*Phys205L/Phys211L*

RLC Series Circuit

1. Object:

To study resonance in an inductor-resistor-capacitor (LRC) circuit.

2. Equipment:

OWON AG1022 function generator (FG), ATTEN 1102CAL+ digital oscilloscope, RLC meter, decade resistance box (DRB), ~50mH inductor and ~4nF capacitor, BNC and banana cables, BNC-to-banana adapters, and T-connectors.

3. Theory:

The amplitude of the AC current *(I)* in a series LRC circuit depends on the amplitude of the applied voltage *(Vin)* and the series impedance *(Z)*.

(1)



with



(2)

Where *X*L = *L* is the inductive reactance, *X*C = 1/*C* is the capacitive reactance and *R* is the *total* series resistance of the circuit. ** is the angular frequency (*ω*= *f*, where *f* is the frequency in Hz). Since the impedance depends on frequency, the current varies with frequency. It can be easily seen that the current will go through a maximum as the frequency is varied. The current peak will occur when *X*L = *X*C, when the circuit is driven at its resonant frequency, *res*:

(3)



At resonance, the impedance *Z* = *R* is at its smallest possible value, the current is at its largest possible value and the voltage across the DRB reaches its maximum value and is in phase with the input voltage. At other frequencies, the phase difference Φ between the current and the input voltage is given by;

Φ = tan-1 {(XL – XC)/R} (4)

We define the quality factor *Q,* which characterizes the sharpness of the resonance peak:

 (5)

Where  = (-) and and  are, respectively, the frequency greater and smaller than *res* at which *I = Ires /.* It can be shown that =*R/L*, and thus:

 (6)

As *R* decreases, *Q* increases, and the resonance peak of the *I* versus *f* curve becomes sharper.

*N.B. R in the above equations is the total series resistance in the circuit, which is the sum* ***RDRB + RL + Ro****, where RL is the resistance of the inductor and Ro=50*Ω is the output impedance of the function generator.

***Consult your textbook of Phys 211 for further explanation of the theory.***

**4. Procedure:**

#### Measure the capacitance and inductance of your capacitor and inductor using the LCR meter. Calculate the resonance frequency from equation (3).

#### A- Determination of the resonant frequency

***Please follow the following steps in performing the experiment:***

1. The circuit connections must be made as shown in Figure 1. Please note that the ground connections are critical and must be made in accordance with the diagram.
2. Connect the FG in series with the DRB, the inductor and the capacitor. **One terminal of the DRB must be connected to the ground terminal (chassis) of the FG.**
3. Connect Channel 1 (CH1) of the oscilloscope across the FG. **The ground terminal of the scope must be connected to the ground terminal of the FG**. In this way, CH1 measures the input voltage, *V*in .

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Function Generator

Vin

Scope

CH 1

**~**

Vout

Scope

CH 2

RDRB

**Figure 1- RLC circuit**

Ground

1. Connect Channel 2 (CH2) of the oscilloscope across the resistor. **The ground terminal of the scope must be connected to the grounded terminal of the DRB**. CH. 2 now measures the output voltage across the DRB (*V*out), which is **proportional** to the current in the circuit.
2. Set the DRB to 300Ω.
3. Choose a sine wave signal on the FG.
4. Select CH1 on the oscilloscope (remember on CH1 *V*in is displayed), adjust the amplitude of *V*in to somewhere between 10 and 15 V (you can do this using the amplitude control knob on the function generator).
5. Now select CH2 on the oscilloscope (on CH2 *V*out is dispalyed), and change the frequency of your FG until you obtain the maximum value of the voltage. This is resonance. Record the value of the frequency. Also record the value of the corresponding voltage (peak-to-peak). In order to measure the peak-to-peak voltage across the resistor, press MEASURE on the oscilloscope for Automated measurement of amplitude. Note: to get a stable reading of amplitude and frequency, you must average (remember signal averaging in the “Oscilloscope and function generator experiment”?) Press ACQUIRE and select Average in Mode, choose the number of times you want to average.
6. Record the value of *V*out for various frequencies according to the table in the form. YOU MUST MAINTAIN THE INPUT VOLTAGE (output of FG) AT THE SAME VALUE FOR ALL MEASUREMENTS.
7. Plot *V*out versus *f* and determine the quality factor of your circuit from the graph.
8. Set the DRB to 10  and repeat steps 8 to 11.
9. Compare the two curves that you have thus obtained.
10. Measure and record the resistance of the inductor.
11. Calculate the *Q-value* using equation (6) for both trials and compare these values with those obtained by the technique of step 11.

#### B- Phase measurements using Time-shift measurement\*

Press CURSORS. Measure the time dt between *V*in and *V*out and calculate the phase difference for five frequencies (as in the table in the form). Calculate the phase difference from eq(4) and compare.

\* Refer to the “Basic Oscilloscope Operations” experiment for more details on Time-Shift Measurement of phase difference.