BIRZEIT UNIVERSITY

Physics Department

# Physics 112

**Experiment #9**

# Impedance and Reactance

**Student's Name :Ahmad Jundi** **Student's NO:1150665**

**Partner's Name:Saleem Abufarha** **Partner's No: 1120076**

**Section:- 18**

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Instructor: Dr.Ghassan Abbas

# Abstract:

- **The aim of the experiment is** :to find out the frequency at which the phase difference equals zero, and compare it with the theoretical one. And also to find out the phase differences between $V_L$ , $V_{in}$ and $V_C$ in an AC-powered RLC circuit.

- **The method used is**: by using the DCO to find the phase shift between the driving voltage and the current, $V_C$ and $V_L$.

- ***The main result***::

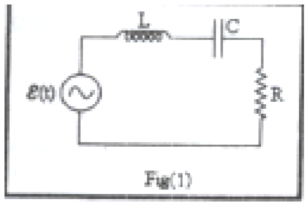
$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(10\times10^{-3})(0.22\times10^{-6})}} = 3394.92Hz$$

Angle between ($V_l$ and $V_R$) = 1. 5076Rad.

Angle between ($V_C$ and $V_R$) = 1.5076 Rad.

# Theory:

*The current in the AC-powered RLC circuit shown in fig.1 is given by:*



Fig(1)

*where* $Z_{eq} = Z_R + Z_C + Z_L$, *and* $Z_R = R$, $\quad I(t) = \dfrac{\varepsilon(t)}{Z_{eq}}$

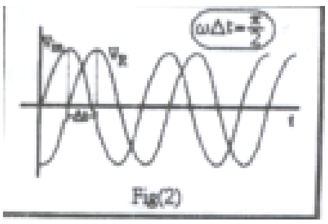
$Z_C = -\dfrac{j}{\omega C}$, $Z_L = j\omega L$

*being the resistive impedance, the capacitive impedance,* $Z_R,\ Z_C,\ and\ Z_L$ *and the inductive impedance respectively. While the quantities* $\dfrac{1}{\omega C}$ *and* $\omega L$ *are the capacitive reactance and inductive reactance respectively.*

*After some mathematical treatment we get the value of the current as follows:*

*where* $I_o = \dfrac{\varepsilon}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}$ *and* $I(t) = I_o \cos(\omega t + \Phi)$

$$\Phi = \tan^{-1}\left(\frac{-\omega L + \dfrac{1}{\omega C}}{R}\right).$$


Fig(2)

*As we can see from fig.2 the current heads or lags the voltage by a time interval that is dependant on the frequency of the cosine function. In other words there exists a phase shift* $\Phi = \omega \Delta t$ *between them.*

*The voltage across the inductor can be obtained as follows:*

$$V_L = L\frac{dI(t)}{dt} = L\frac{d}{dt}\left(I_o \cos(\omega t + \Phi)\right)$$
$$V_L = -\omega L I_o \sin(\omega t + \Phi)$$

*Note that $V_L$ is just the current multiplied by the inductive reactance with a phase shift of $\frac{\pi}{2}$ introduced. (Generalized Ohm's law)*

*The voltage across the resistor is:*

$$V_R = RI(t) = RI_o \cos(\omega t + \Phi)$$

*Note that $V_R$ is just the current multiplied by the resistance. (Ohm's law)*

*And finally the voltage across the capacitor is:*

$$V_C = \frac{1}{C}\int I(t)dt = \frac{1}{C}\int I_o \cos(\omega t + \Phi)dt$$

$$V_C = \frac{I_o}{\omega C}\sin(\omega t + \Phi)$$

*Note that $V_C$ is just the current multiplied by the capacitive reactance with a phase shift of $\frac{\pi}{2}$ introduced.*

*The phase shifts between the current and the voltages across the different circuit elements in fig.1 are also related to Φ which is a function of ω*

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## IV. Calculations:

Phase difference is zero at resonant frequency ( $f_0$) . At resonant frequency,

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(10\times10^{-3})(0.22\times10^{-6})}} = 3394.92Hz$$

Angle between ($V_l$ and $V_R$) = 1. 5076Rad.

Angle between ($V_C$ and $V_R$) = 1.5076 Rad.

# Conclusion:

1 )The phase shift changes in a sinusoidal manner with frequency; it is zero at a certain frequency known to be the resonant frequency .

2) the voltage across inductor and the capacitor are ahead of that across the resistance or behind it by $\pi / 2 = 1.57 rads.$ in the RLC circuit.

As usual the error percentage and the lake of accuracy of the equipment we've used are the main reason of the deference between the results in the experiment and the theoretical results.