5. AC FUNDAMENTALS. (10 Hours) 5.1 The simple AC generato

r. 5.1.1 Sine wave, cycle, wavelength, period, frequency and units.

5.1.2 AC sine wave form and its characteristics. (Instantaneous, peak, average, rms or effective values and their inter relation)

. 5.1.3 Audio and Radio frequencies, wavelengths and periods frequency spectrum.

5.1.4 Types of alternating wave forms(sinusoidal and non-sinusoidal waves). Fundamental wave and harmonics

. 5.2 AC Circuits

5.2.1 AC through pure resistance, Phaser quantities.

5.2.2 Phase angle, in-phase, out of phase waves and phase lag & lead and power factor.

5.2.3 Calculation of V,I and W for resistive circuits through inductance.

5.2.4 Self inductance, and self induced voltage.

5.2.5 Inductive reactance ($XL=2\pi fL$) Phase relation between V & I

. 5.2.6 Phaser diagram and power for pure inductor.

5.2.7 AC through R-L series circuit. 5.2.8 Phaser diagram and power in a R-L series circuit

. 5.2.9 Time constant ,$\tau = L/R$, and its effect.

5.2.10 Impedance, Impedance triangle.

5.2.11 AC through R-L parallel circuit.

5.2.12 Inductive reactance in series, parallel and series-parallel combination.

5.2.13 Skin effect, AF and RF chokes.

5.2.14 Troubles in chokes.

5.2.15 AC through pure capacitor. Phase relation between V&I and power.

5.2.16 Capacitive reactance

5.2.17 AC through R-C series circuit.

5.2.18 Time constant RC and its effect.

5.2.19 Impedance, Impedance triangle.

5.2.20 AC through R-C parallel circuit.

5.2.21 Capacitive reactance in series, parallel, and series parallel combination

. 5.2.22 AC through RLC series circuit, phase relation and power calculation.

5.2.23 AC through RLC parallel circuit phase relation and power calculation.

5.2.24 Simple calculations for RLC circuits.

5.2.25 Concepts of real Power (VI CosΦ) and apparent power (VA), power factor. simple calculations.

Frequency, Cycle, Wavelength, Amplitude and Phase

FREQUENCY

RF Frequency is a electromagnetic wave using AC (Alternating Current).

Just as the name implies, "frequency", its something that happens over and over and over again. It is very frequent, consistent, and repetitive.

There are different types of frequency; light, sound and in our case radio frequency (RF).

"*Frequency is the number of times a specified event occurs within a specified time interval. A standard measure of frequency is hertz (Hz)" - The CWNA definition of frequency v106*

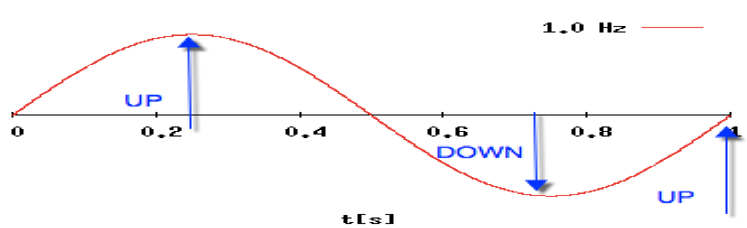
This specified event mentioned in the CWNA Study Guide is the cycle.

CYCLE

"*An oscillation, or cycle, of this alternating current is defined as a single change from up to down to up, or as a change from positive, to negative to positive." - The CWNA definition of cycle v106*

Lets look at a few examples of a Cycle.

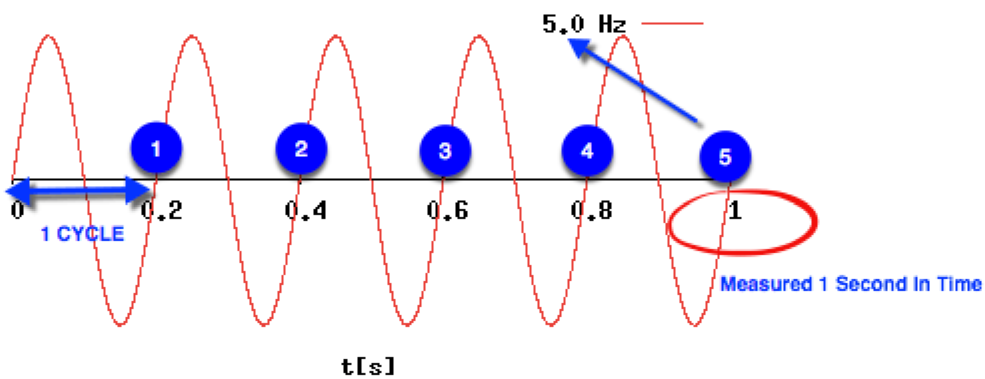
Example 1 - (1) Cycle



One cycle, specified event, is measured 1 second in time which equals 1 Hz. As the CWNA mentioned, "alternating current is defined as a single change from up to down to up, or as a change from positive, to negative to positive"

Example 2 - (5) Cycles

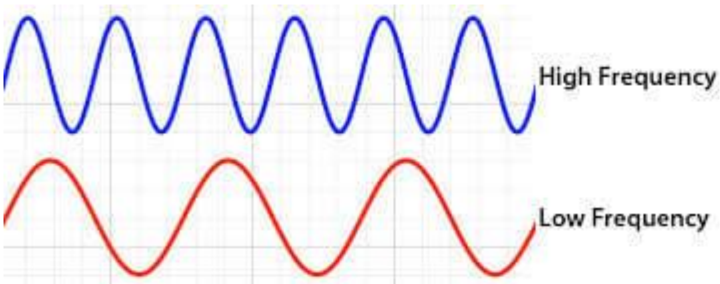
Five cycles, specified events, measured 1 second in time which equals 5 Hz.



We are dealing with simple math - 1 and 5 cycles per second. Imagine for a moment 2,400,000,000 / 5,000,000,000 billion cycles in 1 second. Thats a lot of cycles, eh ? That is the number of cycles 2.4 GHz and 5 GHz (WiFi) uses to transport data from one radio over the air to another radio.

High frequency simple means there are more cycles per second.

Example 3 - Low and High frequency example

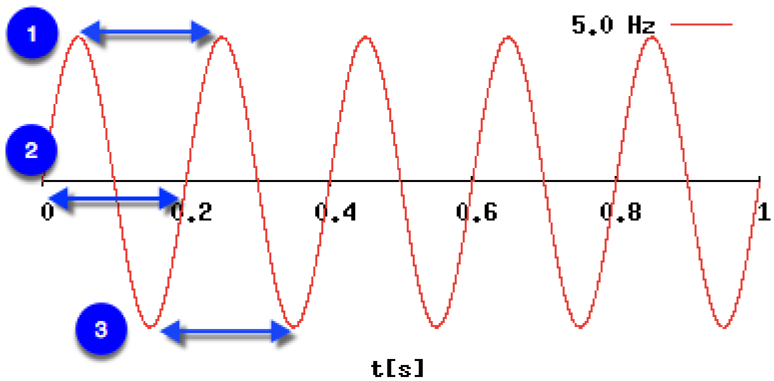


So — Remember —- Frequency is simply something that repeats itself over and over again. It is measured in cycles per seconds. The more cycles per second, the more **frequency or referenced as higher frequency.**

WAVELENGTH *"Wavelength is the distance between similar points on two back-to-back waves." - The CWNA definition of Wavelength v106*

RF Waves can be measured at different points. In the below example, reference #1 is the most often way wavelength is measured.

Example 4

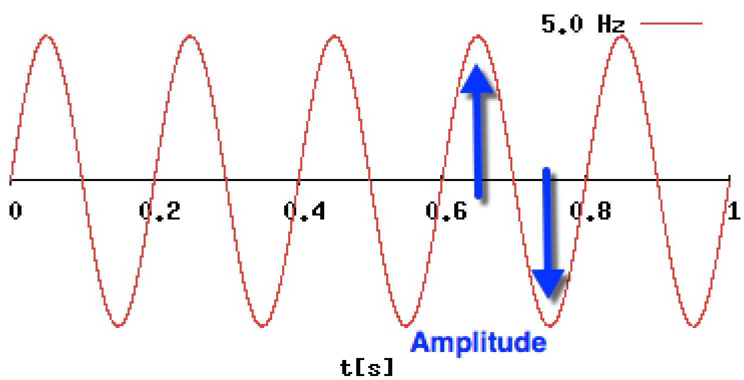


AMPLITUDE

"Amplitude is the height, force or power of the wave" - The CWNA definition of Amplitude v106

What is important to remember — frequency, cycle and wavelength remain constant, however, the hight of the wave form is dynamic based on the power of the wave. The higher power, or amplitude, the higher the wave form peeks. The lower the power, or amplitude, the lower the wave form peeks all while frequency, cycle and wavelength remain the same.

Example 5 - Amplitude shown by the hight or peeks of the wave form.



PHASE

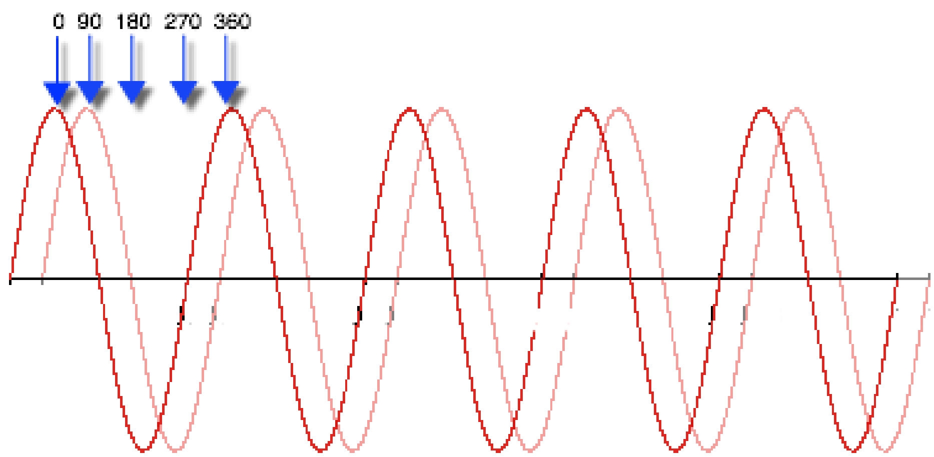
Phase is the same frequency, same cycle, same wavelength, but are 2 or more wave forms not exactly aligned together.

"Phase is not a property of just one RF signal but instead involves the relationship between two or more signals that share the same frequency. The phase involves the relationship between the position of the amplitude crests and troughs of two waveforms.

Phase can be measured in distance, time, or degrees. If the peaks of two signals with the same frequency are in exact alignment at the same time, they are said to be in phase. Conversely, if the peaks of two signals with the same frequency are not in exact alignment at the same time, they are said to be out of phase." - The CWNA definition of Phase v106

Example 6

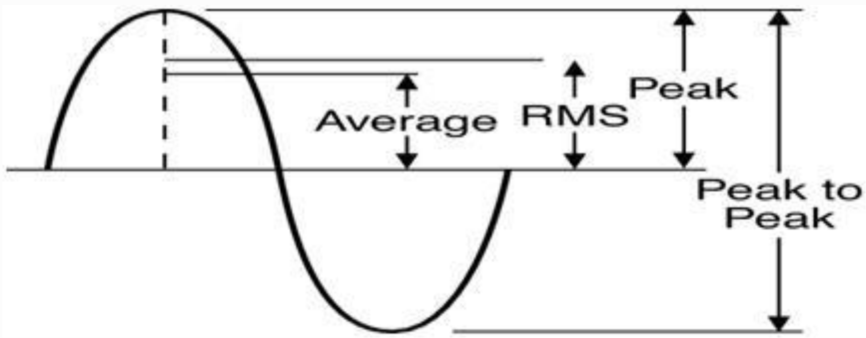
Below is an example of 2 wave forms 90 degree out of phase.



"What is important to understand is the effect that phase has on amplitude when a radio receives multiple signals. Signals that have 0 (zero) degree phase separation actually combine their amplitude, which results in a received signal of much greater signal strength, potentially as much as twice the amplitude. If two RF signals are 180 degrees out of phase (the peak of one signal is in exact alignment with the trough of the second signal), they cancel each other out and the effective received signal strength is null. Phase separation has a cumulative effect. Depending on the amount of phase separation of two signals, the received signal strength may be either increased or diminished. The phase difference between two signals is very important to understanding the effects of an RF phenomenon known as multipath, " - The CWNA definition of Phase v106

Peak vs. Average vs. RMS Voltage

The term "RMS" stands for "Root-Mean-Squared", also called the AC equivalent to DC voltage.

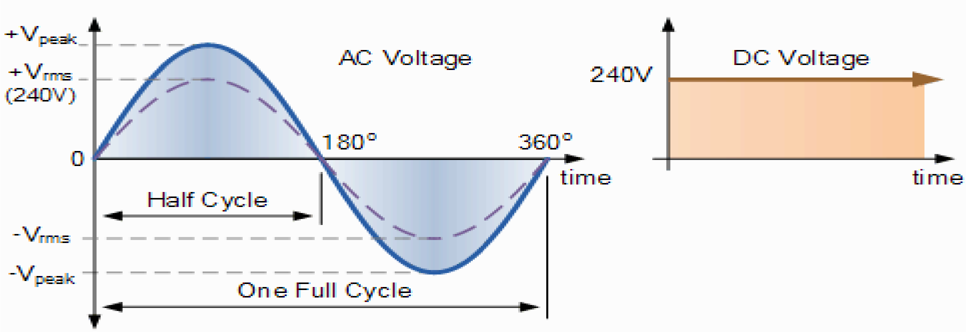


The term "RMS" stands for "Root-Mean-Squared", also called the effective or heating value of alternating current, is equivalent to a DC voltage that would provide the same amount of heat generation in a resistor as the AC voltage would if applied to that same resistor.

RMS is not an "Average" voltage, and its mathematical relationship to peak voltage varies depending on the type of waveform. The RMS value is the square root of the mean (average) value of the squared function of the instantaneous values.

Since an AC voltage rises and falls with time, it takes more AC voltage to produce a given RMS voltage than it would for DC. For example, it would take 169 volts peak AC to achieve 120 volts RMS (.707 x169).

In this example, the heating value of the 169 AC voltage is equivalent to that of a 120 volt DC source. Most multi-meters, either voltmeters or ammeters, measure RMS value assuming a pure sinusoidal waveform.



Peak Voltage (Vp)

The maximum instantaneous value of a function as measured from the zero-volt level. For the waveform shown above, the peak amplitude and peak value are the same, since the average value of the function is zero volts.

Peak-to-Peak Voltage (Vp-p)

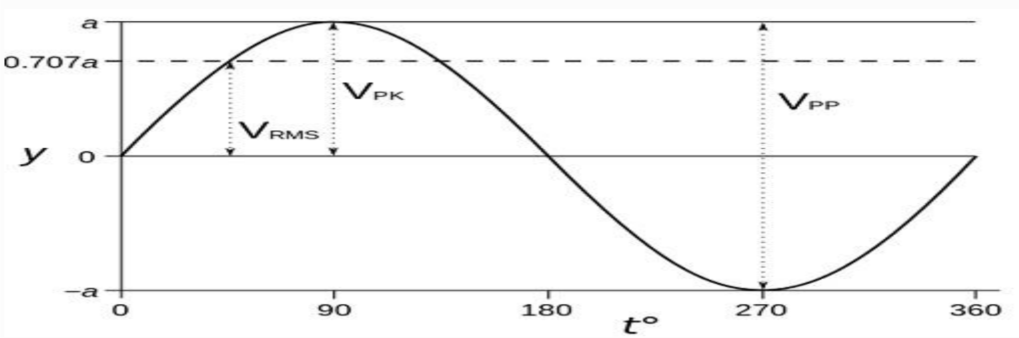
The full voltage between positive and negative peaks of the waveform; that is, the sum of the magnitude of the positive and negative peaks.

RMS Voltage (Vrms)

The root-mean-square or effective value of a waveform.

Average Voltage (Vavg)

The level of a waveform defined by the condition that the area enclosed by the curve above this level is exactly equal to the area enclosed by the curve below this level.



Important Equations to Remember

- Vp x .707 = Vrms
- Vrms = 1.11 x Vavg
- 1.414 x Vrms= Vp
- Vavg= .637 x Vp

What is Radio Frequency?

RF is the lowest portion in the electromagnetic spectrum familiar as a medium of analog and modern digital wireless communication systems. It spreads in the range between 3 kHz and 300 GHz. All known transmission systems work in the RF spectrum range including analog radio, aircraft navigation, marine radio, amateur radio, TV broadcasting, mobile networks, and satellite systems. Let's take a look at each of the RF sub-bands and the areas of RF spectrum uses.

Radio Frequency Spectrum: Ranges

Designation	Abbreviation	Frequencies	Wavelengths
Very Low Frequency	VLF	3 kHz - 30 kHz	100 km - 10 km
Low Frequency	LF	30 kHz - 300 kHz	10 km - 1 km
Medium Frequency	MF	300 kHz - 3 MHz	1 km - 100 m
High Frequency	HF	3 MHz - 30 MHz	100 m - 10 m
Very High Frequency	VHF	30 MHz - 300 MHz	10 m - 1 m
Ultra High Frequency	UHF	300 MHz - 3 GHz	1 m - 100 mm
Super High Frequency	SHF	3 GHz - 30 GHz	100 mm - 10 mm
Extremely High Frequency	EHF	30 GHz - 300 GHz	10 mm - 1 mm

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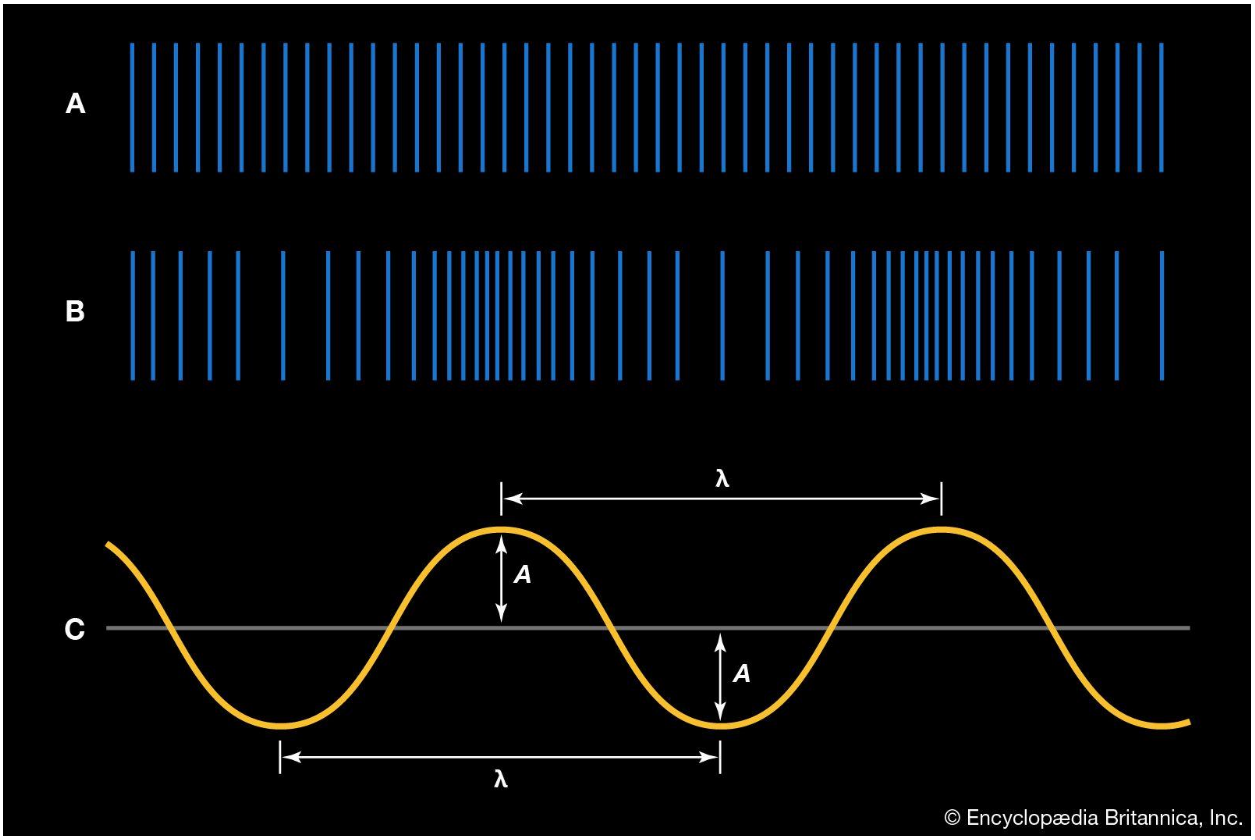
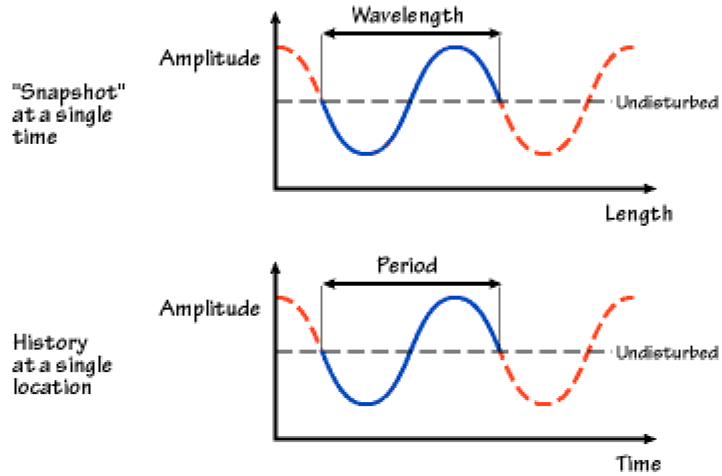
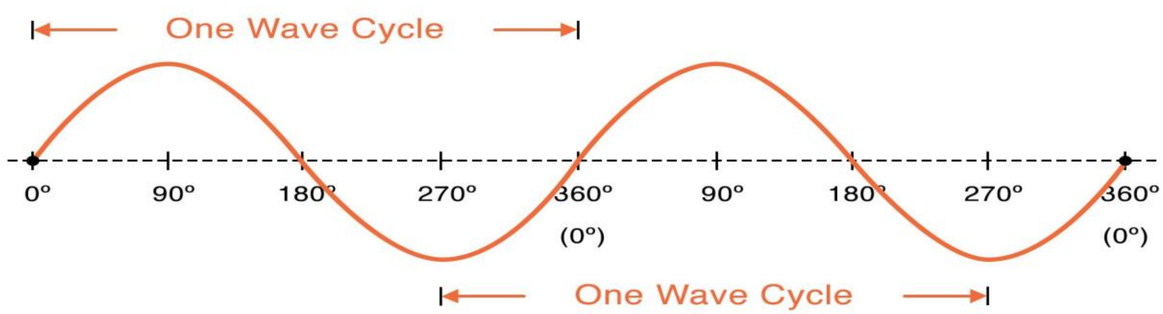


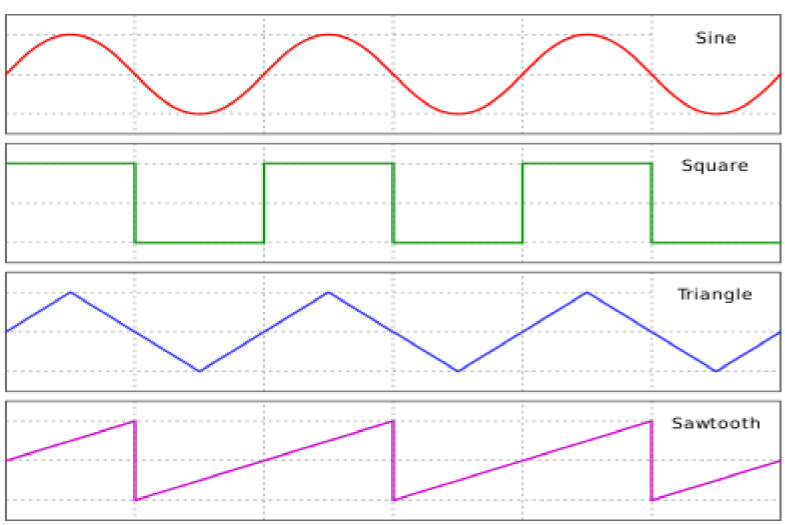
Wavelength and Period

To understand the difference between these seismic recording instruments, we need to discuss a little about the waves. First, we use the term wavelength the refer to the peak-to-peak distance on a wave measured at a single time - like in a snapshot. To measure the wavelength directly, we would need a group of instruments that measure the amplitude of the wave at the same time but at different locations. If we record the ground motion at a single location for a range of time, we can measure the time between peaks in the motion, which we call the wave period. Another important term is frequency, which is the inverse of the period, or one divided by the peak-to-peak time between wave crests.



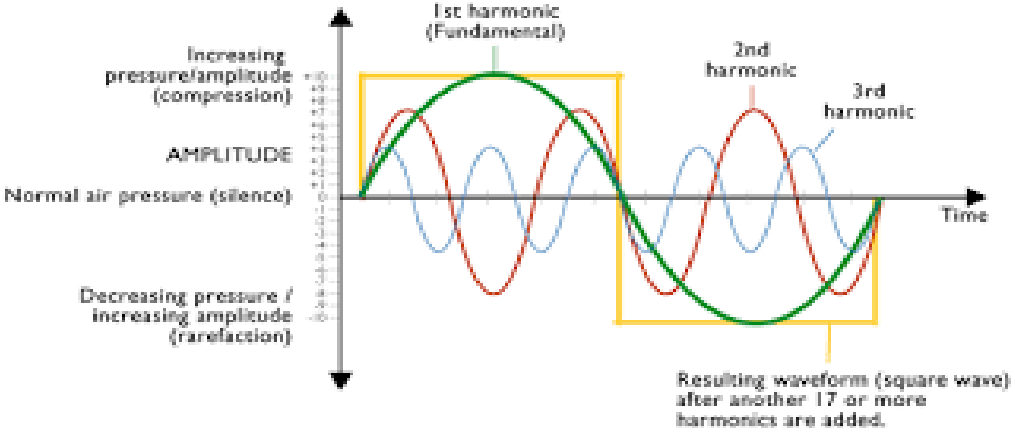
Waves are energy transmitting phenomena that have an amplitude and a wavelength. The upper panel shows a snapshot of the wave at a single time. The lower panel can be thought of as the motion of a single point for an interval of time.





The harmonics are multiples of the fundamental frequency.

So if the fundamental frequency is 100 Hz, the higher harmonics will be 200 Hz, 300 Hz, 400 Hz, 500 Hz, and so on. If the fundamental frequency were 220 Hz, the harmonics would be 440 Hz, 660 Hz, 880 Hz, and so on.



Pure Resistive AC Circuit

The circuit containing only a pure resistance of R ohms in the AC circuit is known as **Pure Resistive AC Circuit**. The presence of inductance and capacitance does not exist in a purely resistive circuit. The alternating current and voltage both move forward as well as backwards in both the direction of the circuit. Hence, the alternating current and voltage follows a shape of the Sine wave or known as the sinusoidal waveform.

-

In the purely resistive circuit, the power is dissipated by the resistors and the phase of the voltage and current remains same i.e., both the voltage and current reach their maximum value at the same time. The resistor is the passive device which neither produce nor consume electric power. It converts the **electrical energy into heat**.

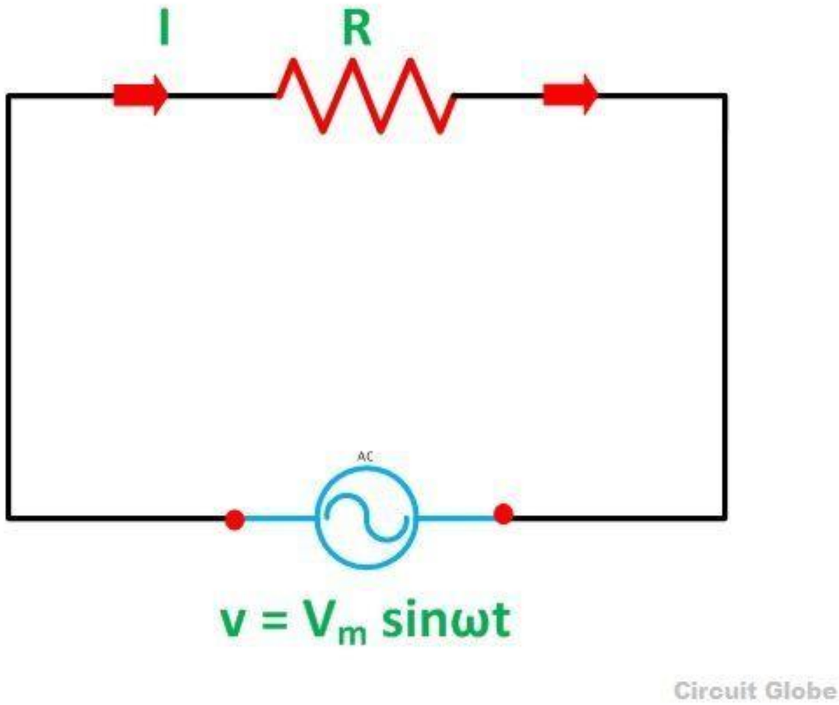
Explanation of Resistive Circuit

In an AC circuit, the ratio of voltage to current depends upon the supply frequency, phase angle, and phase difference. In an AC resistive circuit, the value of resistance of the resistor will be same irrespective of the supply frequency.

Let the alternating voltage applied across the circuit be given by the equation

$$v = V_m \mathrm{Sin}\omega t \ldots\ldots\ldots\ldots\ldots(1)$$

Then the instantaneous value of current flowing through the resistor shown in the figure below will be:



$$i = \frac{v}{R} = \frac{V_m}{R}\,\sin\omega t \ldots\ldots\ldots(2)$$

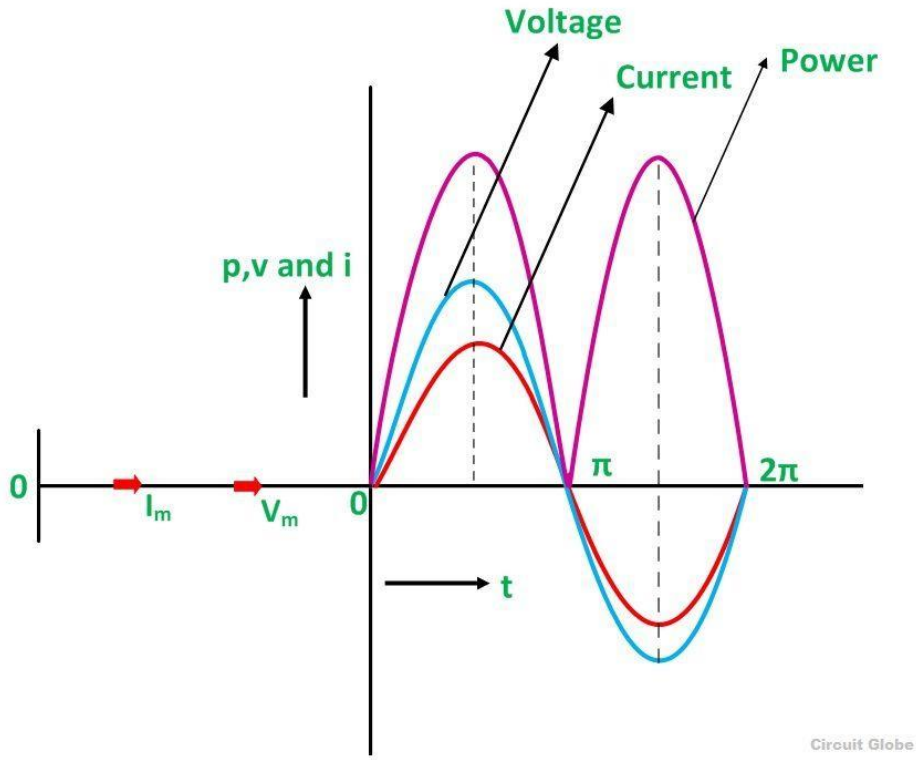
The value of current will be maximum when ωt= 90° or sinωt = 1

Putting the value of sinωt in equation (2) we will get

$$i = I_m \sin\omega t \ldots\ldots\ldots.(3)$$

Phase Angle and Waveform of Resistive Circuit

From equation (1) and (3), it is clear that there is no phase difference between the applied voltage and the current flowing through a purely resistive circuit, i.e. phase angle between voltage and current is **zero**. Hence, in an AC circuit containing pure resistance, the current is in phase with the voltage as shown in the waveform figure below.



Waveform and Phasor Diagram of Pure Resistive Circuit

Power in Pure Resistive Circuit

The three colours red, blue and pink shown in the power curve or the waveform indicate the curve for current, voltage and power respectively. From the phasor diagram, it is clear that the current and voltage are in phase with each other that means the value of current and voltage attains its peak at the same instant of time, and the power curve is always positive for all the values of current and voltage.

As in DC supply circuit, the product of voltage and current is known as the Power in the circuit. Similarly, the power is the same in the AC circuit also, the only difference is that in the AC circuit the instantaneous value of voltage and current is taken into consideration.

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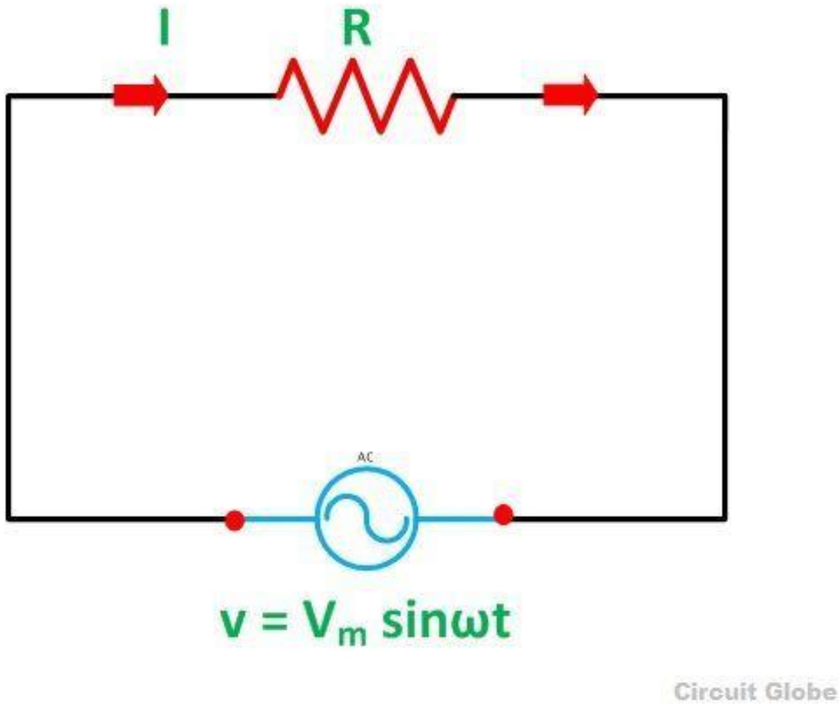

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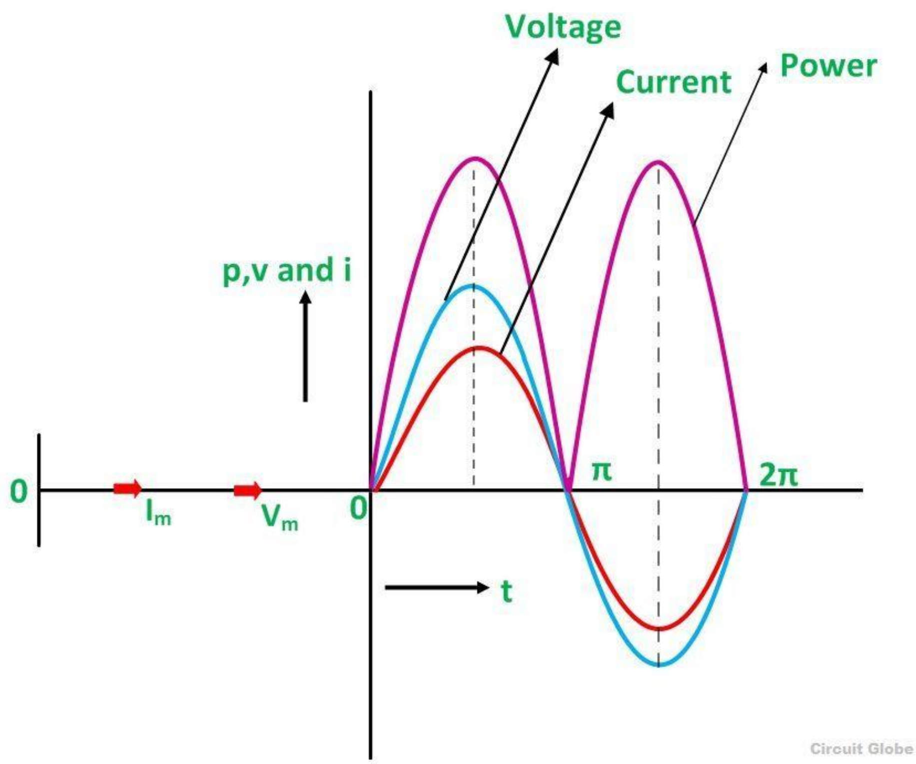

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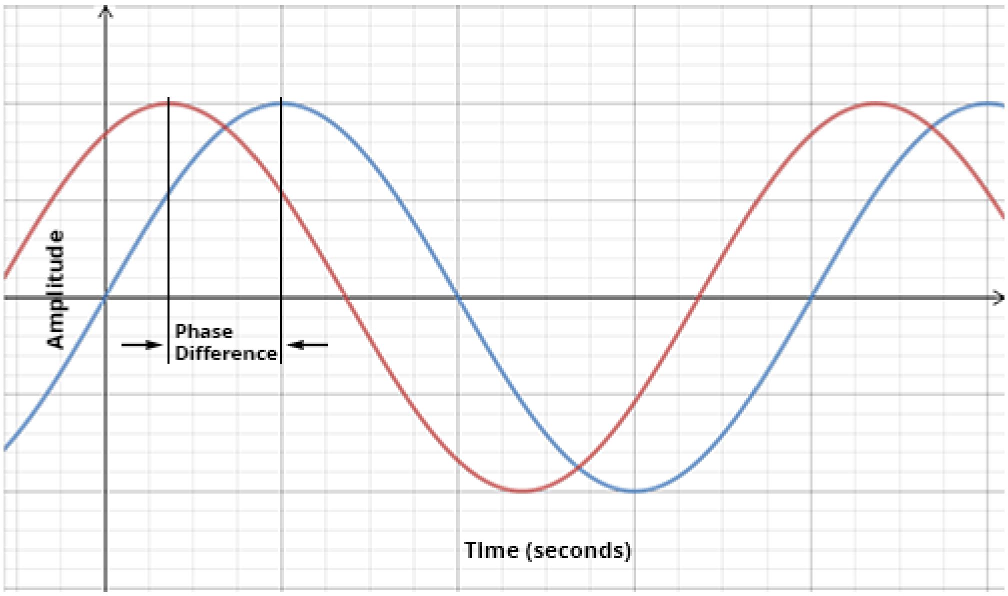
As in DC supply circuit, the product of voltage and current is known as the Power in the circuit. Similarly, the power is the same in the AC circuit also, the only difference is that in the AC circuit the instantaneous value of voltage and current is taken into consideration.

The phase difference between two sound waves of the same frequency moving past a fixed location is given by **the time difference between the same positions within the wave cycles of the two sounds** (the peaks or positive-going zero crossings, for example), expressed as a fraction of one wave cycle



Self inductance is defined as the induction of a voltage in a current-carrying wire when the current in the wire itself is changing. In the case of self-inductance, the magnetic field created by a changing current in the circuit itself induces a voltage in the same circuit. Therefore, the voltage is self-induced.

Induced current always opposes the change in current in the circuit, whether the change in the current is an increase or a decrease. **Self-inductance is a type of electromagnetic induction**.

Self Induction

Self induction is a phenomenon by which a changing electric current produces an induced emf across the coil itself.

Self Inductance

Self inductance is the ratio of induced electromotive force (EMF) across a coil to the rate of change of current through the coil. We denote self inductance or coefficient of with English letter L. Its unit is Henry (H).
Since, the induced emf (E) is proportional to the current changing rate, we can

write,
But the actual equation is

Why there is Minus (-) sign?

According to Lenz's Law, the induced emf opposes the direction of the rate of change of current. So their value is same but sign differs.

Derivation of Inductance

For the DC source, when the switch is ON, i.e. just at $t = 0^+$, a current starts flowing from its zero value to a certain value and with respect to time, there will be a rate of change in current momentarily. This current produces changing flux (φ) through the coil. As current changes flux (φ) also changes

and the rate of change with respect to the time is

What is Inductive Reactance?

An inductor is a coil of wire. An electrical field is generated when a current passes through the coil i.e. the inductor. Thus an electric field has been "induced". The induced field is directly proportional to the length of the coil or the number of turns in the coil. This is called "inductance." In inductors, the current lags the voltage by 90 degrees.

When a voltage is applied across the terminals of an inductor it generates energy. This energy is stored in the form of a magnetic field. Inductors own self-induced or back emf value determines the growth of the current flowing through it and is not instant.

The resistance to the flowing current offered by an inductor in an AC circuit is known as impedance. In DC circuit it is known as reactance. Complex numbers are used to denote these quantities when analysing such circuits. Phase diagrams of such quantities can be drawn to understand them better. These quantities are used extensively in complex analysis.

The Formula:

Inductive reactance or simply reactance is the resistance of an inductive circuit. It is termed as reactance because it is slightly different from the resistance offered by any device. And it is denoted as XL.

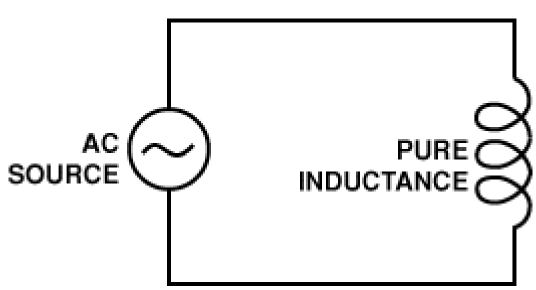
Inductive reactance is the resistance offered by the inductive circuit. It is the opposition to a changing current flow offered by an inductor. The SI unit for it is Ohm(Ω). The inductive reactance formula is:

Inductive reactance(XL) : 2π f L

where f is the frequency of the alternating current measured in Hertz(hz) and L is the inductance measured in henry(h).

It is proportional to the frequency of the current and hence inversely proportional to the Time.

XL α f and XL α (1/T).



Indicators like inductive reactances are used for designing inductors and also while designing circuits, power stations, transformers etc. Since inductors are an important component of designing it is important to know its inductive reactance. Thus it becomes mandatory for suppliers to specify the inductive reactances of the inductors while manufacturing them as those numbers play a very important role in deciding where a particular inductor will be used.

Studying the inductive reactance is important as many complex problems asked in competitive exams have sub-problems wherein calculation of inductive reactance is asked.

Solved Examples for Inductive Reactance Formula

Q: An inductor of 2H is connected to a circuit at a frequency of 50Hz. Find out the inductive reactance of this circuit using inductive reactance formula

Answer: The given parameters are,

$f = 50Hz$ and $L = 2H$

Inductive reactance formula is given as,

$XL = 2\pi fL$

$XL = 2\times3.14\times50\times2 = 628\Omega$.

Q: At what frequency does a 2500mH inductor have 6kΩ of reactance?

Answer:The known parameters are,

XL = 6kΩ = 6000Ω, and

L = 2500mH = 2.5H

Inductive reactance formula is articulated as,

XL = 2π fL

$$So, f = \frac{X_L}{2\pi L}$$

f = 6000 * 7/ (2 * 22 * 2.5) = 381.82 Hz.

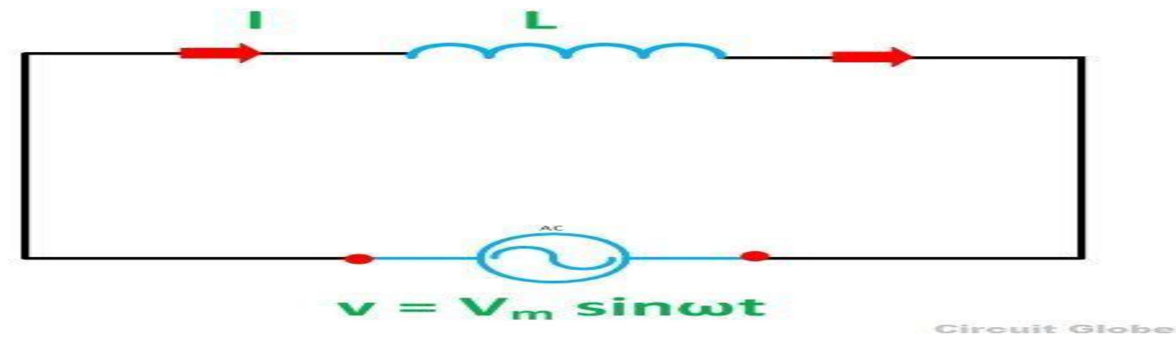
Pure inductive Circuit

The circuit which contains only inductance (L) and not any other quantities like resistance and capacitance in the circuit is called a **Pure inductive circuit.** In this type of circuit, the current lags behind the voltage by an angle of 90 degrees.

The inductor is a type of coil which reserves electrical energy in the magnetic field when the current flow through it. The inductor is made up of wire which is wound in the form of a coil. When the current flowing through inductor changes then time-varying magnetic field causes emf which obstruct the flow of current.The inductance is measured in **Henry**.The opposition of flow of current is known as the **inductive reactance**.

Explanation and Derivation of Inductive Circuit

The circuit containing pure inductance is shown below:



Circuit Diagram of pure Inductive Circuit

Let the alternating voltage applied to the circuit is given by the equation:

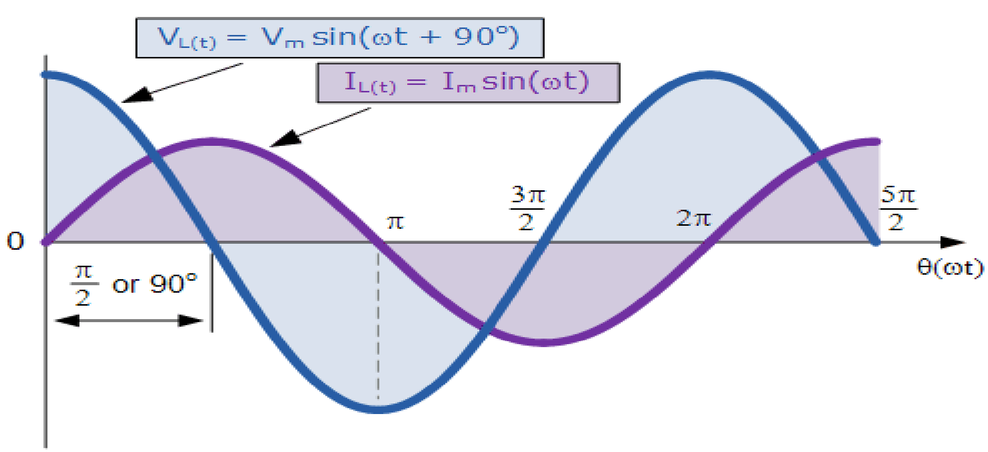
$$v = V_m \text{Sin}\omega t \ldots\ldots\ldots\ldots\ldots(1)$$

As a result, an alternating current i flows through the inductance which induces an emf in it. The equation is shown below:

$$e = -L\frac{di}{dt}$$

The emf which is induced in the circuit is equal and opposite to the applied voltage. Hence, the equation becomes,

$$v = -e \ \ldots\ldots\ldots..(2)$$

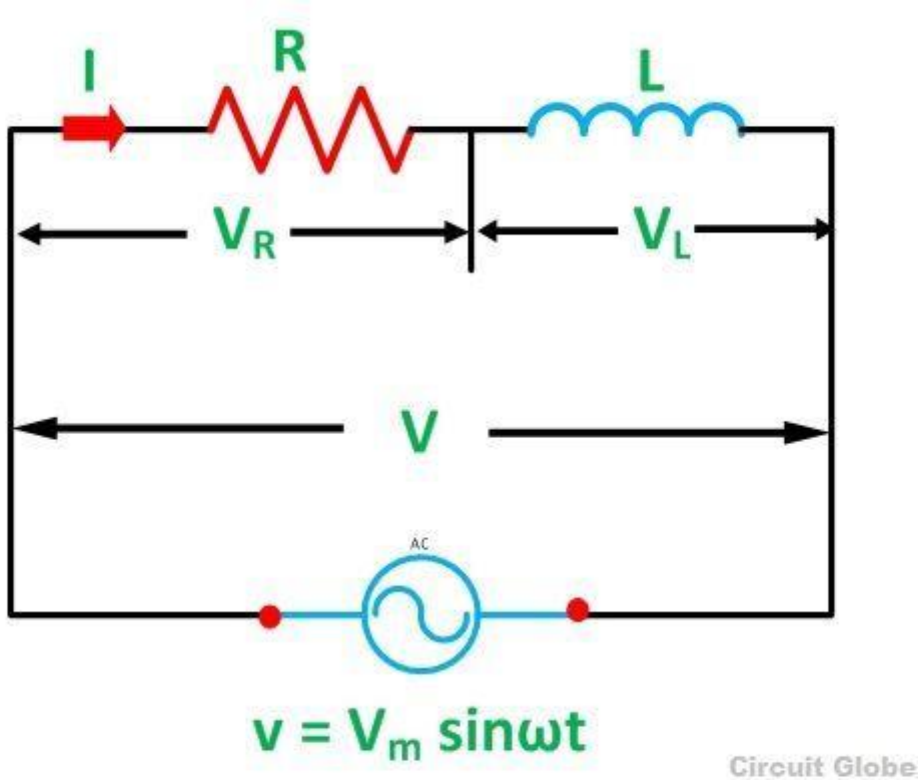


Elements Symbol	RESISTOR	CAPACITOR	INDUCTOR
Denoted by	R	C	L
Equation	$R = \frac{V}{I}$	$C = \frac{Q}{V}$	$L = \frac{V_L}{(di/dt)}$
Series	$R_T = R_1 + R_2$	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$	$L_T = L_1 + L_2$
Parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$	$C_T = C_1 + C_2$	$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2}$

RL Series Circuit

A circuit that contains a pure resistance R ohms connected in series with a coil having a pure inductance of L (Henry) is known as **RL Series Circuit**. When an AC supply voltage V is applied, the current, I flows in the circuit.

So, I_R and I_L will be the current flowing in the resistor and inductor respectively, but the amount of current flowing through both the elements will be same as they are connected in series with each other. The circuit diagram of RL Series Circuit is shown below:



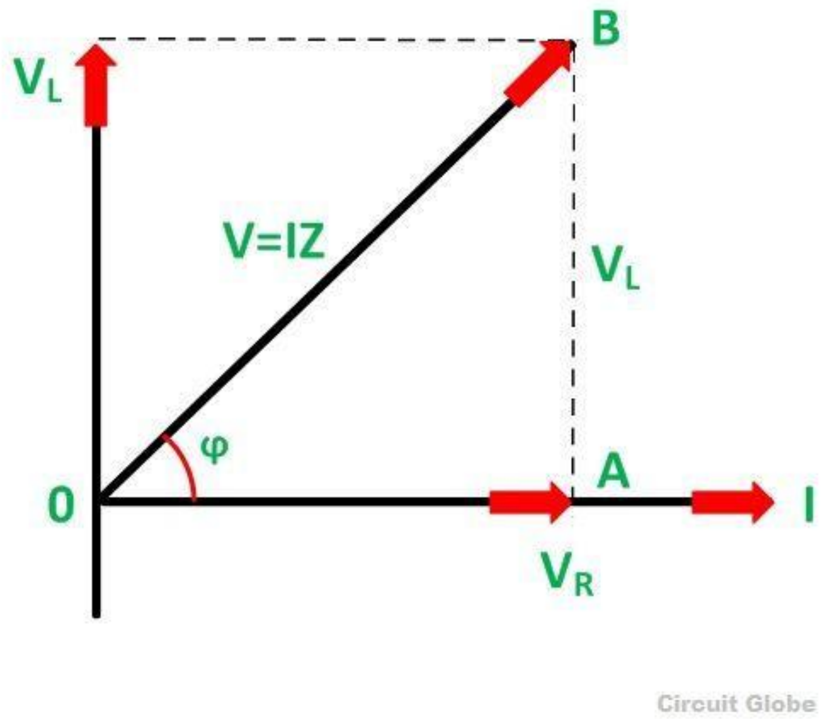
Where,

- V_R – voltage across the resistor R
- V_L – voltage across the inductor L
- V – Total voltage of the circuit

Contents:

Phasor Diagram of the RL Series Circuit

The phasor diagram of the RL Series circuit is shown below:



Steps to draw the Phasor Diagram of RL Series Circuit

The following steps are given below which are followed to draw the phasor diagram step by step:

- Current I is taken as a reference.
- The Voltage drop across the resistance $V_R = I_R$ is drawn in phase with the current I.
- The voltage drop across the inductive reactance $V_L = IX_L$ is drawn ahead of the current I. As the current lags voltage by an angle of 90 degrees in the pure Inductive circuit.
- The vector sum of the two voltages drops V_R and V_L is equal to the applied voltage V.

The time constant τ=LR τ = L R is formally the amount of time for the voltage across the inductor to decrease by a factor of e≈2.7 e ≈ 2.7 , and **gives a measure of how quickly the circuit approaches a steady state configuration**.

Learn About L/R Time Constants

It is often perplexing to new students of electronics why the time-constant calculation for an inductive circuit is different from that of a capacitive circuit. For a resistor-capacitor circuit, the time constant (in seconds) is calculated from the product (multiplication) of resistance in ohms and capacitance in farads: $\tau=RC$.

However, for a resistor-inductor circuit, the time constant is calculated from the quotient (division) of inductance in henrys over the resistance in ohms: $\tau=L/R$.

This difference in calculation has a profound impact on the *qualitative* analysis of transient circuit response. Resistor-capacitor circuits respond quicker with low resistance and slower with high resistance; resistor-inductor circuits are just the opposite, responding quicker with high resistance and slower with low resistance.

While capacitive circuits seem to present no intuitive trouble for the new student, inductive circuits tend to make less sense.

IMPEDANCE

The magnitude of the impedance Z of a circuit is equal to the maximum value of the potential difference, or voltage, V (volts) across the circuit, divided by the maximum value of the current I (amperes) through the circuit, or simply Z = V/I. **The unit of impedance, like that of resistance, is the ohm**

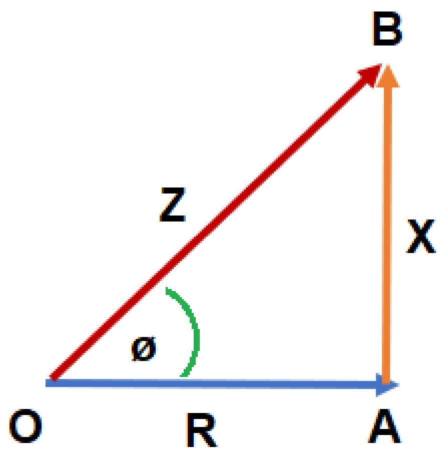
Impedance Triangle

Definition:
Impedance Triangle is a right angled triangle whose base, perpendicular and hypotenuse represents Resistance, Reactance and

Impedance respectively. It is basically a geometrical representation of circuit impedance.

Explanation of Impedance Triangle:

Impedance consists of two components viz. resistance and reactance. Therefore, it can be expressed in these two components. Let the impedance of an alternating current circuit is Z = R+jX where R and X represents the resistance and reactance. It is clear from the expression of Z is that, it is a complex number and hence can be geometrically represented in the same manner as a complex number. The geometrical representation is shown below.



The above triangle OAB so formed is called Impedance Triangle. From this triangle, the magnitude of impedance Z can easily be found using Pythagoras Theorem. The of magnitude of impedance Z is equal to OB and can be find as below.

$OB^2 = OA^2+AB^2$

$Z^2 = R^2+X^2$

Thus, we can say that square of impedance is equal to the sum of square of resistance and reactance.

$Z = \sqrt{(R^2+X^2)}$

The angle which Z makes with R i.e. angle between OA & OB may be find as

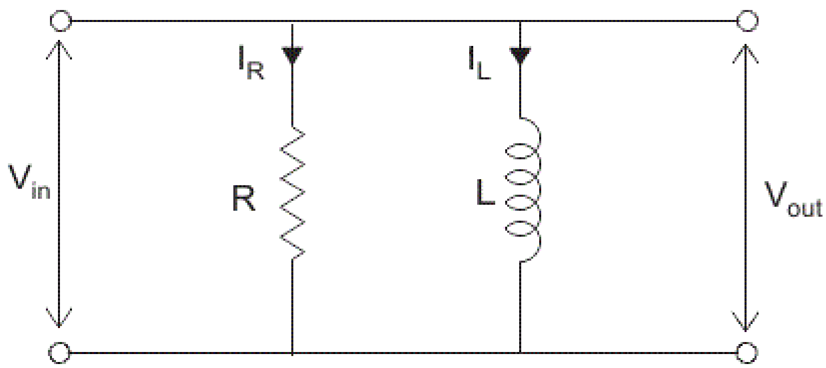
$\tan\Theta = (X/R)$

Hence, Impedance Triangle helps us to find the magnitude as well as the angle of impedance of a circuit.

RL Parallel Circuit

In **RL parallel circuit** resistor and inductor are connected in parallel with each other and this combination is supplied by a voltage source, V_{in}. The output voltage of circuit is V_{out}. Since the resistor and inductor are connected in parallel, the input voltage is equal to output voltage but the currents flowing in resistor and inductor are different.

The **parallel RL circuit** is not used as filter for voltages because in this circuit, the output voltage is equal to input voltage and for this reason it is not commonly used as compared to series RL circuit.



Let us say: I_T = the total current flowing from voltage source in amperes.

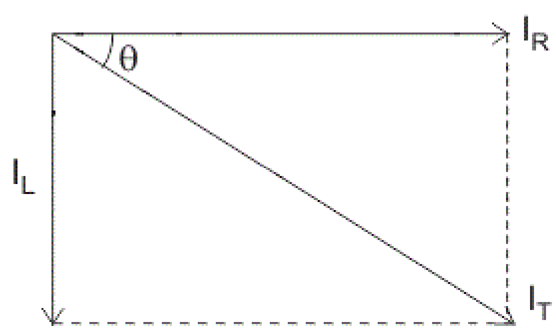
I_R = the current flowing in the resistor branch in amperes.

I_L = the current flowing in the inductor branch in amperes.

θ = angle between I_R and I_T.

So the total current I_T,

$$I_T^2 = I_R^2 + I_L^2$$



In complex form the currents are written as,

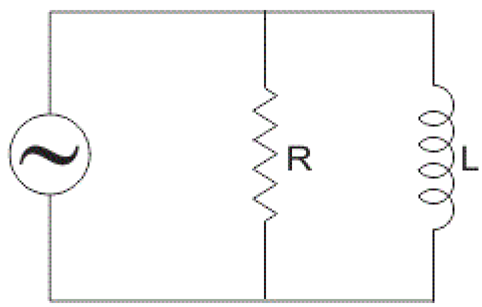
$$I_R = \frac{V_{in}}{R}$$

$$I_L = \frac{V_{in}}{j\omega L}$$

$$\Rightarrow I_L = -j\frac{V_{in}}{\omega L}\left(where\ \frac{1}{j} = -j\right)$$

$$Therefore\ total\ current\ I_T = \frac{V_{in}}{R - j\frac{V_{in}}{\omega L}}$$

Impedance of Parallel RL Circuit



Let, Z = total impedance of the circuit in ohms.
R = resistance of circuit in ohms.
L = inductor of circuit in Henry.
X_L = inductive reactance in ohms.
Since resistance and inductor are connected in parallel, the total impedance of the circuit is given by,

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{jX_L}$$

$$Z = \frac{R * (jX_L)}{R + jX_L}$$

In order to remove "j" from the denominator multiply and divide numerator and denominator by (R – j X_L),

$$Z = \frac{R * (jX_L)}{R + jX_L} * \frac{R - jX_L}{R - jX_L}$$

$$= \frac{(jRX_L)(R - jX_L)}{(R + jX_L)(R - jX_L)} = \frac{jR^2X_L - j^2R^2X_L^2}{R_2 + X_L^2}$$

$$(Since\ j^2 = -1)$$

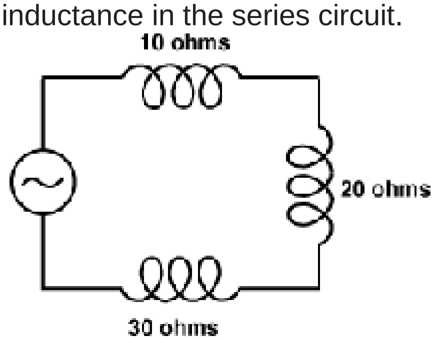
$$= \frac{RX_L^2 + jR^2X_L}{R^2 + X_L^2}$$

$$Z = \frac{RX_L^2}{R^2 + X_L^2} + j\frac{R^2X_L}{R^2 + X_L^2}$$

The combination of a resistor and inductor connected in parallel **to an AC source**, as illustrated in Figure 1, is called a parallel RL circuit. In a parallel DC circuit, the voltage across each of the parallel branches is equal. This is also true of the AC parallel circuit

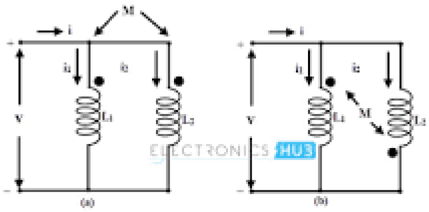
.

For a series circuit with 3 inductive reactances of 10, 20, and 30 ohms, the total inductive reactance is calculated as follows: **If the circuit voltage is 120 volts, then ohms law is used to find the total current flow in the circuit**. 2 amps of current flows through each inductance in the series circuit.



in series or in parallel are combined the same way as ohms of resistance. With series reactances, the total is the sum of the individual values as shown in Fig. 20-5 (a). The combined reactance of parallel reactances is **calculated by the reciprocal formula**.

How do you find inductive reactance in parallel?



$1/L_T = 1/L_1 + 1/L_2 + 1/L_3$ . . . . . This means that the reciprocal of total inductance of the parallel connection is the sum of reciprocals of individual inductances of all inductors. The above equation is true when there is no mutual inductance is affect between the parallel connected coils

What is Skin Effect?

When a DC current is applied to a cylindrical conductor, it gets distributed uniformly over the entire cross section of the conductor. In the case of non-cylindrical conductor, current is not uniformly distributed but it exists in the entire conductor.

On the other hand, when an AC current is applied to a cylindrical conductor, the current concentrates near the surface of the conductor and its strength decreases as you go towards the center of the conductor.

The depth of the AC current in a conductor is inversely proportional to the frequency i.e at lower frequencies the current goes deeper in to the conductor whereas at higher frequencies the current flows almost on the surface of the conductor. This entire phenomenon is called as Skin Effect.

The depth till which conduction takes place in a conductor or the depth till which the current flows in a conductor is called as Skin Depth.

A.F AND F.F CHOKES

An electrical component designed to block audio and power line frequencies while allowing DC to pass.

See also RF (radio frequency). AF (audio frequency) (also abbreviated af or a.f.) refers to alternating current (AC) having a frequency such that, if applied to a transducer such as a loudspeaker or headset, will produce acoustic waves within the range of human hearing.

Differences between af choke and rf choke,

Audio - frequency (A.F) chokes	Radio frequency (R. F) chokes: or high frequency (H.F) chokes
a) Used in low frequency a.c. circuit.	a) used in high frequency a.c. circuit
b) An iron core is used.	b) Air chokes are used.
c) The inductance may be high	c) The inductance may be low
d) Used in fluorescent tubes.	d) Used in wireless receiver circuits

AC through pure capacitor

- Figure given below shows circuit containing alternating voltage source
  $V=V_0\sin\omega t$
  connected to a capacitor of capacitance C

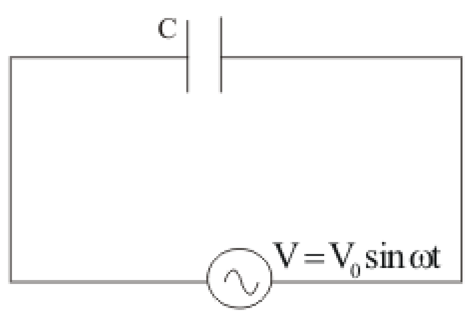


Figure 7. A.C. Circuit containing only capacitor

- Suppose at any time t,q be the charge on the capacitor and i be the current in the circuit
- Since there is no resistance in the circuit, so the instantaneous potential drop q/C across the capacitor must be equal to applied alternating voltage
  so
  $q/C=V_0\sin\omega t$

- Since i=dq/dt is the instantaneous current in the circuit so

$$i = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$$
$$= CV_0 \omega \cos \omega t$$
$$= \frac{V_0}{(1/\omega C)} \cos \omega t$$
$$= i_0 \cos \omega t = i_0 \sin(\omega t + \frac{\pi}{2})$$

where

$$i_0 = \frac{V_0}{(1/\omega C)}$$

is the peak value of current

- Comparing equation (13) with $V=V_0\sin\omega t$,we see that in a perfect capacitor current leads emf by a phase angle of π/2
- This phase relationship is graphically shown below in the figure

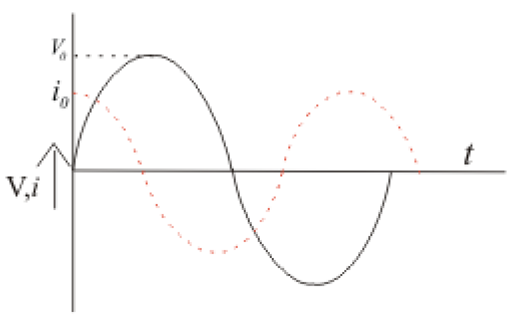


Figure 8 (a). Sinusoidal representation

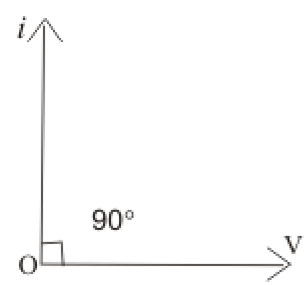


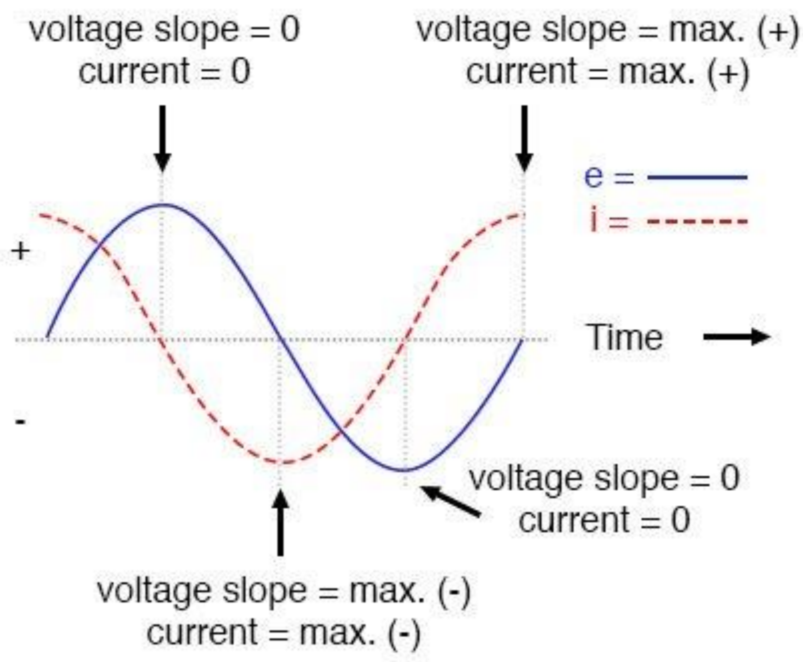
Figure 8 (b). Phaser diagram representation

- Again comparing peak value of current with ohm's law ,we find that quantity 1/ωC has the dimension of the resistance
- Thus the quantity
  $X_C=1/\omega C =1/2\pi fC$ ---(14)
  is known as capacitive reactance
- From equation (14) we see that capacitive reactance decreases with increasing frequency of current and in infinite for direct current for which frequency f=0

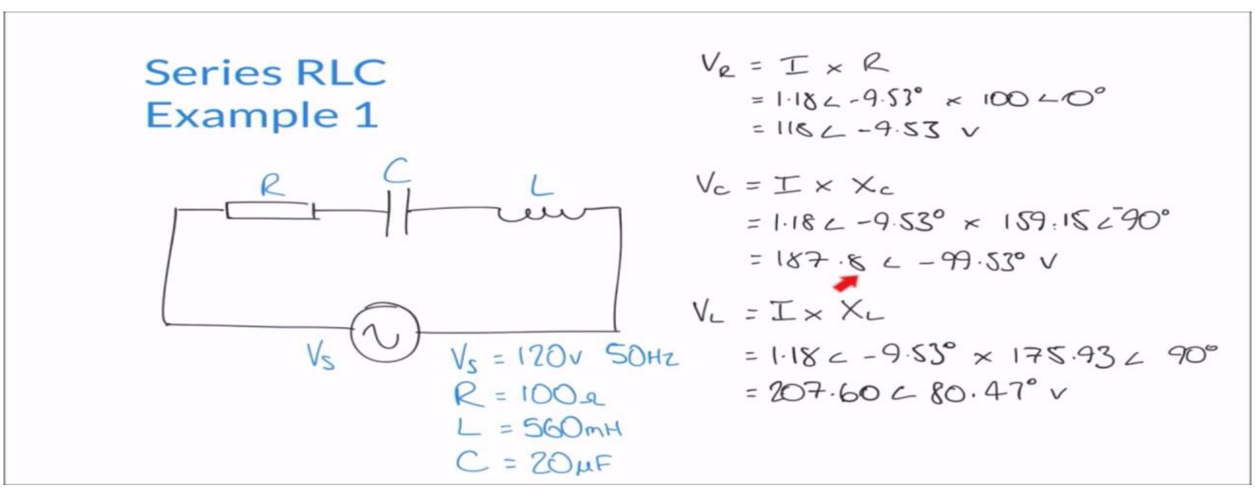
The phase is negative for a capacitive circuit since the current leads the voltage. The useful mnemonic ELI the ICE man helps to remember the sign of the phase.

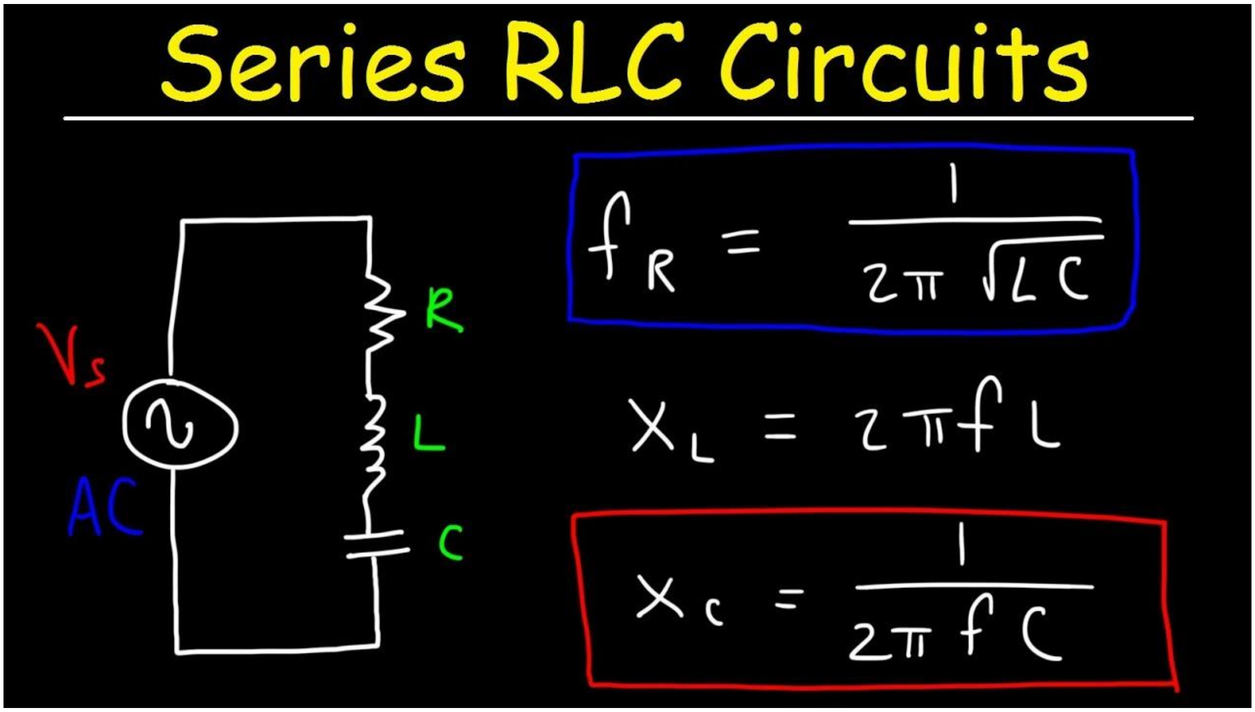
Missing: ~~V&I~~ | Must include: V&I

Voltage lags current by 90° in a capacitor. Mathematically, we say that the phase angle of a capacitor's opposition to current is -90°, meaning that a capacitor's opposition to current is a negative imaginary quantity.



RLC circuit equations that give the impedance measured in volts and phase measured in degrees are: **Z=√R2+(XL−XC)2=√R2+(ω∗L−1ω∗C)2** Z = R 2 + (X L − X C) 2 = R 2 + (ω ∗ L − 1 ω ∗ C) 2




Series RLC Circuits
V_s
AC
R
L
C
$f_R = \frac{1}{2\pi\sqrt{LC}}$
$X_L = 2\pi f L$
$X_C = \frac{1}{2\pi f C}$