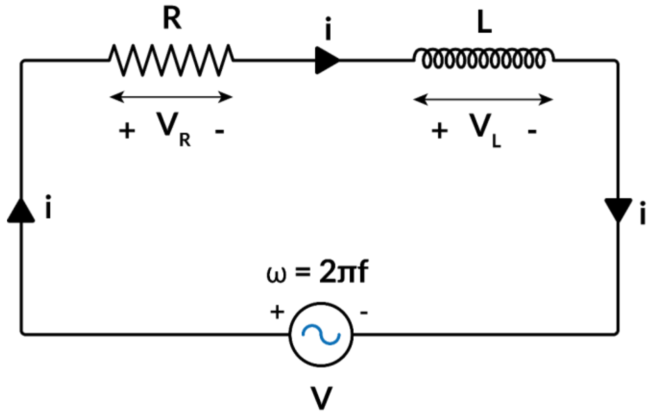
Summary
Single-Phase AC Circuits

Analysis of RL Circuits

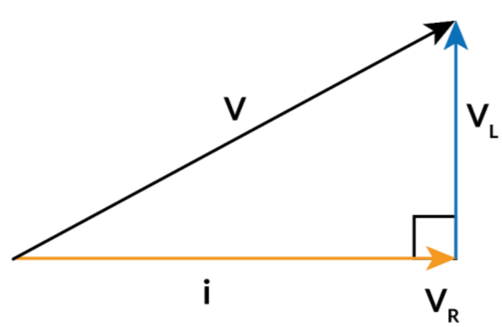
RL circuits have two types: series and parallel RL circuits.

Series RL Circuit
The circuit diagram for the series RL circuit is as follows.

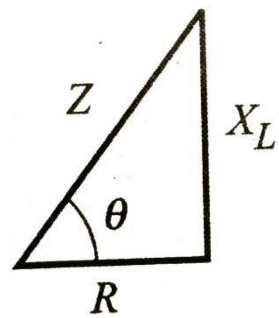


The important takeaways to be remembered are as follows:

- **Voltage equation:** $\underline{v} = \underline{v_R} + \underline{v_L}$
- **Current equation:** $\underline{i} = \underline{i_R} = \underline{i_L}$
- **Phasor diagram:** The following figure represents the phasor diagram of series RL circuits.



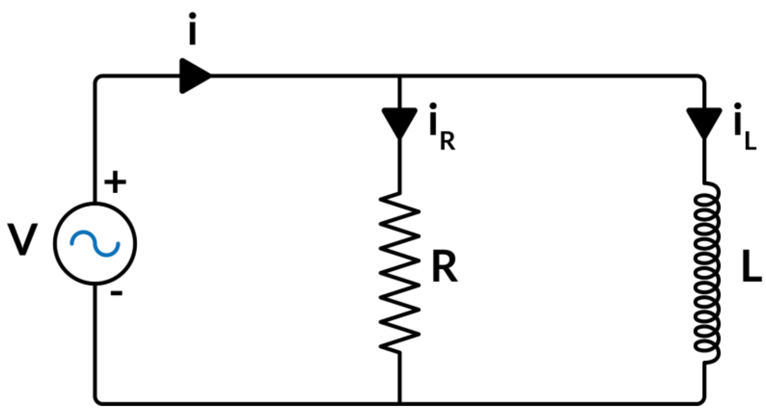
- **Impedance triangle:** The following figure represents the impedance triangle.



- ○ **Impedance:** $Z = R + jX_L$
- ○ **Magnitude of impedance:** $|Z| = \sqrt{R^2 + {X_L}^2}$

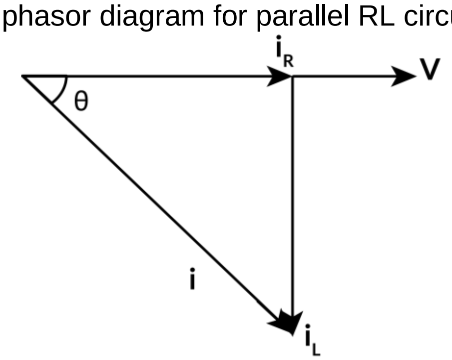
- **Impedance angle:** $\theta \; = \; tan^{-1}\frac{X_L}{R}$
- **Power factor:** $cos\,\theta \; = \frac{R}{Z}$ lagging

Parallel RL Circuit
The circuit diagram for the parallel RL circuit is given as follows.

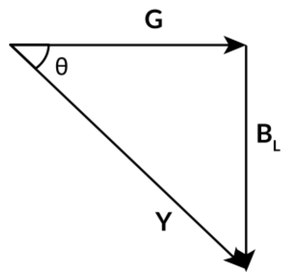


The important takeaways to be remembered are as follows:

- **Current equation:** $\underline{i} = \underline{i_R} + \underline{i_L}$
- **Voltage equation:** $\underline{v} = \underline{v_R} = \underline{v_L}$
- **Phasor diagram:** The phasor diagram for parallel RL circuits is given as follows.



- **Admittance triangle:** The admittance triangle for series RL circuits is given as follows.



- **Admittance:** $Y = G - jB_L$
- **Magnitude of admittance:** $|Y| = \sqrt{G^2 + {B_L}^2}$

  Where,

  Y = admittance = $\frac{1}{Z}$

  G = conductance = $\frac{1}{R}$

  B_L = Inductive susceptance = $\frac{1}{X_L}$

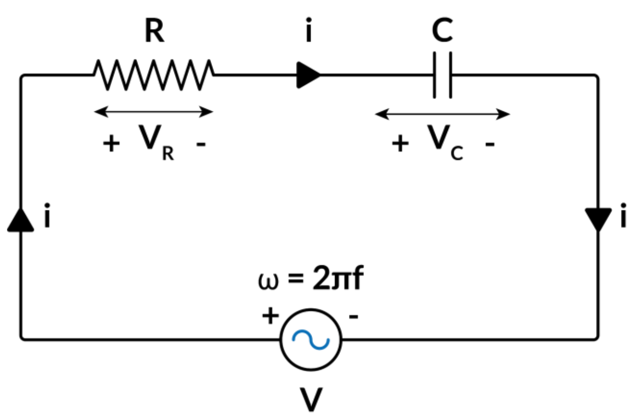
- **Admittance angle:** $\theta = tan^{-1}\frac{B_L}{G}$
- **Power factor:** $cos\ \theta = \frac{G}{Y}$ lagging

Analysis of RC Circuits

RC circuits have two types: series and parallel RC circuits.

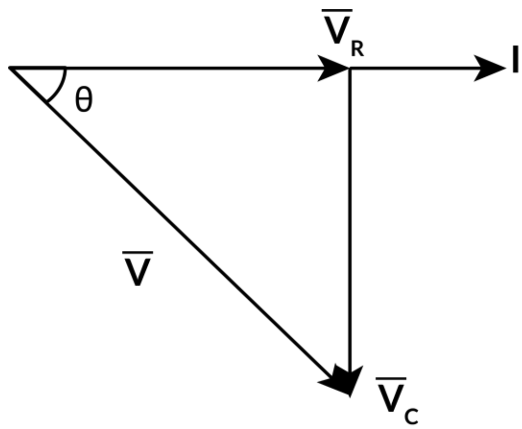
Series RC Circuit

The circuit diagram for series RL circuits is given as follows.

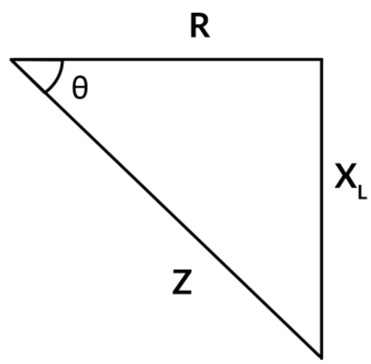


The important takeaways to be remembered are as follows:

- **Current equation:** $\underline{i} = \underline{i_R} = \underline{i_C}$
- **Voltage equation:** $\underline{v} = \underline{v_R} + \underline{v_C}$
- **Phasor diagram:** The phasor diagram for the series RC circuit is given as follows.



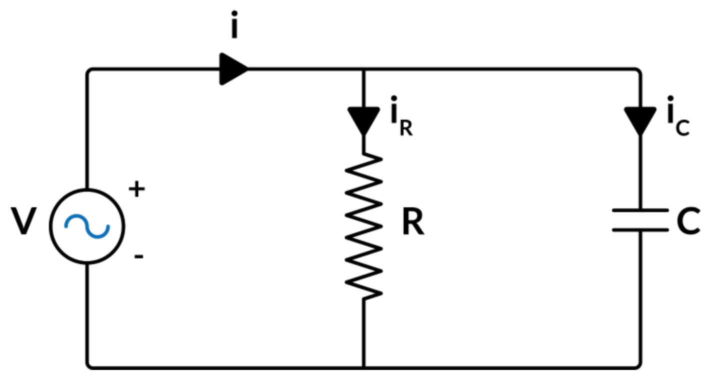
- **Impedance triangle:** The impedance triangle of series RC circuit is given as follows.



  - **Impedance:** $Z = R - jX_C$
  - **Magnitude of impedance:** $|Z| = \sqrt{R^2 + {X_C}^2}$
- **Impedance angle:** $\theta \; = \; tan^{-1}\frac{X_C}{R}$
- **Power factor:** $cos\,\theta \; = \frac{R}{Z}$ leading

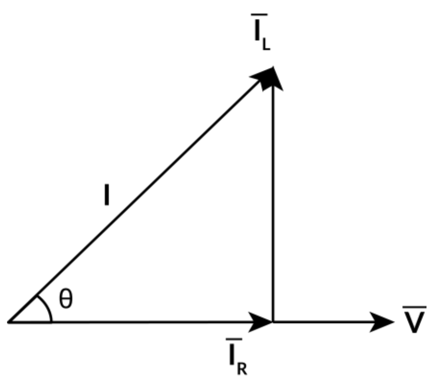
Parallel RC Circuit

The circuit diagram for the parallel RL circuit is given as follows.

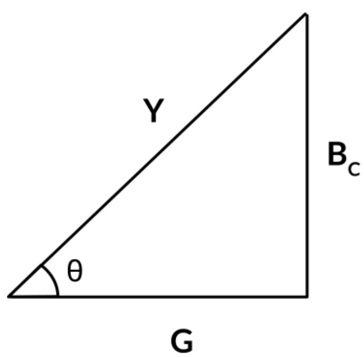


The important takeaways to be remembered are as follows:

- **Voltage equation:** $\underline{v} = \underline{v_R} = \underline{v_C}$
- **Current equation:** $\underline{i} = \underline{i_R} + \underline{i_C}$
- **Phasor diagram:** The phasor diagram of parallel RC circuits is given as follows.



- **Admittance triangle:** The admittance triangle for series RL circuit is given as follows.



  - **Admittance:** $Y = G + jB_C$
  - **Magnitude of admittance:** $|Y| = \sqrt{G^2 + {B_C}^2}$

    Where B_C = capacitive susceptance = $\frac{1}{X_C}$
- **Admittance angle:** $\theta \ = \ tan^{-1}\frac{B_C}{G}$

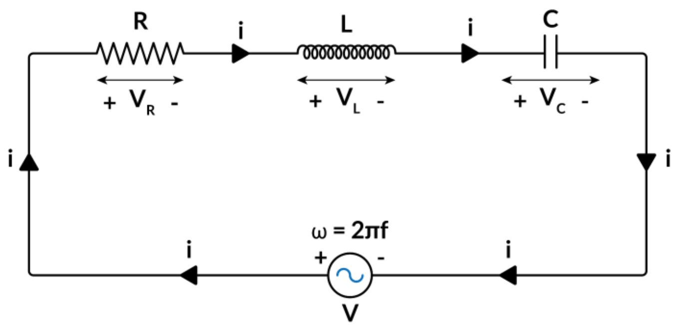
- **Power factor:** $cos\ \theta\ = \frac{G}{Y}$ leading

Analysis of RLC Circuits

RLC circuits have two types: series and parallel RLC circuits.

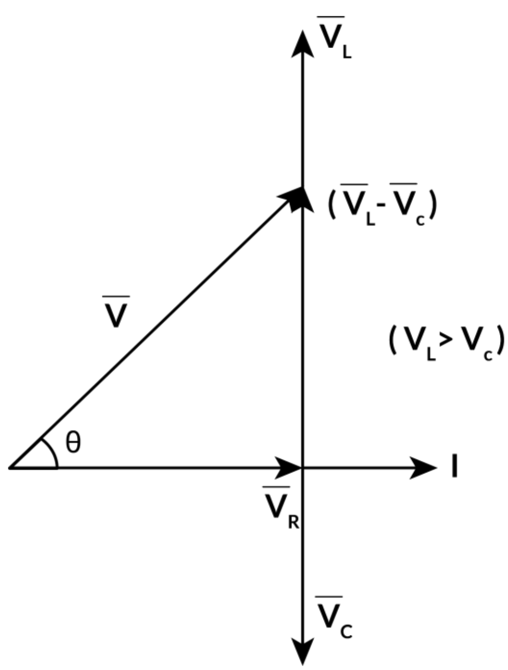
Series RLC Circuits

The circuit diagram of series RLC circuit is shown below.

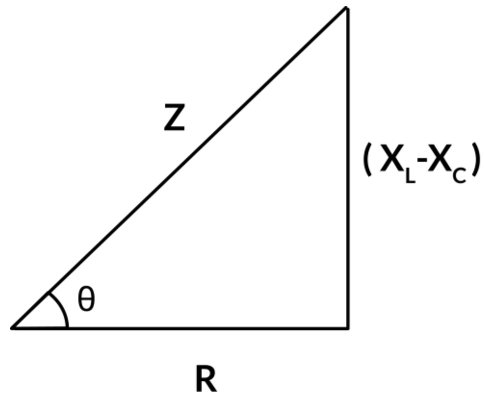


The important takeaways to be remembered are as follows:

- **Current equation:** $\underline{i} = \underline{i_R} = \underline{i_L} = \underline{i_C}$
- **Voltage equation:** $\underline{v} = \underline{v_R} + \underline{v_L} + \underline{v_C}$
- **Phasor diagram:** The phasor diagram of the series RLC circuit for $v_L > v_C$ is given as follows.



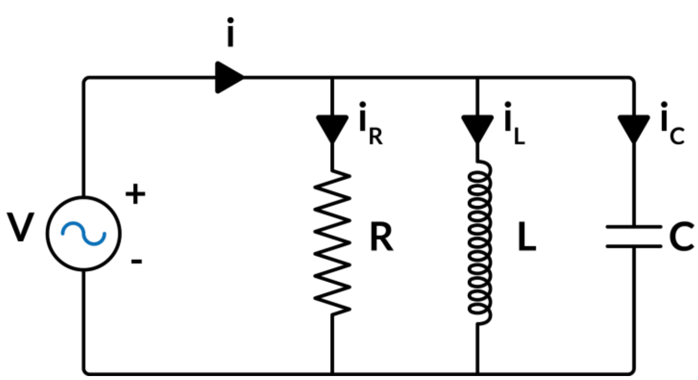
- **Impedance triangle:** The impedance triangle of the series RLC circuit for $X_L > X_C$ is as follows.



    - **Impedance:** $Z = R + j(X_L - X_C)$
    - **Magnitude of impedance:** $|Z| = \sqrt{R^2 + (X_L - X_C)^2}$
- **Impedance angle:** $\theta = tan^{-1}\frac{(X_L - X_C)}{R}$
- **Power factor:** $cos\ \theta\ = \frac{R}{Z}$
    - Power factor will be lagging when net reactance $(X_L - X_C)$ is inductive in nature.
    - Power factor will be leading when net reactance $(X_L - X_C)$ is capacitive in nature.

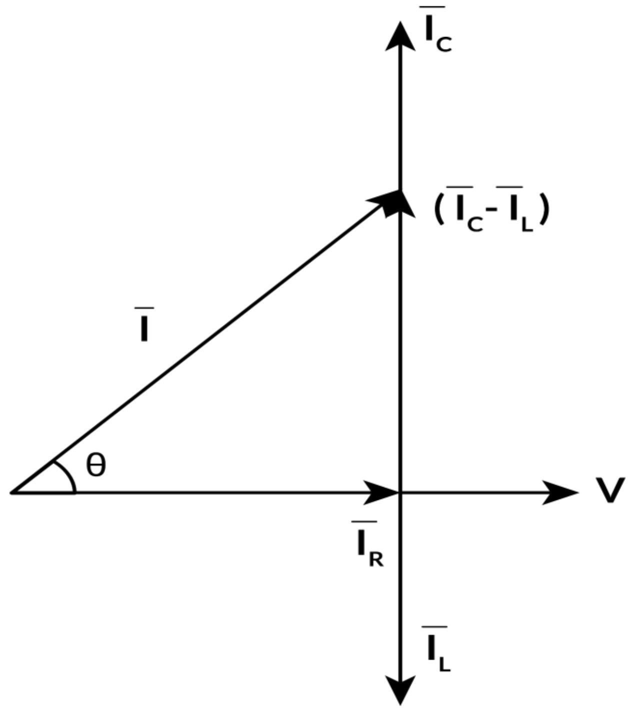
Parallel RLC Circuits

The circuit diagram of parallel RLC circuits is as follows.

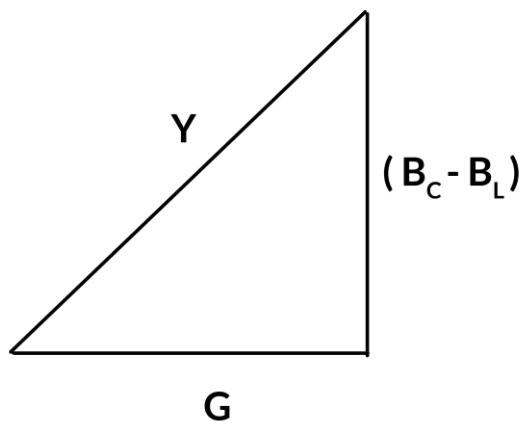


The important takeaways to be remembered are as follows:

- **Voltage equation:** $\underline{v} = \underline{v_R} = \underline{v_L} = \underline{v_C}$
- **Current equation:** $\underline{i} = \underline{i_R} + \underline{i_L} + \underline{i_C}$
- **Phasor diagram:** The phasor diagram of the series RLC circuit for $i_C > i_L$ is given as follows.



- **Admittance triangle:** The admittance triangle of the parallel RLC circuit for $B_C > B_L$ is as follows.



  - **Admittance:** $Y = G + j(B_C - B_L)$
  - **Magnitude of admittance:** $|Y| = \sqrt{G^2 + (B_C - B_L)^2}$
- **Admittance angle:** $\theta = tan^{-1}\frac{(B_C - B_L)}{G}$
- **Power factor:** $cos\,\theta = \frac{G}{Y}$
  - Power factor will be leading when net susceptance $(B_C - B_L)$ is capacitive in nature.
  - Power factor will be lagging when net susceptance $(B_C - B_L)$ is inductive in nature.

<u>Complex Power and Power Factor</u>

Complex power and power factor are interrelated.

Complex Power

Complex power can be written as $S = VI^*$, where V and I are the RMS values of voltage and current. It can be calculated for inductive and capacitive load. Let's look at both:

- **Inductive load**

  Let voltage be $V = V\angle 0°$ and

  current be $I = I\angle -\emptyset$

  The complex power can be calculated as follows:

  $S = (V\angle 0°)\times (I\angle -\emptyset)^* = VI\angle\emptyset$

  $S = VIcos\,\emptyset + jVIsin\,\emptyset$ ....(1)

  $S = P + jQ$...........................(2)

  By comparing both equations:

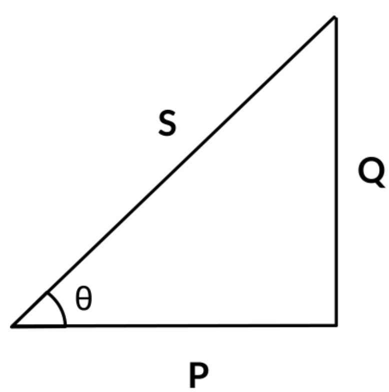
  P = Active (Real) power = $VIcos\,\emptyset$ = Average active power; unit is watt (W)

  Q = Reactive power = $VIsin\,\emptyset$; unit is volt-ampere reactive (VAr)

  For inductive load, reactive power is always positive.

  |S| = Apparent power = $\sqrt{P^2 + Q^2}$ = VI; unit is volt-ampere (VA)

  - **Power triangle:** The representation of the power triangle is as follows.



  - **Power angle:** $\theta = tan^{-1}\frac{Q}{P}$

- **Capacitive load**

  Let voltage be $V = V\angle 0°$ and

  current be $I = I\angle \emptyset$

  The complex power can be calculated as follows:

  $S = (V\angle 0°) \times (I\angle \emptyset)^* = VI\angle - \emptyset$

  $S = VIcos\,\emptyset - jVIsin\,\emptyset$ ....(1)

  $S = P - jQ$...........................(2)

  By comparing both equations:

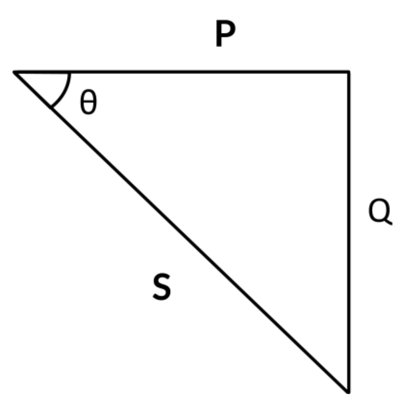
  P = Active (Real) power = $VIcos\,\emptyset$ = Average active power; unit is watt (W)

  Q = Reactive power = $VIsin\,\emptyset$; unit is volt-ampere reactive (VAr)

  For capacitive load, reactive power is always negative.

  |S| = Apparent power = $\sqrt{P^2 + Q^2}$ = VI; unit is volt-ampere (VA)

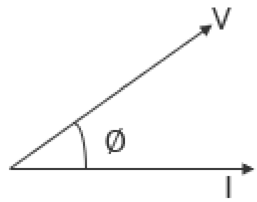
  - **Power triangle:** The representation of the power triangle is given as follows.



Power Factor

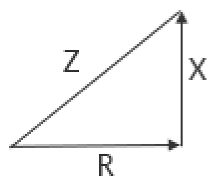
The power factor represents how much apparent power is utilised as active power. It can be defined in three ways:

- Power factor is the cosine of the angle between voltage and the current phasor, as shown in the following figure.



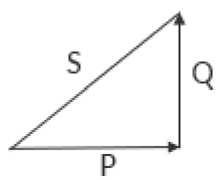
Power factor = $cos\ \emptyset$

- Power factor is the ratio of resistance to the impedance of the circuit, as shown in the following figure.



Power factor = $\frac{R}{Z}$

- Power factor is the ratio of active power to apparent power, as shown in the following figure.



Power factor = $\frac{P}{S}$

- Power factor also depends on the nature of the load:
  - For resistive load, the power factor is unity.
  - For inductive load, the power factor is lagging.
  - For capacitive load, the power factor is leading.

Measurement of Power

Power is the rate of change of energy over time. The relation between power and energy is as follows:

$$P = \frac{dW}{dt}$$

The unit is Watt or Joule/sec.

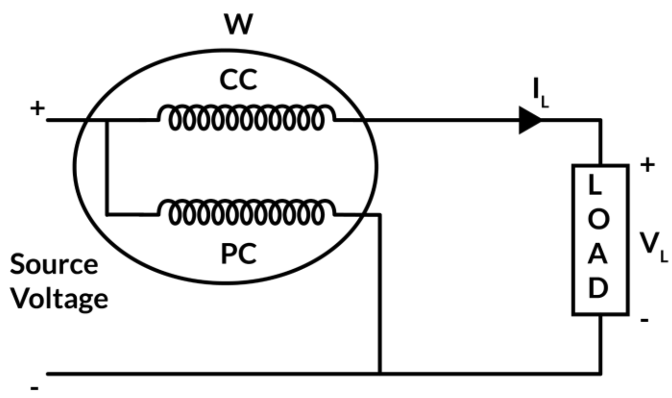
Power is the product of voltage, current and the power factor, as given in the following formula:

$$P = V \times I \times cos\, \emptyset$$

The device directly used to measure power is the wattmeter.

Wattmeter

The connection diagram of the wattmeter is given below.



It consists of two coils:

- **Current coil:** Measures the current (I)
- **Potential coil:** Measures the voltage (V)

The average power is given as $P = VIcos\emptyset$

The reading of a wattmeter gives the average power.

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