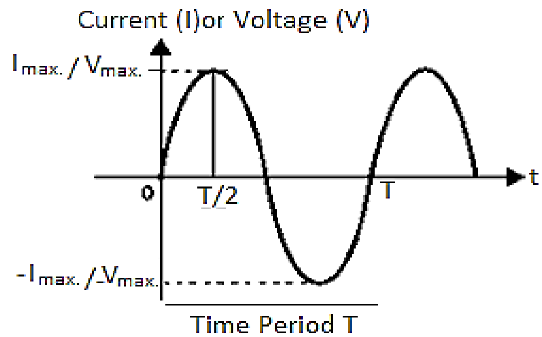
The current drawn from a cell or battery is a direct current (D.C.) and that obtained from a generator or power house is alternating current (A.C.). The frequency of alternating current in India 50 Hz means a bulb lights up with A.C. becomes off 50 times in one second. The frequency of D.C. is zero. The power loss in lighting a resistor by AC is very-very low that is why modern world largely use alternating current. The properties and applications of alternating current are studied with following expressions or formulae.

Such substances are called magnets and behaviours of magnetic substances is called magnetism. A solid bar of a magnetic substance is called bar magnet. Properties of magnets are studied with following expressions or formulae.

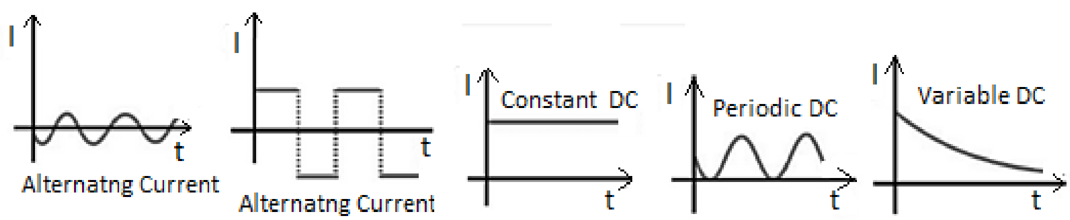
Formulae

AC Voltage Applied to a Resistors:

- The equation of alternating current (a time dependent current) is given by $I = I_{max}\sin\omega t$, here ω is the angular frequency of the current such that $\omega = 2\pi f = 2\pi / T$.
- The equation of voltage is $V = V_{max}\sin(\omega t + \phi)$, here ϕ is the phase difference between current and voltage and $V_{max} = I_{max} \times R$.



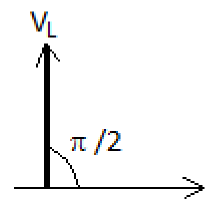
- The power instantaneous power delivered in an AC circuit is $\tilde{P} = \frac{1}{2} I_{max}^2 \times R$ while the power delivered in a dc circuit is $P_{dc} = I_{dc}^2 \times R$. Thus, if $\tilde{P} = P_{dc}$, then $\frac{1}{2} I_{max}^2 \times R = I_{dc}^2 \times R \Rightarrow I_{dc} = \frac{I_{max}}{\sqrt{2}}$ value of current $I_{max.} / \sqrt{2}$ or $0.707 I_{max}$ is called effective or root mean square value of the current.
- There are 5 types of A.C. and D.C.



AC Circuits using different types of Resistors:

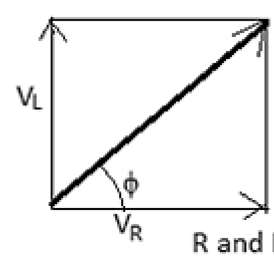
- There are total 7 types of A.C. circuits: (1) R-circuit. (2) L –Circuit, (3) C-Circuit, (4) R-L circuit, (5) C-L circuit, (6) C-R circuit and L-C-R circuit. In these circuit phase difference between voltage (V) and current (I) is different described formulated as: The resistances of A.C. circuits are called impedances denoted by Z. The impedance Z, phase difference ϕ, current I and voltage V are given below:

- **R- circuit**: The R circuit and its vector diagram of is shown above: The phase difference between voltage and current is 0, i.e. both becomes and minimum at same time. The equations of R- circuit are $V = V_{max}\sin(\omega t+\phi)$ and $I = I_{max}\sin\omega t$. Here, $\phi = 0$ and resistance or impedance Z = R.



- **L- circuit**: Equations are $V = V_{max}\sin(\omega t+\phi)$, $\phi = \pi/2$ and $I = I_{max}\sin\omega t$, and the impedance $Z = X_L = \omega L$, $I_{max.} = \frac{V_{max.}}{Z} = \frac{V_{max.}}{X_L} = \frac{V_{max.}}{\omega L}$. The vector diagram and the maximum current is shown here:
- **C- circuit**: Equations are $V = V_{max}\sin(\omega t+\phi)$, $\phi = -\pi/2$ and $I = I_{max}\sin\omega t$, and the impedance $Z = X_C = 1/\omega C$. The Vector diagram and the maximum current,

  $I_{max.} = \frac{V_{max.}}{X_C} = \frac{V_{max.}}{1/\omega C}$.



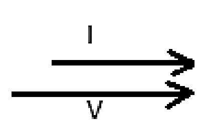
- **R-L- circuit**: Equations are $V = V_{max}\sin(\omega t+\phi)$, $\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right)$

  $= \tan^{-1}\left(\frac{IX_L}{IR}\right) = \tan^{-1}\left(\frac{\omega L}{R}\right)$ and $I = I_{max}\sin\omega t$, and the impedance

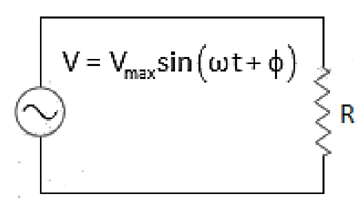
  $Z = \sqrt{X_L^2 + R^2} = \sqrt{\omega^2 L^2 + R^2}$. The Vector diagram and the maximum current,

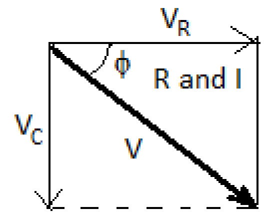
- $I_{max.} = \frac{V_{max.}}{Z} = \frac{V_{max.}}{\sqrt{\omega^2 L^2 + R^2}}$ .Also, $V = \sqrt{V_L^2 + V_R^2}$

  .



Vector diagram





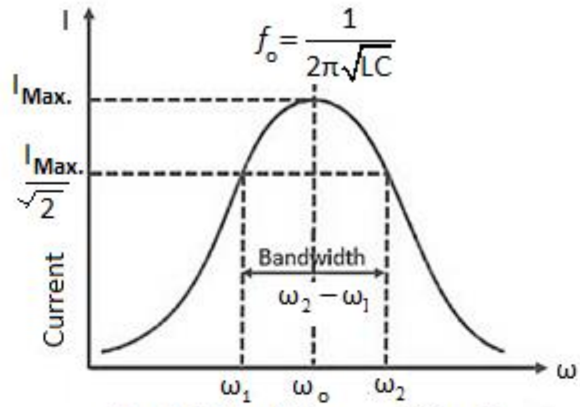
- **R-C- circuit:** Equations are $V = V_{max}\sin(\omega t + \phi)$, $\phi = \tan^{-1}\left(-\frac{V_C}{V_R}\right) = \tan^{-1}\left(-\frac{IX_C}{IR}\right) = \tan^{-1}\left(-\frac{1/\omega C}{R}\right)$ and $I = I_{max}\sin\omega t$, and the impedance $Z = \sqrt{X_C^2 + R^2} = \sqrt{1/\omega^2 C^2 + R^2}$. The Vector diagram and the maximum current, $I_{max.} = \frac{V_{max.}}{Z} = \frac{V_{max.}}{\sqrt{1/\omega^2 C^2 + R^2}}$. Also, $V = \sqrt{V_C^2 + V_R^2}$

- **L-C- circuit:** Equations are $V = V_{max}\sin(\omega t + \phi)$, $\phi = 90°$ and $I = I_{max}\sin\omega t$, and the impedance $Z = X_L - X_C$. The Vector diagram and the maximum current, $I_{max.} = \frac{V_{max.}}{Z} = \frac{V_{max.}}{\omega L - 1/\omega C}$. Also, $V = V_L - V_C$.The L-C circuit is called oscillatory as $Z = X_L - X_C \to 0$ that implies $\omega L - 1/\omega C = 0 \Rightarrow \omega = \frac{1}{\sqrt{LC}} \Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$ that is the frequency of oscillation.

- **L-C-R Circuit:** The Equations are $V = V_{max}\sin(\omega t + \phi)$, $\phi = \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$ and $I = I_{max}\sin\omega t$, and the impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$. The Vector diagram and the maximum current, $I_{max.} = \frac{V_{max.}}{Z} = \frac{V_{max.}}{\sqrt{R^2 + (X_L - X_C)^2}}$. Also, $V = \sqrt{(V_L - V_C)^2 + V_R^2}$.

- When $X_L = X_C$, then total impedance of the circuit is R<Z. So the current in the circuit maximum but oscillatory with the frequency $f = \frac{1}{2\pi\sqrt{LC}}$. This condition of L-C-R circuit is called 'Resonant condition' and the phenomenon is called Resonance.

- The frequency ω or $f = \frac{1}{2\pi\sqrt{LC}}$ at which the current is maximum is called the resonance frequency shown in Fig here: The current $I_{Max.}$ is called resonant current. There are two frequencies ω_1, ω_2 such that if the frequency of resonant circuit is in the range $\omega_1 \leftrightarrow \omega_2$ the current becomes $I_{Max.}/\sqrt{2}$, the range $\omega_2 - \omega_1$ is called band width of resonant circuit.



Bandwidth of Resonant Circuit

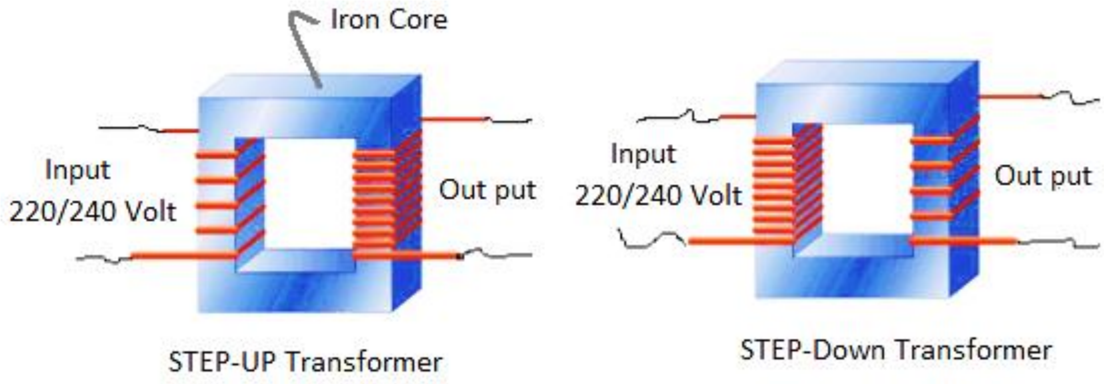
- At resonance the maximum current in L-C-R circuit is $I_{max.} = \frac{V_{max.}}{R}$.
- The 'sharpness of resonance' or quality factor Q of a resonant circuit is given by $Q = \frac{\omega_0 L}{R}$.

Power in AC Circuits:

- The power P delivered in AC (L-C-R) is given by $P = I_{max.}V_{max.}\cos\phi$ or $P = I^2 Z\cos\phi$ where ϕ is the leading angle or phase angle between voltage and current.
- The factor $\cos\phi$ is called power factor of A.C. circuit.
- The total energy of an AC circuit is given by $U = \frac{1}{2}\frac{q_m^2}{C}$.

Transformers:

- A transformer is a device used to change the strength of current to reduce the loss of electrical current (wastage). There are two types of transformers STEP- UP {to increase the strength of voltage} and STEP- DOWN {to decrease the strength of voltage}.
- If N_P and N_S are number of turns in primary and secondary winding or coils then for Step-Up transformer $N_S > N_P$ and for step-down $N_S < N_P$.



- If V_P and V_S are voltage and I_P, I_S the current in primary and secondary coils of a transformer then $\frac{V_P}{V_S} = \frac{N_S}{N_P} = \frac{I_S}{I_P}$.