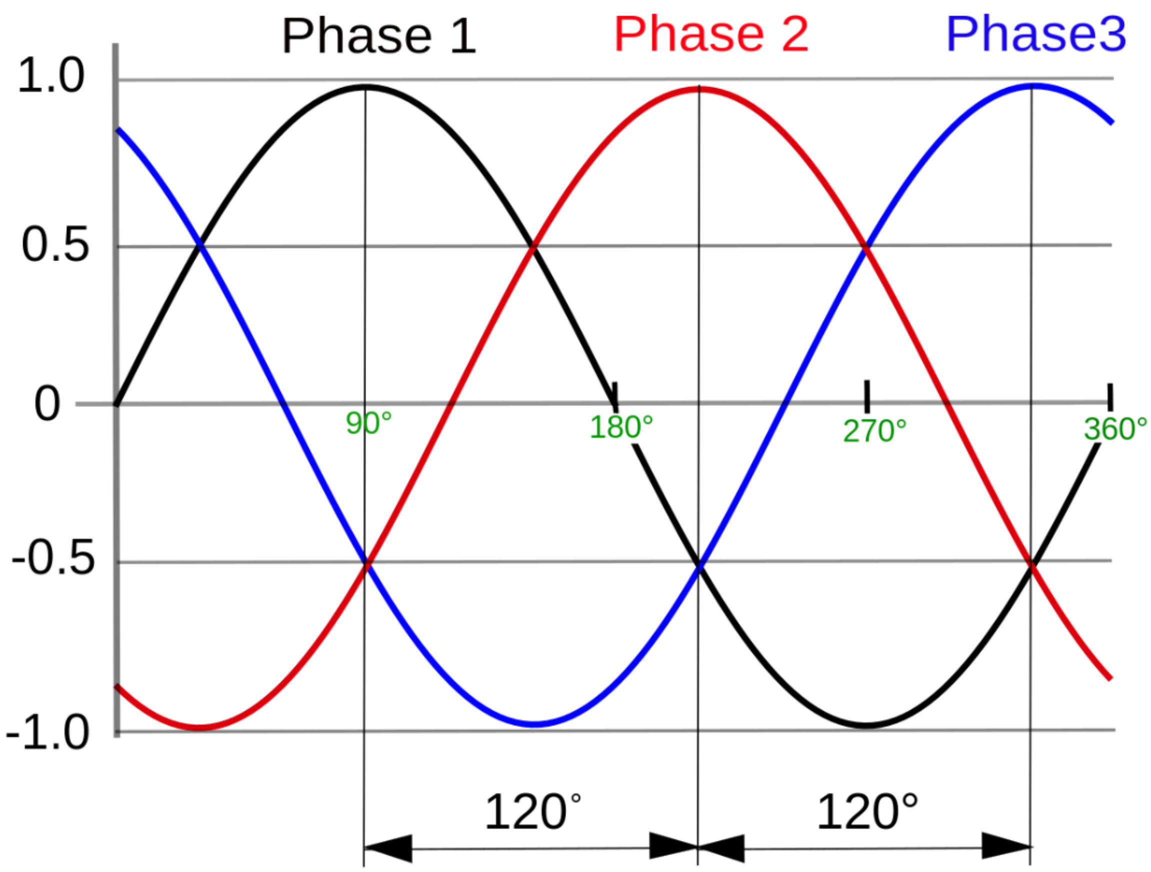


Figure 4

Frequency, Period and Harmonics

A **cycle** is measured from the point where the wave crosses the zero line, goes positive then goes negative and back to the zero line. The time taken for a cycle is called the period.

Period

Period (P) is the time taken for one cycle. Period is measured in seconds.

$$p = \frac{1}{f}$$

Example: What is the period for a frequency of 144MHz?

p = 1 / 144,000,000

p = 0.000000069 seconds or 6.9 nS

Frequency

Frequency (f) is measurement of cycles per second and is measured in Hertz. (Hz) after Heinrich Rudolf Hertz (1857–1894).

$$f = \frac{1}{P}$$

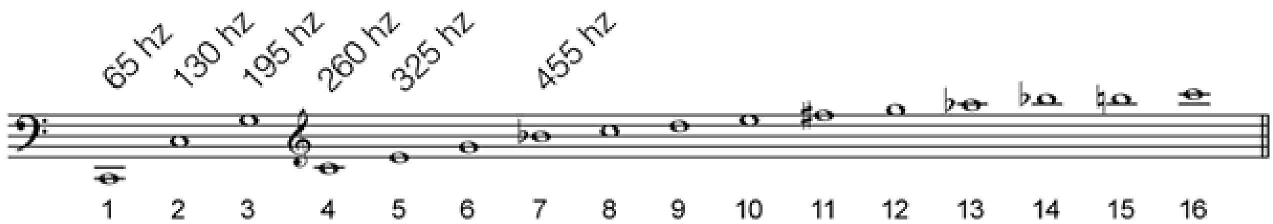
Example : What is the frequency if the period is 0.02 seconds?

f = 1 / 0.02

f = 50 Hz

Harmonics

A harmonic is a frequency that is a multiple fundamental frequency. The fundamental frequency is also called the 1st harmonic and multiples of this frequency are called higher harmonics.



The second harmonic is twice the fundamental frequency. The third harmonic is three times the fundamental frequency.

If the fundamental frequency is 2 MHz, the harmonics will be a multiple of this fundamental frequency.

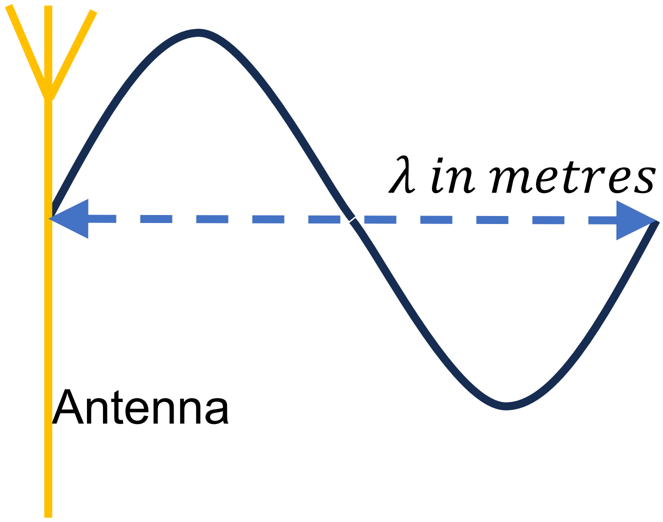
Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic
2 MHz	4 MHz	6 MHz	8 MHz

Example: What is the 3rd harmonic of 14 MHz?

14 x 3 = 42 MHz

Wavelength

Waves travel at the speed of light unless constrained. The distance a wave, of a given frequency, would travel in one cycle, is called the wavelength. The wavelength is measured in metres and has the symbol lambda (λ)



Formula

$$\lambda = c/f$$

$\lambda = Wavelengh$

$\mathrm{C} = \text{constant } 300 \text{ x } 10^6 \text{ metres per second}$

$\mathrm{f} = \text{frequency in Hz}$

Example: What is the wavelength of a wave with a frequency of 144MHz?

Wavelength = 300,000,000 / 144,000,000

λ = 2.083 metres

The 2-metre band.

Radio Frequency Spectrum

The radio frequency (RF) spectrum is the segment of the electromagnetic spectrum used for radio waves, spanning roughly 3 kHz to 300 GHz.

The radio frequency spectrum is divided into groups based on the number three for ease of memory. See below.

Abbreviation	Classification	Range from	Range to
VLF	Very low Frequency	3 kHz	30 kHz
LF	Low frequency	30 kHz	300 kHz
MF	Medium Frequency	300 kHz	3 MHz
HF	High Frequency	3 MHz	30 MHz
VHF	Very High Frequency	30 MHz	300 MHZ
UHF	Ultra-High Frequency	300 MHz	3 GHz
SHF	Super High Frequency	3 GHz	30 GHz
EHF	Extremely High Frequency	30 GHz	300 GHz

Advanced Frequencies

Australian advance amateur operators have access to 26 bands across spectrum. The frequencies start in the LF band and go to the EHF band. There are no amateur frequencies in the VLF band.

Know your frequencies.

Band	Frequency	Classification
2200 m	0.135 - 0.1378 MHz	Low Frequency (LF)
630 m	0.472 – 0.479 MHz	Medium Frequency (MF)
160 m	1.8 – 1.875 MHz	Medium Frequency (MF)
80 m	3.5 – 3.7 and 3.776 – 3.8 MHz	High Frequency (HF)
40 m	7 – 7.3 MHz	High Frequency (HF)
30 m	10.1 – 10.15 MHz	High Frequency (HF)
20 m	14 – 14.35 MHz	High Frequency (HF)
17 m	18.068 – 18.168 MHz	High Frequency (HF)
15 m	21 – 21.45 MHz	High Frequency (HF)
12 m	24.89 – 24.99 MHz	High Frequency (HF)
10 m	28 – 29.7 MHz	High Frequency (HF)
6 m	50 – 54 MHz	Very High Frequency (VHF)
2 m	144 – 148 MHz	Very High Frequency (VHF)

Band	Frequency	Classification
70 cm	430 – 450 MHz	Ultra High Frequency (UHF)
23 cm	1240 – 1300 MHz	Ultra High Frequency (UHF)
13 cm	2300 - 2302 and 2400 – 2450 MHz	Ultra High Frequency (UHF)
10 cm	3300 – 3425 and 3575 – 3600 MHz	Super High Frequency (SHF)
6 cm	5650 – 5850 MHz	Super High Frequency (SHF)
3 cm	10 – 10.5 GHz	Super High Frequency (SHF)
1.25 cm	24 – 24.025 GHz	Super High Frequency (SHF)
7.5 mm	47 – 47.2 GHz	Extremely High Frequency (EHF)
3.7 mm	76 – 81 GHz	Extremely High Frequency (EHF)
2.5 mm	122.25 – 123 GHz	Extremely High Frequency (EHF)
2 mm	134 – 141 GHz	Extremely High Frequency (EHF)
1.25 mm	241 250 GHz	Extremely High Frequency (EHF)

Go to Lesson 5 Questions.