MODULE 01
Introduction to DC & AC Fundamentals

DC Circuits

- Electricity: Electricity plays an important role in our day to day life.
- Electricity is used for
  - Lighting (lamps)
  - Heating(heaters)
  - Cooling
  - Entertainment (T.V. and radio)
- **Electricity:** The invisible energy which constitutes flow of electrons in a closed circuit to do work is called electricity
- **CHARGE:**The most basic quantity in an electric circuit is the electric charge. Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C)
- **Current:**Current is defined as motion of charge through a conducting material measured in Ampere
- **Voltage:**The voltage "V" is nothing but an electromotive force that causes the charge (electrons) to flow

- **POWER:**The power "P" is nothing but the time rate of flow of electrical energy.
- **ENERGY:**Energy is the capacity to do work, and is measured in joules (J)
- **Free Electrons:** The valence electrons which are loosely attached to the nucleus of an atom and free to move when external energy is applied are called free electrons.
- **Electrical Potential:** The capacity of charged body to do work is called electrical potential.
- **Potential Difference:**The difference in electrical potential of the two charged bodies is called potential difference. Unit of potential difference is **Volts.**

- **Electric Circuit:** The close path for flow of electric current is called electric circuit.

- **Circuit Elements:**
  The circuit elements can be categorized as:
  - Active and passive elements
  - Unilateral and bilateral elements
  - Linear and non-linear elements
  - Lumped and distributed elements

- Resistor:A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit.
- Inductor:An inductor is a passive component that is used in most power electronic circuits to store energy in the form of magnetic energy when electricity is applied to it
- Capacitor:capacitor is an electronic component that stores electrostatic energy in an electric field

Voltage and Current Source:

- To deliver electrical energy to the electrical circuits, a source is required and a load is connected to source

- There are two types of sources- Voltage source and current source.

- Sources can be either independent or dependent upon some other quantities.

Ohm’s Law:

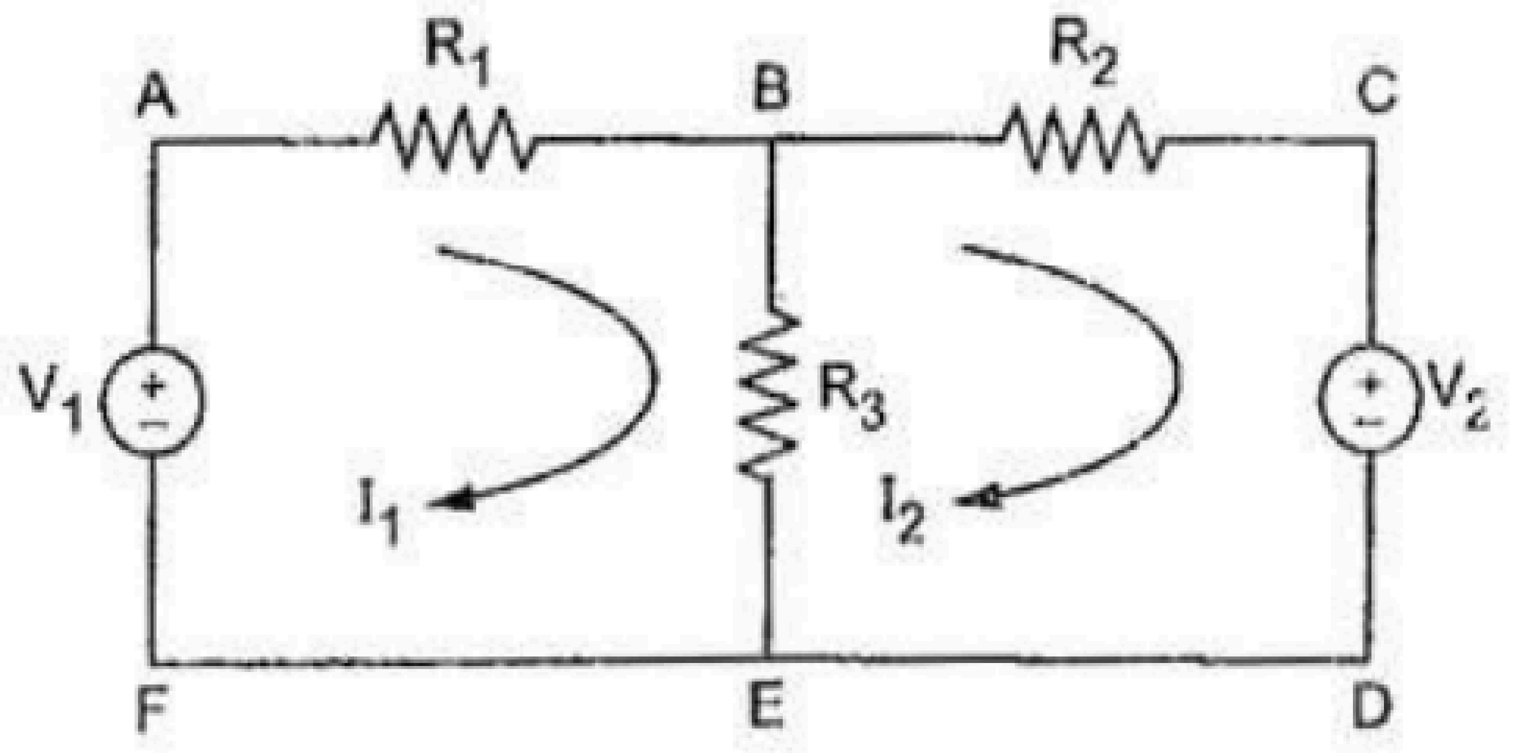
- Ohm‟s laws state that the current through any two points of the conductor is directly proportional to the potential difference applied across the conductor, provided physical conditions i.e. temperature, etc. do not change. It is measured in (Ω) ohm
- V = IR

Limitations of Ohm’s Law

- Ohm’s law is not applicable in unilateral networks
- It is not applicable for the non-linear network

1. **Electric Network:**

Electric network is interconnection of electric components. E.g. Batteries, resistors, inductors and capacitors.



2. **Electric Circuit:**

The path for flow of electric current is called electric circuit.

3. **Active Elements:**

The elements which supplies energy to the circuit. In fig V_1 and V_2 are active elements.

4. **Passive Elements:**

The elements which receives energy. In fig R_1, R_2 and R_3 are passive elements.

5. **Node:**

Node is a point where two or more circuit elements are connected together. In Fig. A, B, C and E are nodes.

6. **Junction:**

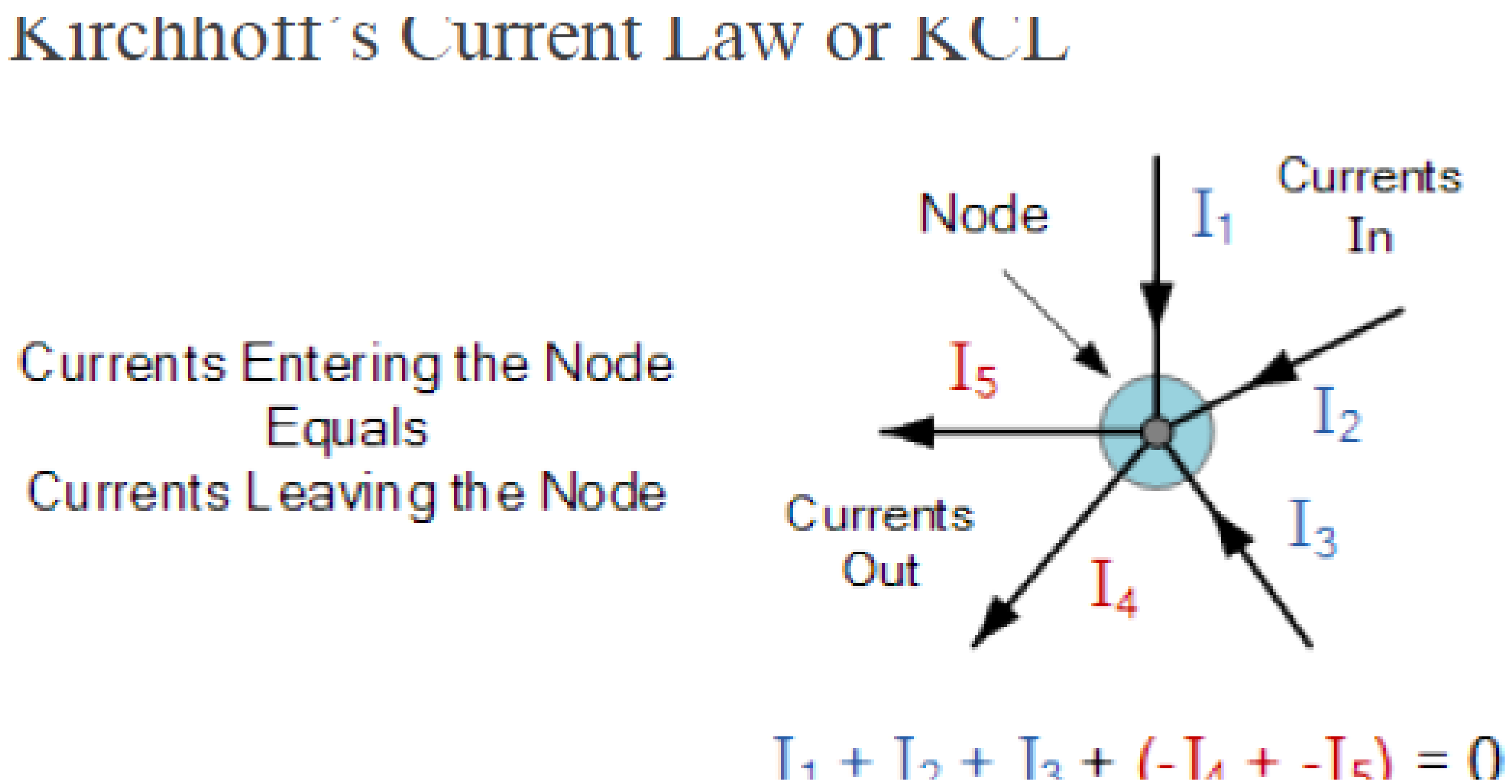
Junction is a point in the network where three or more circuit elements are connected together.

form of loop which cannot be further divided is called mesh.
CDEB are mesh.

k which lies between two junction points. In fig. ABEFA, BCDEB
es.

Kirchhoff's Current Law or KCL

- Kirchhoff"s Current Law or KCL, states that the "total current or charge entering a junction or node is exactly equal to the charge leaving the node". In other words the algebraic sum of all the currents entering and leaving a node must be equal to zero, I(exiting) + I(entering) = 0.



Kirchhoff's Voltage Law

- Kirchhoff‟s Voltage Law or KVL, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero.

Series Circuits

The voltage drop across resistor R_1, $V_1 = IR_1$

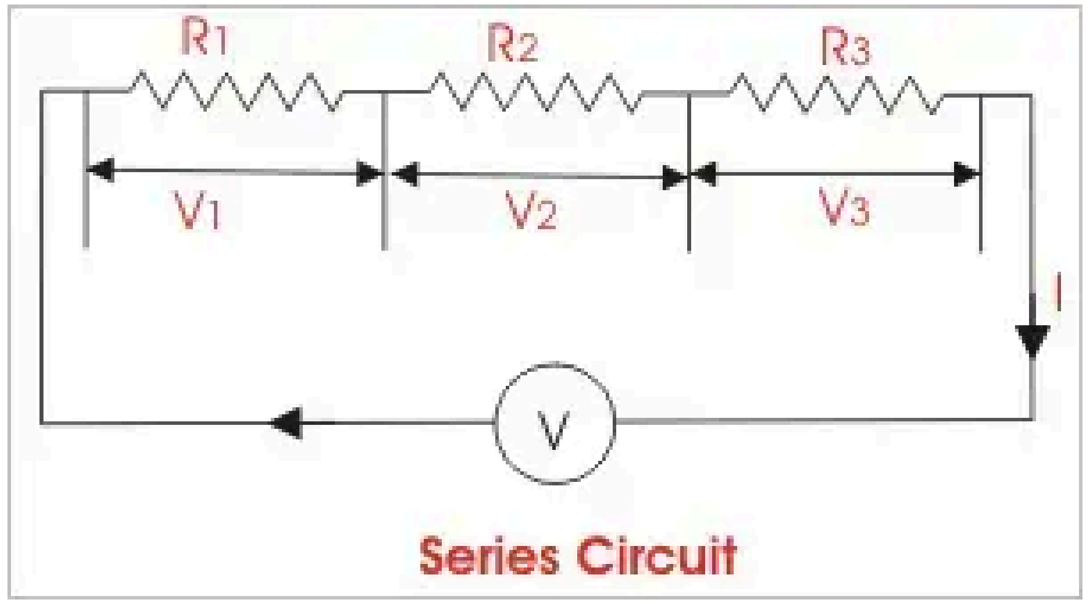
The voltage drop across resistor R_2, $V_2 = IR_2$

The voltage drop across resistor R_3, $V_3 = IR_3$

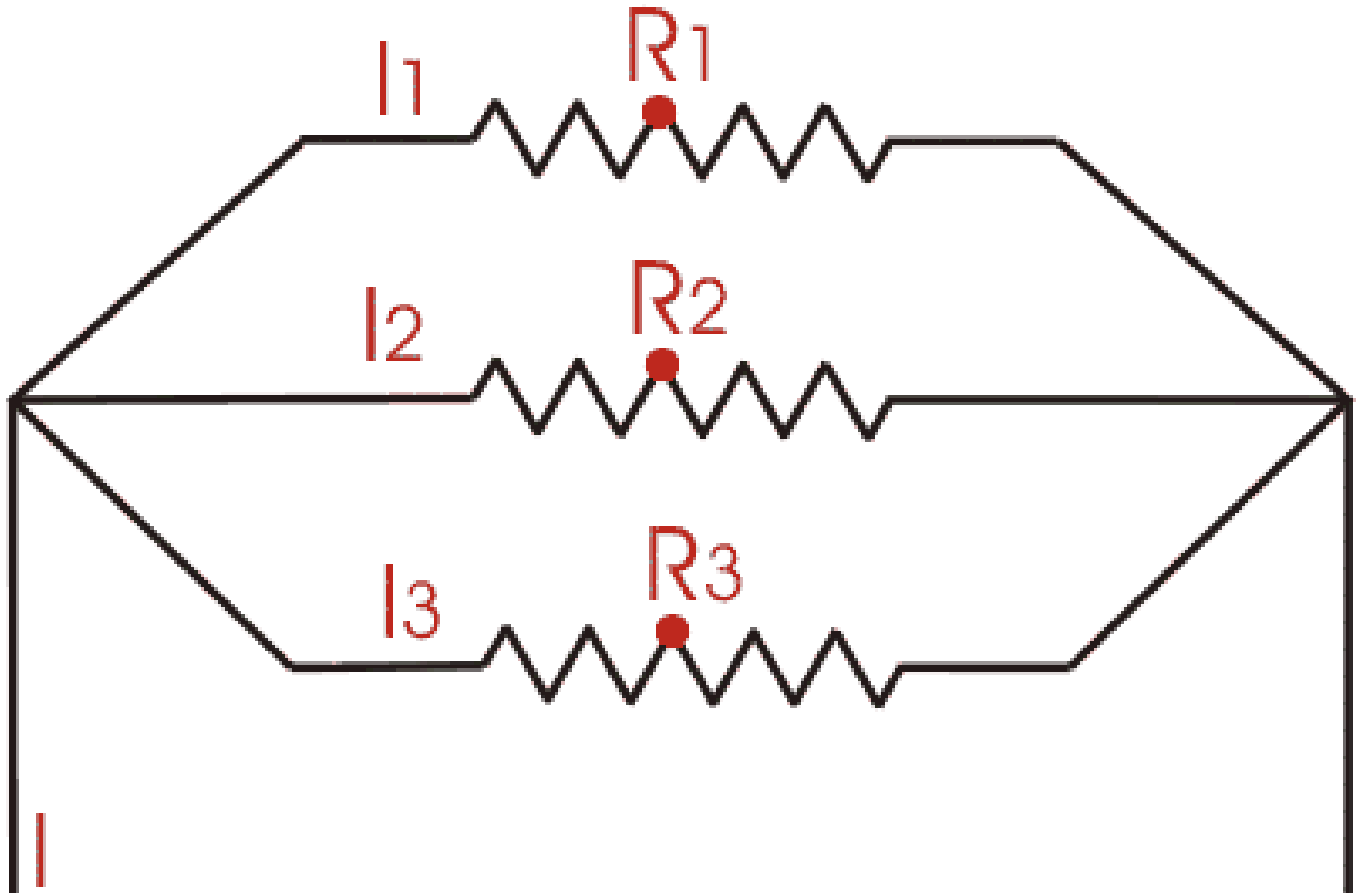
The voltage drop across the whole series DC circuit,

V = Voltage drop across resistor R_1 + voltage drop across resistor R_2 + voltage drop across resistor R_3

$$\Rightarrow V = IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3)$$

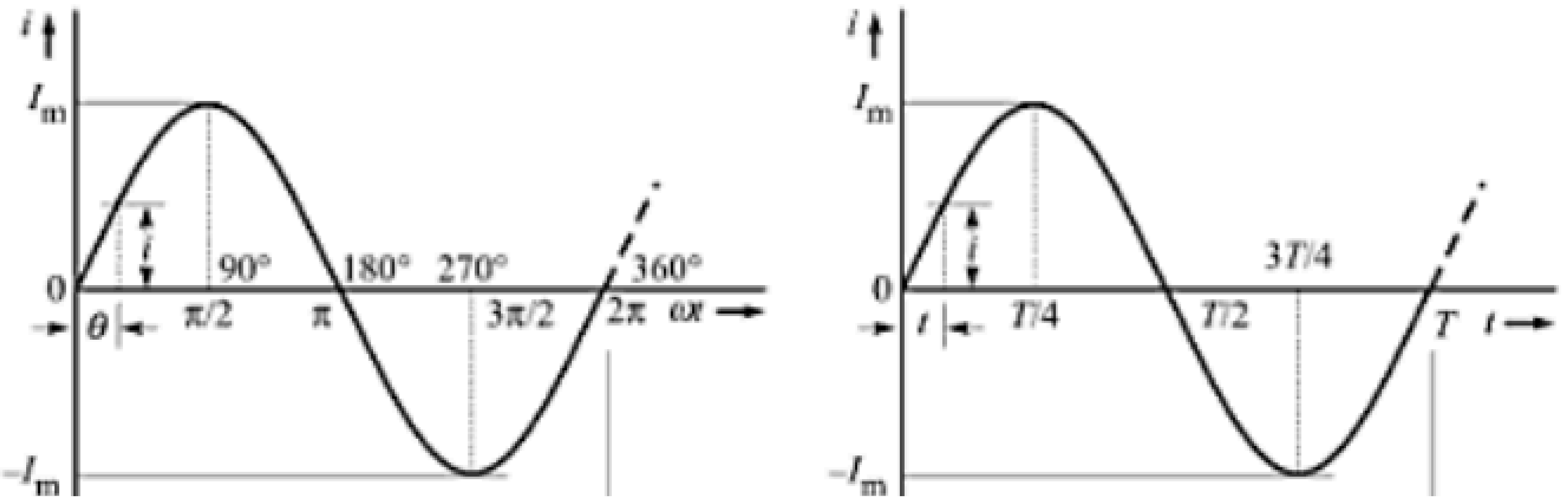


Parallel DC Circuit



AC Circuits

- In electricity, circuits can be found in various types such as open, closed, series, parallel, etc. An AC circuit is a type of electric circuit
- The quantity that changes continuously in magnitude between zero and a maximum value with alternating directions at regular time intervals is known as an alternating quantity such as current (I) or voltage (V).



AVERAGE VALUE

- An average value, by definition, is the algebraic sum of all the values divided by the total number of values. This is exactly what you do while finding the average marks for a class of students. A waveform is a continuous variation of the value of a quantity with time 1 (or angle θ), repeated after each cycle. The area under the waveform is found by integration and full cycle is normally taken as 2 radians or T seconds. Thus, the average value V_{av} of the instantaneous voltage v, taken over full cycle is given as

$$V_{av} = \frac{\text{Area under full cycle}}{\text{Length of one cycle}} = \frac{\int_0^{2\pi} v\, d\theta}{2\pi} = \frac{1}{2\pi}\int_0^{2\pi} v\, d\theta = \frac{1}{2\pi}\int_0^{2\pi} v\, d(\omega t)$$

$$V_{av} = \frac{1}{T}\int_0^{T} v\, dt$$

Thus, the average value of a sinusoidal current i

$$I_{av} = \frac{\text{Area under half cycle}}{\text{Length of half cylcle}} = \frac{1}{\pi}\int_0^{\pi} i\, d(\omega t) = \frac{1}{\pi}\int_0^{\pi} I_m \sin \omega t\, d(\omega t)$$

$$= \frac{I_m}{\pi}[-\cos \omega t]_0^{\pi} = \frac{I_m}{\pi}[-\cos \pi + \cos 0°] = \frac{2I_m}{\pi} = \mathbf{0.637 I_m}$$

$$I_{av} = \frac{1}{2\pi}\int_0^{2\pi} i\, d(\omega t) = \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin \omega t\, d(\omega t) + \int_{\pi}^{2\pi} 0\, d(\omega t)\right]$$

$$= \frac{I_m}{2\pi}[-\cos \omega t]_0^{\pi} = \frac{I_m}{\pi} = \mathbf{0.318 I_m}$$

RMS *Value* Let us examine the procedure of finding the effective value of ac current instantaneous power p absorbed in resistor R, as $p = i^2R$. We then found the average of cycle, as follows.

$$P_{av} = \frac{1}{T}\int_0^T p\,dt = \frac{1}{T}\int_0^T i^2 R\,dt = \left[\frac{1}{T}\int_0^T i^2\,dt\right]R$$

This power, we equated to $I_{eff}^2 R$. Thus, we found that

$$I_{eff}^2 = \frac{1}{T}\int_0^T i^2\,dt \quad \Rightarrow \quad I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2\,dt} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2\,d(\omega t)}$$

$$I_{\text{eff}} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2\, d(\omega t)} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t)} = \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi} (1-\cos 2\omega t)\, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}} = \frac{I_m}{\sqrt{2}}$$

$$I_{\text{eff}} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2\, d(\omega t)} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t) + \frac{1}{2\pi}\int_{\pi}^{2\pi} 0\, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\int_0^{\pi} (1-\cos 2\omega t)\, d(\omega t) + 0} = \sqrt{\frac{I_m^2}{4\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}} = \frac{I_m}{\sqrt{4}} = \frac{I_m}{2}$$

FORM FACTOR AND PEAK FACTOR

- The ratio of the effective value to the average value is known as the form factor of a waveform of any shape (sinusoidal or nonsinusoidal). Thus

$$\text{Form factor,} \qquad K_f = \frac{V_{rms}}{V_{av}}$$

- The peak factor or crest factor or amplitude factor of a waveform is defined as the ratio of its peak (or maximum) value to its rms value

Peak factor, $$K_p = \frac{V_m}{V_{rms}}$$

Let us calculate these two factors for ***a sinusoidal voltage waveform***,

$$K_f = \frac{V_{rms}}{V_{av}} = \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{0.707\,V_m}{0.637\,V_m} = \mathbf{1.11}$$

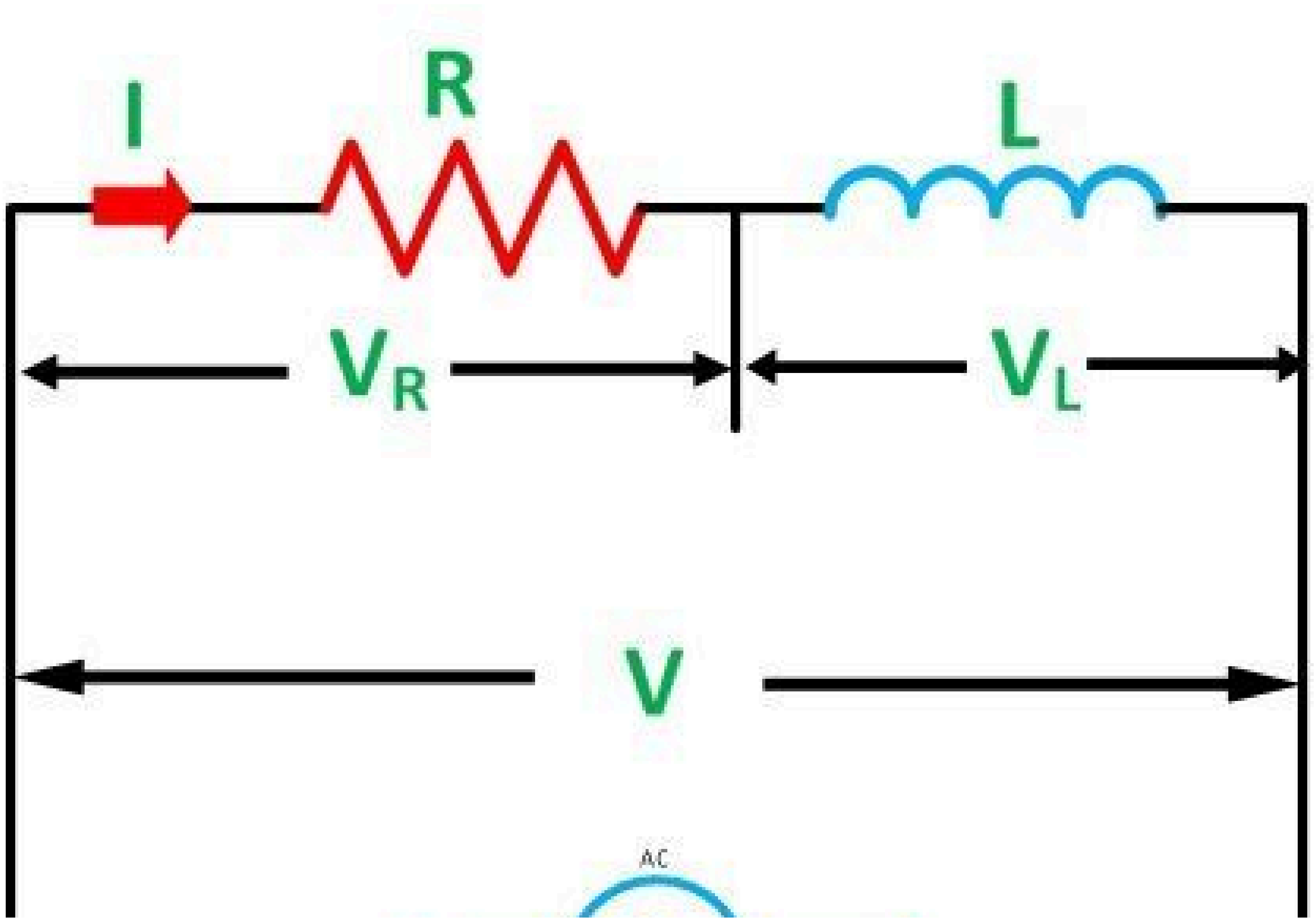
And $$K_p = \frac{V_m}{V_{rms}} = \frac{V_m}{V_m/\sqrt{2}} = \sqrt{2} = \mathbf{1.414}$$

POWER FACTOR

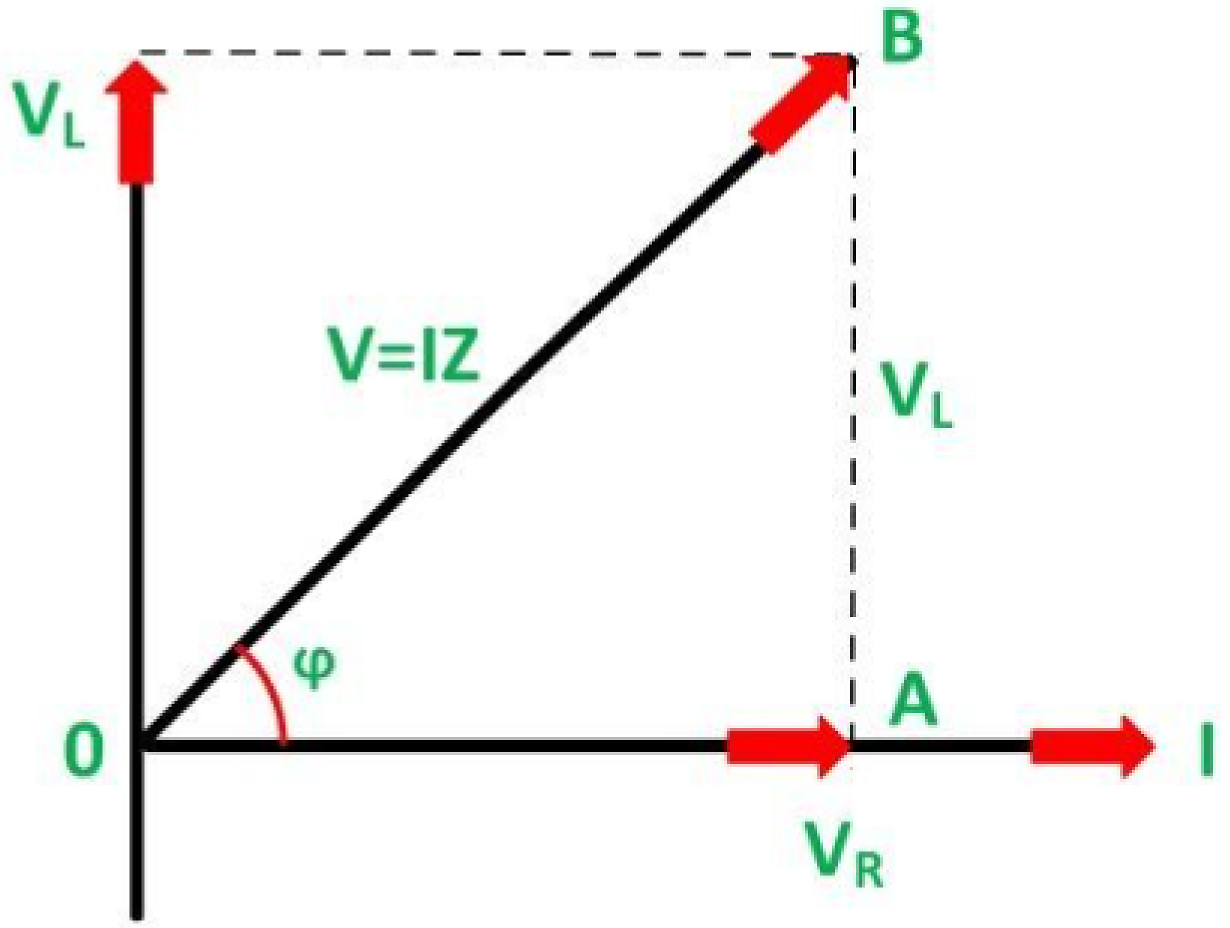
- The product VI is known as apparent power, and the real power is VIcos θ. The power factor is defined as the factor by which the apparent power is to be multiplied so as to get the real power. Thus,
- power factor (pf) = cos θ

BEHAVIOUR OF R,L,C IN AC CIRCUITS

RL Series Circuit



Phasor Diagram of the RL Series Circuit



$$V = \sqrt{(V_R)^2 + (V_L)^2} = \sqrt{(IR)^2 + (IX_L)^2}$$

$$V = I\sqrt{R^2 + X_L^2} \quad \text{or}$$

$$I = L = \frac{V}{Z}$$

Where,

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

Z is the total opposition offered to the flow of alternating current by an RL

PHASE ANGLE

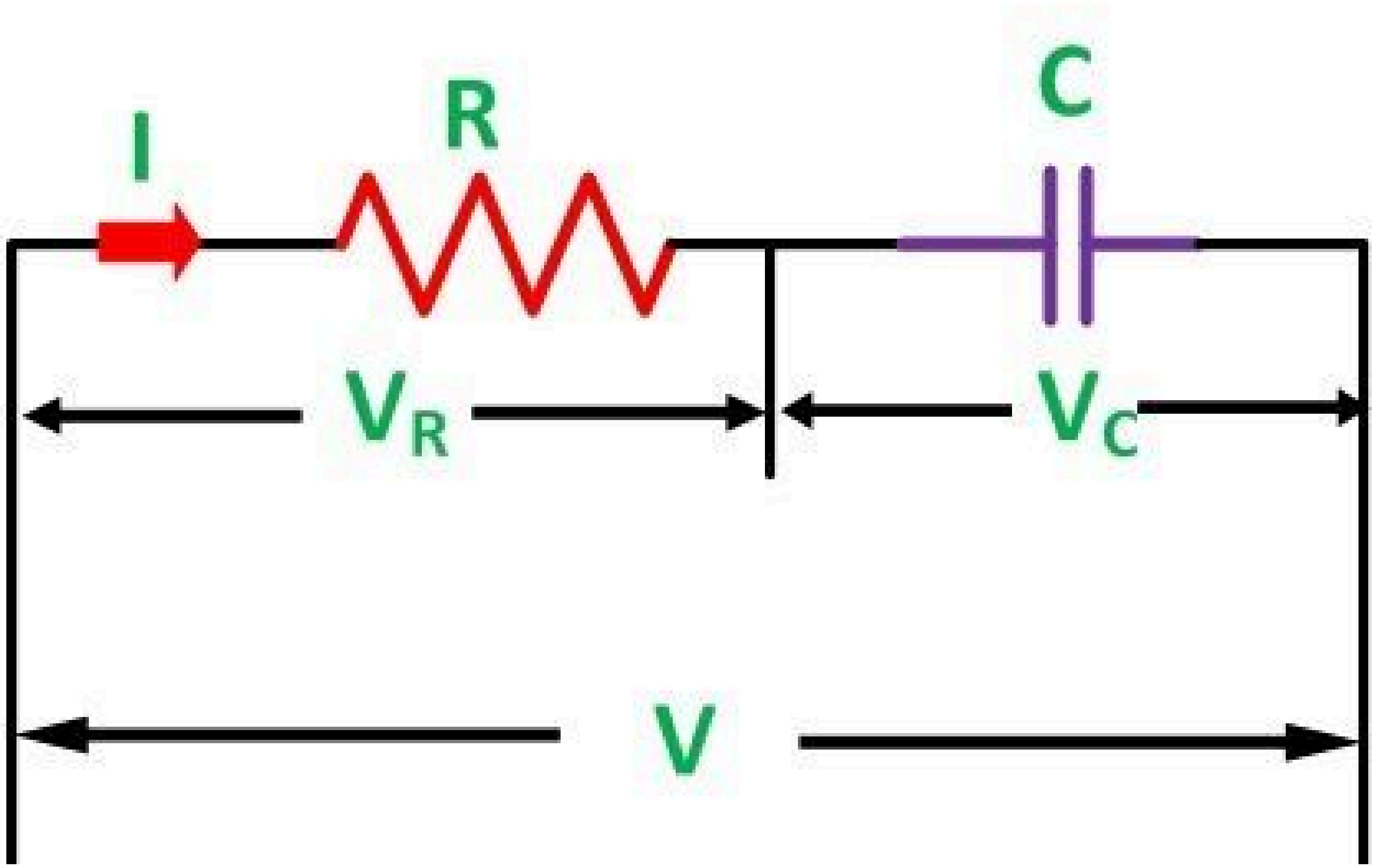
Phase Angle

In RL Series circuit the current lags the voltage by 90 degrees angle known as phase angle. It is given by the equation:

$$\tan\varphi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R} \quad \text{or}$$

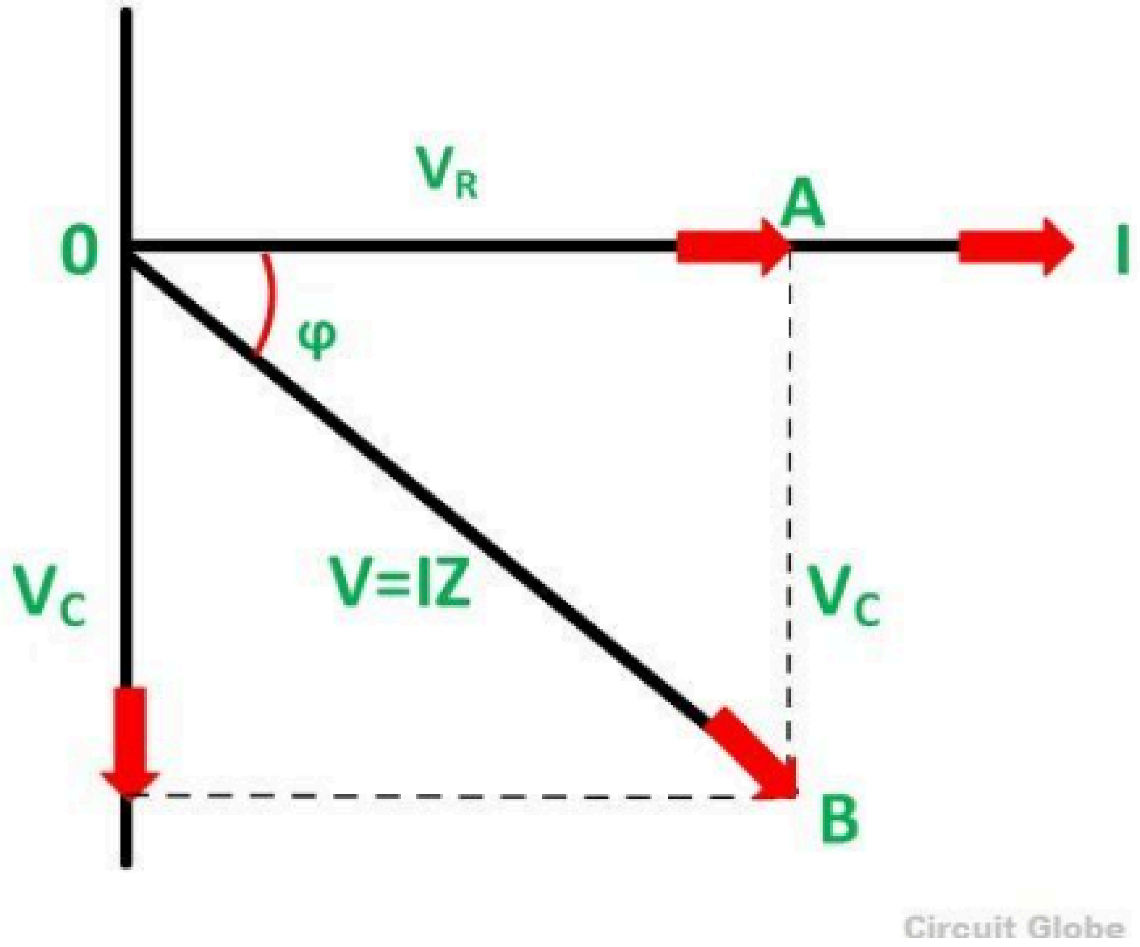
RC Series Circuit

The RC Series circuit is shown in the figure below:



Phasor Diagram of RC Series Circuit

The phasor diagram of the RC series circuit is shown below:



$$V_R = I_R \text{ and } V_C = IX_C$$

Where $X_C = I/2\pi fC$

In right triangle OAB,

$$V = \sqrt{(V_R)^2 + (V_C)^2} = \sqrt{(IR)^2 + (IX_C)^2}$$

$$V = I\sqrt{R^2 + X_C^2} \qquad \text{or}$$

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

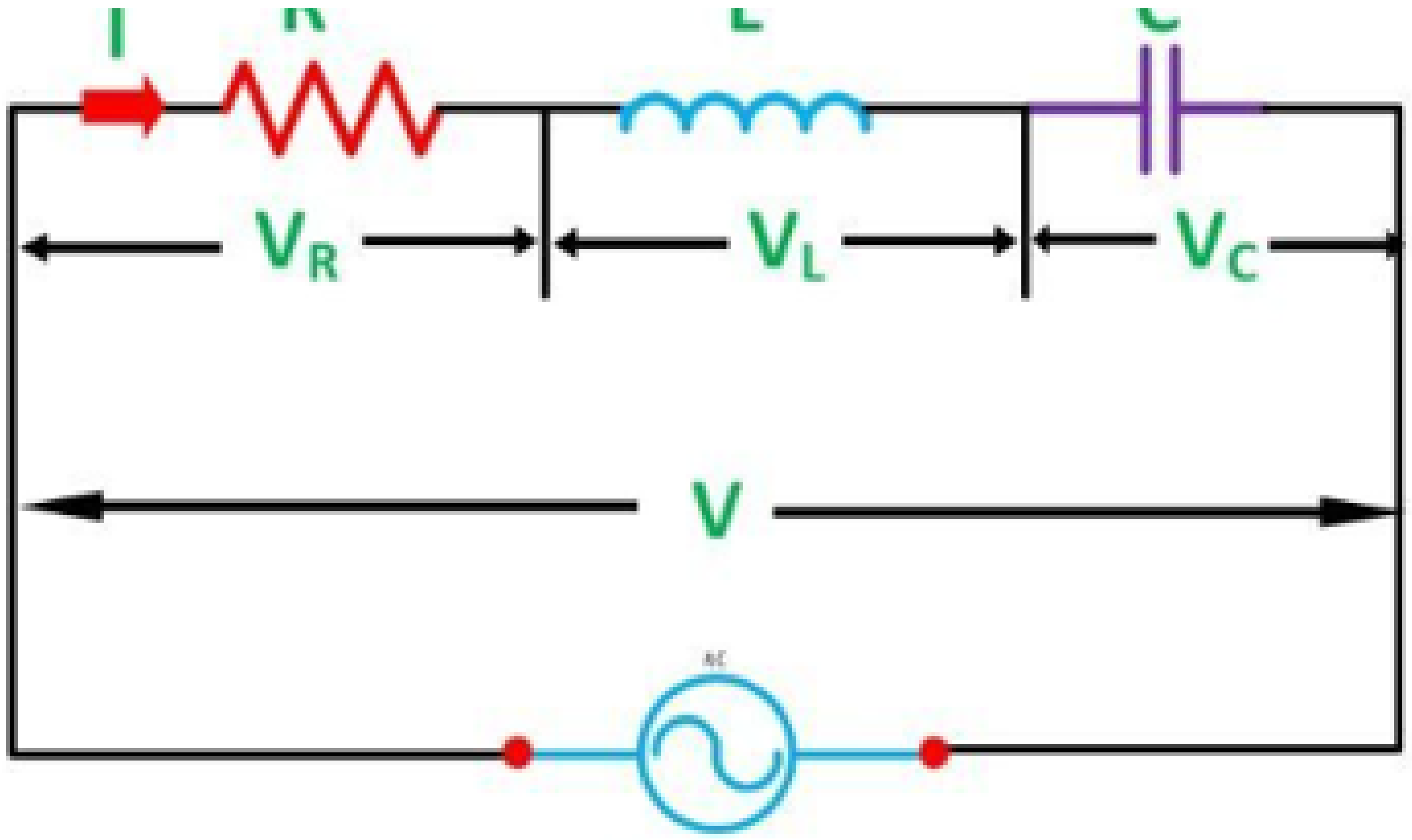
Z is the total opposition offered to the flow of alternating current by an RC series circuit and is called **impedance** of the circuit. It is measured in ohms (Ω).

Phase angle

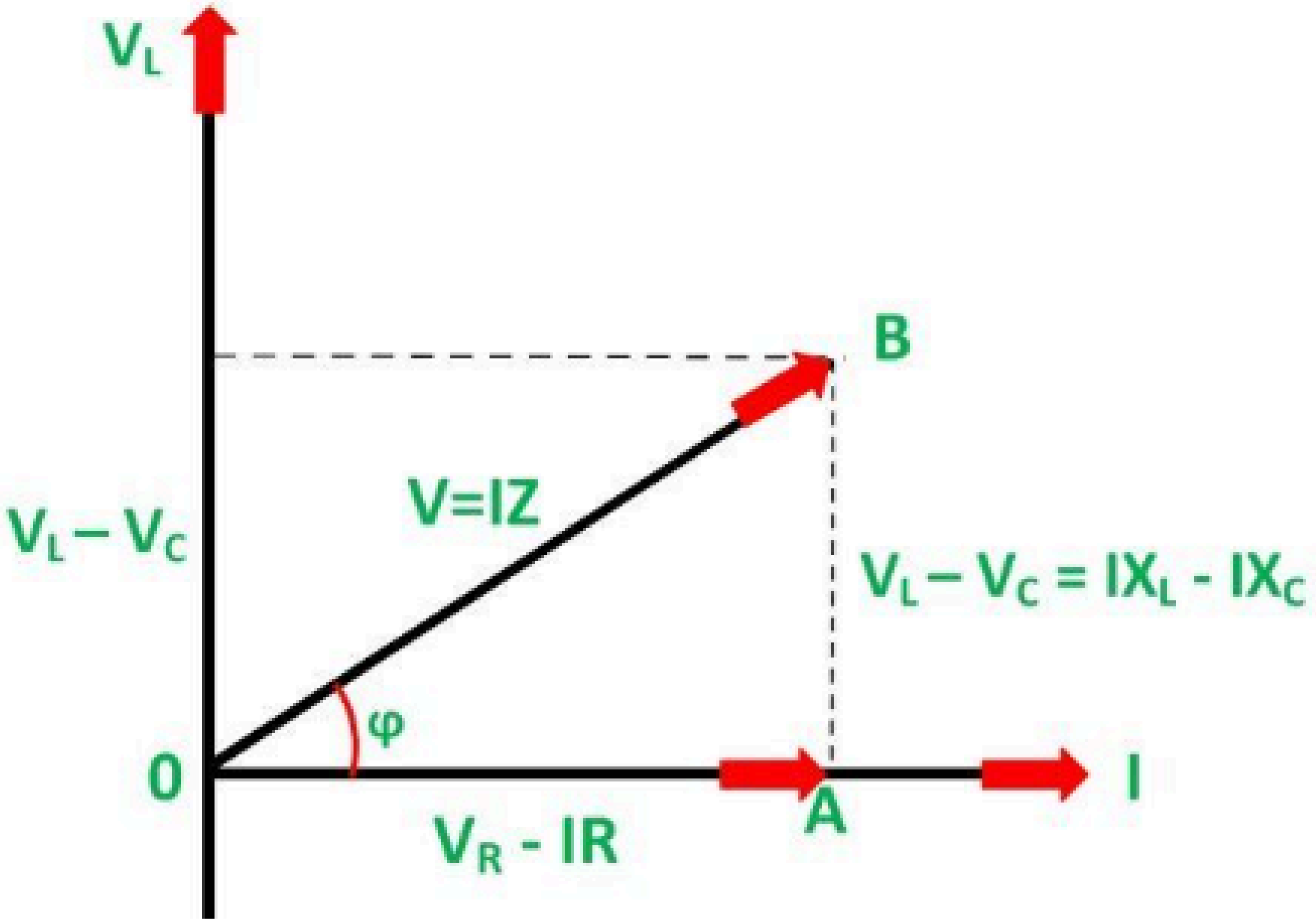
From the phasor diagram shown above, it is clear that the current in the circuit leads the applied voltage by an angle ϕ and this angle is called the **phase angle**.

$$\tan\varphi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R} \quad \text{or}$$

RLC Series Circuit



PHASOR DIAGRAM OF RLC SERIES CIRCUIT



$$V = I\sqrt{R^2 + (X_L - X_C)^2} \quad \text{or}$$

$$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V}{Z}$$

Where,

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

It is the total opposition offered to the flow of current by an RLC Circuit and is known as **Impedance** of the circuit.

Phase Angle

From the phasor diagram, the value of phase angle will be

$$\tan\varphi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} \quad \text{or}$$