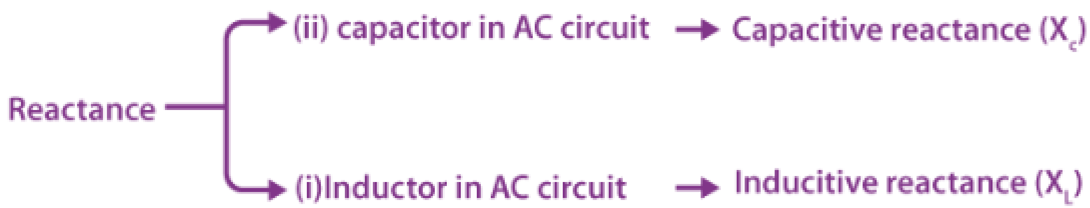
What Is Reactance?

Reactance is the opposition offered by the capacitor and inductor in a circuit to the flow of AC current in the circuit. It is quite similar to resistance, but reactance varies with the frequency of the ac voltage source. It is measured in ohms.

If we look at conductors that carry alternating current, we will find that reactance is always present along with resistance. Moreover, reactance also appears in shorter intervals, as the direct current changes while approaching or departing from a steady flow.



Inductive Reactance (X_L)

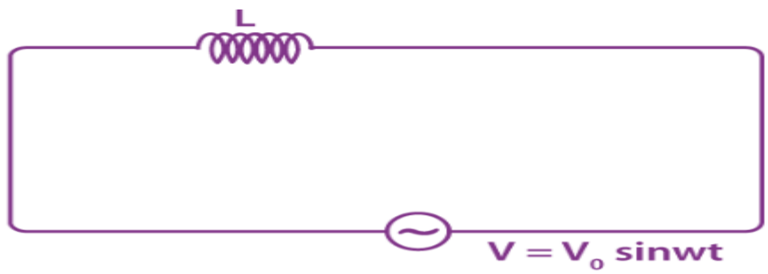
Definition: Inductive reactance is the opposition offered by the inductor in an AC circuit to the flow of AC current.

It is represented by (X_L) and measured in ohms (Ω). Inductive reactance is mostly low for lower frequencies and high for higher frequencies. It is, however, negligible for steady DC current.

The inductive reactance formula is given as follows:

Inductive Reactance, $\mathbf{X_L = 2\pi fL}$

The AC circuit with a pure inductor is represented as,



By KVL

$$V_o \sin wt - \frac{Ldi}{dt} = 0$$
$$\int_0^t \frac{V_o}{L} \sin wt \, dt = \int_0^1 di$$
$$-\frac{V_o}{Lw} \cos wt = i$$
$$-i_o \cos wt = i$$

and

$$i_o = \frac{V_o}{Lw} = \frac{V_o}{X_L}$$

$X_L = Lw = 2\pi Lf$ (inductive reactance)

$X_L \alpha L$

$X_L \alpha w \rightarrow 1$

Where

L – is the inductance of the coil

W – is the angular frequency of the AC voltage source.

From Equation 1,

W → Higher frequency → Higher resistance to the current flow

High (f_{high}) (or)

Current changes more rapidly for higher frequencies

$W = 0 \rightarrow f = 0 \rightarrow X_L = 0$

X_L (Inductive reactance)

$w \neq 0$ $w = 0$

$X_L = Lw$ $X_L = 0$

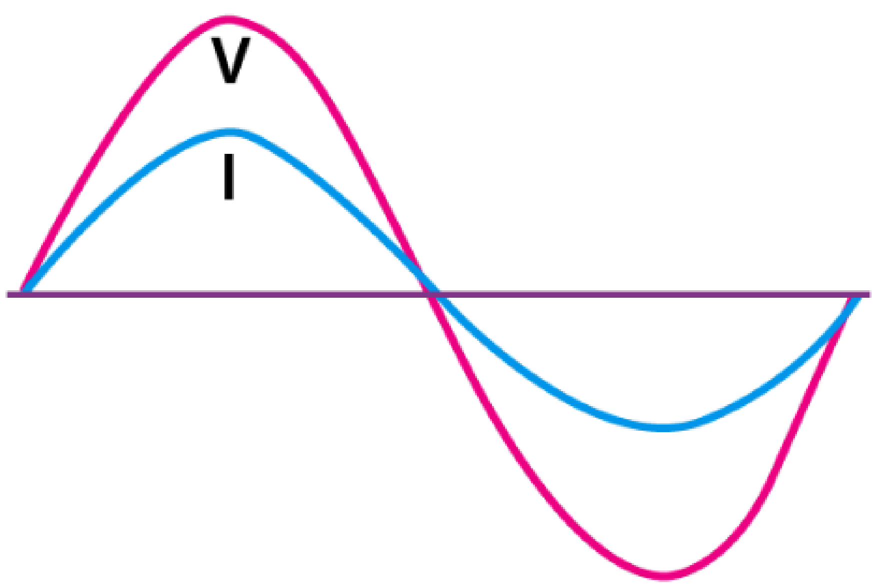
for AC with $f_{high} \rightarrow X_L$ = High for DC XL $\rightarrow$ is zero

for AC with $f_{low} \rightarrow X_L$ = small X_L = resistance of the wire in a circuit.

Since from phasor diagram for AC circuit with only resistor, capacitor and inductor.

For an AC circuit with only a resistor and its phasor diagram:

AC circuit with only a resistor shows that current and voltage are in the same phase, which means an increase in voltage leads to an increase in current (vice-versa).



For an AC circuit with an only inductor (L):

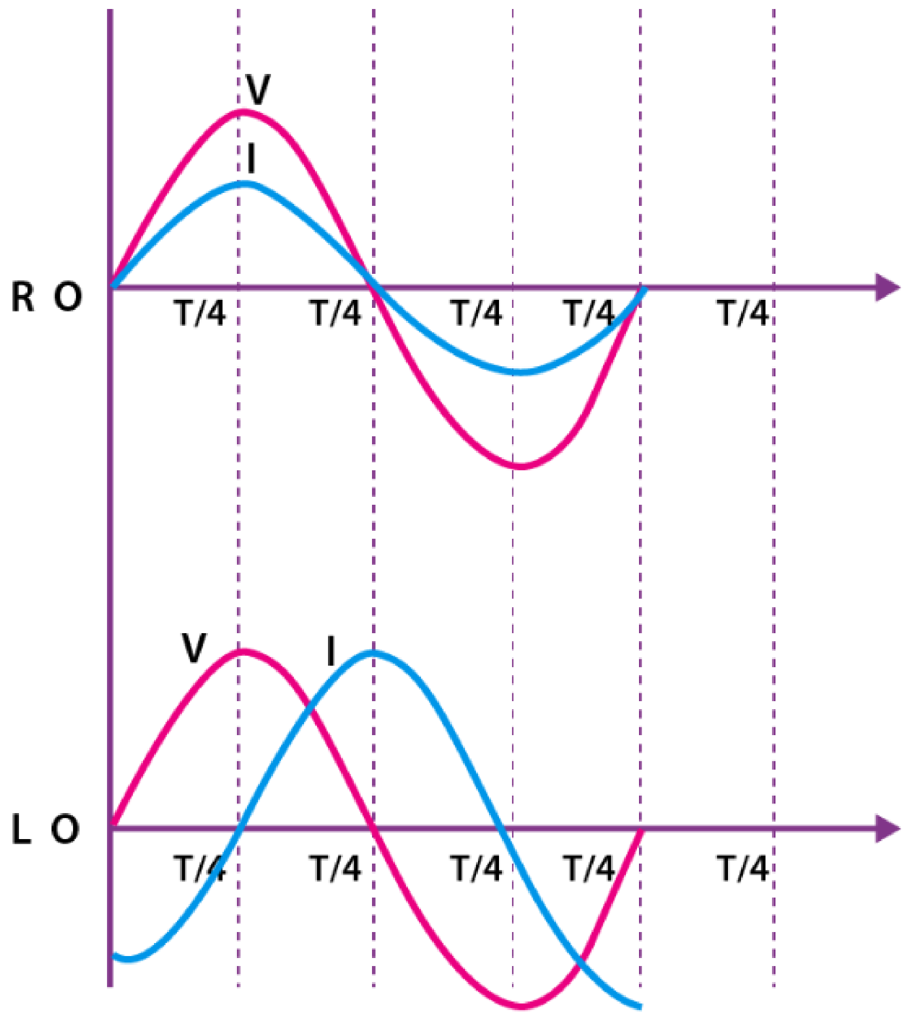
We know that $V = V_o \sin wt$

$i = i_o \cos wt$

=i0sin(wt=−π2)

Current lags behind the voltage with a phase difference of π/2 between them.

$$= i_0 sin \left(wt = \frac{-\pi}{2}\right)$$



AC circuit with R only

$V = v_o \sin wt$

$i = i_o \sin wt$

AC circuit with L

$V = v_o \sin wt$

$i = i_o \sin wt$

(i) As we can clearly see from the given phasor diagram above, in an AC circuit with a pure resistor, the AC current through it and the AC voltage across it rise together (or) fall together, which indicates both current and voltage are in phase.

(ii) But in the case of an AC circuit with $L_{(only)}$, it is clearly seen from the given phasor diagram that V and I are in out of phase. This means if V = max, then i = minimum.

(iii) This is because of the characteristics of the inductor. Inductance always opposes a change in current which means that current through an inductor continuously reverses itself.

(iv) Lenz's Law: According to Lenz's Law, a circuit with inductance offers opposing force to the change in current inducing counter emf (induced emf), maintaining the phase between v and I, which remains the same.

(v) We can see the above figure as four cycles.

(a) First (T/4) cycle

Applied Voltage starts increasing from zero.

When v = o, i = – Ve (max) = $-i_{max}$

When v = V_{max}, i = 0

(b) Second (T/4) cycle

Applied voltage starts decreasing from V_{max}.

When V reaches:

V = o i = i_{max}

(c) Third (T/4) cycle

The applied voltage starts increasing in the opposite direction (or) reverse direction.

When V reaches, V = – V_{max},

i starts decreasing reaches i = 0

(d) Fourth (T/4) cycle

The applied voltage starts decreasing from – V_{max} to zero, but i reaches the –i_{max}.

V = 0 , i = – i_{max}

Inertia Effect by Inductor

We can see from the above analysis that V and i are continuously changing in magnitude and direction. This is because the inductor continuously reverses the current through it by itself due to the inertia effect of emf.

Inertia effect for > inertia effect for DC

Similarly, for AC,

Greater the value of (L) inductance → greater the opposition by inertia effect

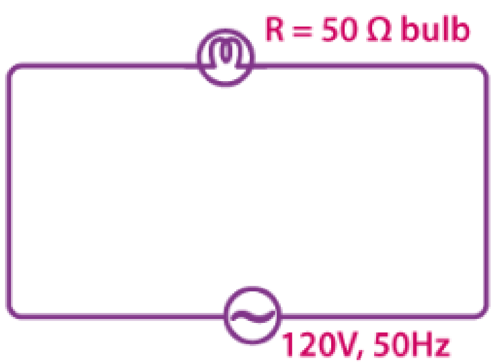
Faster the reversal of current → greater the opposition by inertia effect.

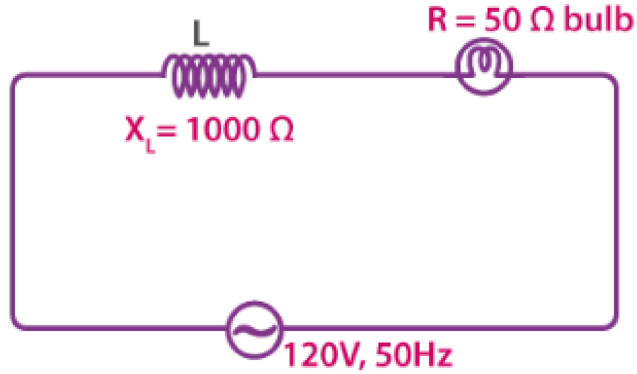
For the opposition that is offered by the inductor to the flow of an alternating current, we cannot call it resistance because this is not friction within the conductor; this is the reaction of the inductor to the change in alternating current.

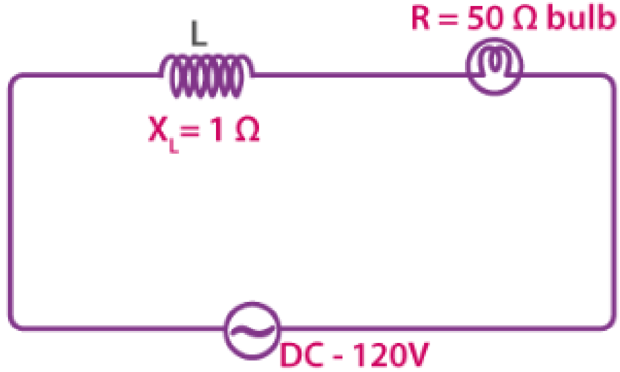
Special Cases

An inductor (L) → has appreciable X_L for AC source and reduces the amount of current.

Case (I): Inductor and a bulb in series with an AC source


R = 50 Ω bulb
120V, 50Hz


L
R = 50 Ω bulb
X_L = 1000 Ω
120V, 50Hz


L
R = 50 Ω bulb
X_L = 1 Ω
DC - 120V

(i) Circuit without inductor (ii) circuit with a high inductor (iii) circuit with low inductor

There is no inductor, X_L = 1000Ω for DC inductor offers

AC source causes the bulb glows

$$i = \frac{V}{X_L} = \frac{120}{1000}$$

X_L = 0

With full bright = 0.012 A i = 1.4 A

$$i = \frac{V}{R} = \frac{120}{50} = 1.4A$$

Here, the glows with full bright.

Case (II): Combination of inductive reactance

X_L = provides opposition to an AC source. So, it is summed in the same way as resistance.