التيار المتردد

Fundamental of Alternating Current

دكتور

عبدالجليل عبدالعال حسن

2024 -2023

Chapter one

Fundamental of Alternating Current

Introduction

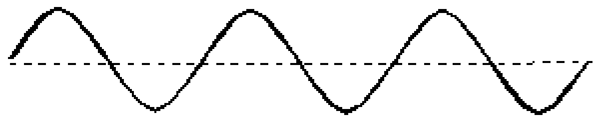
Electric current can be direct current (DC) or alternating current (AC). Direct current such as the power from dry cells and it is characterized by a uniform direction of flow and amount (voltage) of electricity.

Alternating current is characterized by direction of flow and amount of electricity that changes cyclically over time.

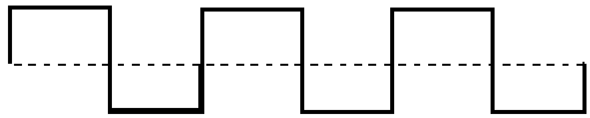
All the houses and most of the electrical devices are used AC. The solar cells are producing a constant electric current. so that we can operate electrical devices that operate with an electric current, we must convert the current from DC to AC by a device called inverter If we want to convert AC to DC power, we use a device called Rectifier

The wave of AC takes different shape sine, square, triangle and saw tooth wave

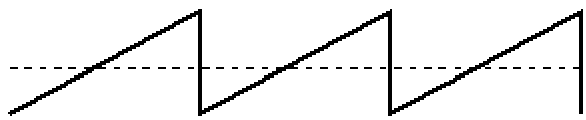
1. The sine wave is a common type of alternating current (AC) and alternating voltage
2. The square waves use in digital electronics and transformer electronics to test their work.
3. The triangle AC wave is used in sound synthesis, and is also useful in linear electronics testing
4. Sawtooth AC wave
5. ramp waves



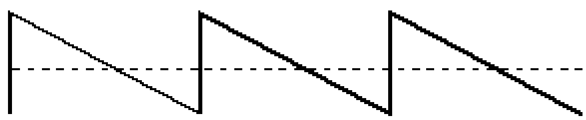
sine



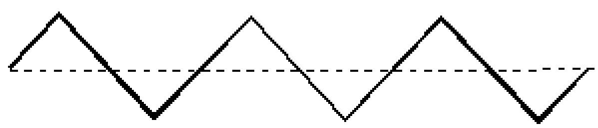
square



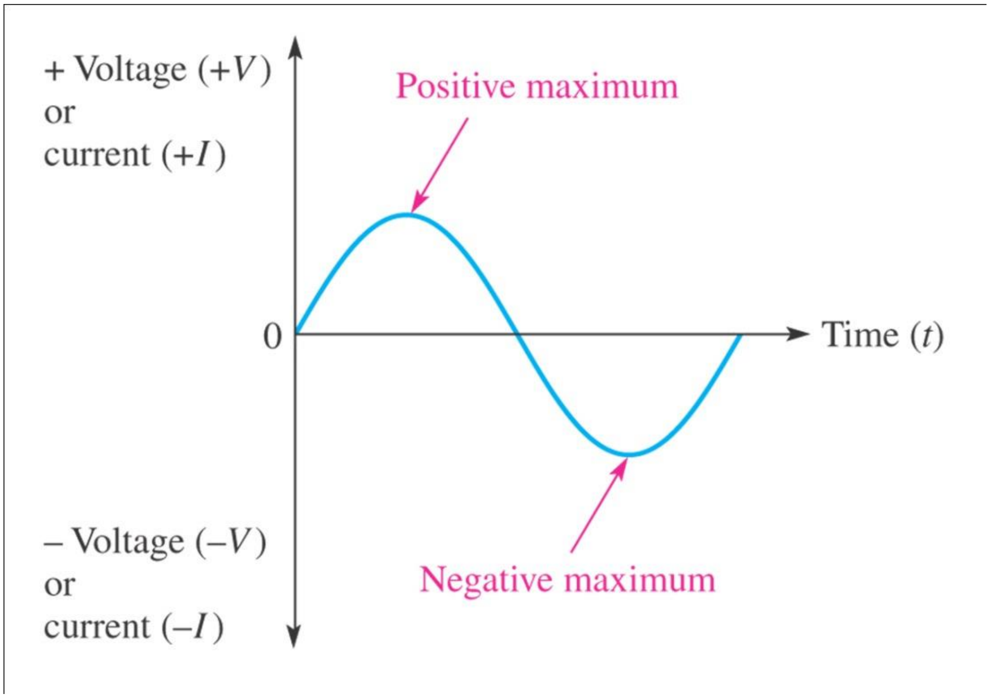
ramp



sawtooth

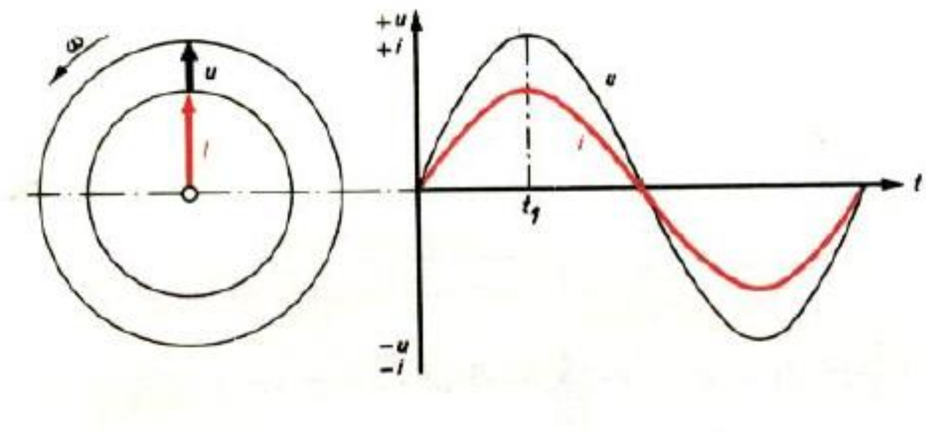


triangular

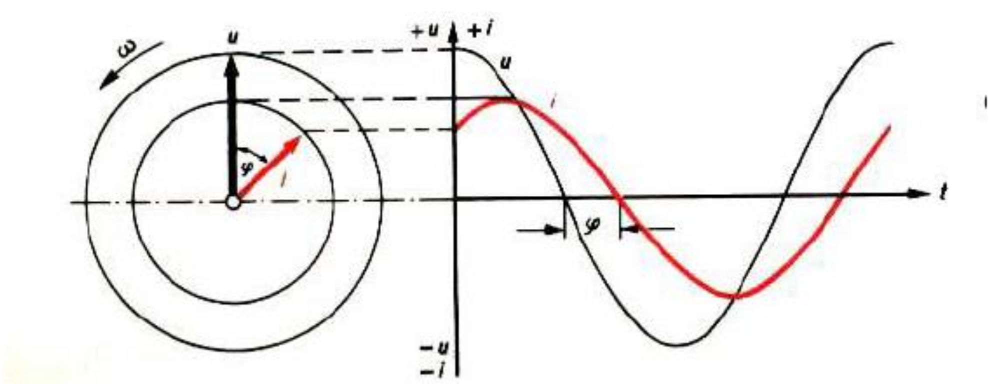


- The wave is the path drawn by the voltage or the current in terms of time

Two waves are in consistent in phase, if they reach the maximum and minimum value in same time



Two waves: The angle between them is Q (displacement angle). It is said that the current wave was delayed from the voltage wave at an angle of Q as the following shape



- Period of sine wave is the time required to complete a complete cycle and is denoted by T

- Frequency: is the number of oscillations generated by current or voltage per second and is denoted by **f** and measured by Hz

The angular frequency is the value of angle per second and is given by

$$w = 2\pi f$$

In addition, it measures by rad/second

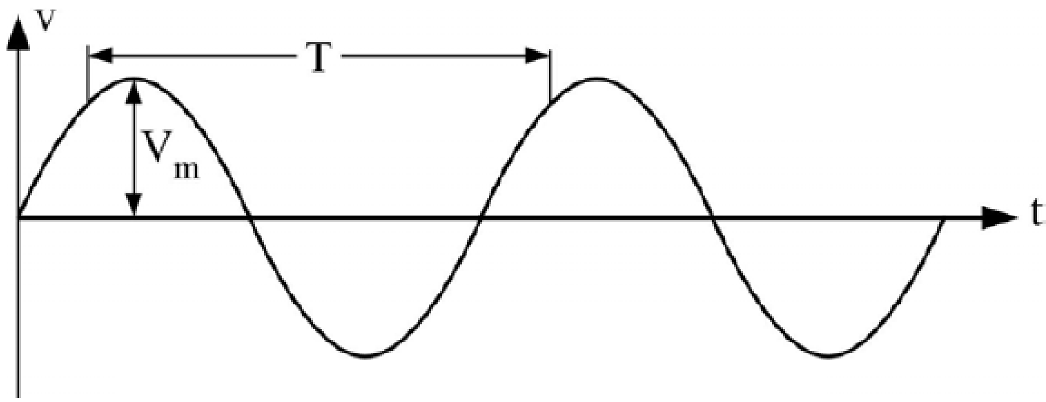
- The V_t instantaneous value : is the amount of voltage at any given time and is given by

$$V_t = V_m \sin wt$$

- The effective value of the AC(V_{eff} or V_{rms}) is the DC current that generates the same thermal energy generated by the AC during the same time period in the same resistance and is given from ;

$$I_{rms} = \frac{I_{\max}}{\sqrt{2}}$$

$$V_{rms} = \frac{V_{\max}}{\sqrt{2}}$$

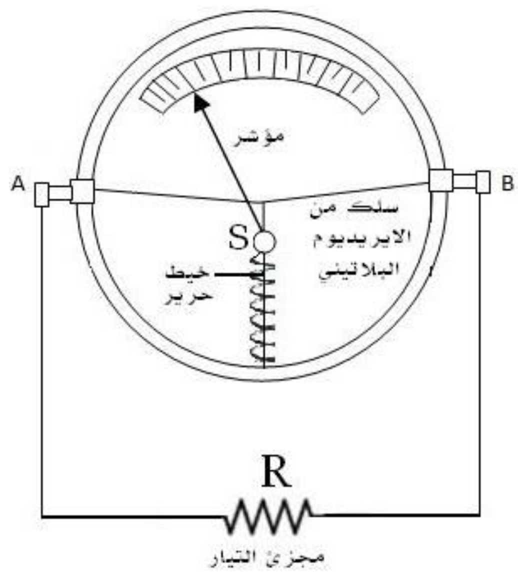


AC properties;

1. The electrical current can be increased or reduced using electrical transformers.
2. It can be transported long distances without much loss of electrical energy.
3. it can be converted to DC
4. 4. It can be used in lighting, heating processes, not use in electrolysis, and electroplating.
5. It has thermal effect

Measuring AC

AC current is measuring using the hot-coil Ammeter Its idea depends on the thermal effect of the current



Thermal Ammeter consist of:

1. A thin wire of iridium alloy and platinum is tight between the two screws A, B.
2. The wire is connected from the middle of a silk thread wrapped around a roll S
3. The silk is tightened by a spring fixed in the wall and is always tight.
4. A pointer is supported on the roller and it moves in front of an irregular gradient to measure current intensity
5. The wire is connected in parallel to the R resistance
6. The thermal Ammeter gives the effective value of AC

- When the current passes in the wire, then its temperature and expand are raising and relax to the bottom.
- The silk thread tightens the wire and turns the pulley ,the indicator moves on scale
- Reading is taken when the indicator is stable (equilibrium)
- The (irregular) scale indicates the effective value of AC
- When the AC is cut, the wire cools and shrinks

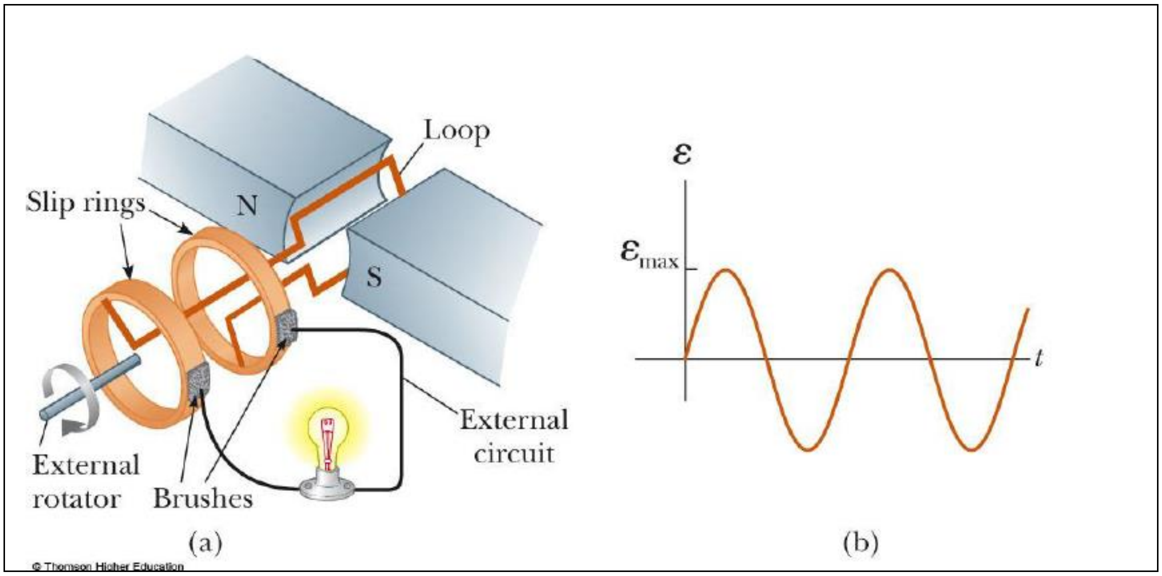
Disadvantages of AC Ammeter

- The indicator moves slowly when measured and returns to zero slowly after the measurement is finished.
- There is a zero error (effect of ambient temperature)

Generating AC

The electric generator or dynamo converts mechanical energy into electrical energy for transmission and distribution through power lines for use in industry and commerce. The dynamo is also used to produce the electric energy needed for the movement of cars, ships, planes and trains. This is done by falling waterfalls or burning oil or nuclear energy.

The electric generator consists of a coil of copper rotates by an external force between the magnet. The following figure shows the electric generator magnetic



Ex1

1- Calculate the time period(T) of a AC wave, its frequency

A. 50 Hz

B. 60 Hertz

Sol

A- $T = \frac{1}{f}$ =1/50 =0.02 second

B - $T = \frac{1}{f}$ =1/60 = 0.01667 second

2- If the equation of the voltage wave is

$$V = 100\sin\left(377t + \frac{\pi}{6}\right)V$$

Calculate the following:

1. **Maximum value of voltage**
2. **Phase angle at the beginning of time**
3. **Phase angle at time 0.025 second**
4. **Instantaneous value at the time 0.025 second**

Solution

$$V_m = 100\ V$$

$$\theta_v = \frac{\pi}{6}\ \text{rad} = 30^\circ$$

$$\alpha = 377 \times 0.025 + \frac{\pi}{6} = 9.95\,\text{rad} = \frac{9.95 \times 180}{\pi}\,\text{deg} = 570^\circ$$

$$v = 100 \times \sin 570^\circ = -50\ V$$

Chapter Two

Alternating-Current Circuits

1- Purely Resistive load

Consider a purely resistive circuit with a resistor connected to an AC generator, as shown in Figure 1 (As we shall see, a purely resistive circuit corresponds to infinite capacitance $C = \infty$ and zero inductance $L = 0$.)

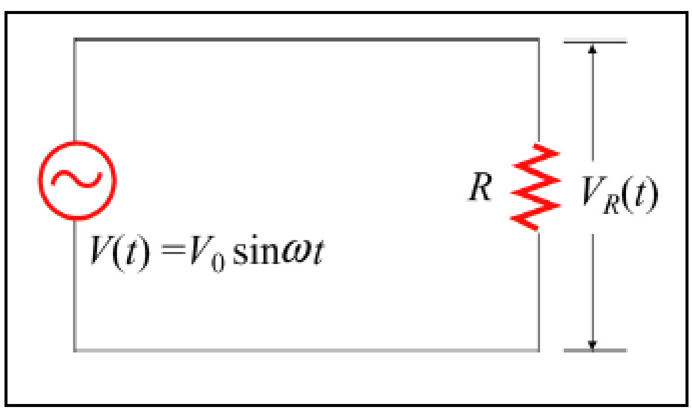


Fig 1; - Purely Resistive load

Applying Kirchhoff's loop rule yields

$$V_t - V_R = V_t - I_R R = 0$$

The instantaneous voltage drop across the resistor. The instantaneous current in the resistor is given by

$$I_R = \frac{V_R}{R} = \frac{V_m \sin wt}{R} = I_m \sin wt$$

$$I_m = \frac{V_m}{R}$$

It is clear that both current and voltage are in phase with each other, meaning that they reach their maximum or minimum values at the same time. The time dependence of the current and the voltage across the resistor is depicted in Fig. 2.

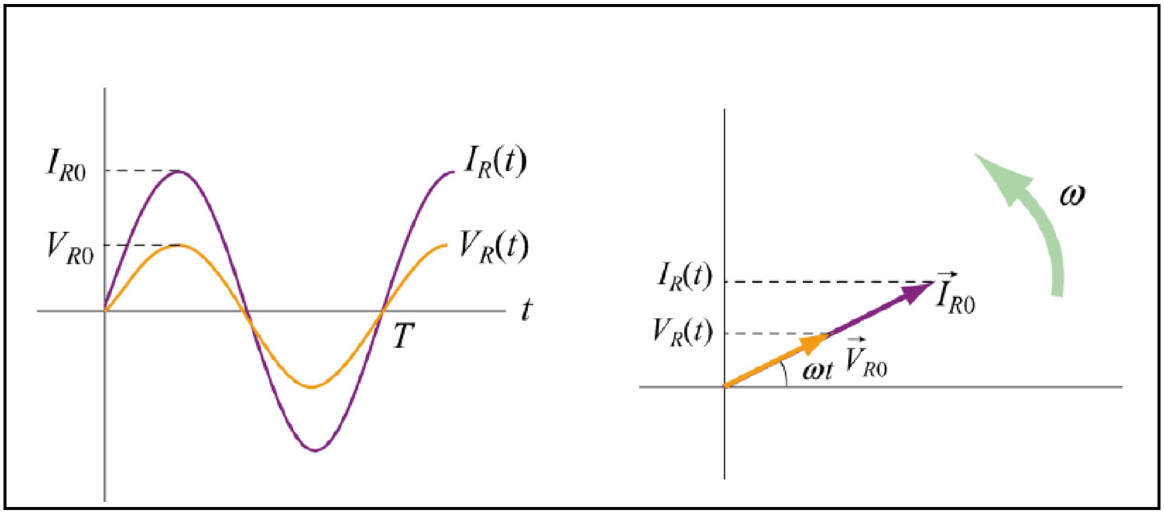


Fig. 2 -Phase diagram for the resistive circuit

2- Purely Inductive Load

Consider now a purely inductive circuit with an inductor connected to an AC generator, as shown in Figure.3.

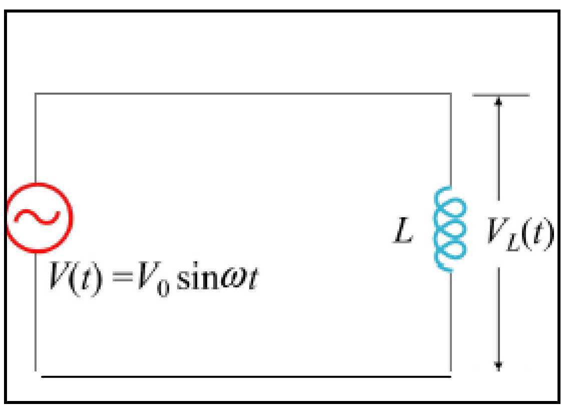


Figure 3- A purely inductive circuit

As we shall see below, a purely inductive circuit corresponds to infinite capacitance (C) and zero resistance (R). Applying the modified Kirchhoff's rule for inductors, the circuit equation reads

$$V_t - V_L = V_t - L\frac{dI}{dt} = 0$$

$$V_t = L\frac{dI}{dt}$$

$$\frac{V_m}{L}\sin wt.dt = dI$$

$$\frac{V_m}{L}\int \sin wt.dt = \int dI$$

$$-\frac{V_m}{L.w}.\cos wt = I$$

$$\cos wt = -\sin\left(wt - \frac{\pi}{2}\right)$$

$$I = \frac{V_m}{L.w}.\sin\left(wt - \frac{\pi}{2}\right)$$

$$I = I_m \sin\left(wt - \frac{\pi}{2}\right)$$

Rewriting the last expression. , we see that the amplitude of the current through the inductor is

$$I_m = \frac{V_m}{wL}$$

$$\frac{V_m}{I_m} = wL$$

$$X_L = 2\pi f L$$

X_L is called the *inductive reactance*. It has SI units of ohms (Ω), just like resistance. However, unlike resistance, X_L depends linearly on the angular frequency *w*. Thus, the resistance to current flow increases with frequency. This is because at higher frequencies the current changes more rapidly than it does at lower frequencies. On the other hand, the inductive reactance vanishes as *w* approaches zero.

The current and voltage plots and the corresponding phase diagram are shown below.

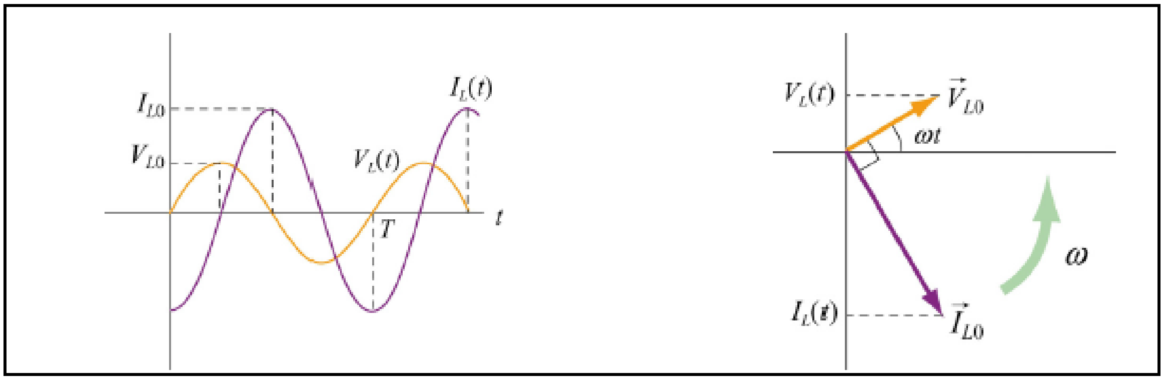


Figure 4 Phase diagram for the inductive circuit.

As can be seen from the figures, the current is out of phase with voltage by angle equals $\pi/2$. It reaches its maximum value after does by one quarter of a cycle. Thus, we say that:

The current lags (delays) voltage by π / 2 in a purely inductive circuit

Example

Consider a purely inductive circuit with an inductor, its self inductance equals 2 Henery, connected to an AC generator (V=12 volts and its frequency equals 50Hz) . Calculate the following:

- Current intensity
- The current intensity when self inductance changes to 6 Henery

Solution

$$X_L = 2\pi f L = 2\times 3.14\times 50\times 2$$
$$X_L = 628\ \Omega$$

$$I = \frac{V}{X_L} = \frac{12}{628} = 19\,\text{mA}$$

$$X_L = 2\pi f L = 2\times 3.14\times 50\times 6$$
$$X_L = 1884\ \Omega$$

$$I = \frac{V}{X_L} = \frac{12}{1884} = 6\,\text{mA}$$

4-Purely Capacitive Load

In the purely capacitive case, both resistance *R* and inductance *L* are zero. The circuit diagram is shown below:

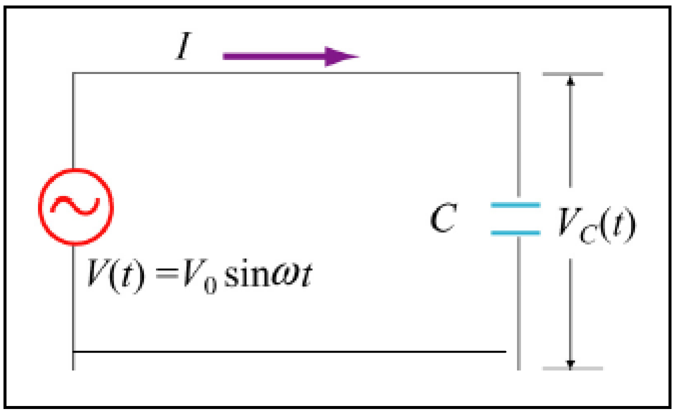


Figure 5 A purely capacitive circuit

In addition, Kirchhoff's voltage rule implies:

$$V_t - V_c = 0$$

$$V_t - \frac{Q}{C} = 0$$

We know that

$$Q = CV = CV_c = CV_m \sin wt$$

$$I = \frac{dQ}{dt} = \frac{d(CV_m \sin wt)}{dt}$$

$$I = CwV_m \cos wt$$

$$I = CwV_m \sin\left(wt + \frac{\pi}{2}\right)$$

$$I = I_m \sin(wt + 90)$$

$$I_m = CwV_m$$

$$\frac{V_m}{I_m} = \frac{1}{wC} = X_C$$

$$X_C = \frac{1}{2\pi fC}$$

X_C is called the ***capacitance reactance***. It also has SI units of ohms and represents the effective resistance for a purely capacitive circuit. Note that X_C is inversely proportional to both C and ω , and it diverges as ω approaches zero. The current and voltage plots and the corresponding phase diagram are shown in the Figure below :

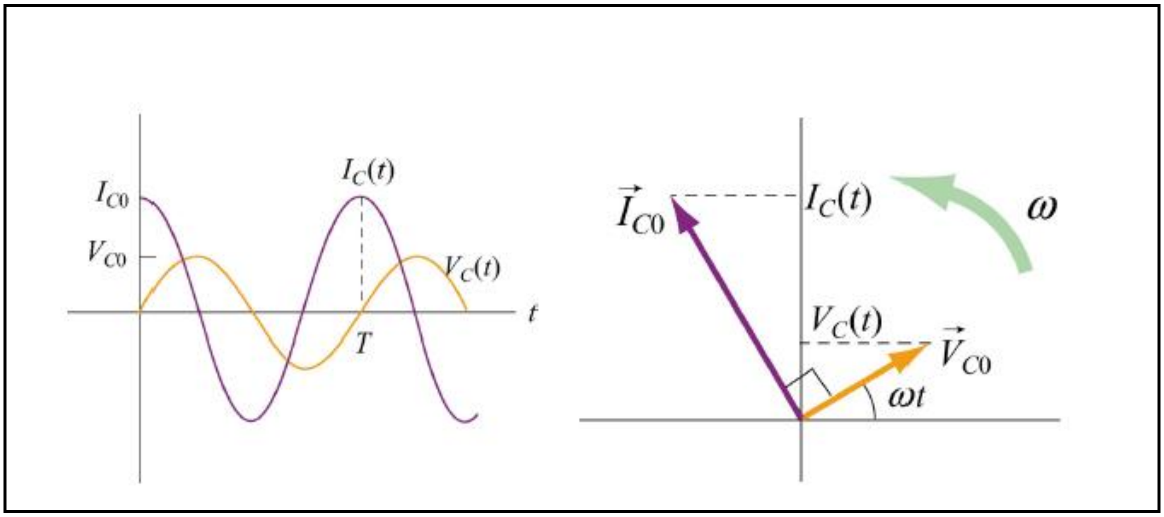


Figure 6 : Phase diagram for the capacitive circuit.

Notice that at, the voltage across the capacitor is zero while the current in the circuit is at a maximum. In fact that current reaches its maximum before by one quarter of a cycle ($\pi/2$) voltage. Thus, we say that

The current leads the voltage by $\pi/2$ in capacitive circuit

Example:

Capacitor C, its capacity 1 micro Farad, has been used in radio circuit with frequency equals 1000Hz and $I_{r.m.s}$ equals 2 mA .Calculate the voltage across capacitor and what is current when $V_{r.m.s}$ equals 20 volts and frequency equals 50Hz.

Solution

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\times 3.14\times 1000\times 10^{-6}} = 159 \text{ ohom}$$

$$V = IX_c = \frac{2}{1000}\times 159 = 0.32 \text{ volt}$$

For f= 50 Hz and voltage =20 volts , then the capacitance reactance X_C

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\times 3.14\times 50\times 10^{-6}} = 3180 \text{ ohom}$$

$$\mathrm{I} = \frac{V}{X_c} = \frac{20}{3180} = 6.3\times 10^{-3}\, Ampere$$

A summary for the above case in AC circuit

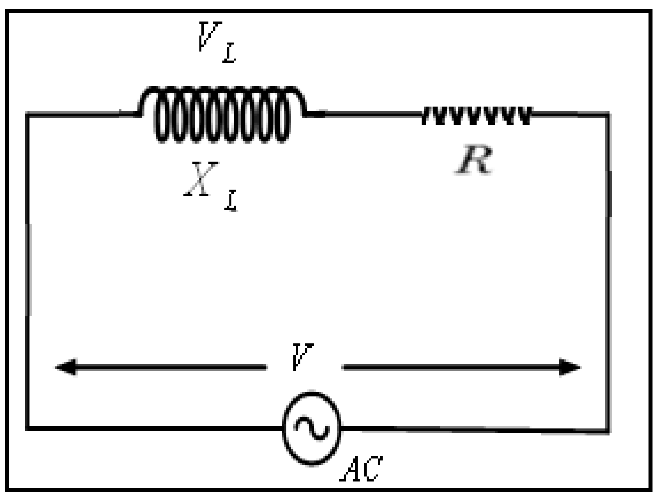
Simple Circuit	R	L	C	$X_L = \omega L$	$X_C = \dfrac{1}{\omega C}$	$\phi = \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right)$	$Z = \sqrt{R^2 + (X_L - X_C)^2}$
purely resistive	R	0	∞	0	0	0	R
purely inductive	0	L	∞	X_L	0	$\pi / 2$	X_L
purely capacitive	0	0	C	0	X_C	$-\pi / 2$	X_C

Chapter Three

Alternating Series circuit

1-L R Alternating Series Circuit

Figure 1 represents a one of the Alternating Series Circuit have a resistance R and inductance L



- In the resistance, the voltage and current are in the same phase.
- In the inductance, the voltages (leads) precedes the current by $\pi / 2$

The voltage is calculated by

$$\boxed{V = \sqrt{V_R^2 + V_L^2}}$$

$$\boxed{V = Z\,I \qquad \mathrm{V_R} = I\,R \qquad \mathrm{V_L} = I\,X_L}$$

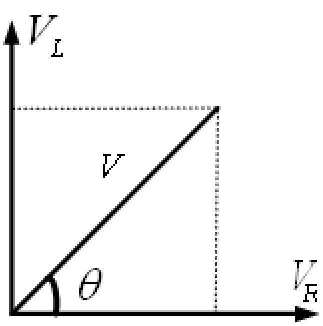
By substituting

$$\boxed{IZ = I\sqrt{R^2 + X_L{}^2}}$$

Therefore, the total impedance is

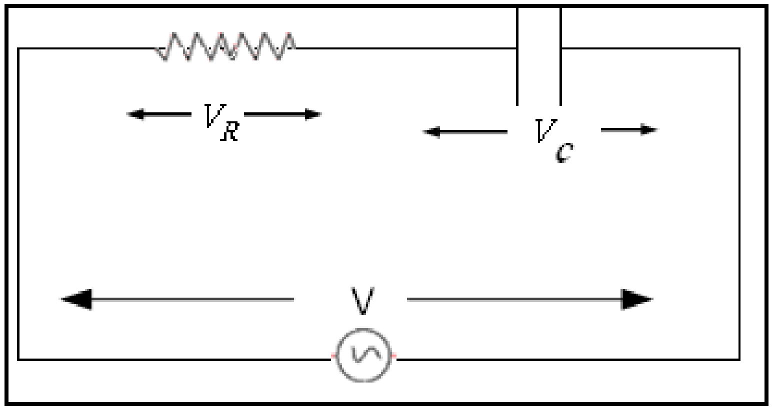
$$\boxed{Z = \sqrt{R^2 + X_L{}^2}}$$

The angle phase



$$\tan\theta = \frac{V_L}{V_R} = \frac{X_L}{R}$$

2-R C Alternating series circuit

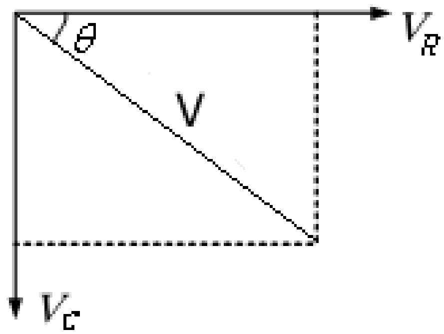


The figure represents AC Source and capacitor (C)connect in series with ohomic resistance (R)

As we know before:

- In the resistance, the voltage and current are in the same phase
- In capacitor, the voltage delays current by π / 2

The total voltage is



$$V = \sqrt{V_R^2 + V_C^2}$$

$$V_C = I\,X_C \qquad \mathrm{V_R} = IR \qquad \text{and} \qquad \mathrm{V = I\,Z}$$

By substituting

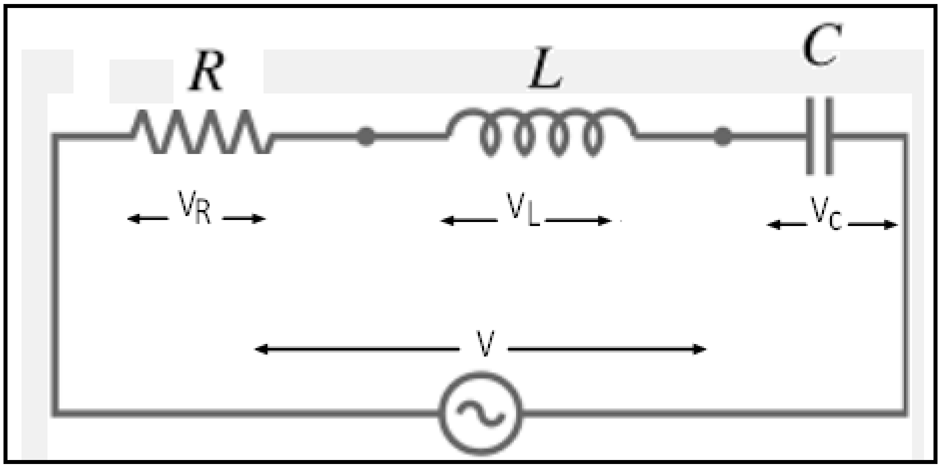
$$IZ = I\sqrt{R^2 + X_C^2}$$

$$Z = \sqrt{R^2 + X_C^2}$$

The angle phase is the angle between the voltages obtained with current

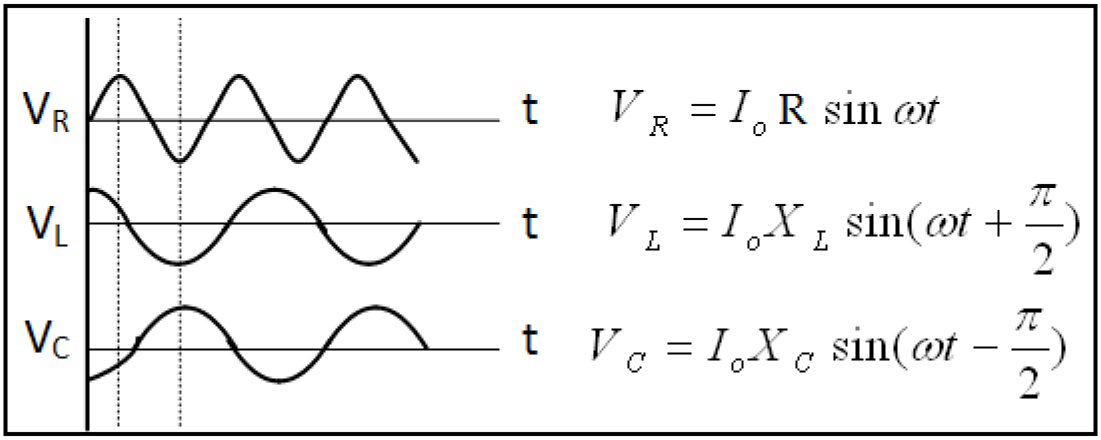
$$\tan\Phi = \frac{-V_c}{V_R} = \frac{-IX_C}{IR} = \frac{-X_C}{R}$$

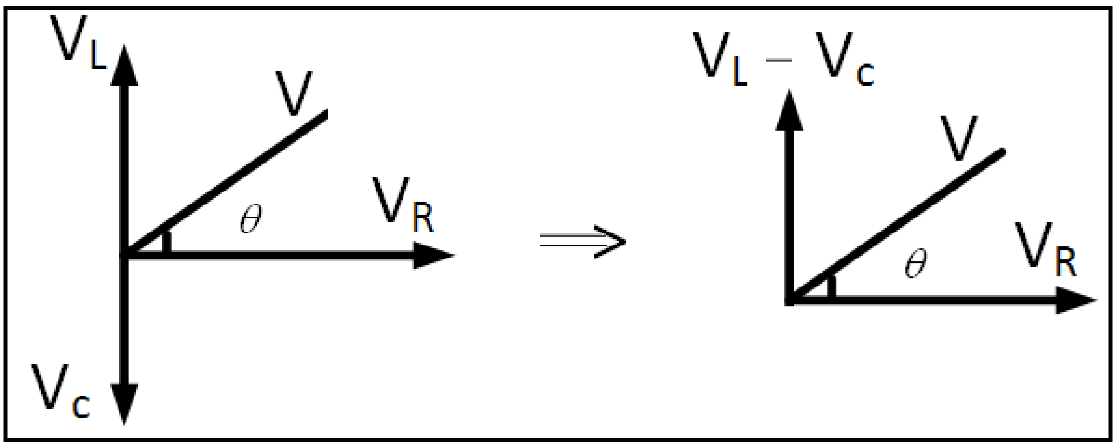
3- RLC alternating series circuit



The above circuit consists of Capacitor (C), Inductance (L) and Resistance (R) is connecting in series with AC power. As we mentioned before:

- In the resistance, the voltage and current are in the same phase
- In capacitor, the voltage delays current by π / 2





From the above figure (vector pattern), we can calculate the impedance as follow

$$\boxed{V = \sqrt{V_R^{\,2} + (V_L - V_C)^2}}$$

$$\boxed{V_L = IX_L \quad \mathrm{V_C} = IX_C \quad \mathrm{V_R} = IR \quad \mathrm{V} = \mathrm{IZ}}$$

By substituting to calculate the impedance Z

$$\boxed{IZ = I\sqrt{R^2 + \left[\left(X_L - X_C\right)^2\right]}}$$

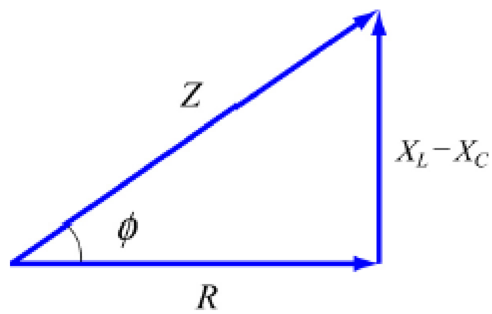
We have already seen that the inductive reactance and capacitance reactance play the role of an effective resistance in the purely inductive and capacitive circuits, respectively. In the series *RLC* circuit, the effective resistance is the *impedance*, defined as

$$\boxed{Z = \sqrt{R^2 + \left[\left(X_L - X_C\right)^2\right]}}$$

To calculate the phase angle, find the angle tangent between the obtained voltage and current

$$\boxed{\tan\Phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}}$$

The relationship between Z, X_L and X_C can be represented by the diagram shown in below



The impedance also has SI units of ohms. In terms of Z, the current may be rewritten as

Notice that the impedance Z also depends on the angular frequency ω, as do X_L and X_C.

The above equation in RLC circuit indicates that the amplitude of the current reaches a maximum when Z is at a minimum. This occurs when $X_L = X_C$

$$wL = \frac{1}{wC}$$

$$w_0 = \frac{1}{\sqrt{LC}}$$

The phenomenon at which I_0reaches a maximum is called a resonance, and the frequency ω_0 is called the resonant frequency. At resonance, the impedance becomes $Z=R$, the amplitude of the current is

$$I_0 = \frac{V_0}{R}$$

In addition, phase angle is

$$\phi = 0$$

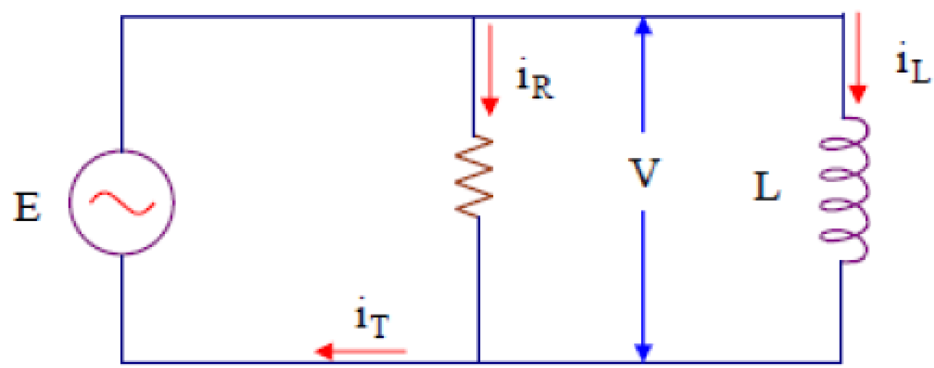
When resonance occurs in serial RLC circuit

1. Inductive reactance = capacitive reactance
2. The resistance in the circuit is equal to the ohmic resistance only.

3. The total voltage is equal to the voltage difference between the two ends of the ohmic resistance.
4. The phase difference between current and voltage is zero.
5. Consistent current and total voltage in phase.
6. The circuit has less resistance.
7. Passing in the circuit maximum current intensity

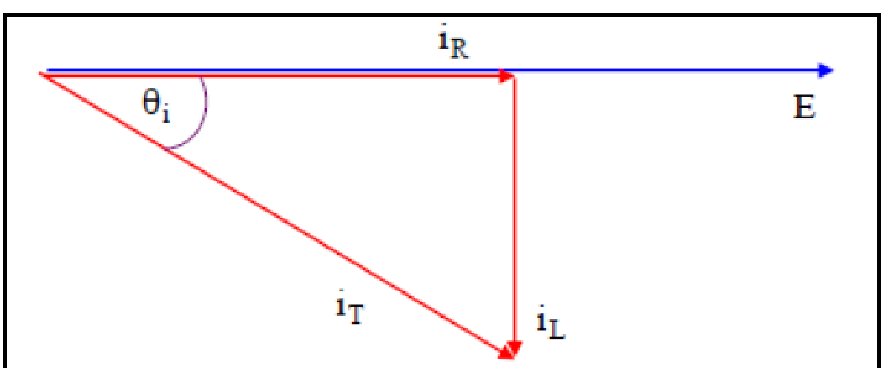
Alternating parallel circuit

1- A circuit containing resistance R connected with inductive L in parallel with an AC source



مقاومة وملف على التوازي

The previous figure represents an AC circuit containing only two elements, R and L are connected in parallel.



المخطط الاتجاهي لملف ومقاومة على التوازي.

It is known before that the I_L current is delayed from the I_R current because the I_R current in the same phase with voltage V, and the induction current I_L delayed with 90 degrees from voltage then

$$I_t^2 = I_R^2 + I_L^2$$

$$= \left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_L}\right)^2$$

$$I_t = V\sqrt{\frac{1}{R^2} + \frac{1}{X_L{}^2}}$$

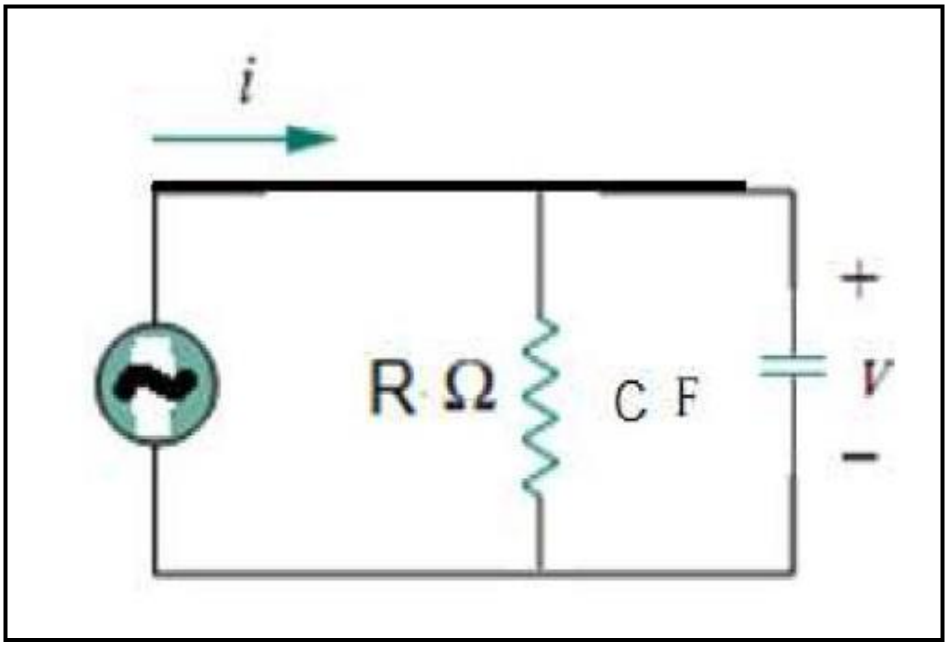
The impedance in this case

$$Z = \frac{V}{I_t} = \frac{1}{\sqrt{\frac{1}{R^2} + \frac{1}{X_L{}^2}}}$$

The total current delayed with total voltage by angel

$$\tan \Phi_i = \frac{I_L}{I_R} = \frac{R}{X_L}$$

2- A circuit containing capactance C connected with resistance R in parallel with an AC source



in this case the current of the capacitor leads to the current of the resistance with 90 degree because the resistance current is in the same phase with the voltage.

$$I_t^2 = I_R^2 + I_c^2$$

$$= \left(\frac{V}{R} \right)^2 + \left(\frac{V}{X_C} \right)^2$$

$$I_t = V \sqrt{\frac{1}{R^2} + \frac{1}{{X_C}^2}}$$

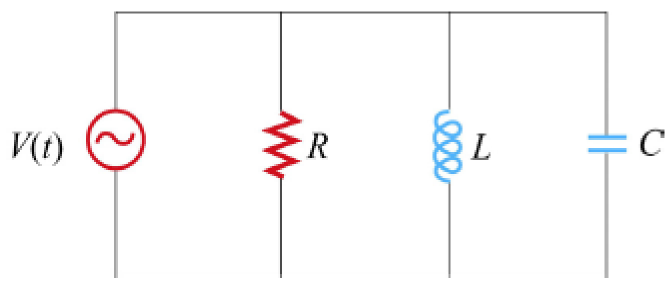
$$\frac{V}{I_t} = \frac{1}{\sqrt{\frac{1}{R^2} + \frac{1}{{X_C}^2}}} = Z$$

$$\tan \Phi_i = \frac{I_C}{I_R} = \frac{R}{X_C}$$

3- Parallel *RLC* Circuit

Consider the parallel *RLC* circuit illustrated in the following Figure 12.6.1. The AC voltage source is

$$V = V_0 \sin wt$$



Unlike the series RLC circuit, the instantaneous voltages across all three-circuit elements R, L, and C are the same, and each voltage is in phase with the current through the resistor. However, the currents through each element will be different.

In analyzing this circuit,. The current in the resistor is

$$I_R = \frac{V}{R} = \frac{V_0}{R}\sin wt$$
$$= I_{R0}\sin wt$$

The voltage across the inductor is

$$I_L = I_{L0}\sin\left(wt - \frac{\pi}{2}\right)$$

Similarly, the voltage across the capacitor is

$$I_C = I_{C0}\sin\left(wt + \frac{\pi}{2}\right)$$

Using Kirchhoff's junction rule, the total current in the circuit is simply the sum of all three currents.

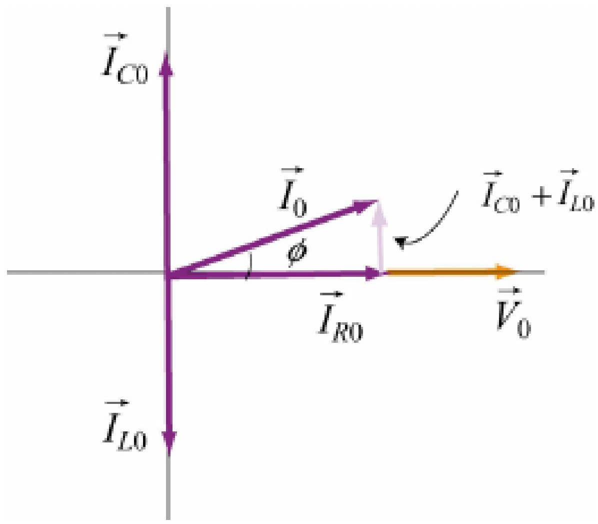
$$I = I_R + I_L + I_C$$

$$= I_{R0}\sin\omega t + I_{L0}\sin\left(\omega t - \frac{\pi}{2}\right) + I_{C0}\sin\left(\omega t + \frac{\pi}{2}\right)$$

The currents can be represented with the phasor diagram shown in Figure. I_0, can be obtained as

$$I_0 = |\vec{I}_0| = |\vec{I}_{R0} + \vec{I}_{L0} + \vec{I}_{C0}| = \sqrt{I_{R0}^2 + (I_{C0} - I_{L0})^2}$$

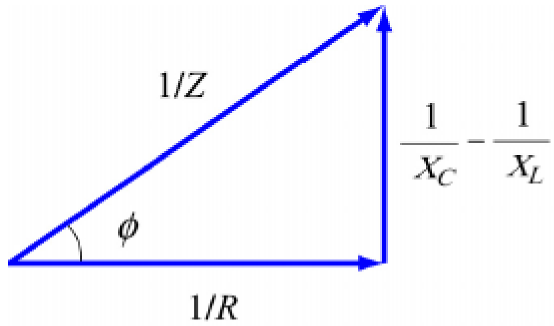
$$= V_0 \sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2} = V_0 \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$



With $I_0 = V_0 / Z$ the (inverse) impedance of the circuit is given by

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$

The relationship between *Z*, *R*, and *L* is shown in below Figure



From the figure or the phasor diagram shown in below Figure, we see that the phase can be obtained as

The resonance condition for the parallel *RLC* circuit is given by φ=0, which implies

$$\frac{1}{X_C} = \frac{1}{X_L}$$

The resonant frequency is

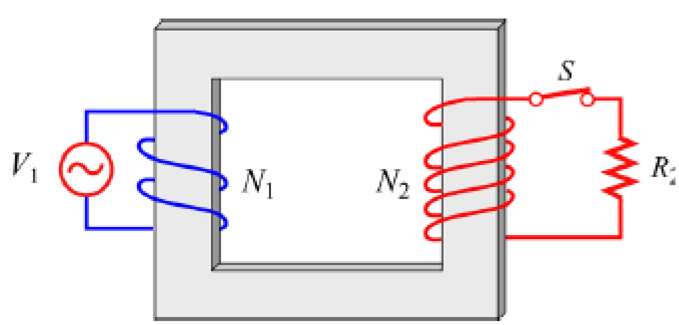
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

which is the same as for the series *RLC* circuit., we readily see that 1/*Z* is minimum (or *Z* is maximum) at resonance. The current in the inductor exactly cancels out the current in the capacitor, so that the total current in the circuit reaches a minimum, and is equal to the current in the resistor:

$$I_0 = \frac{V_0}{R}$$

Transformer

A transformer is a device used to increase or decrease the AC voltage in a circuit. A typical device consists of two coils of wire, a primary and a secondary, wound around an iron core, as illustrated in down Figure. The primary coil, with N_1 turns, is connected to alternating voltage source V_t . The secondary coil has N_2 turns and is connected to a "load resistance" R_2. The way transformers operate is based on the principle that an alternating current in the primary coil will induce an alternating emf on the secondary coil due to their mutual inductance



In the primary circuit, neglecting the small resistance in the coil, Faraday's law of induction implies

$$V_1 = -N_1 \frac{d\Phi_B}{dt}$$

where Φ_B is the magnetic flux through one turn of the primary coil. The iron core, which extends from the primary to the secondary coils, serves to increase the magnetic field produced by the current in the primary coil and ensure that nearly all the magnetic flux through the primary coil also passes through each turn of the secondary coil. Thus, the voltage (or induced emf) across the secondary coil is

$$V_2 = -N_2 \frac{d\Phi_B}{dt}$$

In the case of an ideal transformer, power loss due to Joule heating can be ignored, so that the power supplied by the primary coil is completely transferred to the secondary coil:

$$I_1V_1 = I_2V_2$$

In addition, no magnetic flux leaks out from the iron core, and the flux Φ_B through each turn is the same in both the primary and the secondary coils. Combining the two expressions, we are lead to the transformer equation

$$\boxed{\frac{V_2}{V_1} = \frac{N_2}{N_1}}$$

By combining the two equations above, the transformation of currents in the two coils may be obtained as:

$$I_1 = \left(\frac{V_2}{V_1} \right) I_2 = \left(\frac{N_2}{N_1} \right) I_2$$

Thus, we see that the ratio of the output voltage to the input voltage is determined by the *turn ratio* N_2/N_1 if $N_2>N_1$ then $V_2>V_1$ which means that output voltage in the second coil is greater than the input voltage in the primary coil. A transformer with $N_2>N_1$ is called a *step-up* transformer. On other hand if $N_2<N_1$ then $V_2<V_1$ and the transformer is called step down transformer

Summary

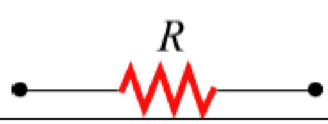
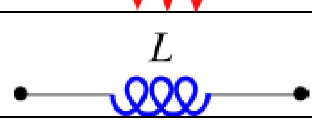
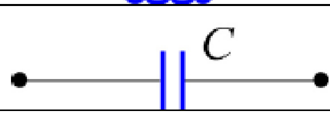
In an AC circuit with a sinusoidal voltage source

$V = V_0 \sin wt$

the current is given by

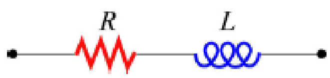
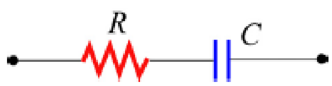
$I = I_0 \sin(wt - \phi)$

Where , I_0 is the amplitude and ϕ is the phase constant. For simple circuit with only one element (a resistor, a capacitor or an inductor) connected to the voltage source, the results are as follows:

Circuit Elements	Resistance /Reactance	Current Amplitude	Phase angle ϕ
	R	$I_{R0} = \frac{V_0}{R}$	0
	$X_L = \omega L$	$I_{L0} = \frac{V_0}{X_L}$	$\pi / 2$ current lags voltage by $90°$
	$X_C = \frac{1}{\omega C}$	$I_{C0} = \frac{V_0}{X_C}$	$-\pi / 2$ current leads voltage by $90°$

whereX_L is the **inductive reactance** and X_C is the **capacitive reactance**

For circuits which have more than one circuit element connected in series, the results are

Circuit Elements	Impedance Z	Current Amplitude	Phase angle ϕ
	$\sqrt{R^2 + X_L^2}$	$I_0 = \dfrac{V_0}{\sqrt{R^2 + X_L^2}}$	$0 < \phi < \dfrac{\pi}{2}$
	$\sqrt{R^2 + X_C^2}$	$I_0 = \dfrac{V_0}{\sqrt{R^2 + X_C^2}}$	$-\dfrac{\pi}{2} < \phi < 0$
	$\sqrt{R^2 + (X_L - X_C)^2}$	$I_0 = \dfrac{V_0}{\sqrt{R^2 + (X_L - X_C)^2}}$	$\phi > 0$ if $X_L > X_C$ $\phi < 0$ if $X_L < X_C$

where Z is the **impedance** Z of the circuit. For a series RLC circuit, we have

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$$

The phase angle between the voltage and the current in an AC circuit is

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

- In the parallel *RLC* circuit, the impedance is given by

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$

and the phase is

$$\phi = \tan^{-1}\left[R\left(\frac{1}{X_C} - \frac{1}{X_L}\right)\right] = \tan^{-1}\left[R\left(\omega C - \frac{1}{\omega L}\right)\right]$$

- The **rms** (root mean square) voltage and current in an AC circuit are given by

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}, \qquad I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

The **resonant frequency**

At **resonance**, the current in the series *RLC* circuit reaches the maximum, but the current in the parallel *RLC* circuit is at a minimum.

- The **transformer equation** is

$$\boxed{\frac{V_2}{V_1} = \frac{N_2}{N_1}}$$

where V_1 is the voltage source in the primary coil with N_1 turns, and V_2 is the output voltage in the secondary coil with N_2 turns. A transformer with $N_2>N_1$ is called a *step-up* transformer, and a transformer with $N_2<N_1$ is called a *step-down* transformer.

- Keep in mind the phase relationships for simple circuits

(1) For a resistor, the voltage and the phase are always in phase.

(2) For an inductor, the current lags the voltage by. 90°

(3) For a capacitor, the current leads to voltage by . 90°

When circuit elements are connected in *series*, the instantaneous current is the same for all elements, and the instantaneous voltages across the elements are out of phase. On the other hand, when circuit elements are connected in *parallel*, the instantaneous voltage is the same for all elements, and the instantaneous currents across the elements are out of phase.

Ex1.

A series *RLC* circuit with L=160 mH and C=100 μF and

R = 40 Ω is connected to a sinusoidal voltage V=40 sin wt

With w =200 rad/s

1. What is the impedance of the circuit

2. What is the phase φ

The impedance of a series *RLC* circuit is given by

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$$

$$X_L = \omega L$$

$$X_C = \frac{1}{\omega C}$$

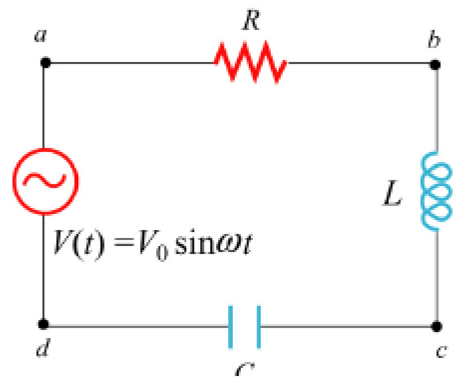
$$Z = \sqrt{(40.0\ \Omega)^2 + \left((200\ \text{rad/s})(0.160\ \text{H}) - \frac{1}{(200\ \text{rad/s})(100 \times 10^{-6}\ \text{F})}\right)^2}$$
$$= 43.9\,\Omega$$

The phase between the current and the voltage is determined by

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{\omega L - \dfrac{1}{\omega C}}{R}\right)$$

$$= \tan^{-1}\left(\frac{(200\ \text{rad/s})(0.160\ \text{H}) - \dfrac{1}{(200\ \text{rad/s})\left(100 \times 10^{-6}\ \text{F}\right)}}{40.0\ \Omega}\right) = -24.2^\circ$$

Ex2



Suppose an AC generator with V=150 sin 100t is connected to a series *RLC* circuit with R=40 ohm , L=80 mH and C=50 μF

Calculate V_{R0}, V_{L0} and V_{C0} the maximum of the voltage drops across each circuit element

The inductive reactance, capacitive reactance and the impedance of the circuit are given by

$$X_C = \frac{1}{\omega C} = \frac{1}{(100 \text{ rad/s})(50.0 \times 10^{-6} \text{ F})} = 200\ \Omega$$

$$X_L = \omega L = (100 \text{ rad/s})(80.0 \times 10^{-3} \text{ H}) = 8.00\ \Omega$$

Mark (√) to the True sentence and (×) to False one.

1. AC current is a constant current
2. Solar cells are a source of AC
3. Inverter is used to convert DC to AC
4. AC is using in lighting and operation of electrical tools
5. AC power is using in metal coating
6. AC is passing through the capacitors while not passing the DC through capacitors
7. The hot-coil Ammeter is used in DC measurement
8. Frequency: is the number of oscillations generated by current or voltage per second
9. The electrical current (AC) can be increased or reduced using electrical transformers
10. For the resistive circuit, both current and voltage are reaching their maximum or minimum values at the same time.
11. The inductive reactance X_L. has units of ohms (Ω),
12. X_L depends linearly on the angular frequency *w*.

13. The inductive reactance, $X_{L,}$ vanishes as *w* approaches maximum value

14. The current lags (delays) voltage by π / 2 in a purely inductive circuit.

15. In purely inductive circuit the inductive reactance is $X_L = 2fL$

16. The capacitance reactance ,$X_{C,}$ is direct proportional to both Capacitor (C) and angular frequency(w)

17. ,X_C diverges as ω approaches zero.

18. In capacitive circuit, the current delays the voltage by $\pi/2$ in capacitive circuit

19. The capacitance reactance in capacitive circuit is calculated from $X_C = \dfrac{1}{2\pi fC}$

20. Capacitance is the amount of electrical charge required to raise the voltage difference between the two panels by one volt

21. Resonance occurs in the case of an RLC circuit connected in serial with a voltage source when $X_C = X_L$.

22. In resonance RLC case, the phase difference between current and voltage is 90 degrees

23.

Choose the Correct answer

The voltage in AC is expressed by :

A. Vsin ω
B. sin t
C. V_o sin ωt
D. V=IR

The Current intensity in AC is expressed by :

A. Isin ω
B. sin t
C. V_o sin ωt
D. V=IR

The current and voltage of the AC current have two corresponding phases if they are:

A. They reach to their maximum and minimum at same time.
B. The current delayed to the voltage with angle
C. The current precedes the voltage at an angle
D. The minimum value of the voltage equals the maximum value of the current

The electric generator or dynamo converts mechanical energy into:

A. Electrical energy
B. Solar energy
C. Kinetic energy
D. DC current

The generated power in resistance is calculated from

A. $P=I_{max} V_{max}/2$
B. $P=V_{max}/2$
C. $P=I_{max}/2$
D. $P=V_{rms}/2$

The maximum value of AC current produces a heat equal three times the produced heat from 2 Ampere DC

A. 3.3 Ampere
B. 2.9 Ampere
C. 4.94 Ampere
D. 5.8 Ampere

The maximum value of AC current produces a heat equal three times the produced heat from 2 Ampere DC

E. 3.3 Ampere
F. 2.9 Ampere
G. 4.94 Ampere
H. 5.8 Ampere

AC volts its value equal 4 is connected with 100 ohm of pure resistance. it was found that the current in mA is

A. 20 mA
B. 30.3 mA a
C. 28 mA
D. 22 mA

AC volts its value equal 4 is connected with 100 ohm of pure resistance . it was found that the power in mW is

A. 105 mW
B. 22.8 mW
C. 78 mW
D. 13.6 mW

In AC circuit has a capacitor , the X_C is -A

B- $X_c = \frac{1}{2\pi fC}$

C- $X_c = \frac{1}{\pi fC}$

D- $X_c = \frac{1}{fC}$

E- $X_c = \frac{1}{f}$

In a AC circuit with a capacitor its capacity equals 1 microfarad, if the frequency is 1000 Hz and the current in the circuit is equal to 2 mA. It was found that voltage through the capacitor is

A. 21.2 volts
B. 33.2 volts
C. 0.32 volts
D. 0.56 volts

In a AC circuit with a capacitor its capacity equals 1 microfarad if the frequency of the current 50 Hz, then X_C is

A. X_C =2500 Ohm
B. X_C =1702 Ohm
C. X_C =3180 Ohm
D. X_C =2652 Ohm

The inductance X_L for AC circuit has a conductance L is

A. $X_L = \pi f L$
B. $X_L = wL$
C. $X_L = fL$
D. $X_L = 2L$

The generated power in resistance is calculated from

E. $P=I_{max} V_{max}/2$
F. $P=V_{max}/2$
G. $P=I_{max}/2$
H. $P=V_{rms}/2$

The maximum value of current produces a heat equal three times the produced heat from DC its value 2 Ampere

I. 3.3 Ampere
J. 2.9 Ampere
K. 4.94 Ampere
L. 5.8 Ampere

AC volts its value equal 4 is connected with 100 ohm of pure resistance . it was found that the current in mA is

E. 20 mA
F. 30.3 mA a
G. 28 mA
H. 22 mA

وصل جهد متردد قيمته العظمى 4 فولت مع مقاومه قيمتها 100 اوم فكانت القدرة مقدرة بالملى وات

E. 105 mW
F. 22.8 mW
G. 78 mW
H. 13.6 mW

فى دائـــــــرة تيار متردد تحتوى على مكثف تكون المفاعلة السعوية

In AC circuit has a capacitor , the X_C is

A. $X_c = \frac{1}{2\pi fC}$
B. $X_c = \frac{1}{\pi fC}$
C. $X_c = \frac{1}{fC}$
D. $X_c = \frac{1}{f}$

فى دائـــــــرة تيار متردد تحتوى على مكثفت تتناسب المفاعلة السعوية طرديا مع كلا من تردد التيار وسعة المكثف

فى دائرة تيار متردد تحتوى على مكثف سعته 1 ميكروفاراد أذا كان التردد 1000 هيرتز والتيار المنساب خلال الدائرة يساوى2 مللى امبيريكون الجهد عبر المكثف

E. 21.2 volts
F. 33.2 volts
G. 0.32 volts
H. 0.56 volts

فى دائرة تيار متردد تحتوى على مكثف سعته 1 ميكروفاراد أذا كان تردد التيار 50 هيرتز تكون المفاعلة السعوية

E. X_C =2500 Ohm
F. X_C =1702 Ohm
G. X_C =3180 Ohm
H. X_C =2652 Ohm

The inductance X_L for AC circuit has a conductance is

E. $X_L = \pi f L$
F. $X_L = wL$
G. $X_L = fL$
H. $X_L = 2L$

ملف حثى حثه الذاتى 2 هنرى مهمل المقاومة الكهربية وصل بمصدر جهد متردد 12 فولت وتردده 50 هيرتـ ز فكانت شدة التيار:

A- 27.2 mA
B- 14.76 mA
C- 19.1 mA
D- 20.2 mA

ملف حثى حثه الذاتى 6 هنرى مهمل المقاومة الكهربية وصل بمصدر جهد متردد 12 فولت وتردده 50 هيرتـ ز فكانت الـ مـ فاعـ لة الحثية

A. 1487 ohm
B. 1884 ohm
C. 2018ohm

D. 1654 ohm

فى دائرة تيار متردد تحتوى على ملف حث حثه الذاتى L ومقاومة كهربية R متصلين على التوالى مع مصدر الجهد المتردد يكون فرق الجهد الكلى هو

A. $V\sqrt{V_R{}^2 + V_L^2}$
B. $V\sqrt{V_R \;\; + V_L}$
C. $V\sqrt{V_R{}^2 . V_L^2}$
D. $V\sqrt{V_R{}^2 \,/\, V_L^2}$

فى دائرة تيار متردد تحتوى على ملف حث حثه الذاتى L ومقاومة كهربية R متصلين على التوالى مع مصدر الجهد المتردد تكون المعاوقة الكلية Z

A. $Z = \sqrt{R + X_L}$
B. $Z = \sqrt{R^2 / X_L{}^2}$
C. $Z = \sqrt{R^2 + X_L{}^2}$
D. $Z = \sqrt{R^2 . X_L{}^2}$

ملف حثه الذاتى 2 هنرى ومقاومته الكهربية 50 اوم وصل على التوالى مع مقاومة كهربية 450 اوم ومصدر جهد متردد 100 فولت ذو تردد 50 هيرتز فكانت شدة التيار المار فى الملف

A. 13.9 mA
B. 12.45 mA
C. 29,1 mA
D. 92.32 mA

دائرة تحتوى على مكثف سعته (C) متصل على التوالى مع مقاومة أوميه (R) ومصدر جهد متردد فتكون زاوية التى يصنعها الجهد المحصل مع التيار هى.

A. $\tan\Phi = \dfrac{-V_C}{R^2}$

B. $\tan\Phi = \dfrac{V}{R}$

C. $\tan\Phi = \dfrac{-V_C}{R}$

D. $\tan\Phi = \dfrac{-V^2{}_C}{R^2}$

دائرة تحتوى على مكثف سعته (C)متصل على التوالى مع مقاومة أوميه (R) ومصدر جهد متردد فتكون المعاوقه الكلية Z هى.

A. $Z = \sqrt{R + X_C}$

B. $Z = \sqrt{R^2 / X_C{}^2}$

C. $Z = \sqrt{R^2 + X_C{}^2}$

D. $Z = \sqrt{R^2 . X_C{}^2}$

دائرة تحتوى على كل من مكثف و مقاومة وملف حث متصلين على التوالى مع مصدر تيار متردد تكون المعاوقة الكلية

A. $Z = \sqrt{R^2 + (X_C - X_L)^2}$

B. $Z = \sqrt{R^2 + (X_C + X_L)^2}$

C. $Z = \sqrt{R^2 + (X_C / X_L)^2}$

D. $Z = \sqrt{R^2 .(X_C - X_L)^2}$

حالة الرنين تحدث عند قيمة معينة من التردد فى حالة دائرة RLC المتصلة على التوالى مع مصدرجهد متردد وقيمته هى

A. $f = \frac{1}{\sqrt{LC}}$

B. $f = \frac{1}{2\pi\sqrt{LC}}$

C. $f = \frac{1}{2\pi LC}$

D. $f = \frac{1}{2\pi\sqrt{Lw}}$