UNIT-II

FUNDAMENTAL OF AC CIRCUITS

Lecture 11

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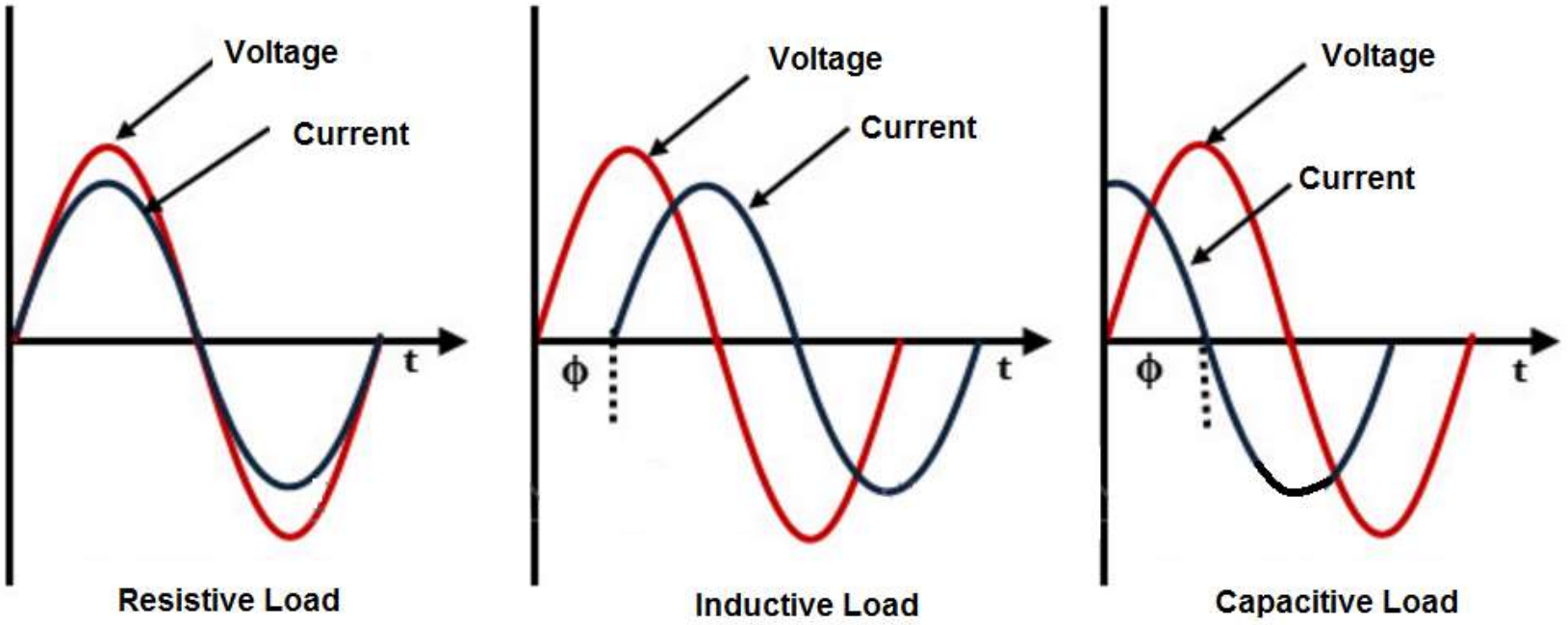
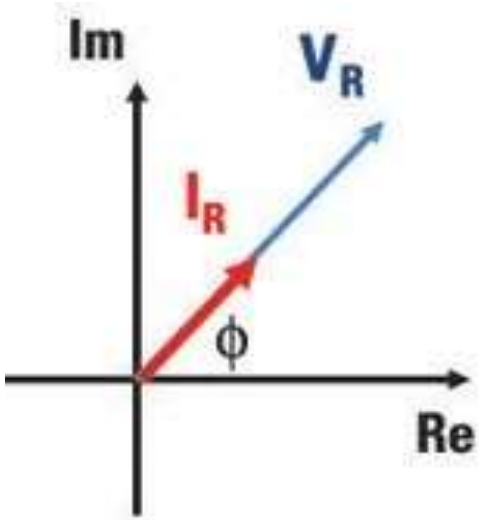
AC Circuits

- An AC circuit consists of a combination of circuit elements and a power source.
- The power source provides an alternating voltage, Δv.
- Notation note:
  - Lower case symbols will indicate instantaneous values.
  - Capital letters will indicate fixed values.

Current and Voltages in Resistive, Inductive and Capacitive Circuits

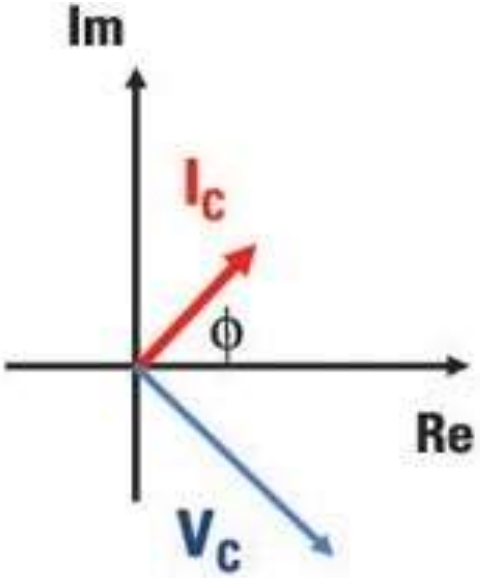


Phasor Diagram for Purely Resistive, Capacitive and Inductive Circuits



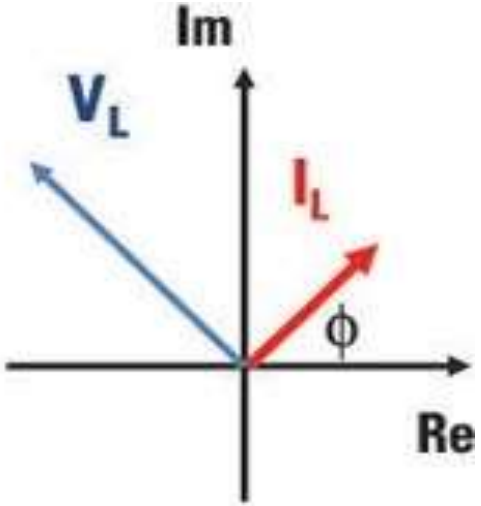
Resistor

Voltage in phase with current



Capacitor

Voltage lags current by 90°



Inductor

Voltage leads current by 90°

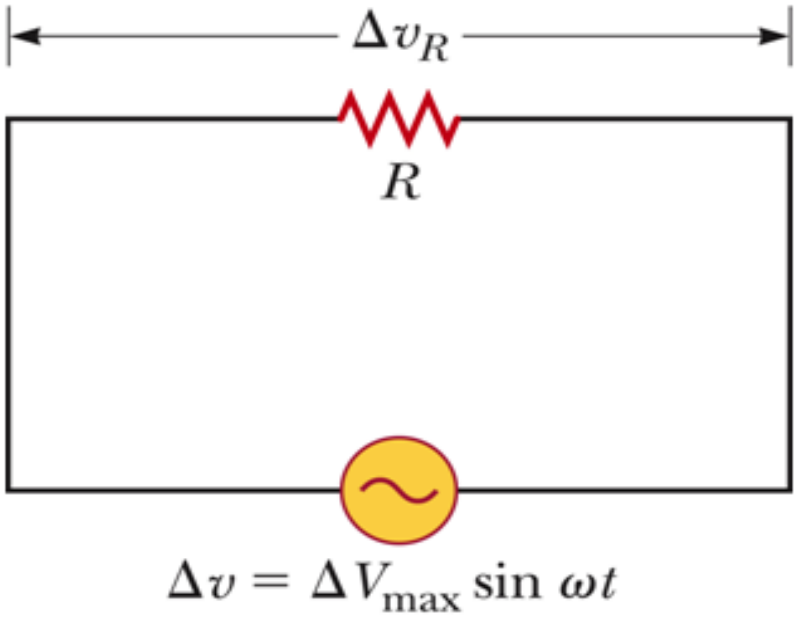
Resistors in an AC Circuit

Consider a circuit consisting of an AC source and a resistor.

The AC source is symbolized by 

$\Delta v_R = \Delta V_{max} = V_{max} \sin \omega t$

Δv_R is the instantaneous voltage across the resistor.



Resistors in an AC Circuit, cont.

The instantaneous current in the resistor is

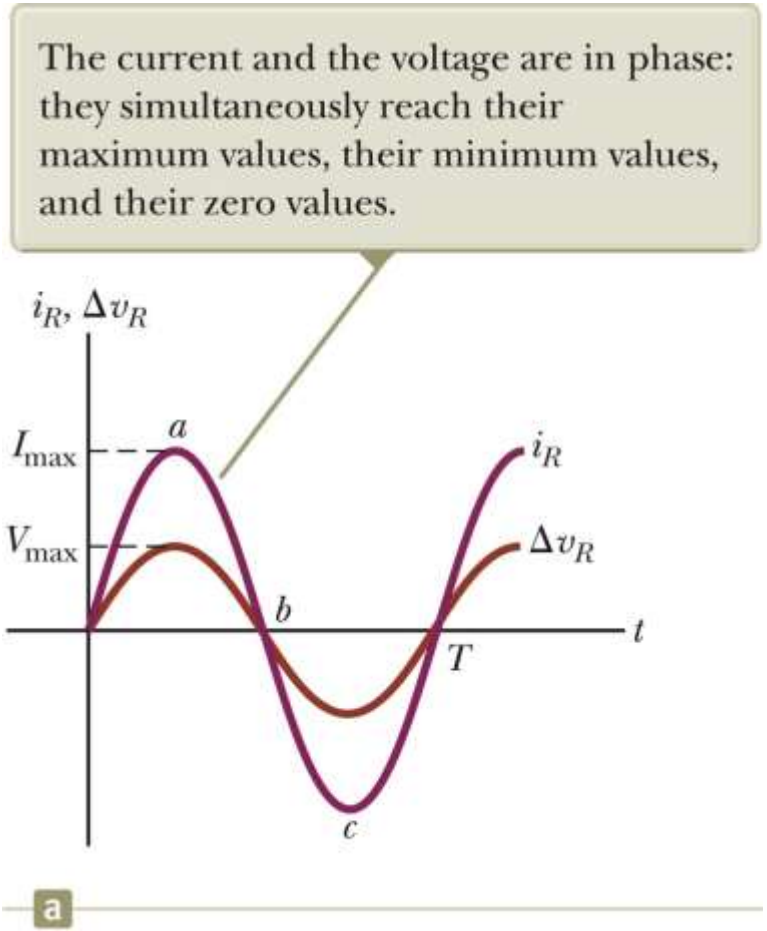
$$i_R = \frac{\Delta v_R}{R} = \frac{\Delta V_{max}}{R} \sin \omega t = I_{max} \sin \omega t$$

The instantaneous voltage across the resistor is also given as

$$\Delta v_R = I_{max} R \sin \omega t$$

Resistors in an AC Circuit, final

- The graph shows the current through and the voltage across the resistor.
- The current and the voltage reach their maximum values at the same time.
- The current and the voltage are said to be *in phase.*
- For a sinusoidal applied voltage, the current in a resistor is always in phase with the voltage across the resistor.
- The direction of the current has no effect on the behavior of the resistor.
- Resistors behave essentially the same way in both DC and AC circuits.



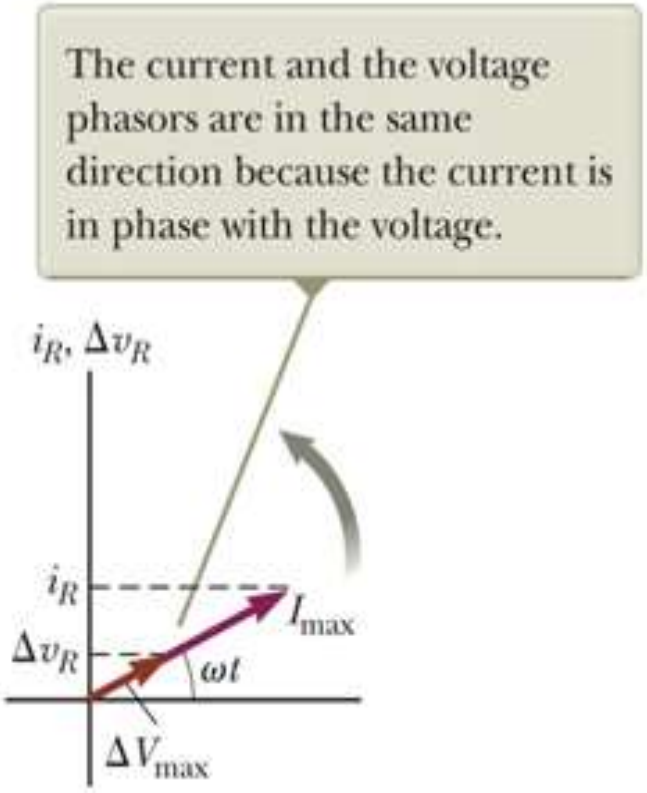
Phasor Diagram

To simplify the analysis of AC circuits, a graphical constructor called a *phasor diagram* can be used.

A **phasor** is a vector whose length is proportional to the maximum value of the variable it represents.

The vector rotates counterclockwise at an angular speed equal to the angular frequency associated with the variable.

The projection of the phasor onto the vertical axis represents the instantaneous value of the quantity it represents.



Power

The rate at which electrical energy is delivered to a resistor in the circuit is given by

- $P = i^2 R$
  - i is the *instantaneous current*.
  - The heating effect produced by an AC current with a maximum value of I_{max} is not the same as that of a DC current of the same value.
  - The maximum current occurs for a small amount of time.
- The average power delivered to a resistor that carries an alternating current is

$$P_{av} = I_{rms}^2 R$$

Quick Quiz (Poll 1)

- Find the value of the instantaneous voltage if the resistance is 2 ohm and the instantaneous current in the circuit is 5A.
  a) 5V
  b) 2V
  c) 10V
  d) 2.5V

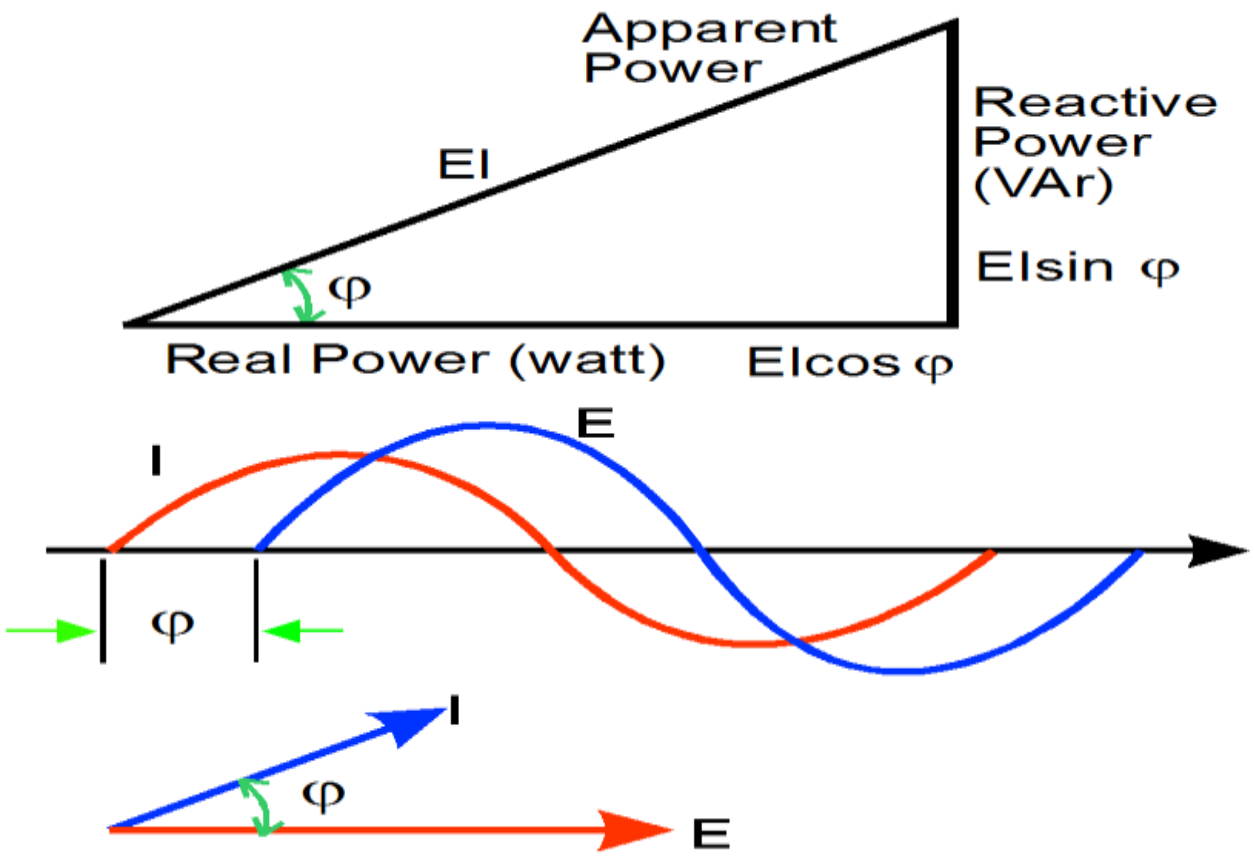
Quick Quiz (Poll 2)

- The correct expression for the instantaneous current in a resistive circuit is?
  a) $i=V_m(\sin\omega t)/R$
  b) $i=V_m(\cos\omega t)/R$
  c) $i=V(\sin\omega t)/R$
  d) $i=V(\cos\omega t)/R$

Concept of Power Factor

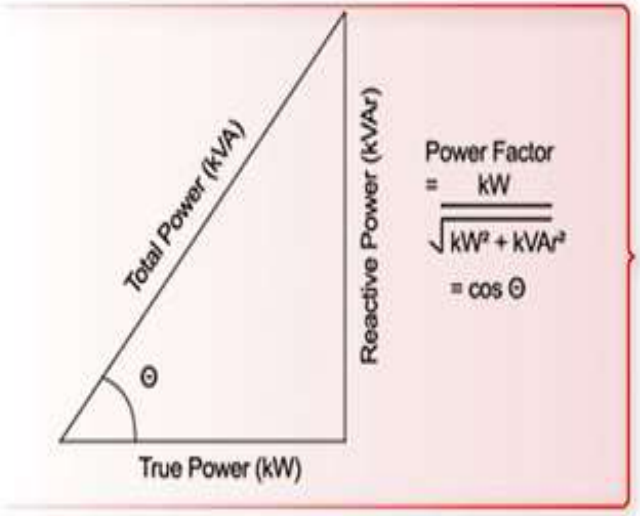
- Ratio of real power to apparent power is called the power factor, F_p
- $F_p = P/S = \cos \theta$
- Angle θ is angle between voltage and current

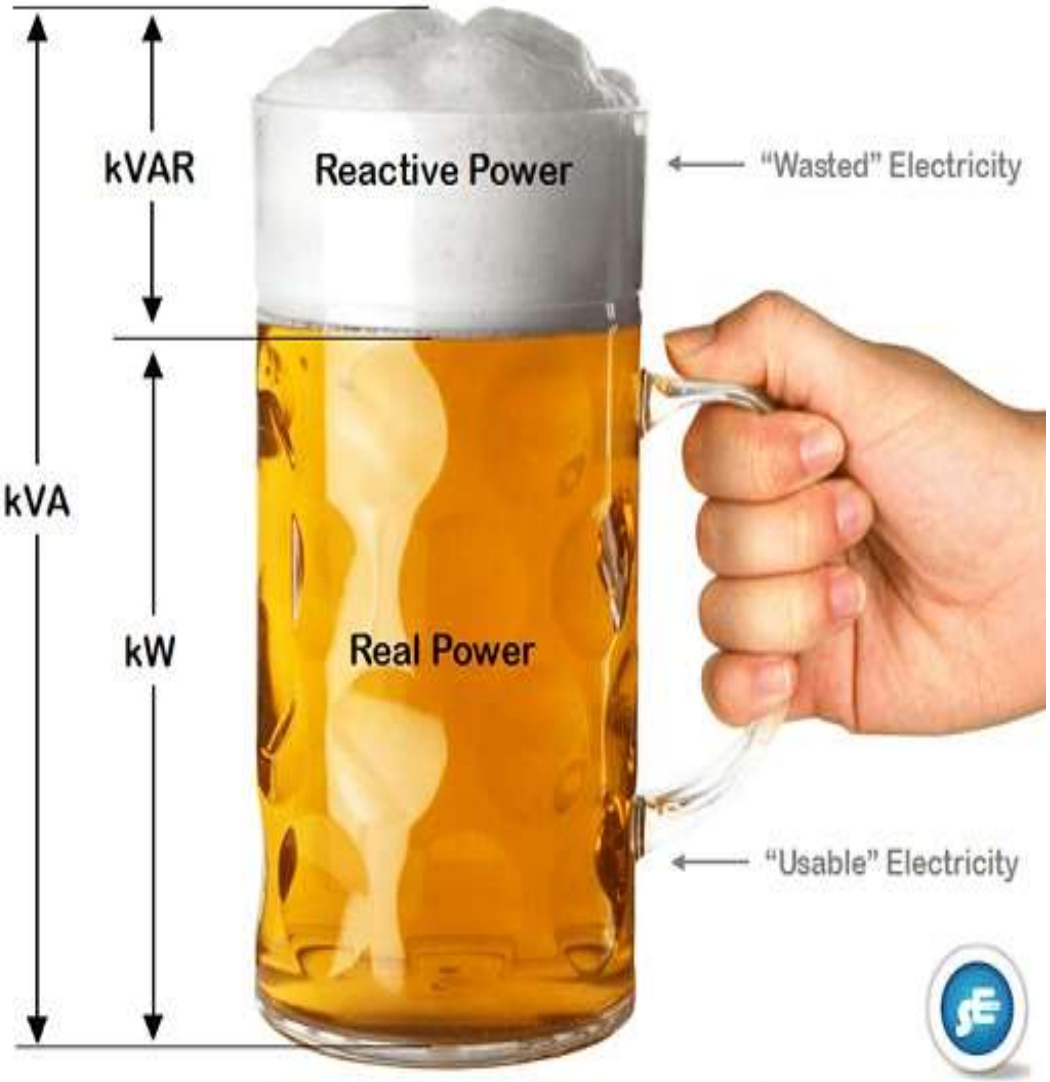
POWER TRIANGLE



What is Power Factor?

Power Factor is the percentage of apparent power that does real work. Understand Power Factor using Beer Mug Analogy.





SIGNIFICANCE OF Mvar

APPARENT POWER
Beer: Full glass
Electricity: Available from utility

REACTIVE POWER (MVAR)
Beer: Foam
Electricity: Unable to do work

REAL POWER (MW)
Beer: Drinkable
Electricity: Able to do work

It is the Active Power that contributes to the energy consumed, or transmitted. Reactive Power does not contribute to the energy. It is an inherent part of the "total power" which is often referred as "Useless Power".

Power Factor

- For pure resistance $\theta = 0°$
- For inductance, $\theta = 90°$
- For capacitance, $\theta = -90°$
- For a circuit containing a mixture, θ is somewhere between 0° and $\pm 90°$

Power Factor

- Unity power factor
  - For a purely resistive circuit, the power factor will be one
- For load containing resistance and inductance
  - Power factor will be less than one and lagging
  - Current lags the voltage
- For a circuit containing resistance and capacitance
  - F_p is less than one and is leading

Power Factor Correction

- A load with a small power factor can draw a large current
- Can be alleviated by
  - Cancelling some or all reactive components of power by adding reactance of opposite type to the circuit
    - This is power factor correction

Power Factor Correction

- Industrial customers may pay a penalty for low power factors due to large currents required for highly reactive loads

Quick Quiz (Poll 3)

What is maximum value of power factor?

a. 0.5
b. 1
c. 1.5
d. 0.95

Quick Quiz (Poll 4)

For which among the following consumers is penalty imposed for low power factor?

a. Residential and commercial consumers.
b. Industrial consumers.
c. Agricultural consumers.
d. All of the above.