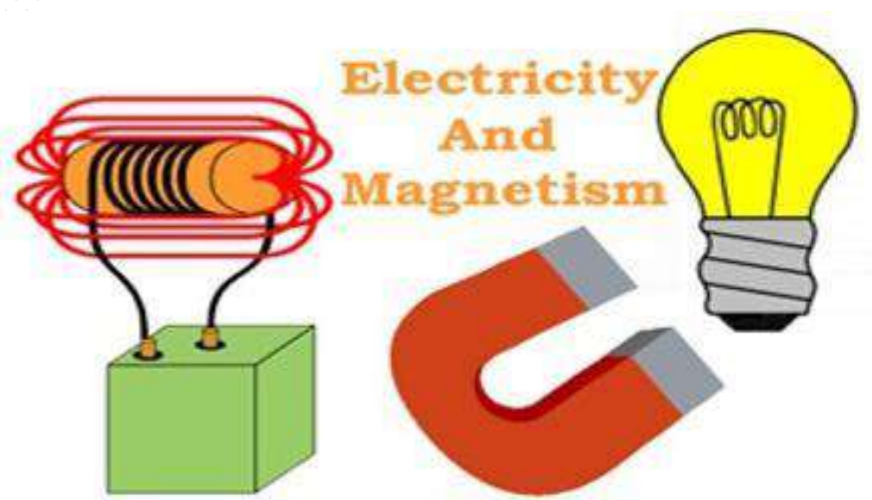
University of Salahaddin – Erbil
College of Science
Physics Department

Laboratory Manual
Electricity and Magnetism
2nd Course



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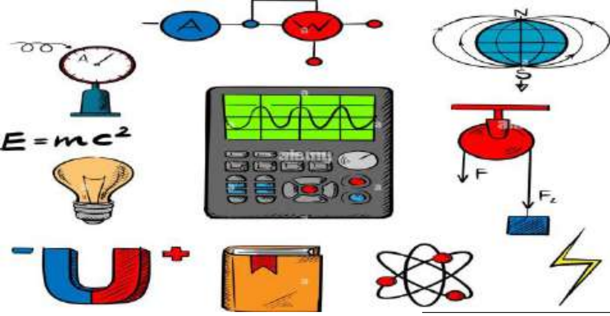
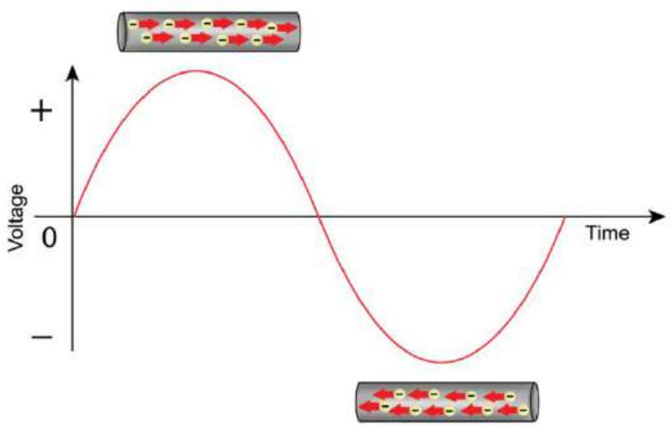
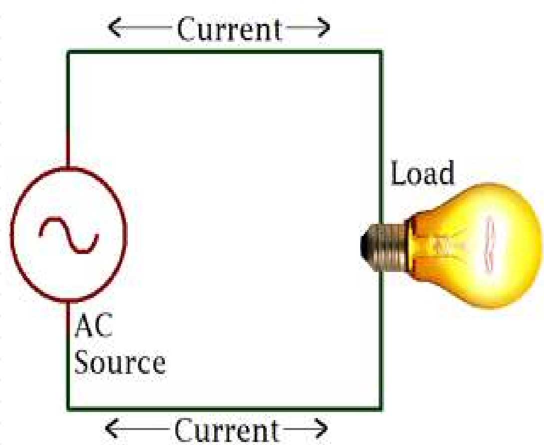
1Year – Physics
2022-2023

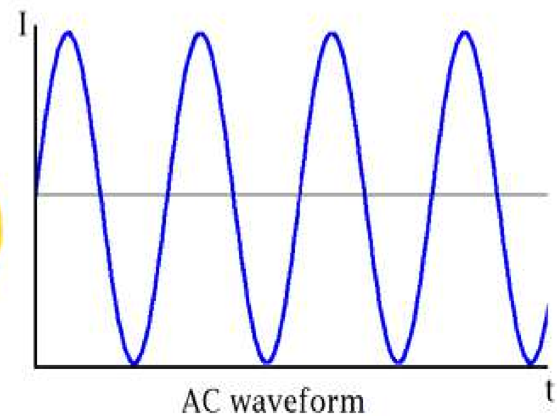


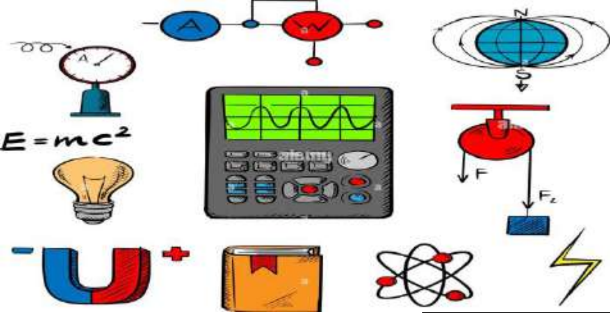
AC Circuit

An alternating current (AC) is an electrical current that regularly reverses direction and changes its value constantly with time .







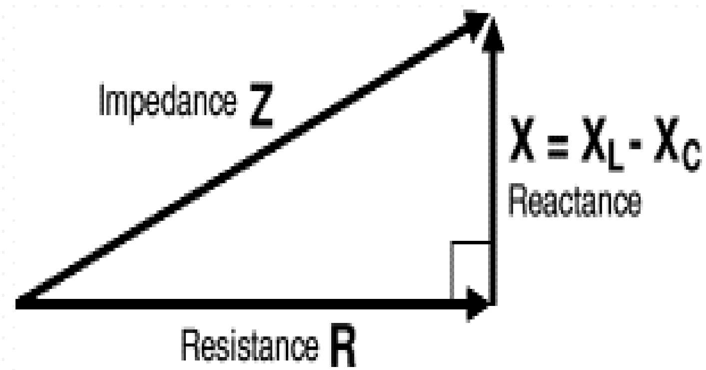


Impedance Z

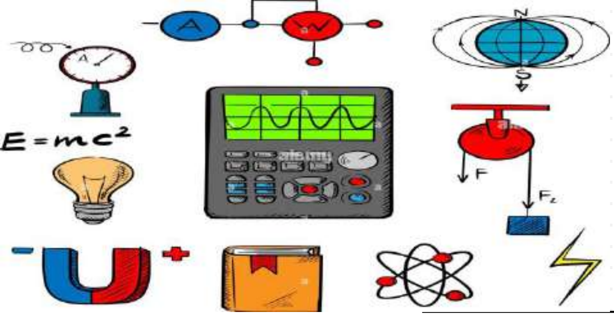
is how much the circuit impedes the flow of charge. It is like resistance, but it also takes into account the effects of capacitance and inductance. Impedance is measured in ohms (ohm).

Impedance can be split into two parts:

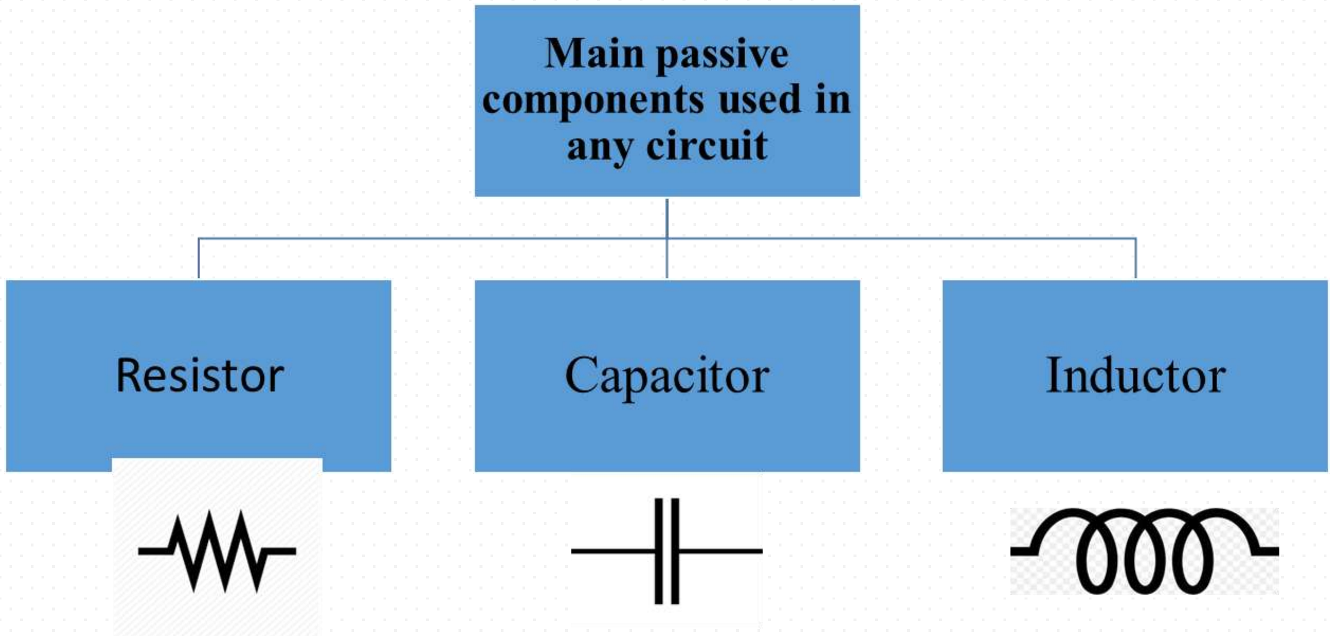
- ***Resistance R (the part which is constant regardless of frequency)***
- ***Reactance X (the part which varies with frequency due to capacitance and inductance) .***



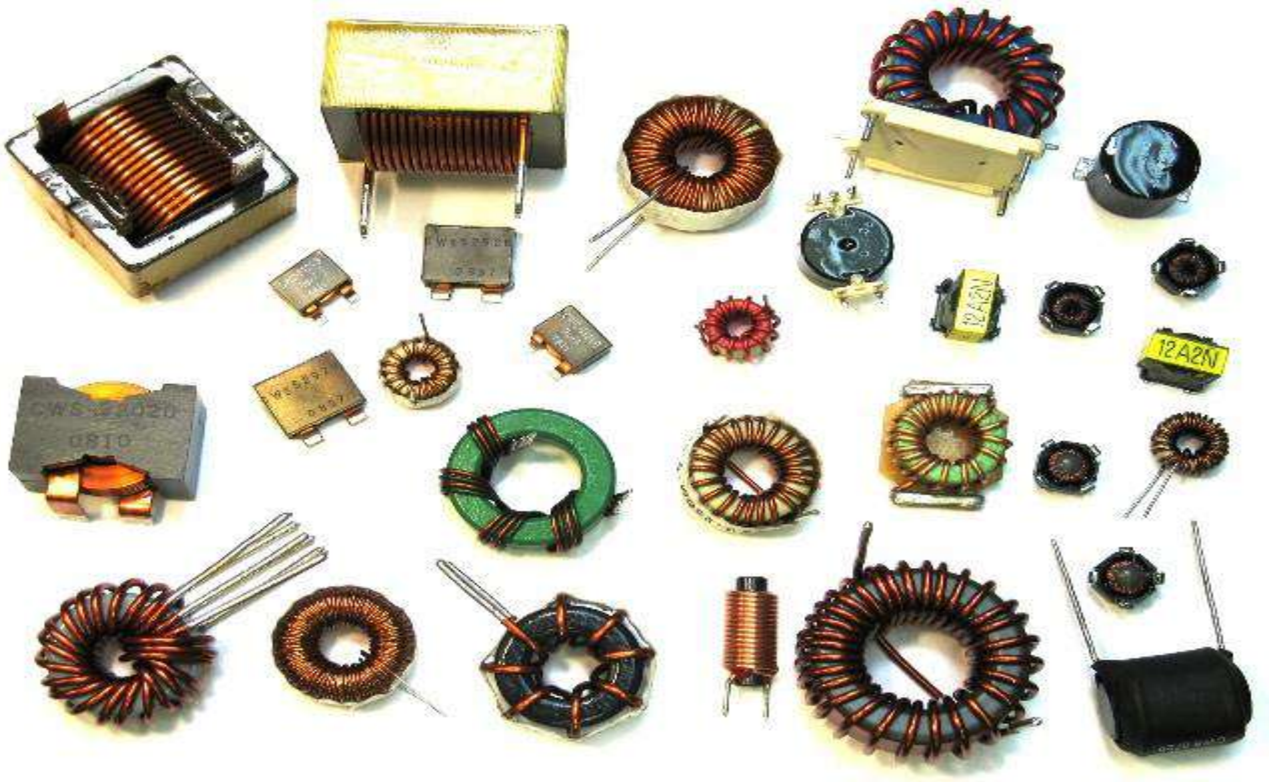
Impedance, $Z = \sqrt{R^2 + X^2}$

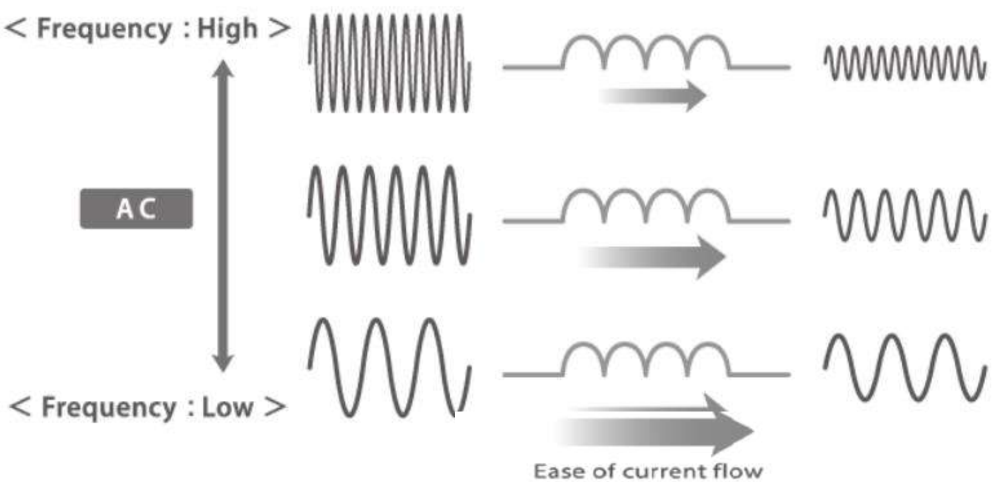


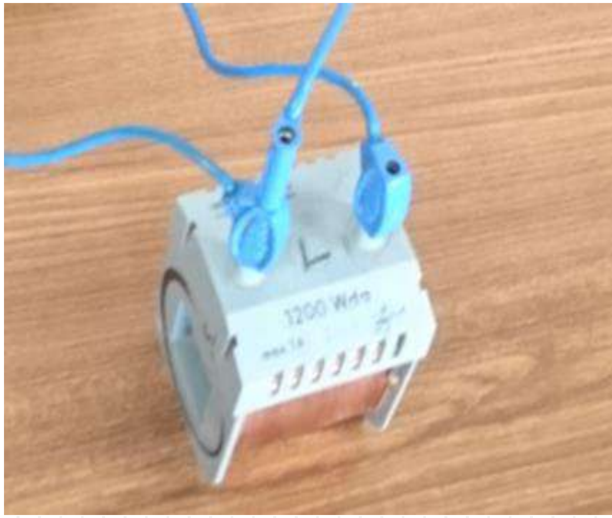
Passive Components in AC Circuits

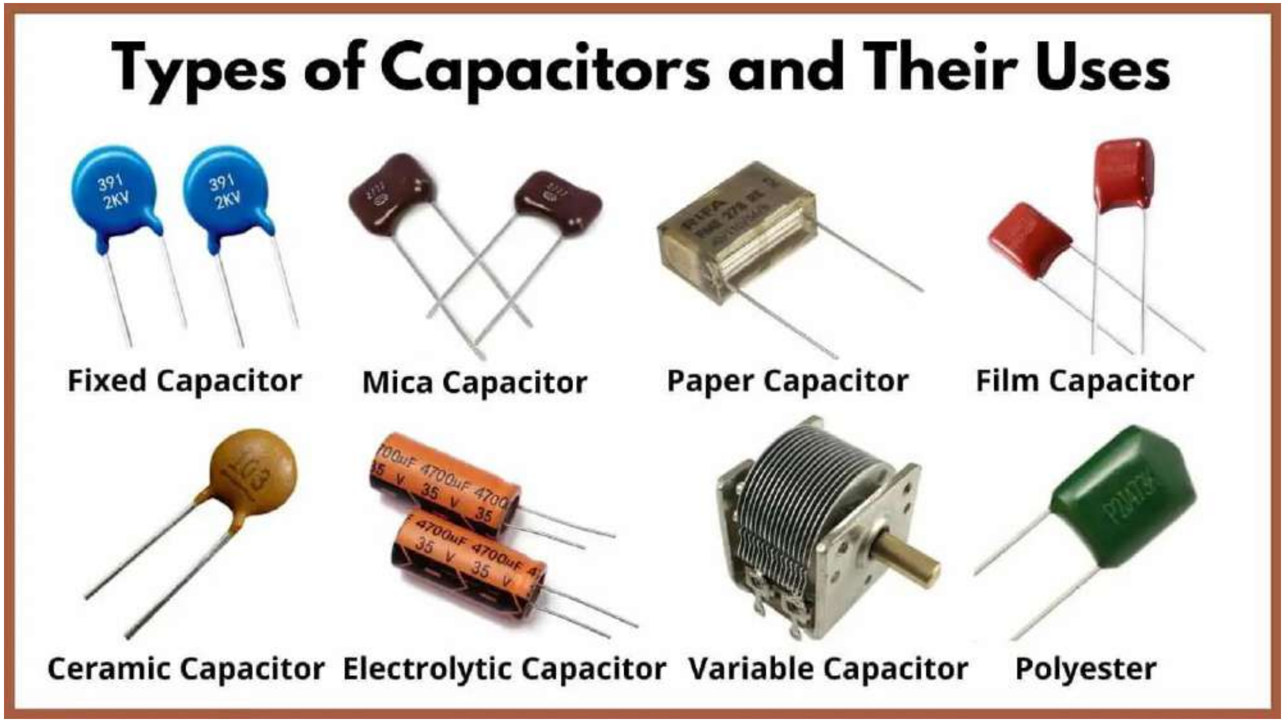


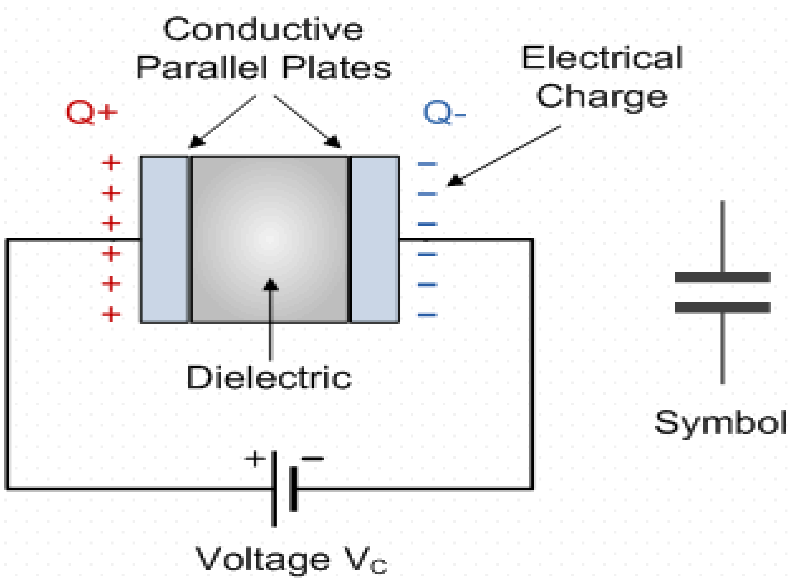
The opposition to current flow through a passive component in an AC circuit is called: resistance, R for a resistor, capacitive reactance, XC for a capacitor and inductive reactance, XL for an inductor. The combination of resistance and reactance is called Impedance.

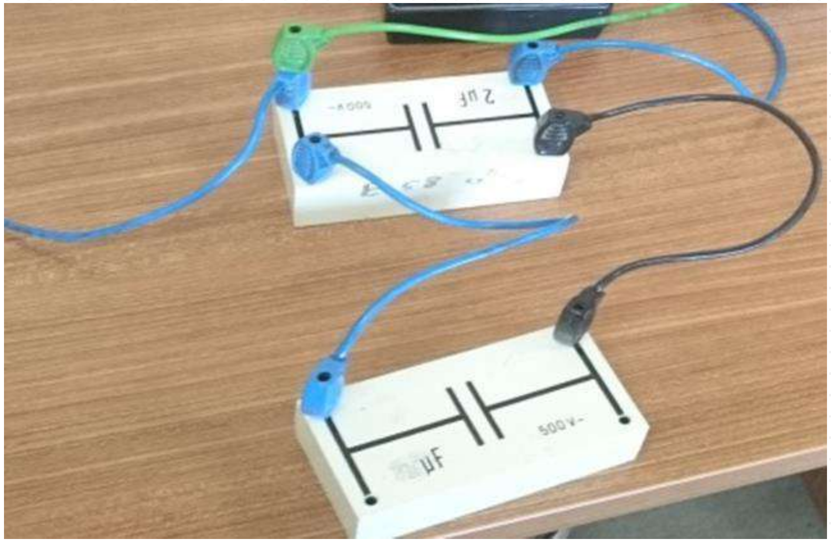

12A2N
12A2N

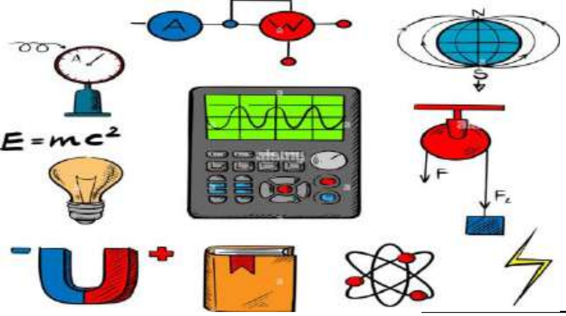

< Frequency : High >
AC
< Frequency : Low >
Ease of current flow




Types of Capacitors and Their Uses
Fixed Capacitor
Mica Capacitor
Paper Capacitor
Film Capacitor
Ceramic Capacitor
Electrolytic Capacitor
Variable Capacitor
Polyester

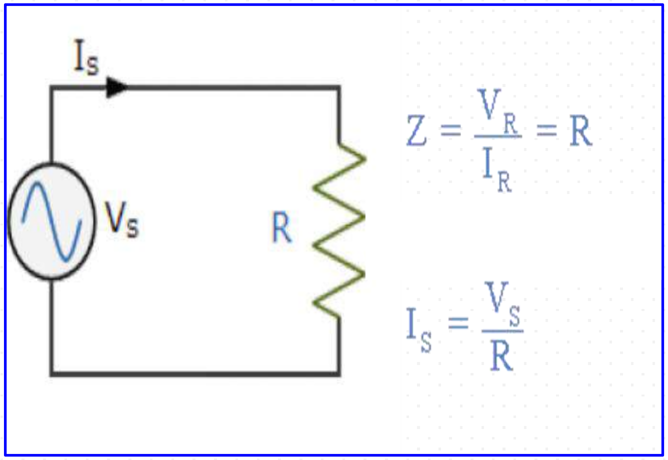

Conductive Parallel Plates
Electrical Charge
Q+
Q-
Dielectric
Voltage Vc
Symbol

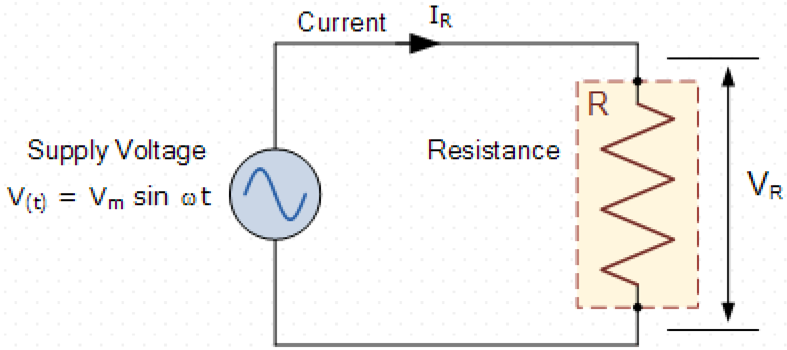


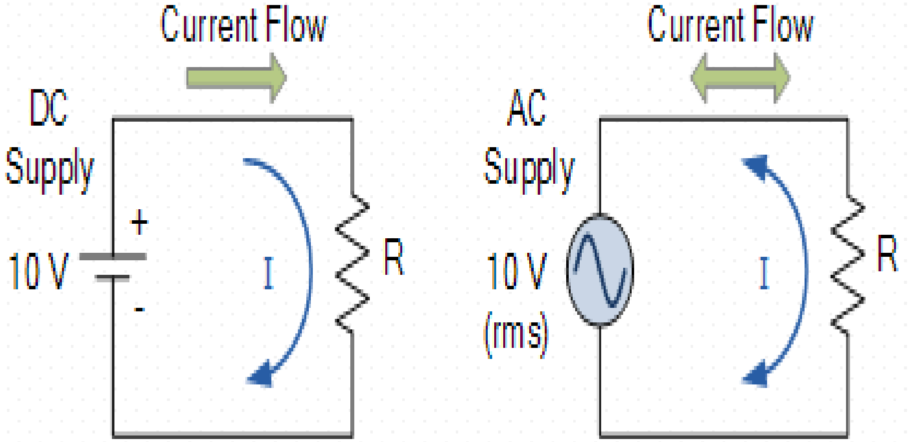


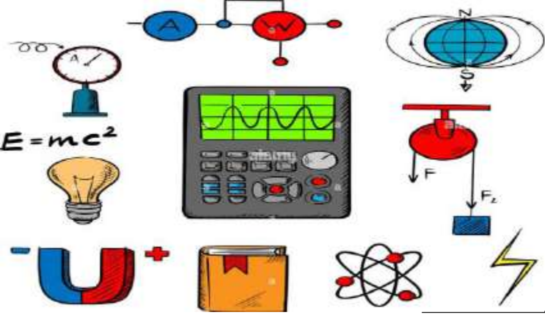
Purely Resistive Circuit (A Resistive Load)

Resistors are "passive" devices, that is they do not produce or consume any electrical energy, but convert electrical energy into heat .



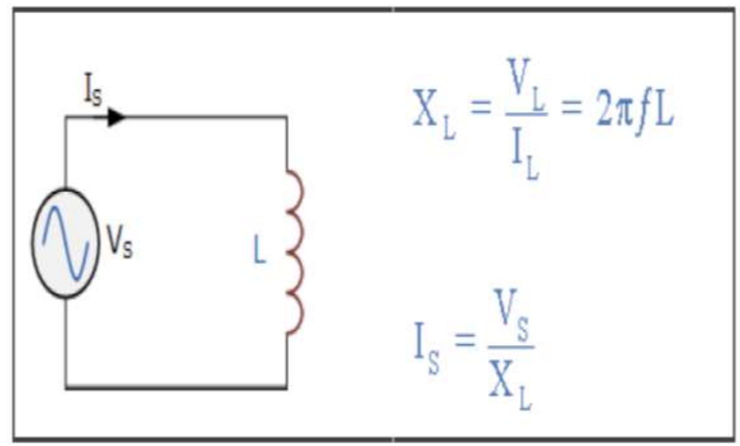






Purely Inductive Circuit (An Inductive Load)

The inductive reactance of the AC circuit can be represented as :



The X_L is called the inductive reactance of an inductor. The SI unit of X_L is the *ohm*.

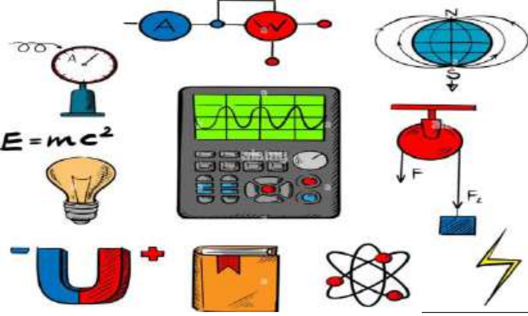
Inductive Reactance, $X_L = 2\pi fL$

The current and voltage are related by an equation similar to Ohm's Law with

$$V_L = IX_L$$

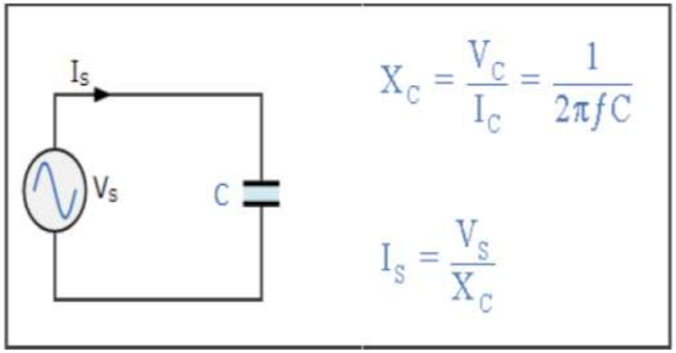
where X_L is known as the **inductive reactance**, is measured in units of ohms, and is given by

$$X_L = 2\pi fL = \omega L.$$



Purely Capacitive Circuit (A Capacitive Load)

The capacitance reactance of the AC circuit can be represented as :



$$\text{Capacitive Reactance, } \mathbf{X_C} = \frac{1}{2\pi f C}$$

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

$$X_C = \frac{1}{\omega_d C} \qquad \text{(capacitive reactance).}$$

$$V_C = I_C X_C \qquad \text{(capacitor).}$$

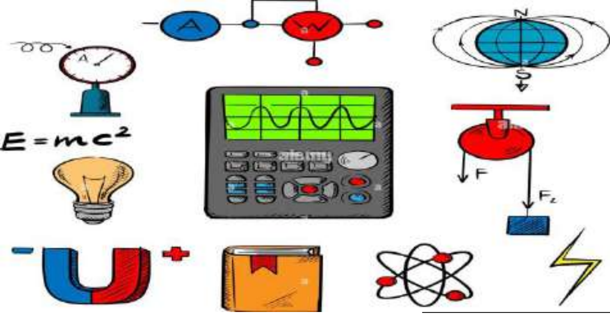
$$X_c = \frac{1}{2\pi f C} \quad (As\ \omega C = 2\pi f C)$$

$Where, \omega = Angular\ Frequency$

$f = Frequency$

$C = Capacitance\ Value\ of\ Capacitor$

X_C is called the capacitive reactance of a capacitor. The SI unit of X_C is the *ohm,* just as for resistance *R.*



AC Circuit

Resistance

Inductance

Capacitance

RL

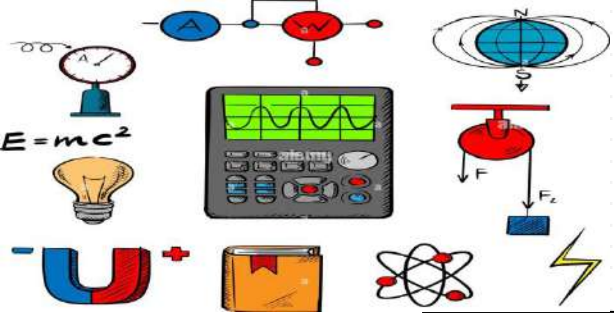
RC

CL

Impedance Z

RLC

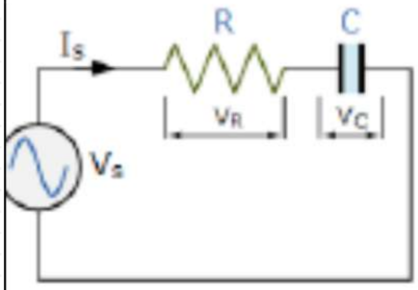
Series



Series AC Circuits

Passive components in AC circuits can be connected together in series combinations to form RC, RL and LC circuits as shown.

Series RC Circuit

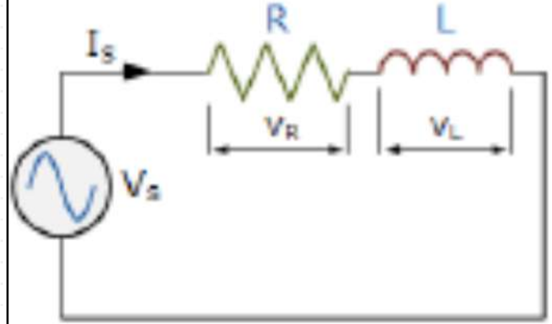


$$Z = \sqrt{R^2 + X_C^2}$$

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

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

Series RL Circuit

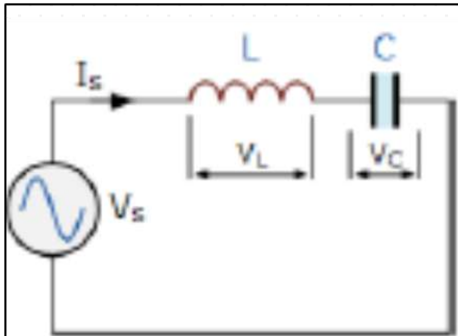


$$Z = \sqrt{R^2 + X_L^2}$$

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

$$V_S = \sqrt{V_R^2 + V_L^2}$$

Series LC Circuit



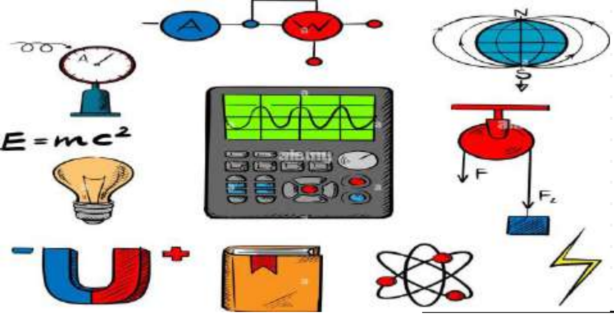
$$Z = \sqrt{X_L^2 - X_C^2}$$

$$\therefore Z = X_L - X_C \text{ or } X_C - X_L$$

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

at f_R $X_L = X_C$ and $V_L = V_C$

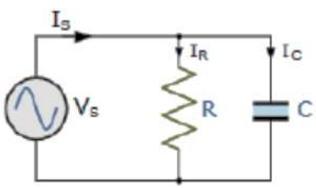
$$I_S = I_L = I_C$$



Parallel AC Circuits

Passive components in AC circuits can be connected together in Parallel combinations to form RC, RL and LC circuits as shown.

Parallel RC Circuit



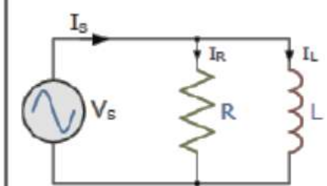
$$I_R = \frac{V_S}{R}, \quad I_C = \frac{V_S}{X_C}$$

$$I_S = \sqrt{I_R^2 + I_C^2}$$

$$Y = \frac{1}{Z} = \sqrt{G^2 + B_C^2}$$

$$V_S = V_R = V_C$$

Parallel RL Circuit



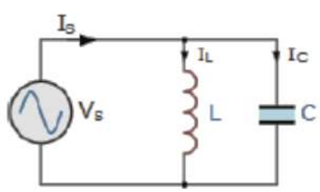
$$I_R = \frac{V_S}{R}, \quad I_L = \frac{V_S}{X_L}$$

$$I_S = \sqrt{I_R^2 + I_L^2}$$

$$Y = \frac{1}{Z} = \sqrt{G^2 + jB_L^2}$$

$$V_S = V_R = V_L$$

Parallel LC Circuit



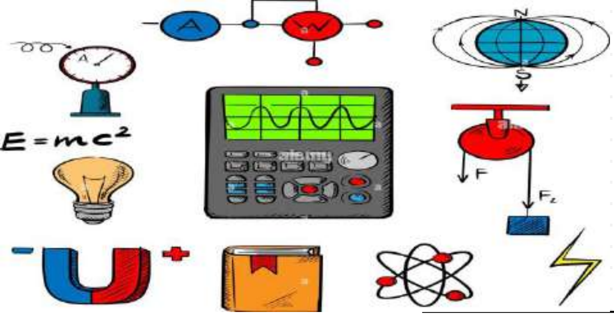
$$B_L = \frac{1}{X_L}, \quad B_C = \frac{1}{X_C}$$

$$Y = \frac{1}{Z} = B_L + B_C$$

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

at f_R $X_L = X_C$ and $I_L = I_C$

$$V_S = V_L = V_C$$



RLC Circuits

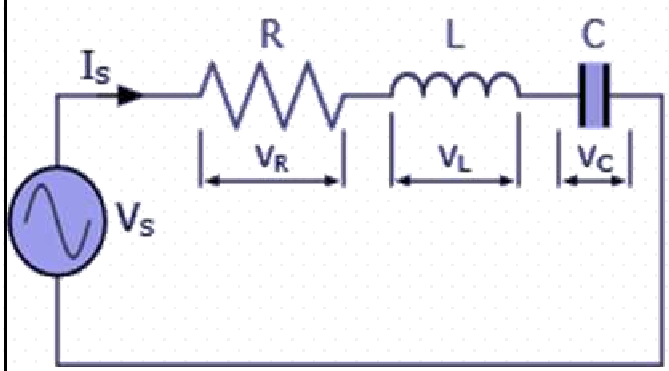
All three passive component in AC circuits can also be connected together in series combinations as shown below .

KVL: $V_S - V_R - V_L - V_C = 0$

$$V_S - IR - L\frac{di}{dt} - \frac{Q}{C} = 0$$

$$\therefore V_S = IR + L\frac{di}{dt} + \frac{Q}{C}$$

Series RLC Circuit

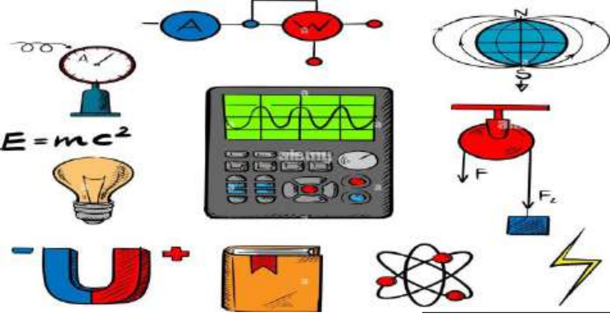


$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$V_S = \sqrt{V_R^2 + (V_L - V_C)^2}$$

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

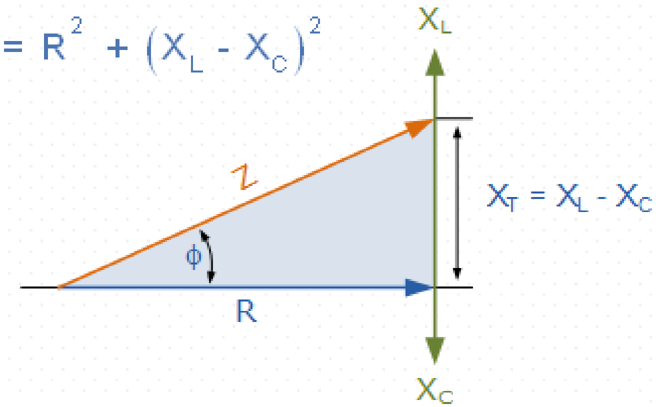
$$I_S = I_R = I_L = I_C$$



The impedance Z of a series RLC circuit depends upon the angular frequency, ω as do XL and XC

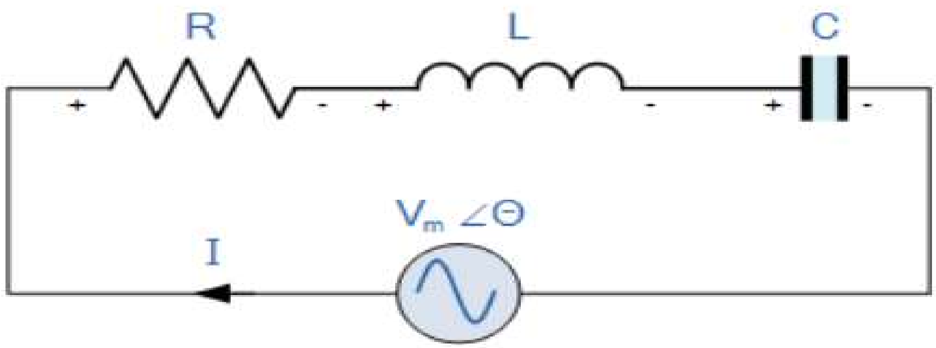
- If the capacitive reactance is greater than the inductive reactance, $X_C > X_L$ then the overall circuit reactance is capacitive .
- if the inductive reactance is greater than the capacitive reactance, $X_L > X_C$ then the overall circuit reactance is inductive .
- If the two reactance's are the same and $X_L = X_C$ then the angular frequency at which this occurs is called the resonant frequency and produces the effect of **resonance .**

$$Z^2 = R^2 + (X_L - X_C)^2$$



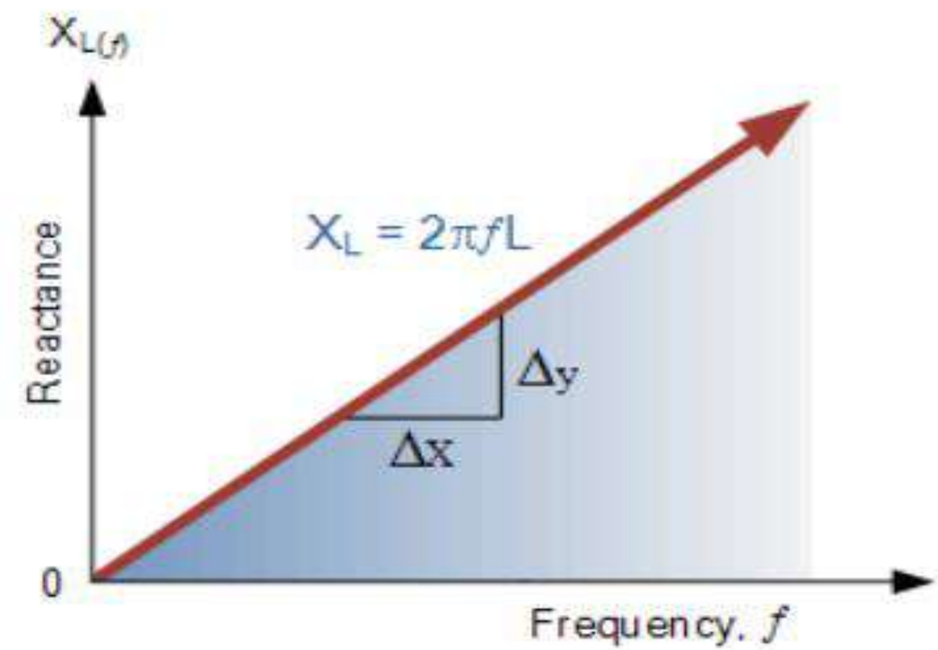
$$Z = \sqrt{R^2 + (X_C - X_l)^2}$$

Series RLC Circuit

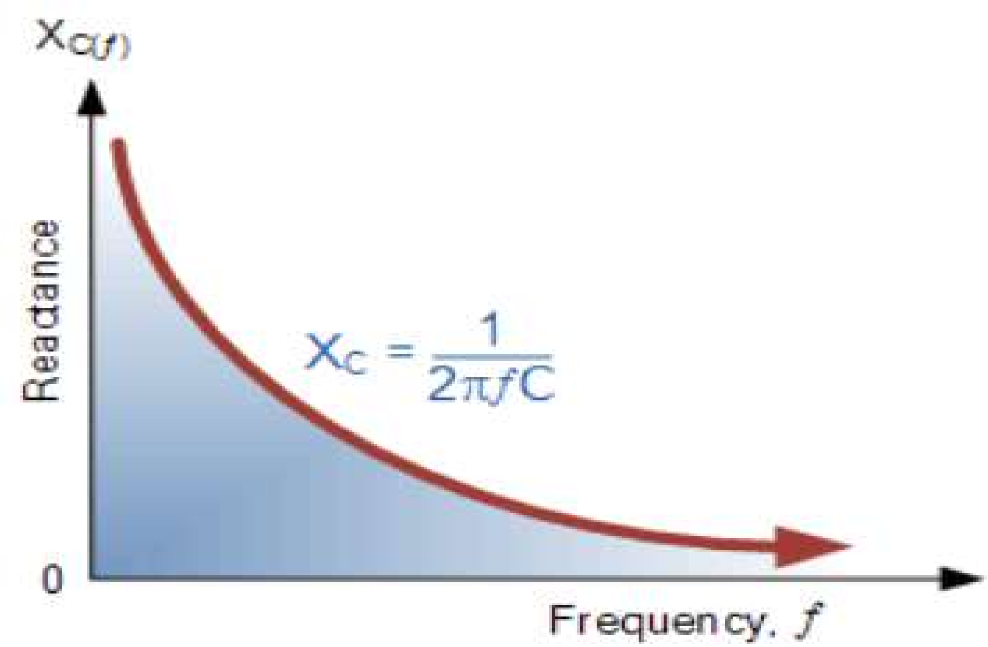


Firstly, let us define what we already know about series RLC circuits.

- Inductive reactance : $X_L = 2\pi f L = \omega L$
- Capacitive reactance : $X_C = \frac{1}{2\pi f C} = \frac{1}{\omega C}$
- When $X_L > X_C$ the circuit is Inductive
- When $X_C > X_L$ the circuit is Capacitive
- Total circuit reactance = $X_T = X_L - X_C$ or $X_C - X_L$
- Total circuit impedance = $Z = \sqrt{R^2 + X_T^2} = R + jX$

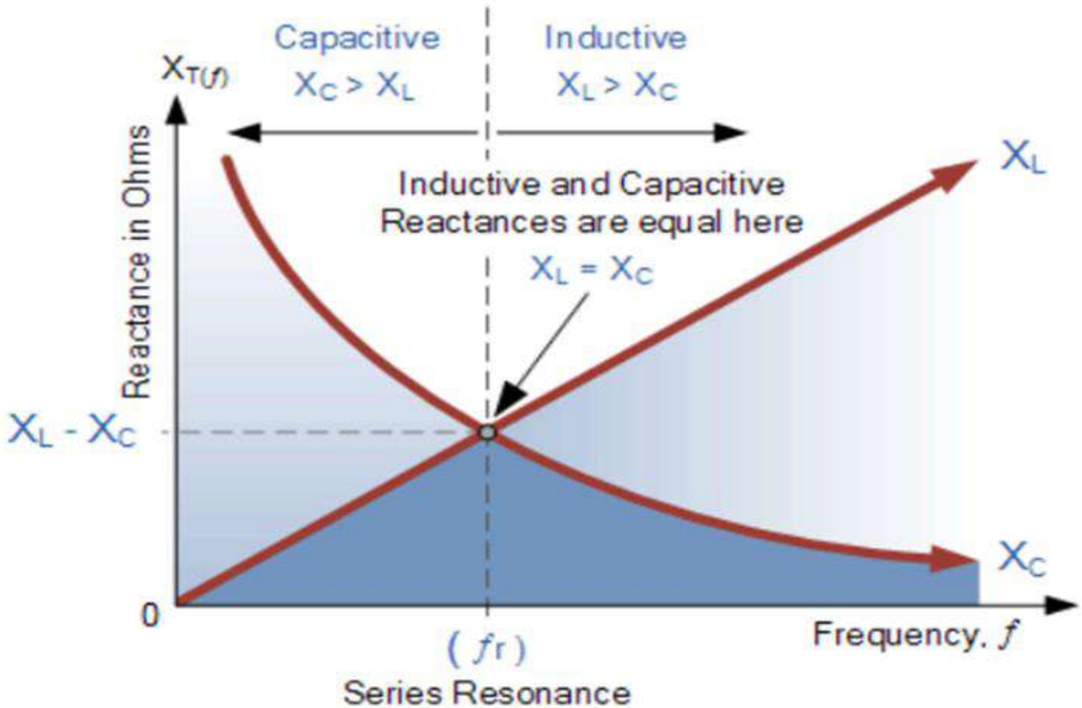


Inductive Reactance against Frequency



Capacitive Reactance against Frequency

Series Resonance Frequency

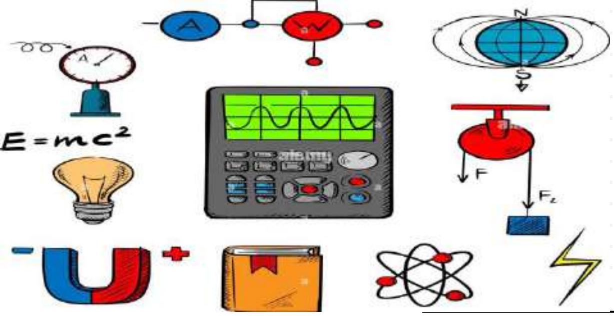


$$X_L = X_C \quad \Rightarrow \quad 2\pi f L = \frac{1}{2\pi f C}$$

$$f^2 = \frac{1}{2\pi L \times 2\pi C} = \frac{1}{4\pi^2 LC}$$

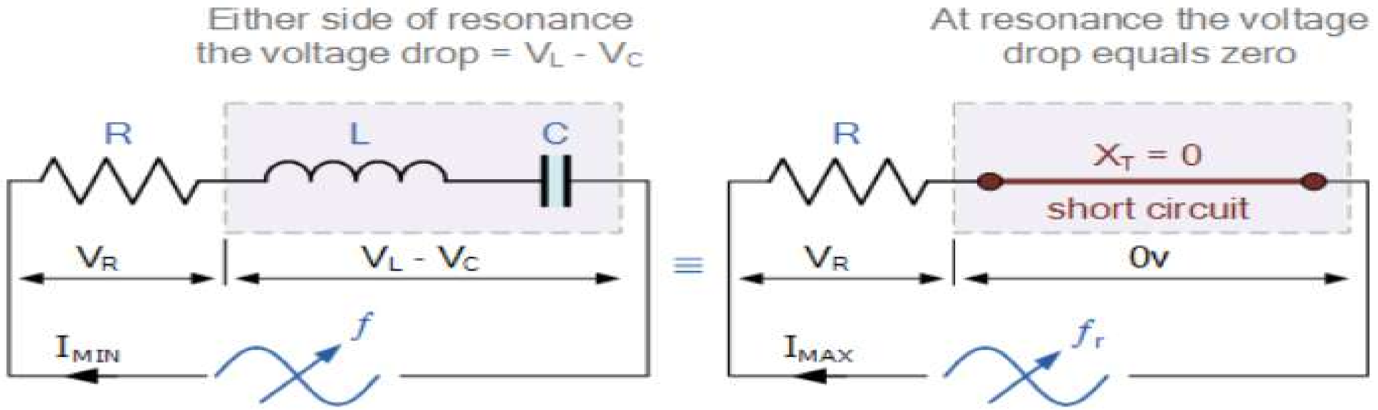
$$f = \sqrt{\frac{1}{4\pi^2 LC}}$$

$$\therefore \; f_r = \frac{1}{2\pi\sqrt{LC}} \text{ (Hz)} \quad \text{or} \quad \omega_r = \frac{1}{\sqrt{LC}} \text{ (rads)}$$



Series RLC *resonance frequency*

Series RLC Circuit at Resonance

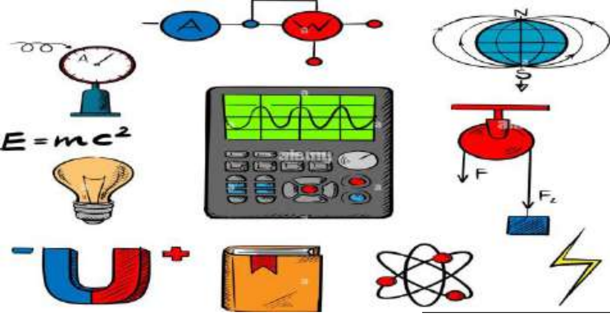


where: f_r is in Hertz, L is in Henries and C is in Farads.

Electrical resonance occurs in an AC circuit when the effects of the two reactances, which are opposite and equal, cancel each other out as $X_L = X_C$. The point on the above graph at which this happens is were the two reactance curves cross each other.

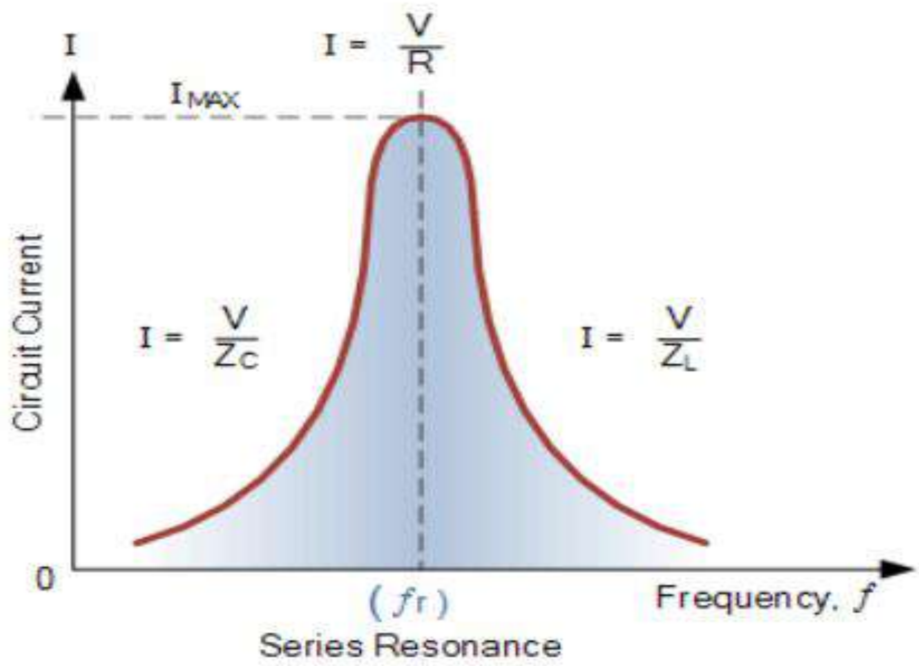
In a series resonant circuit, the resonant frequency, f_r point can be calculated as follows.

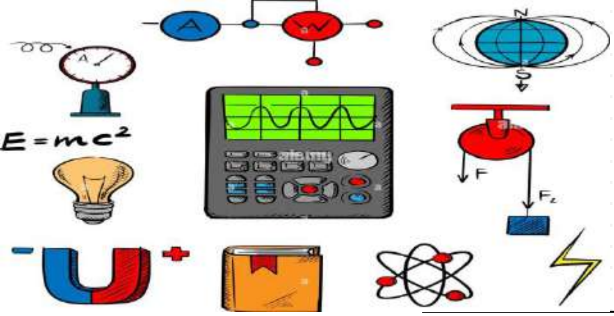
$$X_L = X_C \quad \Rightarrow \quad 2\pi f L = \frac{1}{2\pi f C}$$



Series RLC resonance frequency

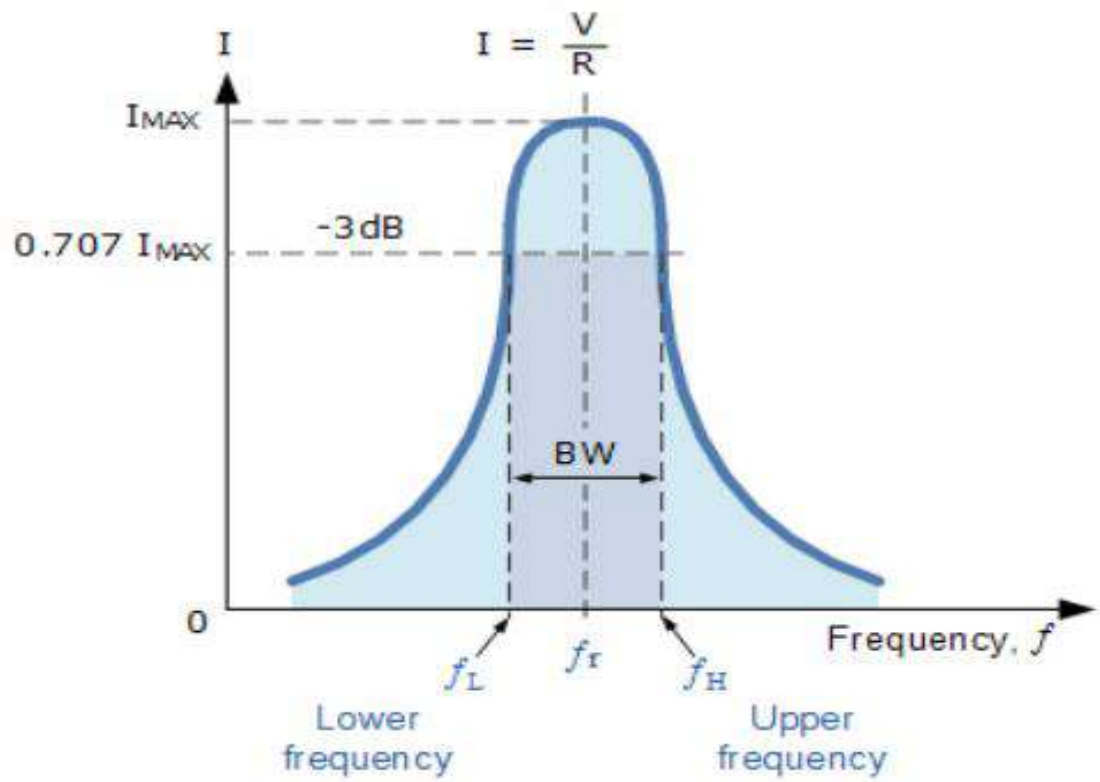
Series Circuit Current at Resonance

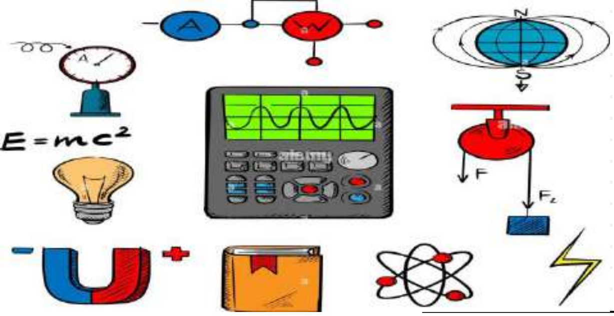




Series RLC *resonance frequency*

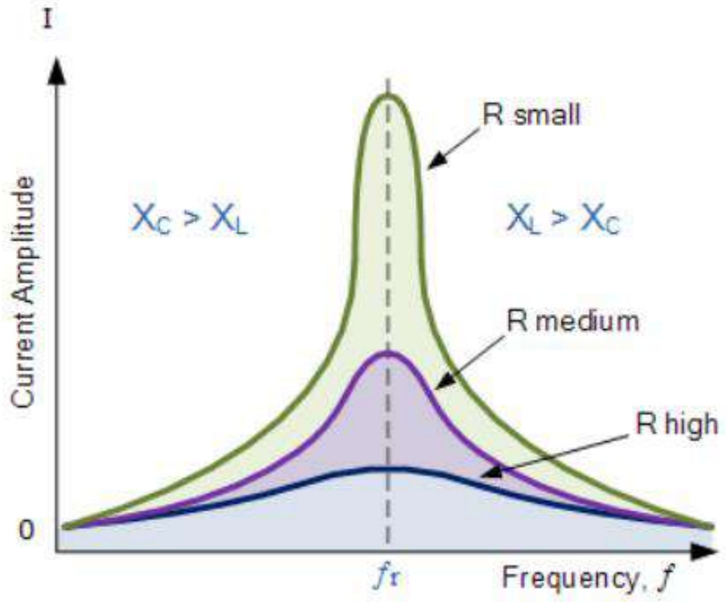
Bandwidth of a Series Resonance Circuit



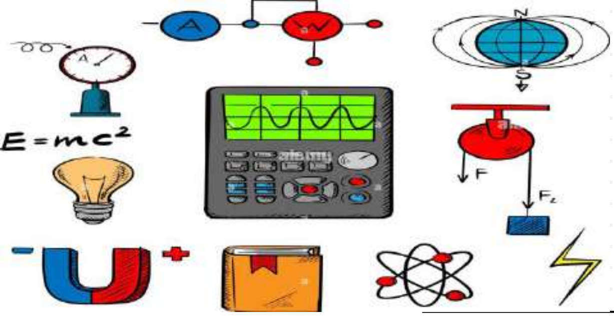


Series RLC resonance frequency

Bandwidth of a Series RLC Resonance Circuit



Then the relationship between resonance, bandwidth, selectivity and quality factor for a series resonance circuit being defined as:



Series RLC resonance frequency

1). Resonant Frequency, (f_r)

$$X_L = X_C \Rightarrow \omega_r L - \frac{1}{\omega_r C} = 0$$

$$\omega_r^2 = \frac{1}{LC} \quad \therefore \quad \omega_r = \frac{1}{\sqrt{LC}}$$

2). Current, (I)

at ω_r $Z_T = \text{min}$, $I_S = \text{max}$

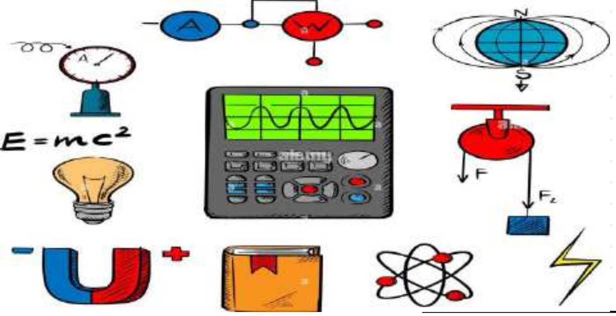
$$I_{max} = \frac{V_{max}}{Z} = \frac{V_{max}}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V_{max}}{\sqrt{R^2 + \left(\omega_r L - \frac{1}{\omega_r C}\right)^2}}$$

3). Bandwidth, (BW)

$$BW = \frac{f_r}{Q}, \quad f_H - f_L, \quad \frac{R}{L} \text{ (rads)} \quad \text{or} \quad \frac{R}{2\pi L} \text{ (Hz)}$$

4). Quality Factor, (Q)

$$Q = \frac{\omega_r L}{R} = \frac{X_L}{R} = \frac{1}{\omega_r CR} = \frac{X_C}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$



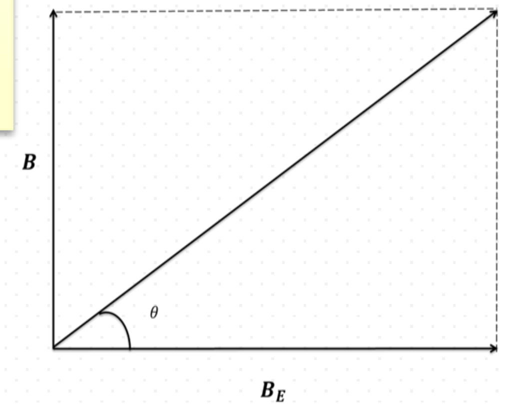
The magnetic flux density

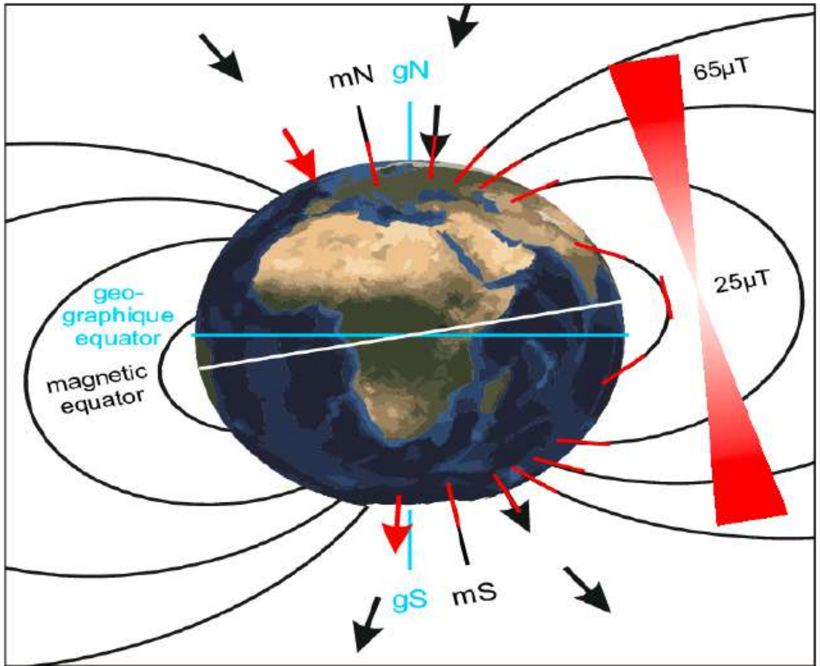
the number of lines of force passing through a unit area of material, B. The unit of magnetic induction is the tesla (T).

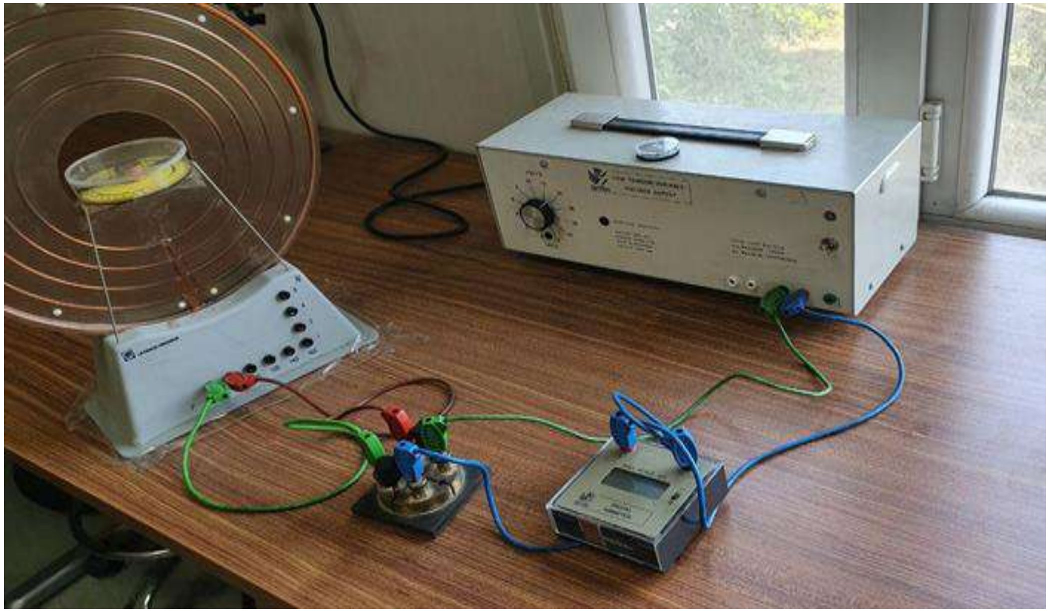
- ❑ **With the current**
- ❑ **With the distance**

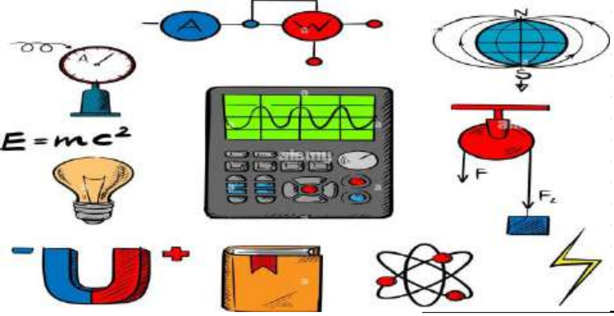
$$B_{E1}\ \tan\theta = \frac{\mu_\circ \mathrm{I}}{2\pi\ D}$$

$$D = \frac{\mu_\circ \mathrm{I}}{2\pi\ B_{E2}}\cot\theta$$





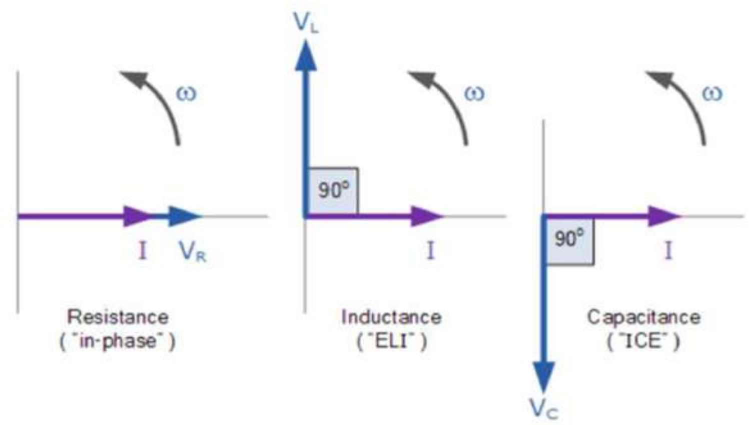




AC Circuit

Element Impedance

Circuit Element	Resistance, (R)	Reactance, (X)	Impedance, (Z)
Resistor	R	0	$Z_R = R$ $= R\angle 0^0$
Inductor	0	ωL	$Z_L = j\omega L$ $= \omega L\angle +90^0$
Capacitor	0	$\frac{1}{\omega C}$	$Z_C = \frac{1}{j\omega C}$ $= \frac{1}{\omega C}\angle -90^0$



Circuit Element	Symbol	Current-Voltage Relationship in Time	Impedance
Resistor	I → + V −	$V = IR$	R
Capacitor	I → + V −	$I = C\frac{dV}{dt}$	$\frac{1}{j\omega C}$
Inductor	I → + V −	$V = L\frac{dI}{dt}$	$j\omega L$

Page (2)

Introduction

Introduction

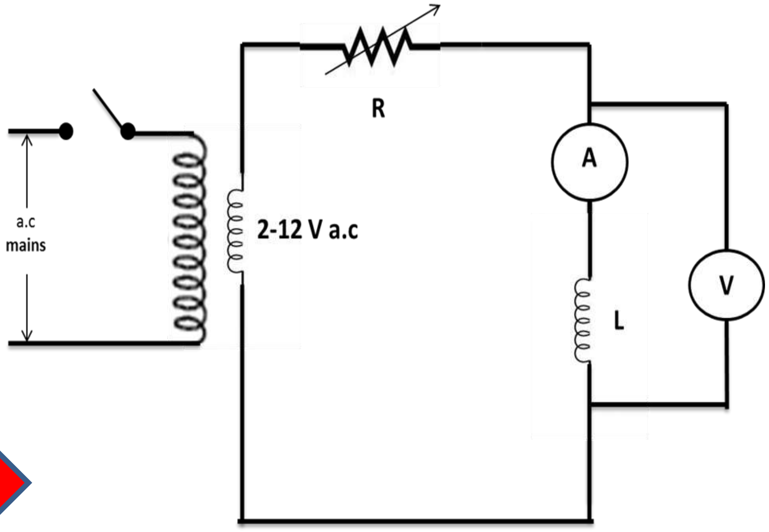
1 Marks

- Definition one of the main device in the Exp. or the principle .

  for example Exp.1 (inductance)

- Write Apparatus of the Exp. (exist on the sheet)

- Plot the Circuit of EXP. ,
  for example Exp. (1)



Thanks