Electric circuits & Networks

Semester - 3 Sub Code : 3041

Baiju.G.S
Lecturer in Electronics Engineering

Course Objectives

To develop the skill to diagnose and rectify the electric circuit networks and understand the operations of electrical machines

Corse Outcome 1 (CO 1)

Solve a given AC circuit to find various parameters using the concept of AC signals and the behaviour of AC through various components.

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Course Outline:

Module Outcomes	Description	Duration (Hours)	Cognitive Level
CO1	**Solve a given AC circuit to find various parameters using the concept of AC signals and the behavior of AC through various components.**		
M1.01	Illustrate the concept of AC signals	1	Understanding
M1.02	Explain the behavior of AC through R-L-C components	2	Understanding
M1.03	Solve the power in given AC circuits by keeping the concept of phasor diagram.	3	Applying
M1.04	Solve given series and parallel RLC circuits and find the various parameters.	3	Applying

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Contents:

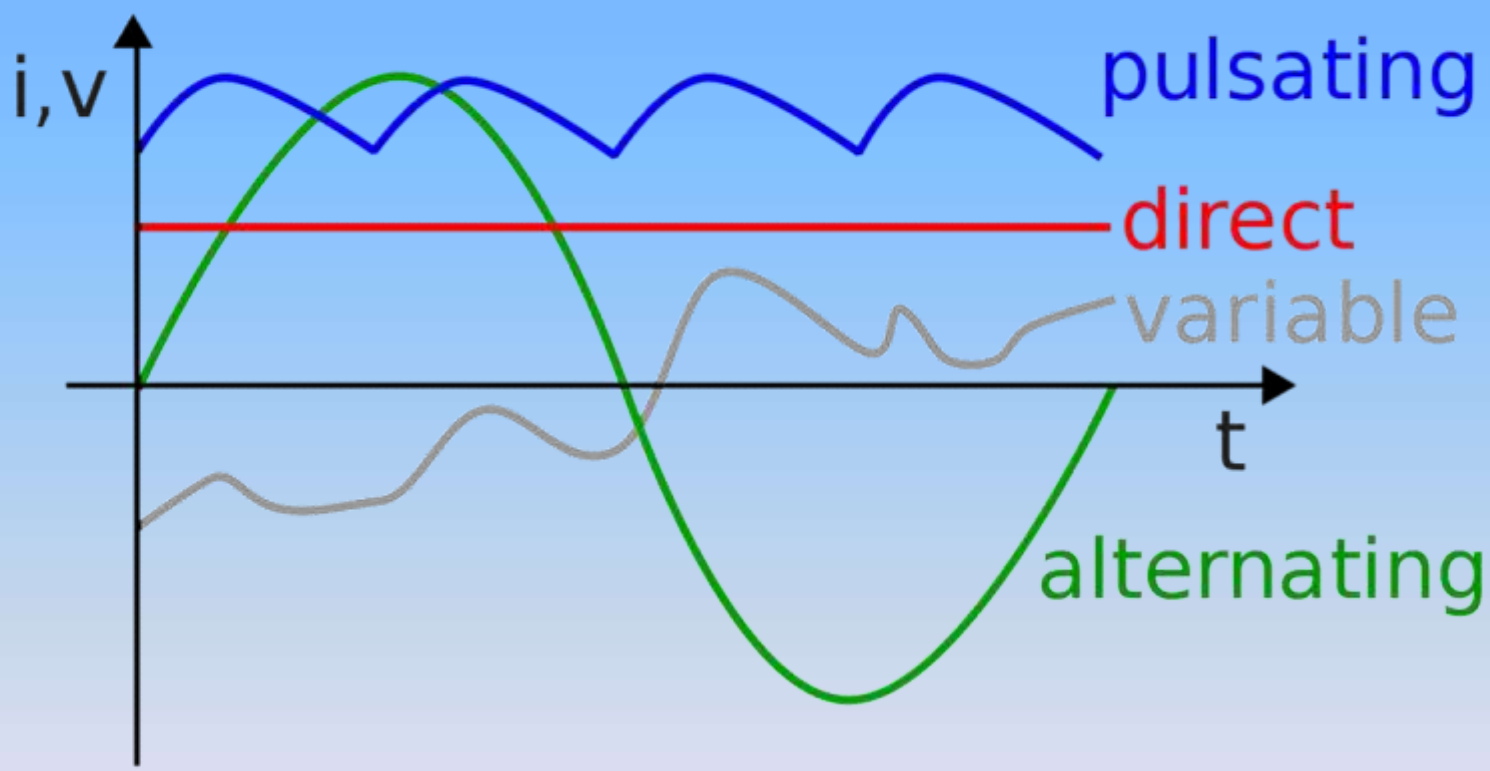
Concept of alternating voltage and current - Different waveforms (Sine, Square, Triangular and Sawtooth)

- representation of alternating quantities - define the terms cycle, time period, frequency, amplitude, phase, maximum value, rms value, average value, form factor

AC through resistance, inductance, and capacitance (Solve simple problems) – Phasor diagrams- power factor definition - calculation of active, reactive and apparent power

Resonance and Q factor in an RLC circuit - series and parallel AC circuits (simple problems)

Types of Signals based on Signal Shape

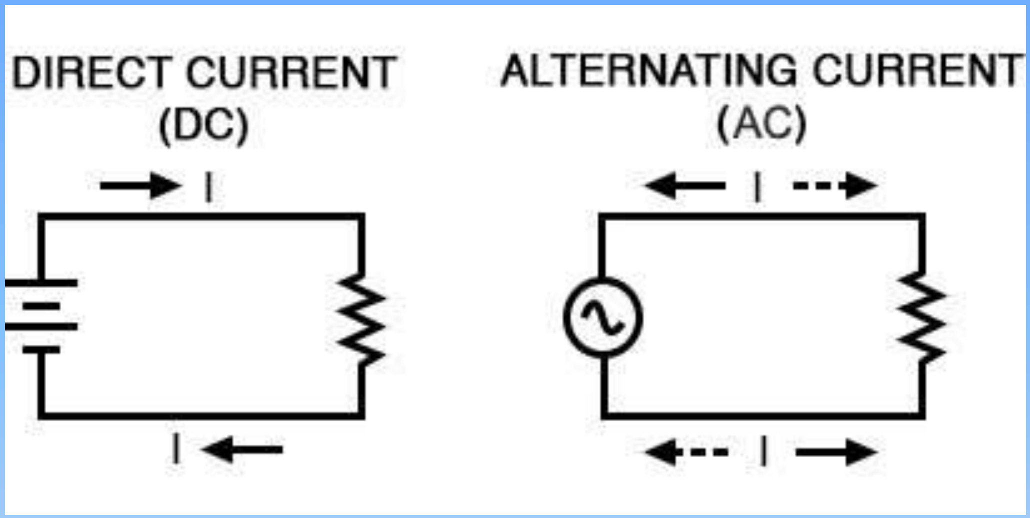


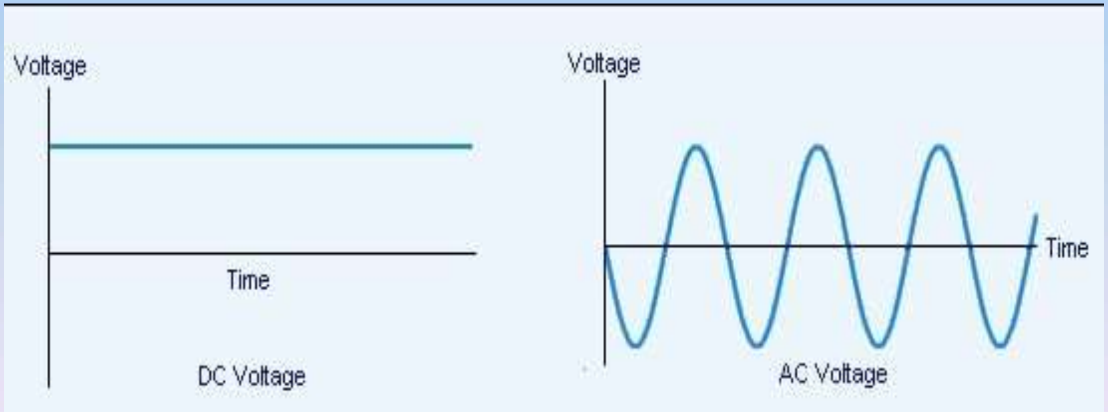
Introduction to Alternative Current (AC)

The majority of electrical power in the world is generated, distributed, and consumed in the form of 50- or 60-Hz sinusoidal alternating current (AC) and voltage.

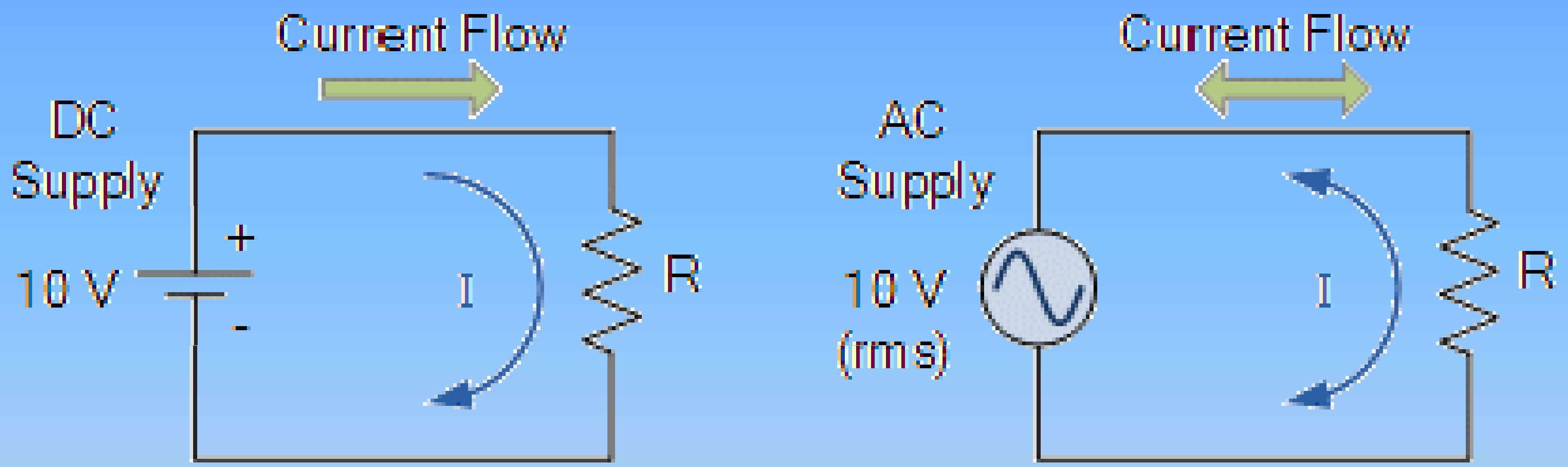
It is used for household and industrial applications such as television sets, computers, microwave ovens, electric stoves, to the large motors used in the industry.

AC & DC


DIRECT CURRENT
(DC)
I
I
ALTERNATING CURRENT
(AC)
I
I


Voltage
Time
DC Voltage
Voltage
Time
AC Voltage

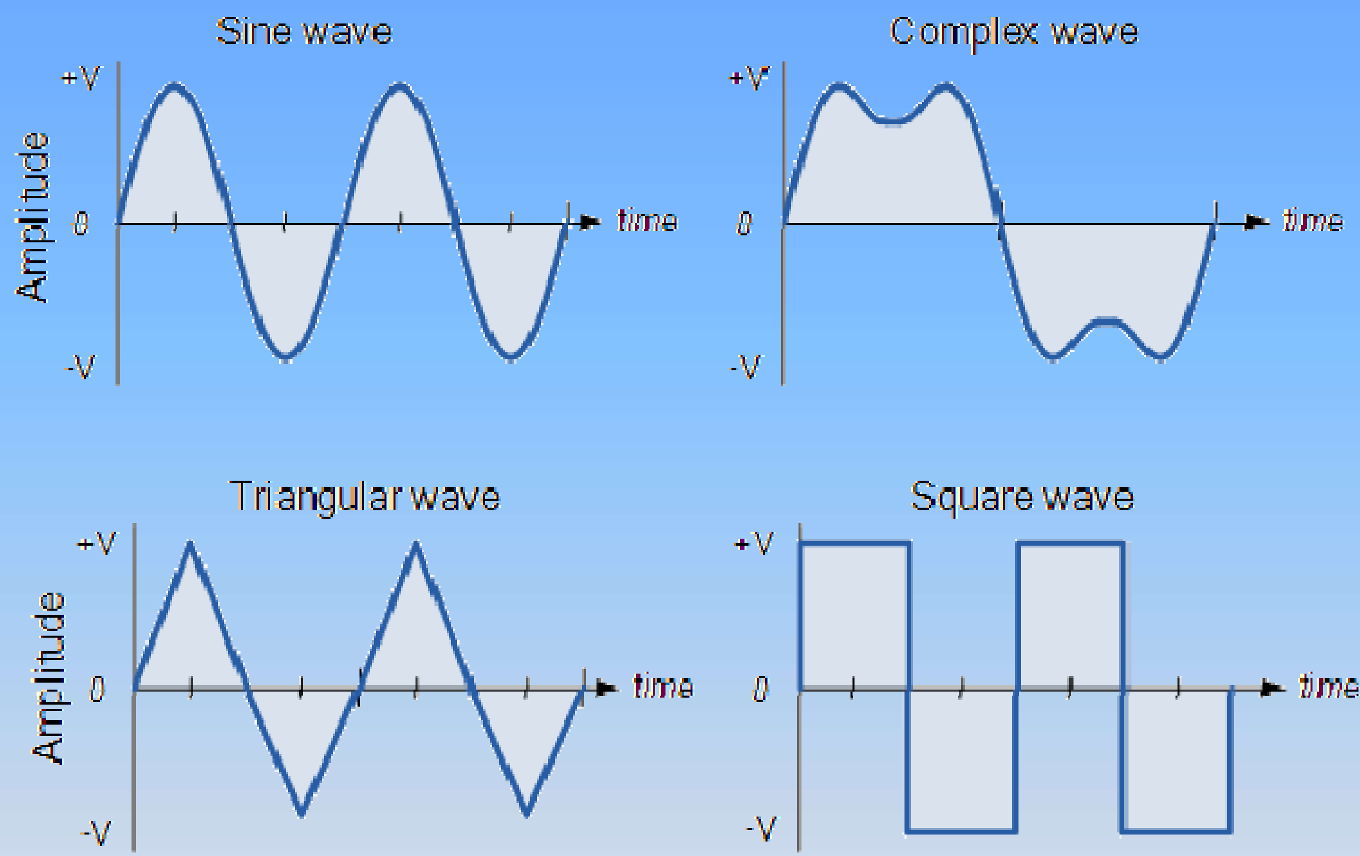
Direction of Current flow

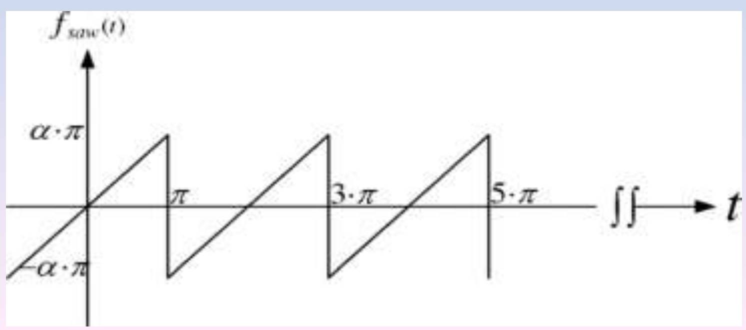


Defining Alternating Current

Alternating current is simply the movement of electrical charge through a medium that changes direction periodically. This is in contrast with **direct current (DC)**, where the movement of charge is only in one direction and is constant.

Examples for Alternating signal





Swatooth wave

Sine Wave

A sine wave or sinusoid is a mathematical curve that describes a smooth periodic oscillation. A sine wave is a continuous wave. It is named after the function sine, of which it is the graph. It occurs often in pure and applied mathematics, as well as physics, engineering, signal processing and many other fields.

ts most basic form as a function of time (t) is:

$$y(t) = A \sin(2\pi f t + \varphi) = A \sin(\omega t + \varphi)$$

Square wave is a non-sinusoidal periodic waveform in which the amplitude alternates at a steady frequency between fixed minimum and maximum values, with the same duration at minimum and maximum. In an ideal square wave, the transitions between minimum and maximum are instantaneous.. A true square wave has a 50% duty cycle (equal high and low periods).

Square waves are often encountered in electronics and signal processing, particularly digital electronics and digital signal processing. Its stochastic counterpart is a two-state trajectory.

Sawtooth wave (or **saw wave**) is a kind of non-sinusoidal waveform. It is so named based on its resemblance to the teeth of a plain-toothed saw with a zero rake angle. A single sawtooth, or an intermittently triggered sawtooth, is called a **ramp waveform**.

The convention is that a sawtooth wave ramps upward and then sharply drops. In a reverse (or inverse) sawtooth wave, the wave ramps downward and then sharply rises.

Triangular wave or **triangle wave** is a non-sinusoidal waveform named for its triangular shape. It is a periodic, piecewise linear, continuous real function

<u>Complex wave</u> is **a wave made up of a series of sine waves**; it is therefore more complex than a single pure sine wave. This series of sine waves always contains a wave called the "FUNDAMENTAL", that has the same FREQUENCY (repetition rate) as the COMPLEX WAVE being created considered the extreme case of an asymmetric triangle wave.

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Equation of a AC sine wave

$$a = A_m \sin(\omega_t + \varphi)$$

$$a = Instaneous\ voltage\ or\ current$$

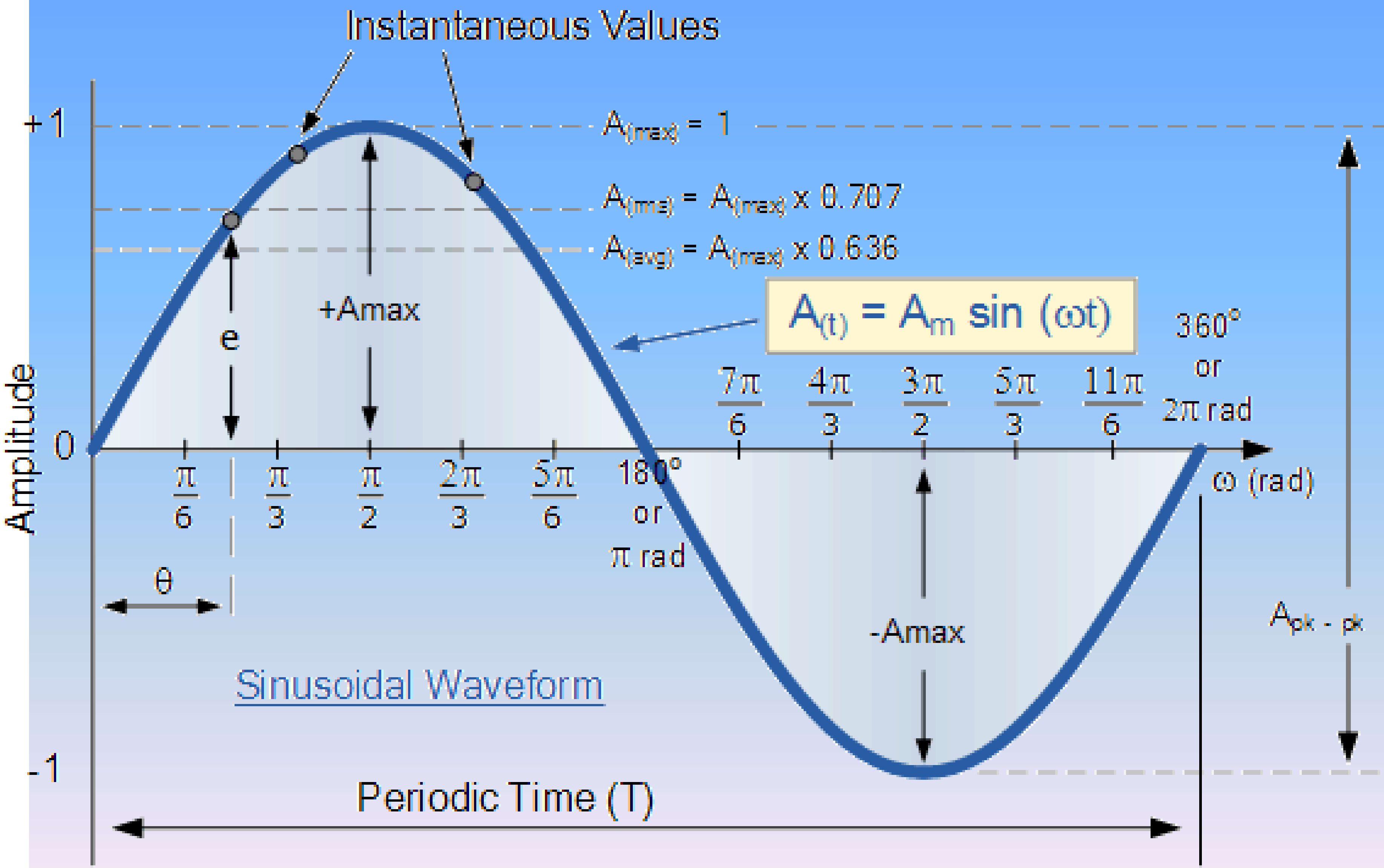
$$A_m = Maximum\ amplitude\ or\ peak\ value$$

$$\omega_t = Angular\ frquency$$

$$\varphi = phase$$

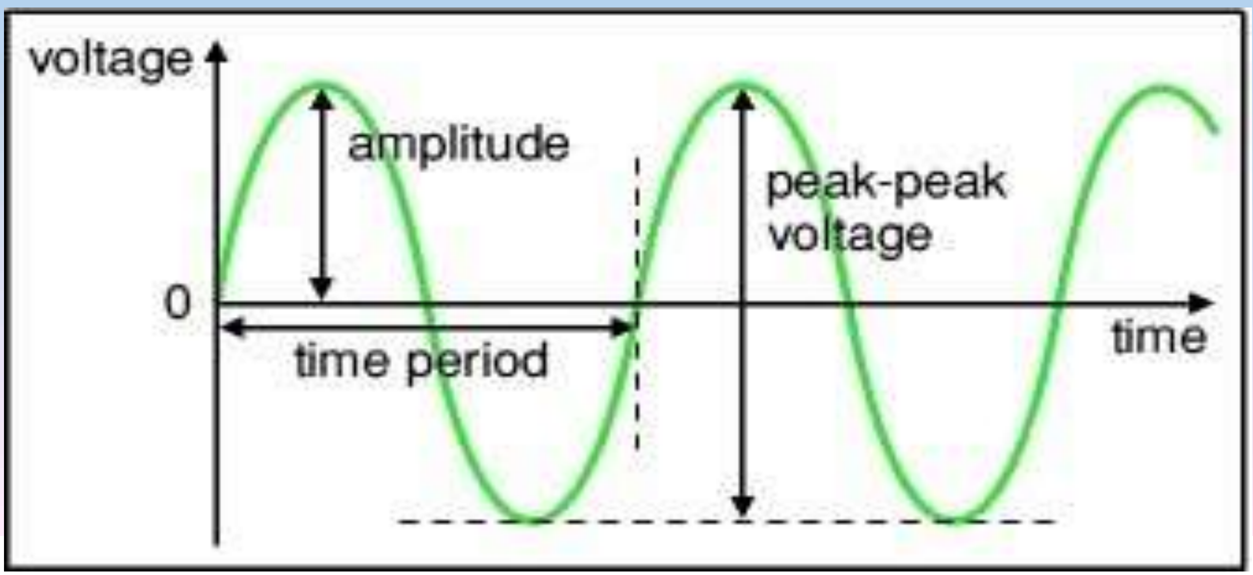
$$\omega \quad = 2\pi f$$

AC Waveform Characteristics



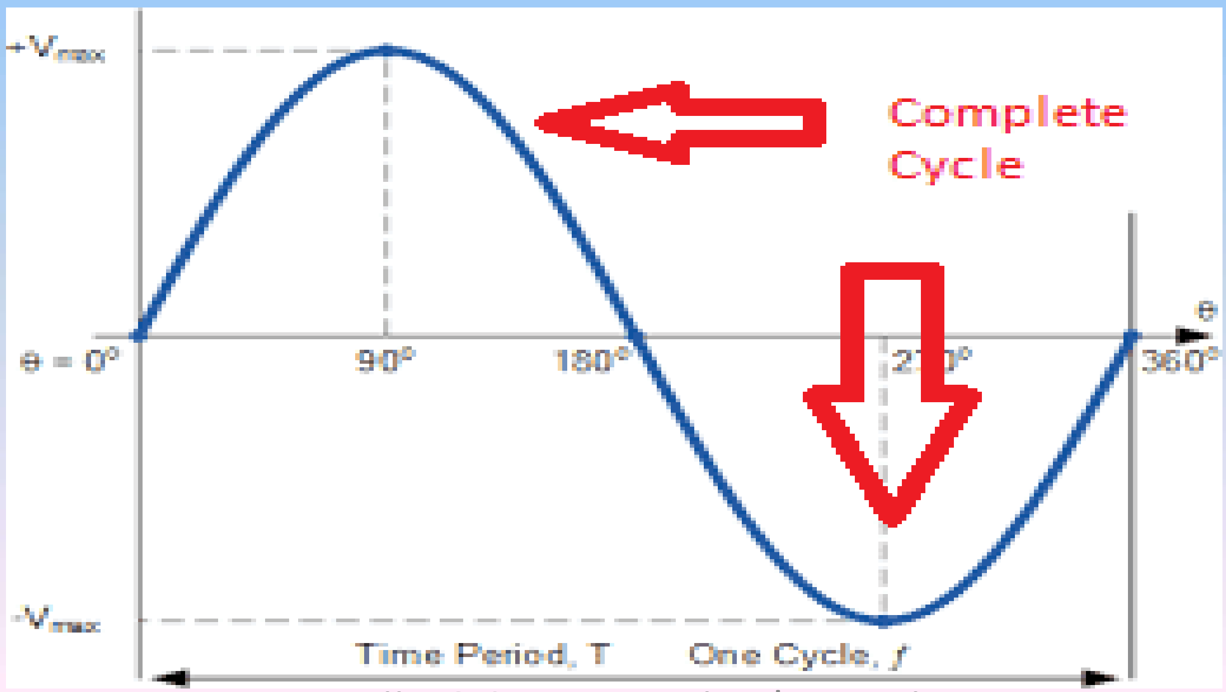
Amplitude

•The amplitude of an AC waveform is **its height as depicted on a graph over time**. An amplitude measurement can take the form of peak, peak-to-peak, average, or RMS quantity. Peak amplitude is the height of an AC waveform as measured from the zero mark to the highest positive or lowest negative point on a graph. **The Amplitude** (A) is the magnitude or ntensity of the signal waveform measured in volts or amps.



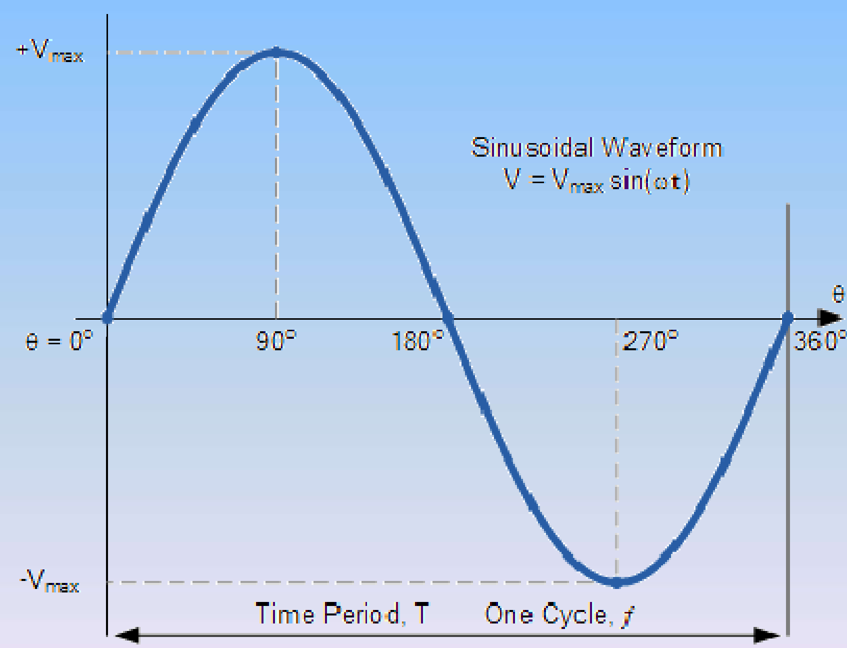
Cycle

A cycle is **a single repetition of "back and forth" alternating current flow**. The time it takes for one complete cycle of the AC signal is called the period. The unit of measurement for the period is seconds (s). The frequency of alternating current signal is the number of cycles in a single second.



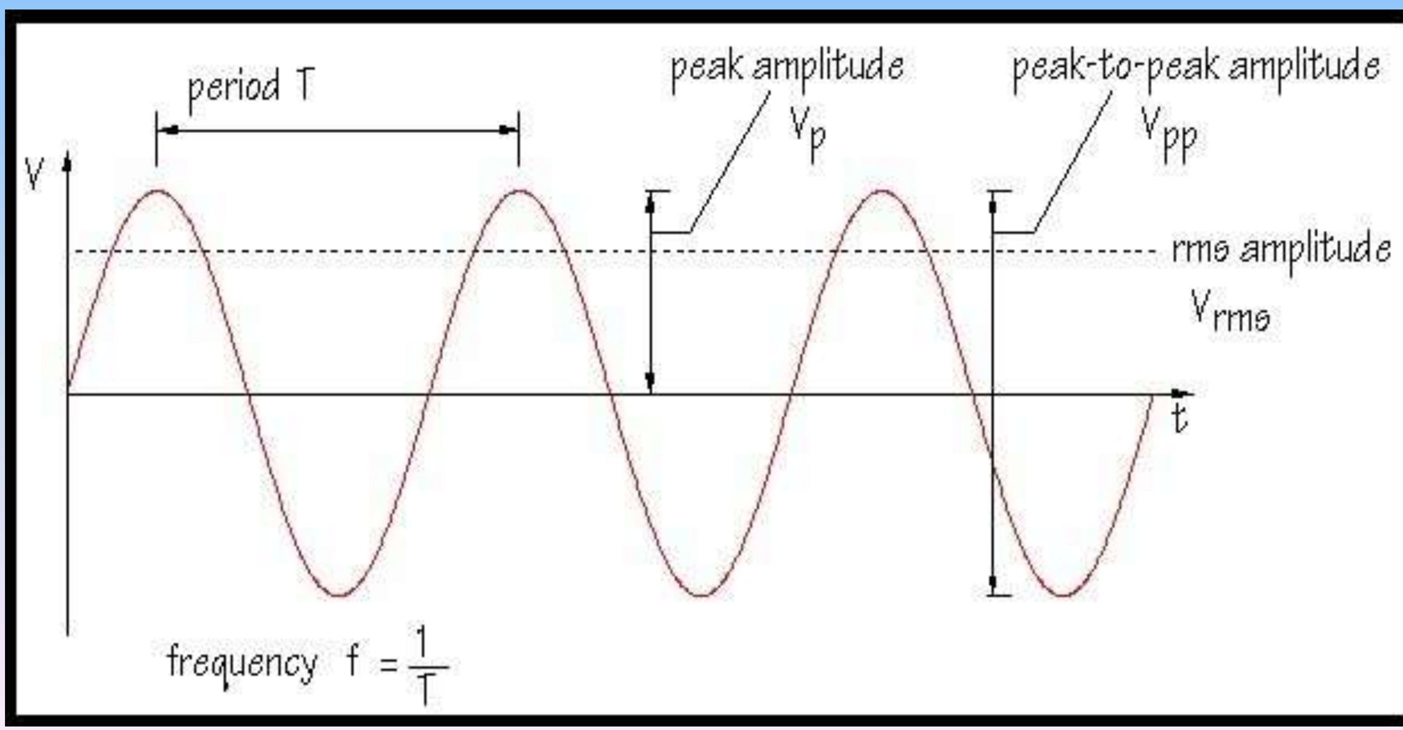
Time Period

The Period, (T) is the length of time in seconds that the waveform takes to repeat itself from start to finish. This can also be called the *Periodic Time* of the waveform for sine waves, or the *Pulse Width* for square waves.



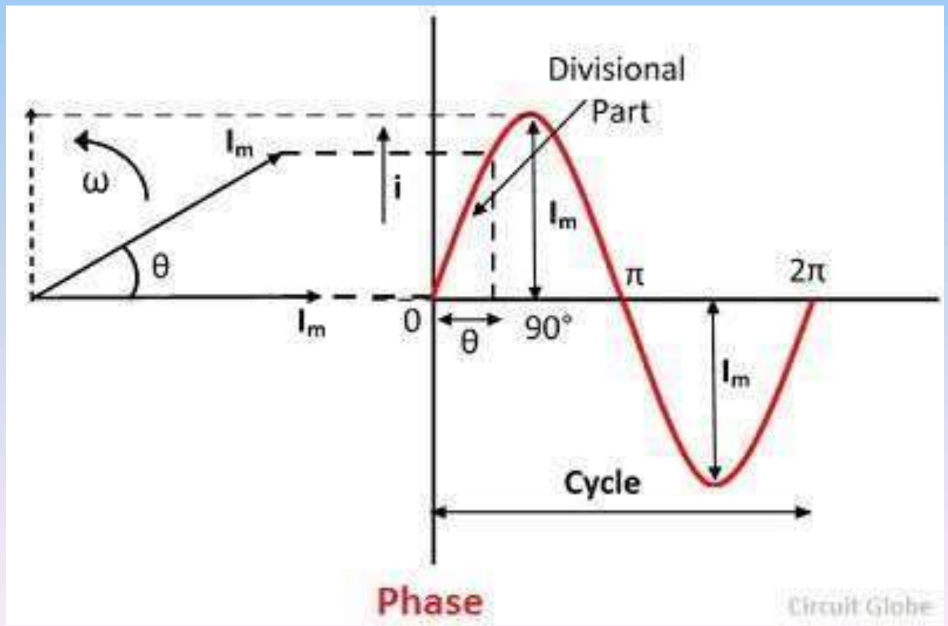
Frequency

- **The Frequency**, (ƒ) is the number of times the waveform repeats itself within a one second time period. Frequency is the reciprocal of the time period, ($ƒ = 1/T$) with the unit of frequency being the *Hertz*, (Hz).



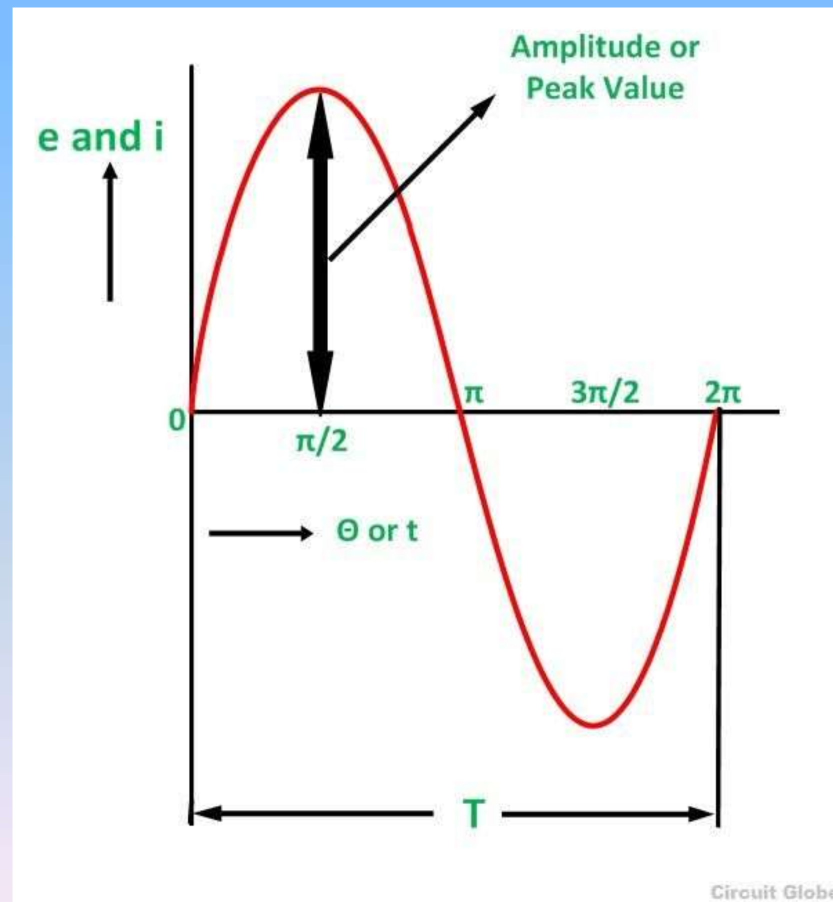
Phase

The phase of an alternating quantity is defined as the divisional part of a cycle through which the quantity moves forward from a selected origin. When the two quantities have the same frequency, and their maximum and minimum point achieve at the same point, then the quantities are said to have in the same phase.



Maximum or Peak Value

The maximum value attained by an alternating quantity during one cycle is called its Peak value. It is also known as the maximum value or amplitude or crest value. The sinusoidal alternating quantity obtains its peak value at 90 degrees



Average value of a sine wave

The average value of a whole sinusoidal waveform over one complete cycle is zero as the two halves cancel each other out, so the average value is taken over half a cycle.

The average value of a sine wave of voltage or current is 0.637 times the peak value, (Vp or Ip)

$$V_{AVE} = \frac{2V_P}{\pi} = 0.637V_p$$

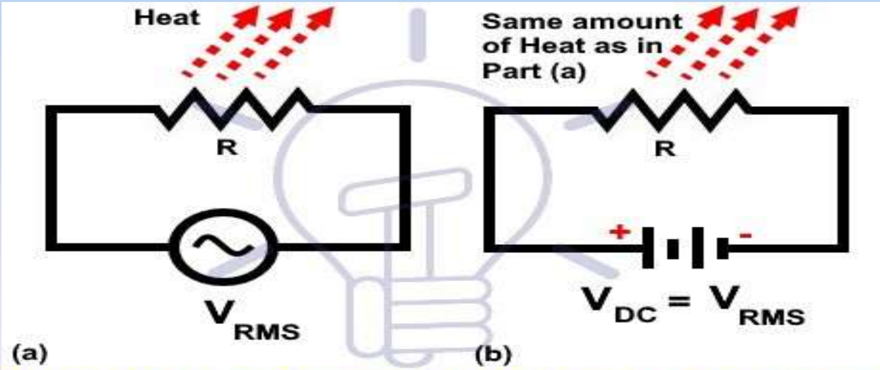
RMS Value of Alternating Current

The **RMS** (**Root Mean Square**) value (also known as **effective** or **virtual** value) of of an alternating current (AC) is the value of direct current (DC) when flowing through a circuit or resistor for the specific time period and produces same amount of heat which produced by the alternating current (AC) when flowing through the same circuit or resistor for a specific time.

The RMS value of AC is greater than the average value.

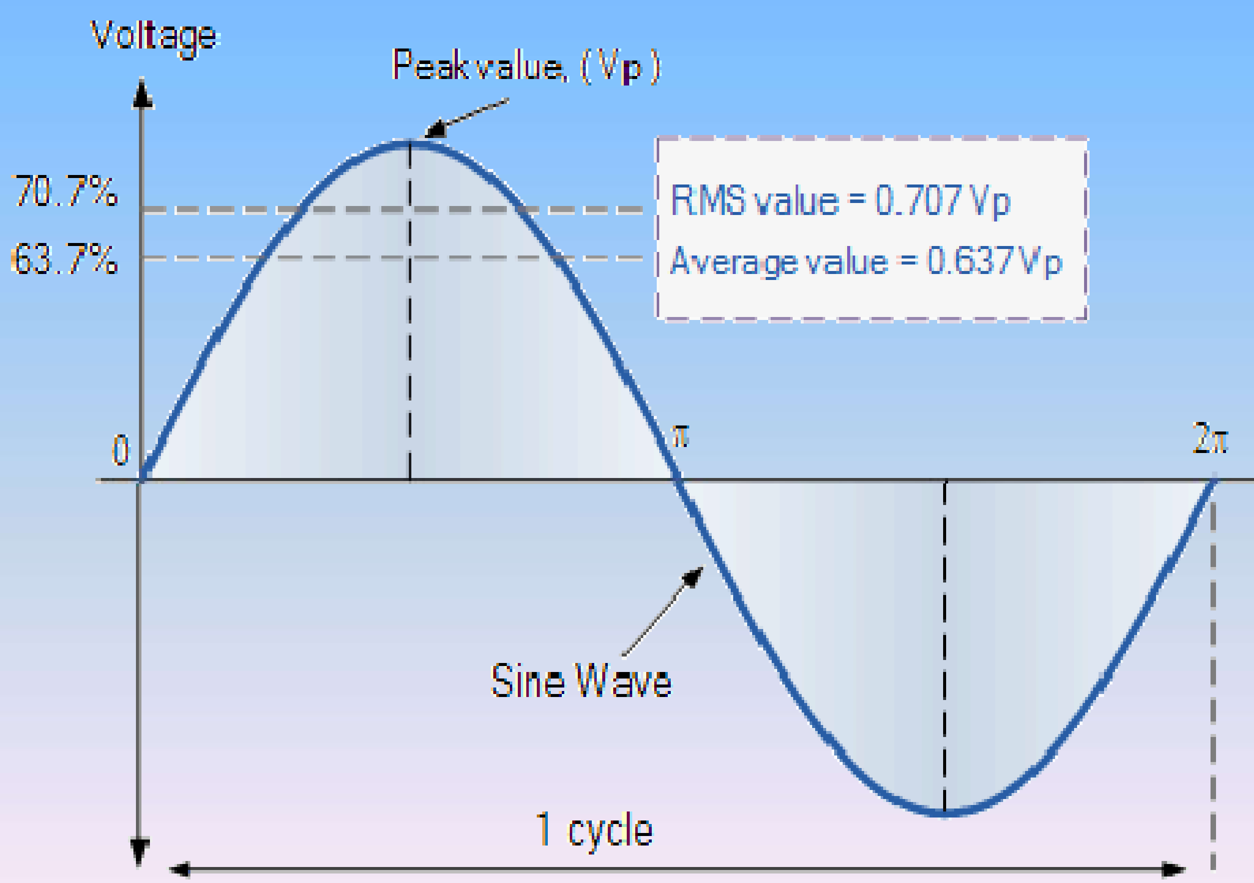
It is denoted by I_{rms} / V_{rms}

$$Vrms = {}^{Vm}/_{\sqrt{2}} = 0.707\,Vm$$



RMS Value of Current & Voltage in Sine wave

- **Average value** = 0.637 × maximum or peak value, Vpk
- **RMS value** = 0.707 × maximum or peak value, Vpk



Form Factor

The ratio between RMS value and Average value of an alternating quantity (Current or Voltage) is known as Form Factor.

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average Value}}$$

$$= \frac{0.707\ E_M}{0.637\ E_M} \text{ Or } \frac{0.707\ I_M}{0.637\ I_M} = \mathbf{1.11}$$

Form factor is a ratio and therefore has no electrical units.

Resistance , Reactance and Impedance

Resistance (R) is **a measure of the opposition to current flow in an electrical circuit**. Resistance is measured in ohms, symbolized by the Greek letter omega (Ω). Ohms are named after Georg Simon Ohm (1784-1854), a German physicist who studied the relationship between voltage, current and resistance.

Conductance (G) is the degree to which an object conducts electricity, calculated as the ratio of the current which flows to the potential difference present. This is the reciprocal of the resistance, and is measured in siemens

Reactance X is the **measure of the opposition that a circuit or a part of a circuit presents to electric current insofar as the current is varying or alternating**. Steady electric currents flowing along conductors in one direction undergo opposition called electrical resistance, but no reactance

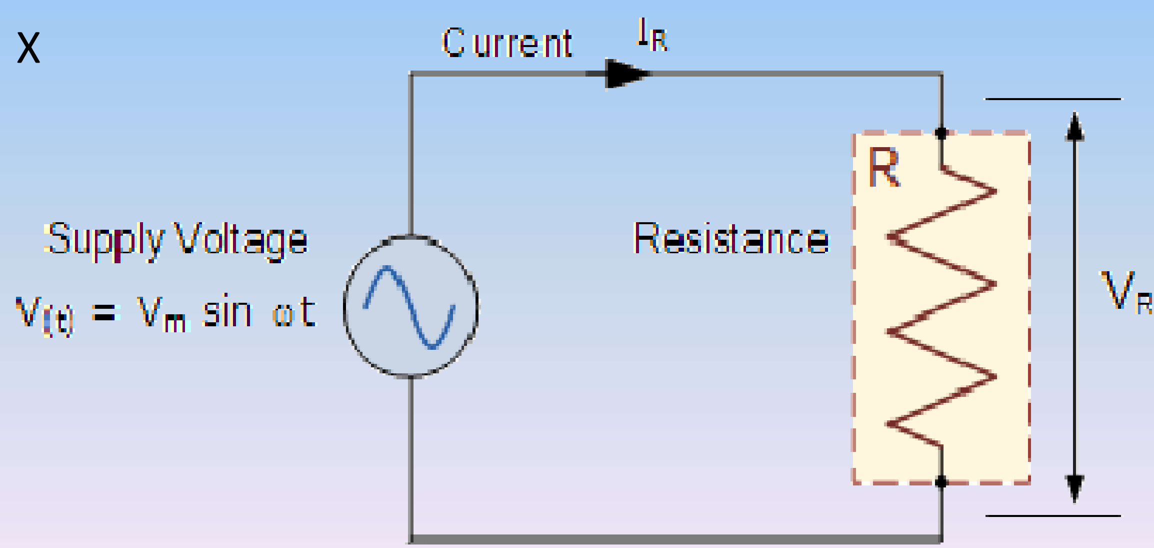
Susceptance (B) is **an expression of the ease with which alternating current (AC) passes through a capacitance or inductance** . In some respects, susceptance is like an AC counterpart of direct current (DC) conductanc mpedance, denoted Z, is **an expression of the opposition that an electronic component, circuit, or system offers to alternating and/or direct electric current**. Impedance is a vector (two-dimensional)quantity consisting of two independent scalar (one-dimensional) phenomena: resistance and reactance.

Admittance Y is a measure of electrical conduction, numerically equal to the reciprocal of the impedance

AC Through Resistance

In pure resistance within an AC circuit the current and voltage will oscillate in phase, that is, when the current is at its maximum the voltage will also be at its maximum, hence there is no phase shift. In addition, the resistance value is not affected by the height of the frequency.

X



Input voltage = Vm Sinwt

Voltage across Resistor

$$V_R = V_{max} \sin \omega t$$

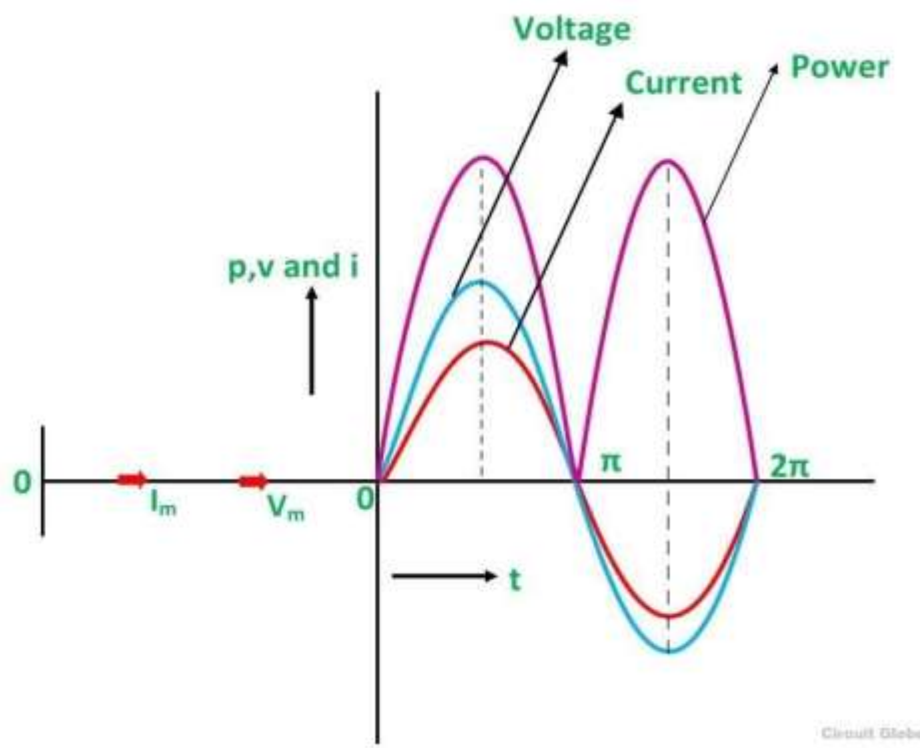
According to Ohms law , I = V/R

$$I_R = \frac{V_R}{R} = \frac{V_{max}}{R} \sin \omega t = I_{max} \sin \omega t$$

$$V_R = I_{max} R \sin \omega t$$

Power in a pure resistive circuit

Instantaneous power, p= vi



$$p = (V_m \sin\omega t)(I_m \sin\omega t)$$

$$p = \frac{V_m I_m}{2} 2\sin^2\omega t = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}(1 - \cos 2\omega t)$$

$$p = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}} - \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos 2\omega t$$

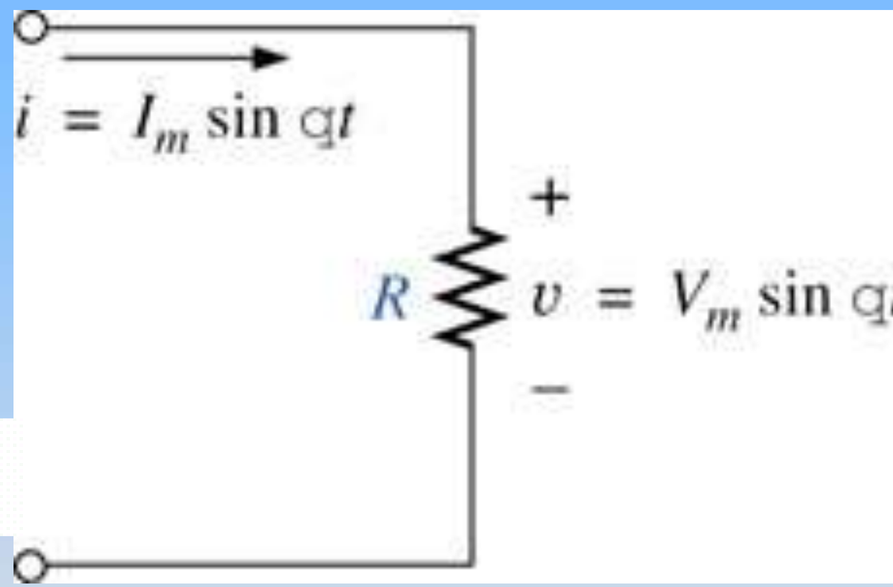
$$P = \text{average of } \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}} - \text{ average of } \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos\omega t \ldots\ldots (4)$$

$$P = V_{r.m.s} I_{r.m.s} - 0$$

Phasor Diagram

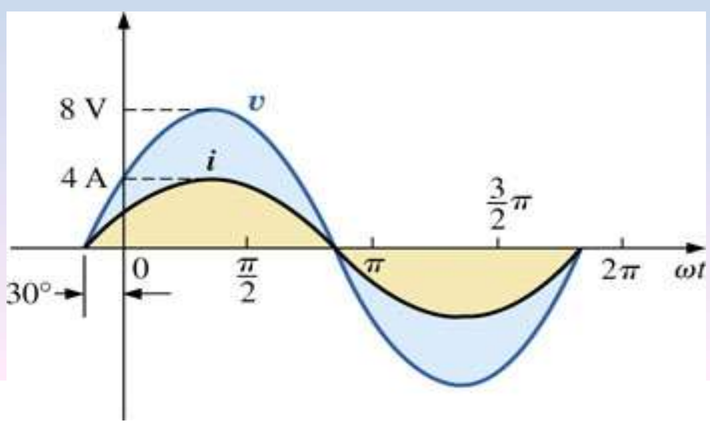
For purely resistive circuit v and *i* were in phase, and the magnitude:

$$I_m = \frac{V_m}{R} \qquad \text{or} \qquad V_m = I_m R$$

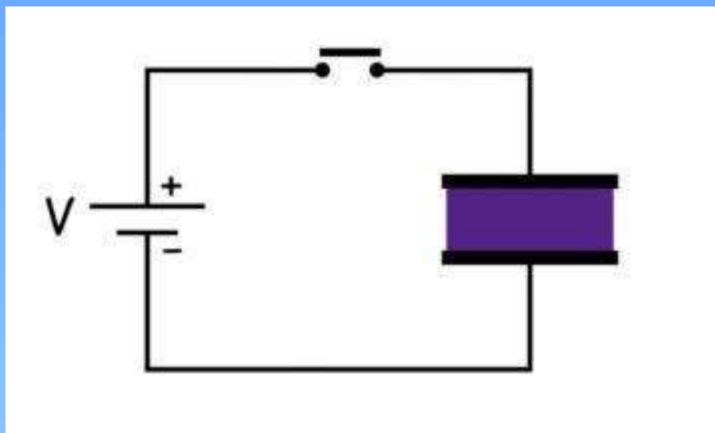


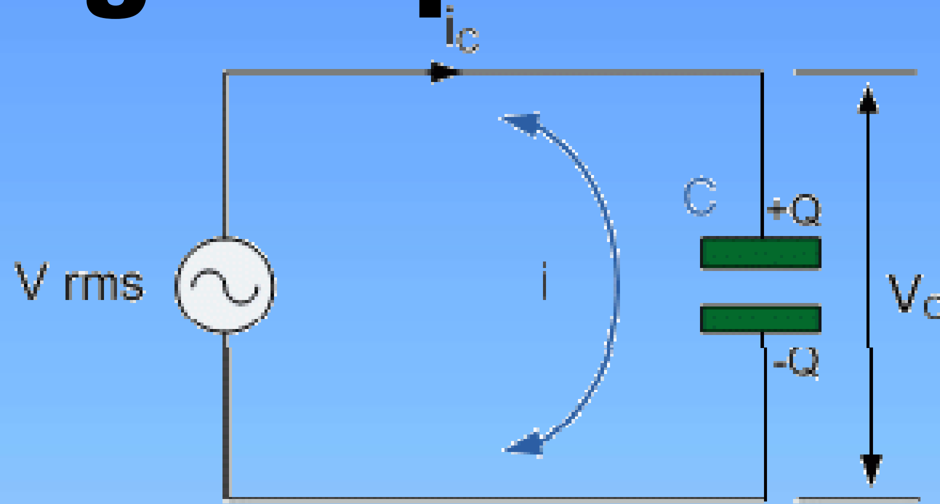
- In phasor form,

$$\upsilon = V_m \sin \omega t \Rightarrow \mathbf{V} = V \angle 0°$$



AC & DC through Capacitance



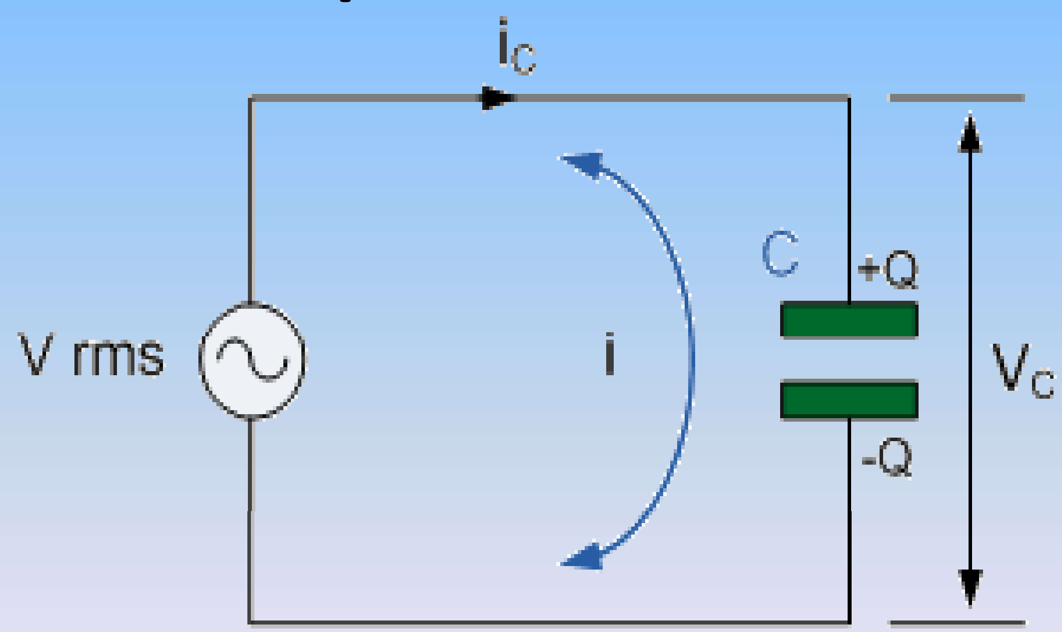


When capacitors are connected across a direct current DC supply voltage they become charged to the value of the applied voltage, acting like temporary storage devices and maintain or hold this charge indefinitely as long as the supply voltage is present.

- During this charging process, a charging current, (i) will flow into the capacitor opposing any changes to the voltage at a rate that is equal to the rate of change of the electrical charge on the plates.
- This charging current can be defined as: i = CdV/dt. Once the capacitor is "fully-charged" the capacitor blocks the flow of any more electrons onto its plates as they have become saturated.

AC through capacitance

Capacitance in AC Circuits **results in a time-dependent current which is shifted in phase by 90º with respect to the supply voltage producing an effect known as capacitive reactance.**



Capacitive Reactance Xc = ½#fC

Capacitive Reactance

- for the pure capacitor, the current leads the voltage by 90° and that the reactance of the capacitor X_C is determined by 1/ψ*C*.

$$v = V_m \sin \omega t \Rightarrow \text{phasor form } \mathbf{V} = V \angle 0°$$

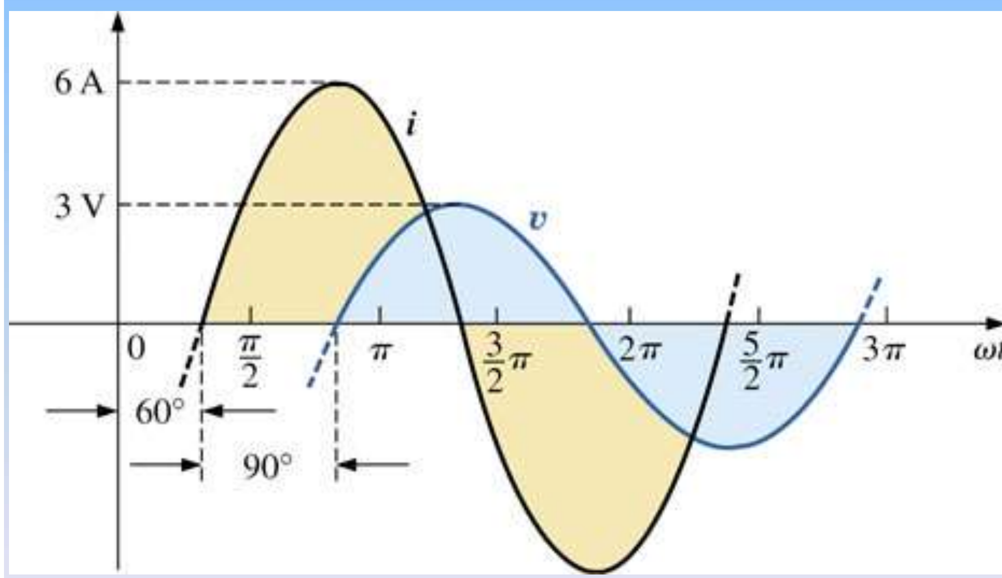


FIG. 15.17 *Waveforms for Example 15.6.*

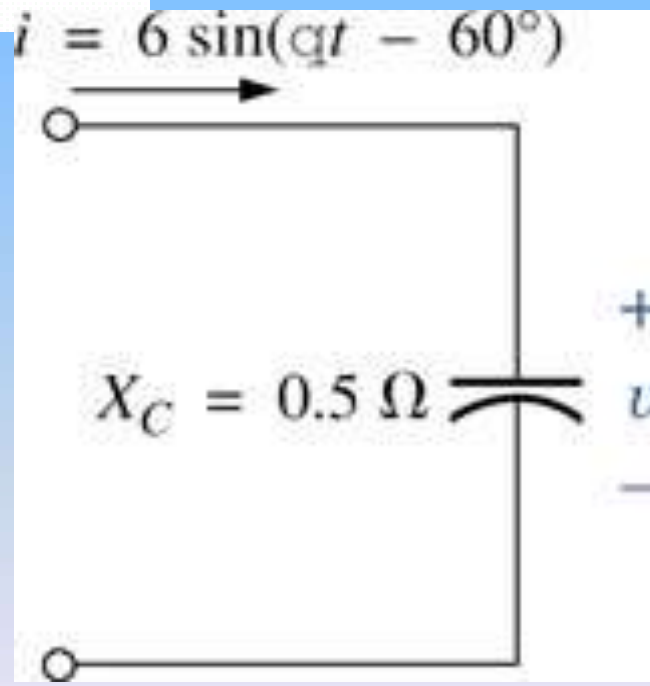
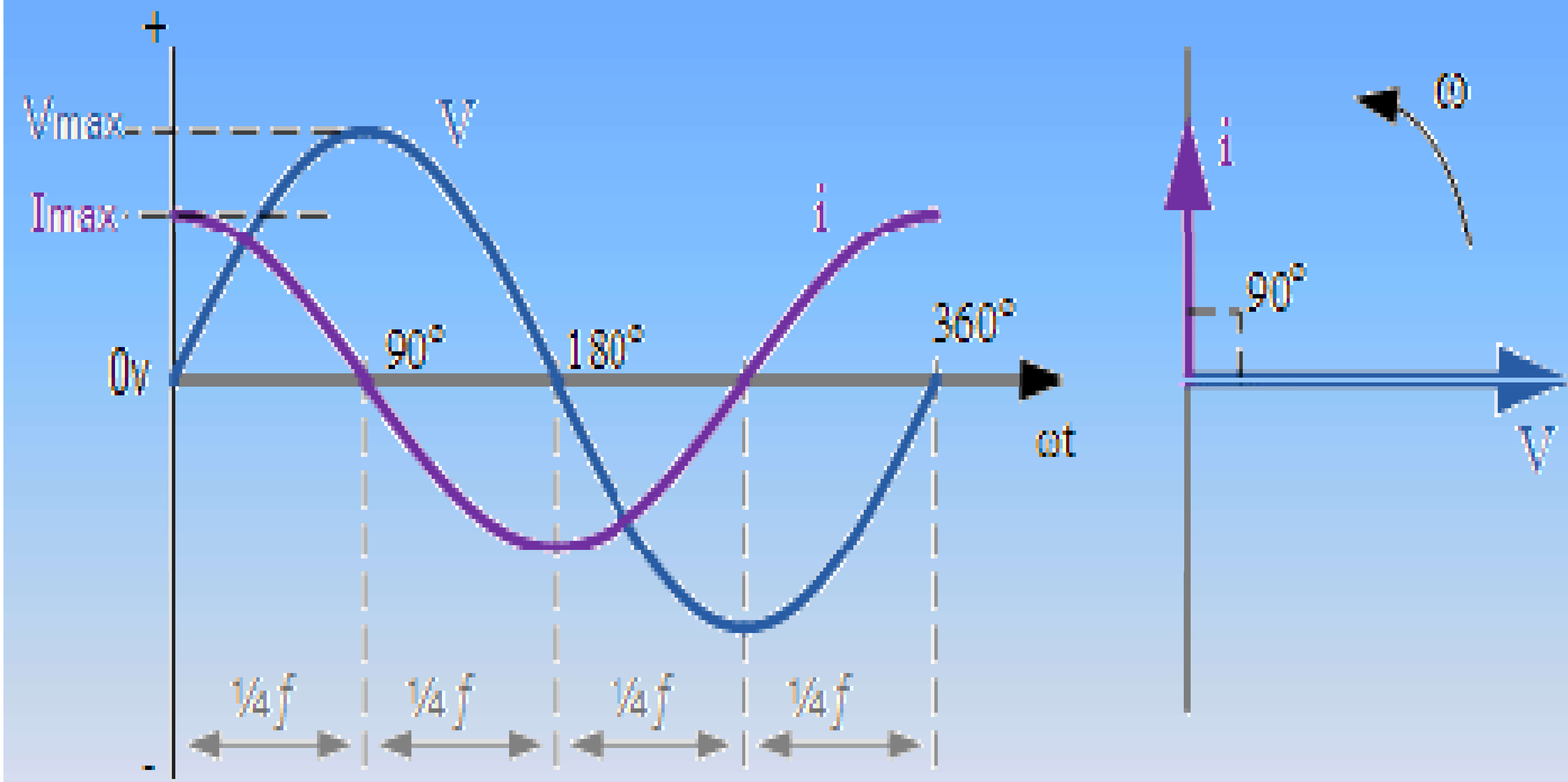
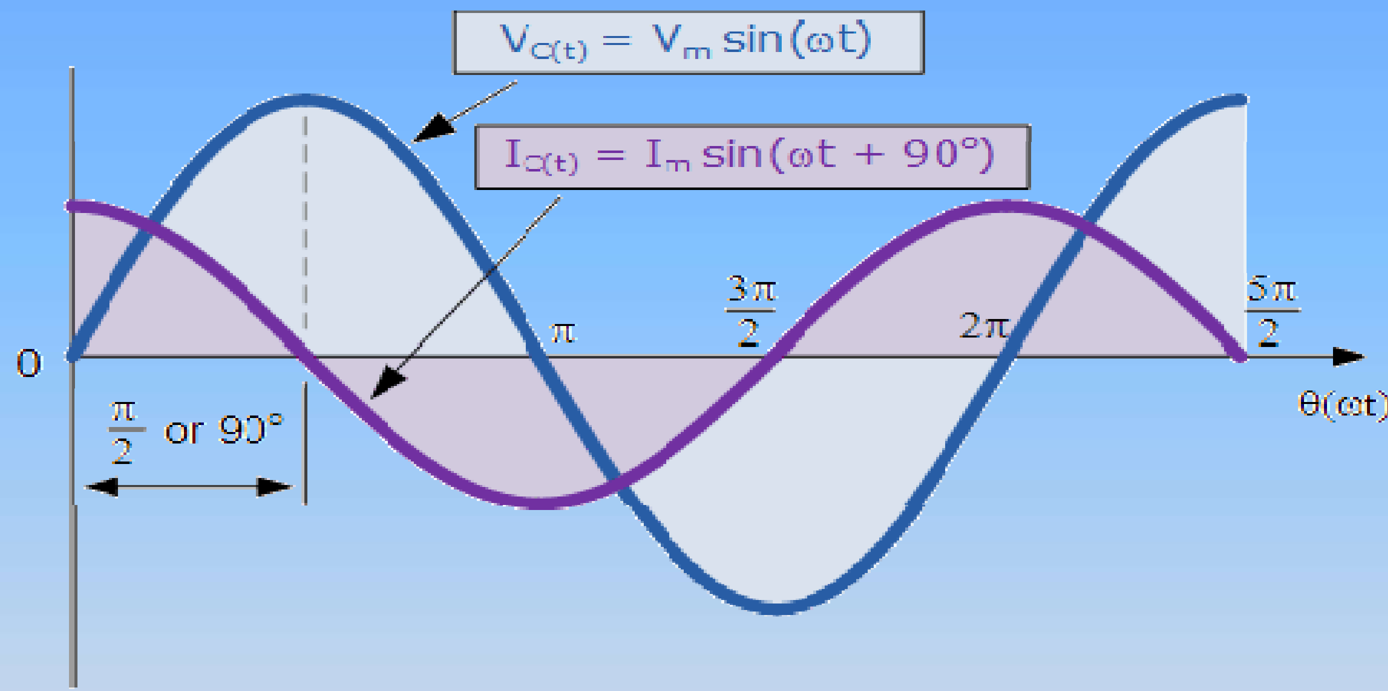


FIG. 15.16 *Example 15.6.*



+
Vmax
Imax
V
i
0v
90°
180°
360°
ωt
¼ f
¼ f
¼ f
¼ f
-
i
ω
90°
V

V & I in capacitive circuit with AC



$v = V_m \sin \omega t \Rightarrow$ phasor form $\mathbf{V} = V \angle 0°$

I = Im sinwt+90 Phasor form I = IL+90

Power in Capacitive circuit

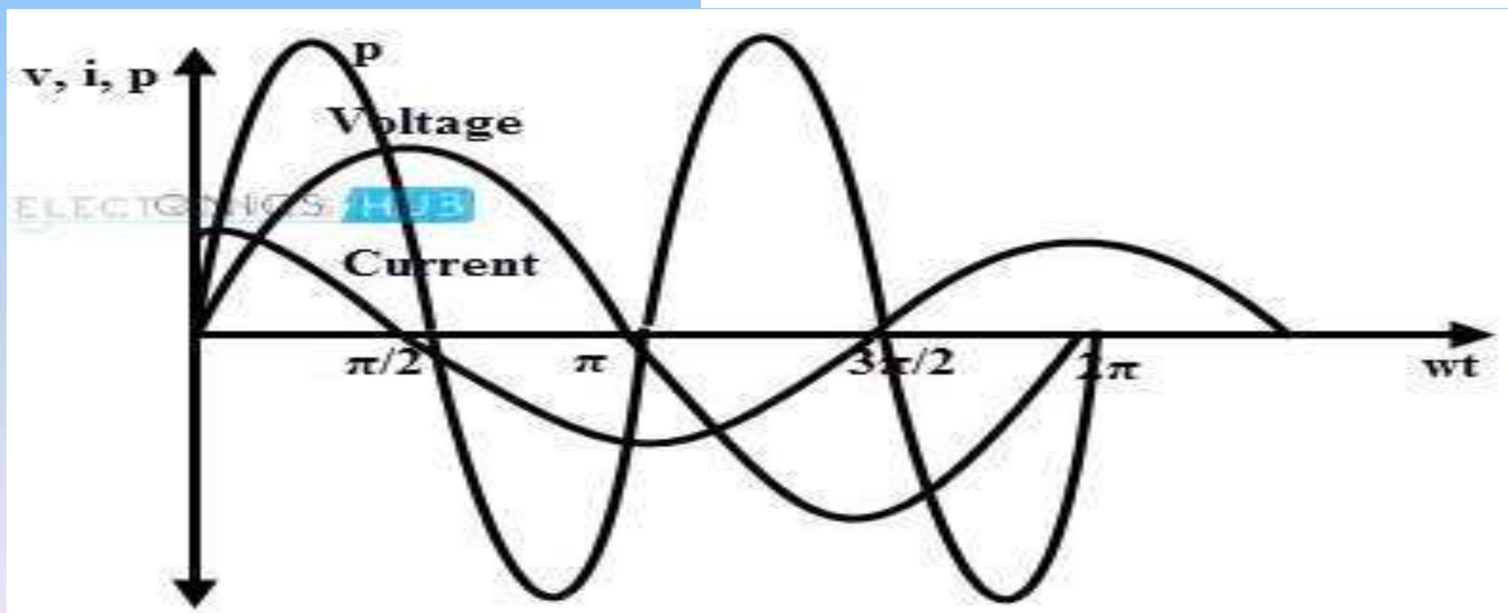
Instantaneous power is given by

$$P = (V_m \sin\omega t)(I_m \sin(\omega t + {}^{\pi}/_{2}))$$

$$P = V_m I_m \sin\omega t \cos\omega t$$

$$P = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \sin 2\,\omega t \quad \text{or}$$

$$P = 0$$



AC through Pure inductive Circuit

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

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

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

$$v = -\left(-L\frac{di}{dt}\right) \quad \text{or}$$

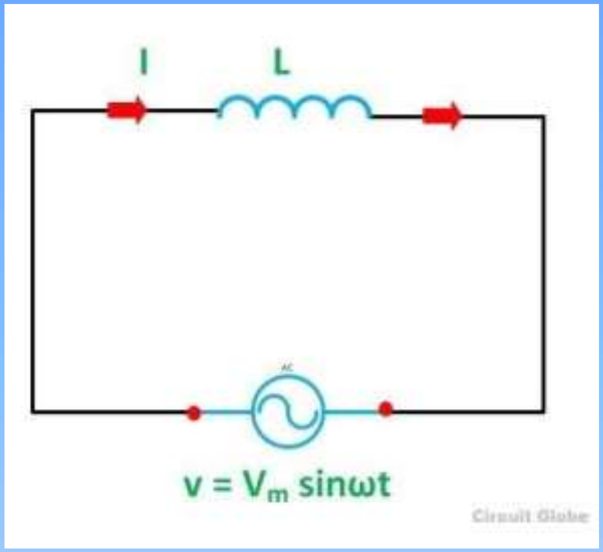
$$V_m \mathrm{Sin}\omega t = L\frac{di}{dt} \quad \text{or}$$

$$di = \frac{V_m}{L}\sin\omega t\, dt \ \ldots\ldots\ldots\ldots (3)$$

$$\int di = \int \frac{V_m}{L}\sin\omega t\, dt \quad \text{or}$$

$$i = \frac{V_m}{\omega L}(-\cos\omega t) \quad \text{or}$$

$$i = \frac{V_m}{\omega L}\sin\left(\omega t - \pi/_2\right) = \frac{V_m}{X_L}\sin\left(\omega t - \pi/_2\right) \ \ldots\ldots\ldots (4)$$



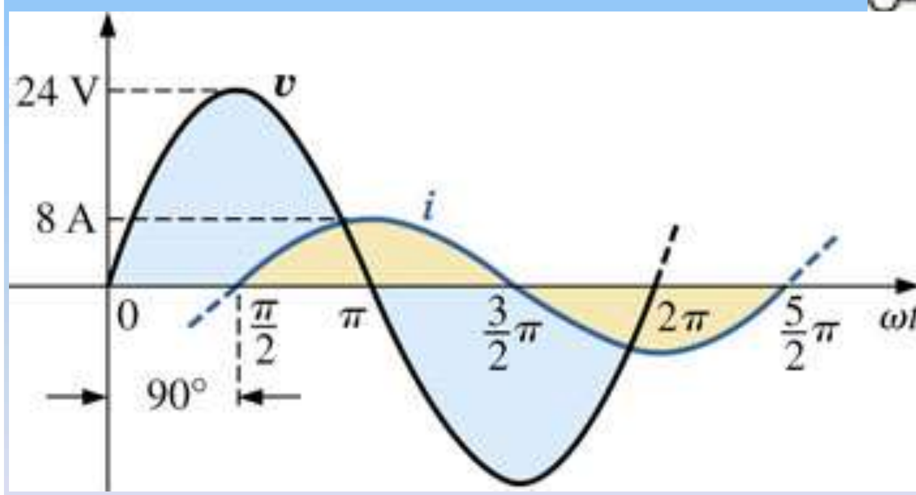
$$I_m = \frac{V_m}{X_L} \ldots\ldots\ldots\ldots (5)$$

$$i = I_m \sin\left(\omega t - \pi/_2\right)$$

Inductive Reactance

- for the pure inductor, the voltage leads the current by 90° and that the reactance of the coil X_L is determined by ψ*L. = 2#fL*

$$v = V_m \sin \omega t \Rightarrow \text{phasor form } \mathbf{V} = V \angle 0°$$



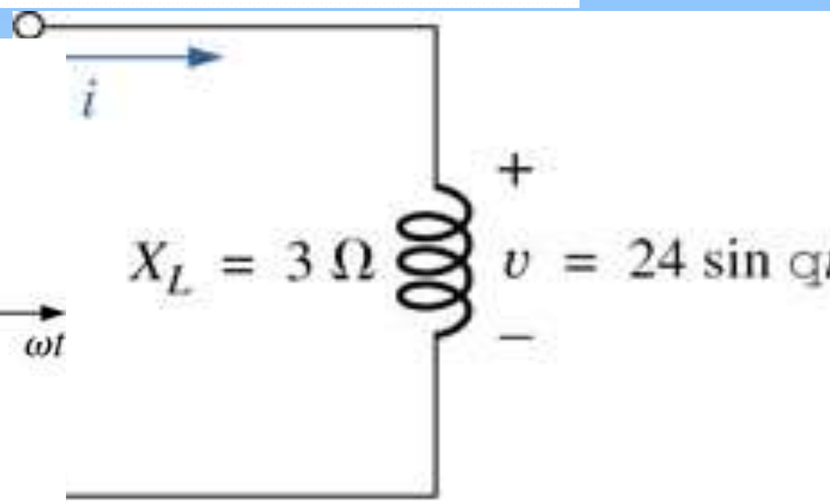
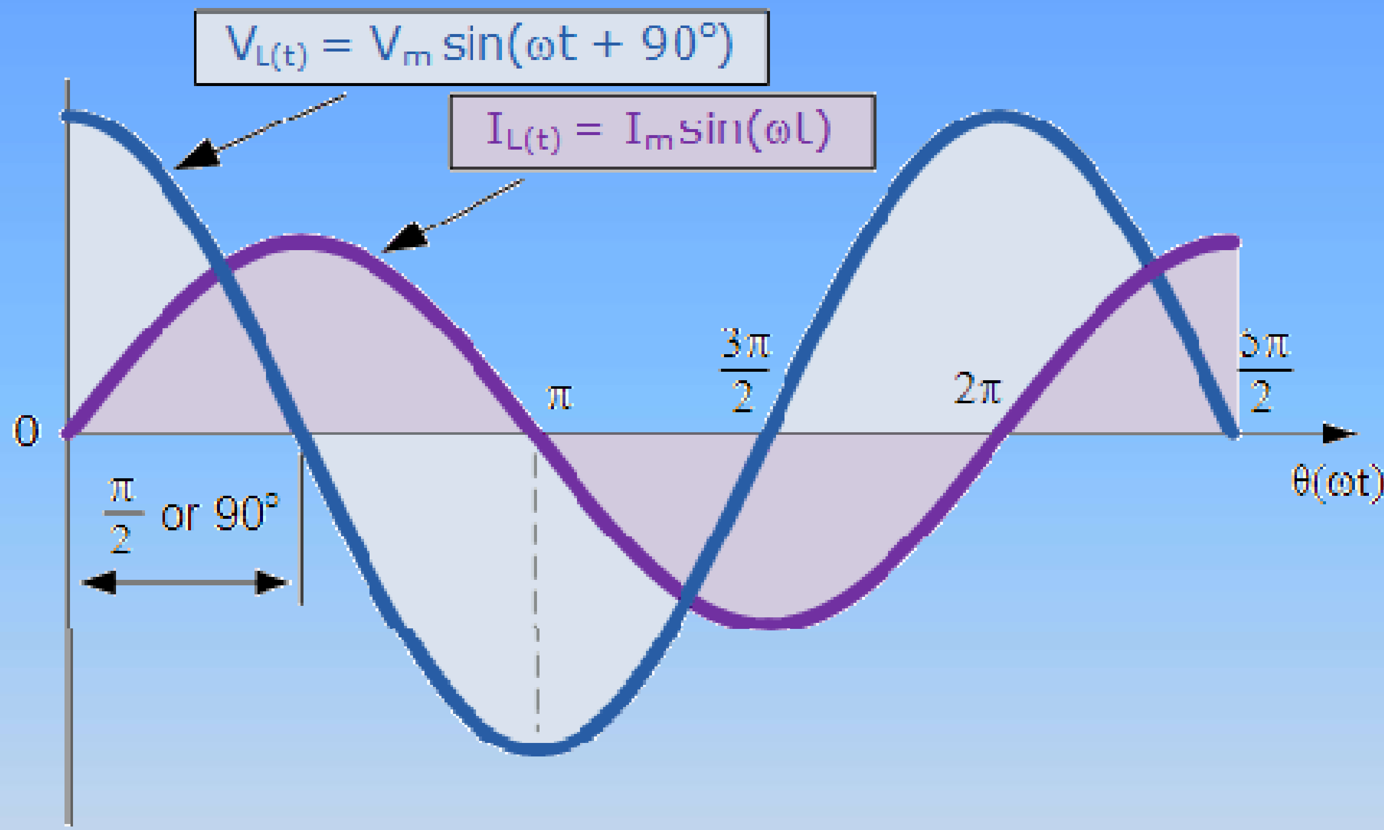


FIG. 15.9 *Waveforms for Example 15.3.*

FIG. 15.8 *Example 15.3.*



$$v = V_m \sin \omega t \Rightarrow \text{phasor form } \mathbf{V} = V \angle 0°$$

I = Im sinwt-90 Phasor form I = IL-90

Power in Pure inductive circuit

$$p = vi$$

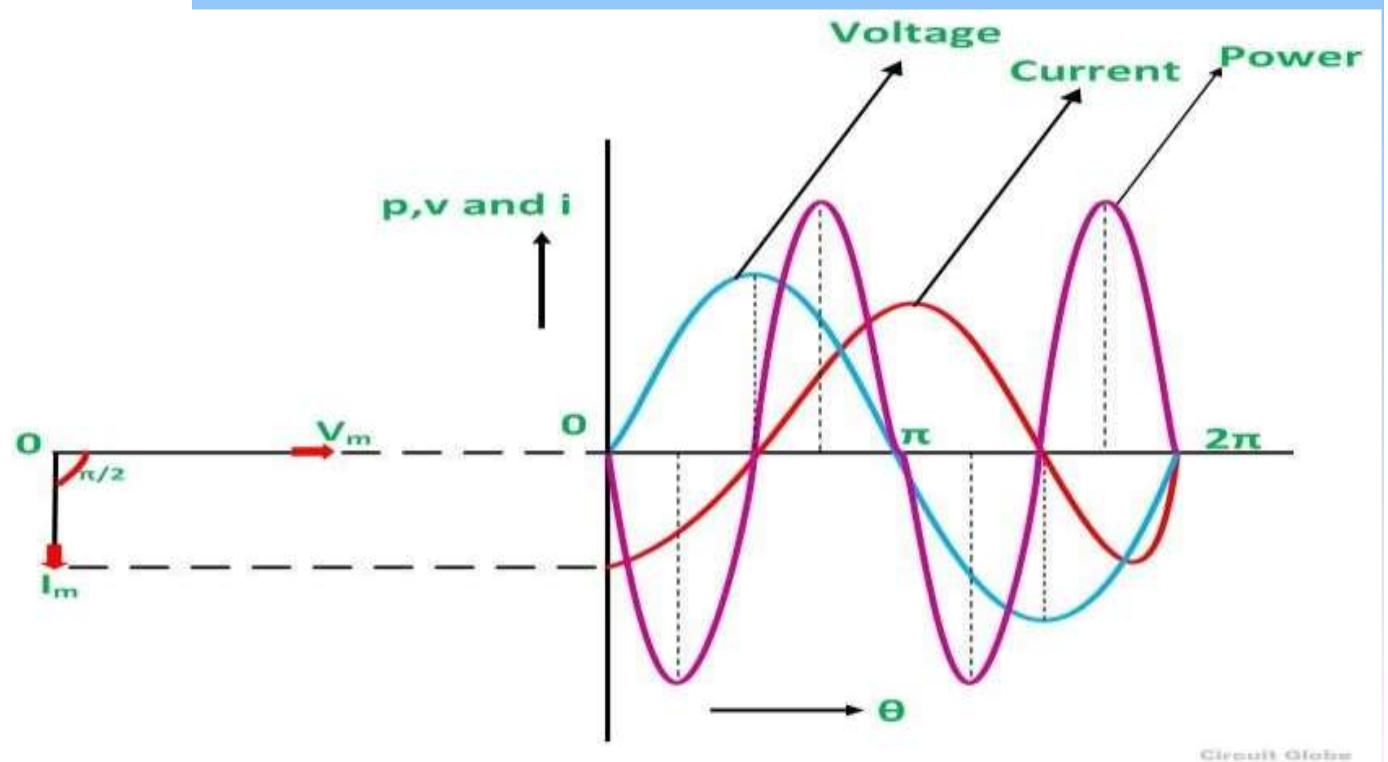
$$P = (V_m \sin\omega t)(I_m \sin(\omega t - \pi/2))$$

$$P = V_m I_m \sin\omega t \cos\omega t$$

$$P = \frac{V_m I_m}{2} 2 \sin\omega t \cos\omega t$$

$$P = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \sin 2\omega t \text{ or}$$

$$P = 0$$



IMPEDANCE AND THE PHASOR DIAGRAM

Impedance Diagram

Now that an angle is associated with resistance R, inductive reactance XL, and capacitive reactance XC, each can be placed on a complex plane diagram.

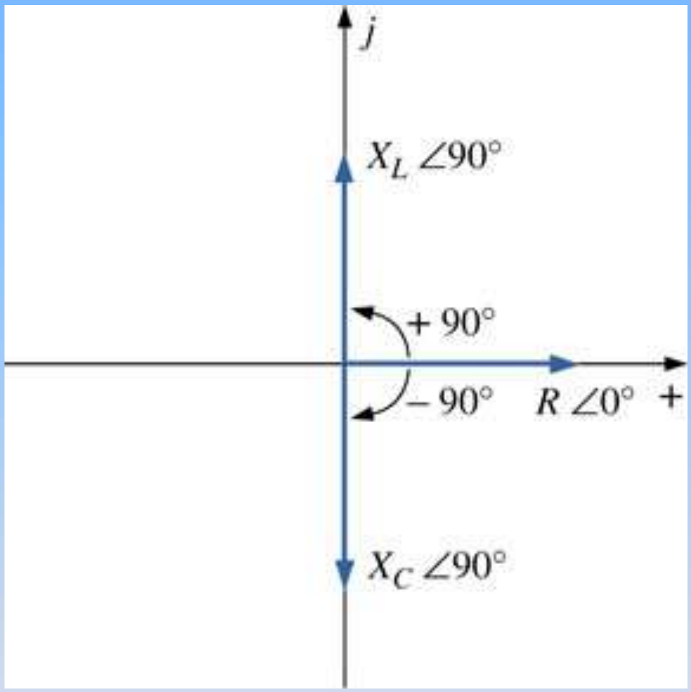


FIG. 15.19 *Impedance diagram.*

FREQUENCY RESPONSE FOR SERIES ac CIRCUITS

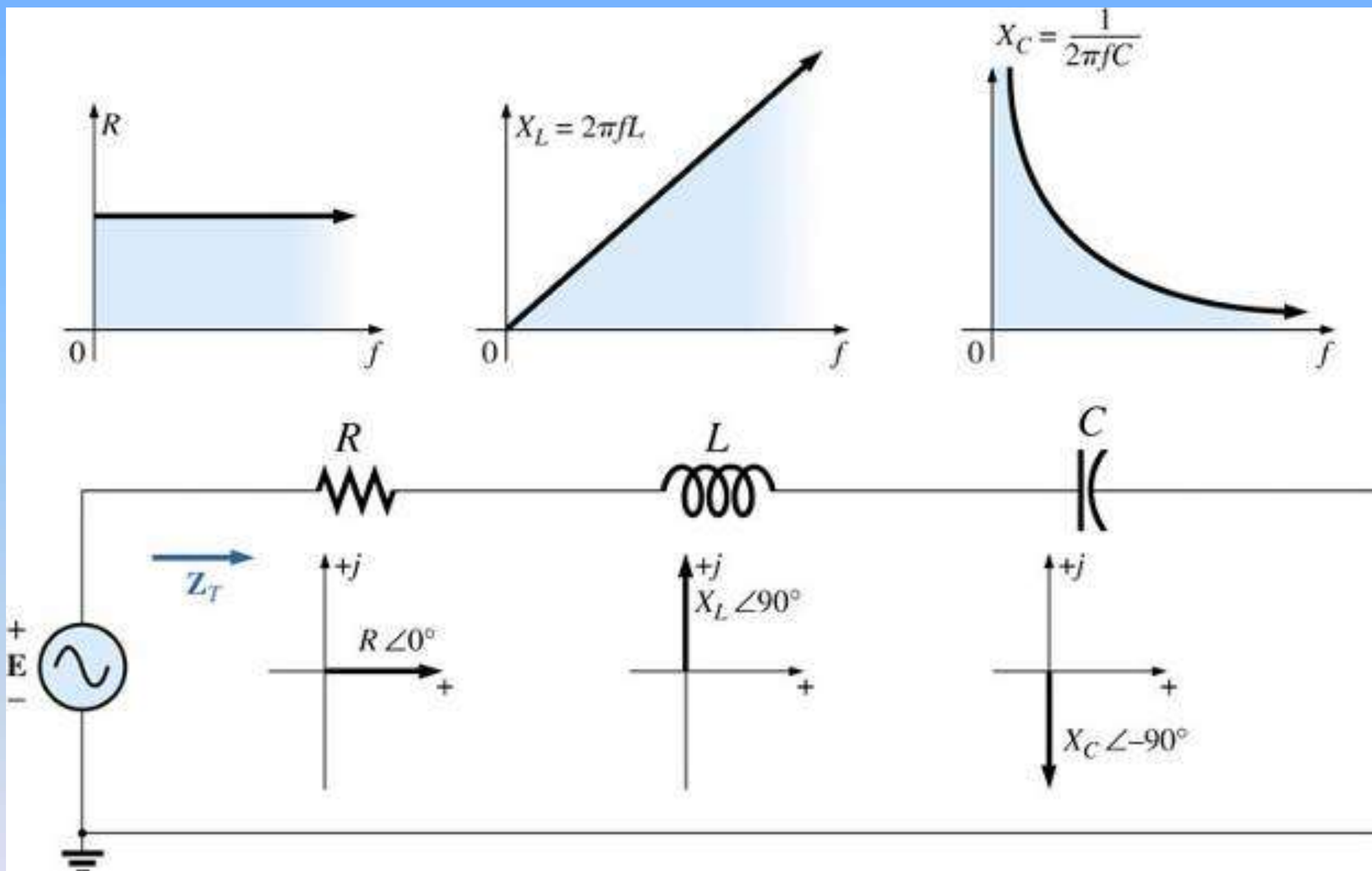


FIG. 15.46 *Reviewing the frequency response of the basic elements.*

Thank you