Experiment No. 10
ALTERNATING CURRENT CIRCUITS II

Objective: To study the AC circuit containing a resistor, a capacitor and an inductor.

Apparatus: A cathode ray oscilloscope, a decade resistance box, a capacitor, an inductor, a multimeter, a signal generator.

Theory: Let an external alternating voltage of effective value V_E and of frequency f be applied to a circuit containing R, L and C as shown in Fig. 1.

The effective current I in the circuit is given by

$$I = V_E/Z, \quad (1)$$

the impedance Z, in this case, being

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

where the inductive reactance

$$X_L = 2\pi f L, \quad (3)$$

and the capacitive reactance

$$X_C = 1/2\pi f C. \quad (4)$$

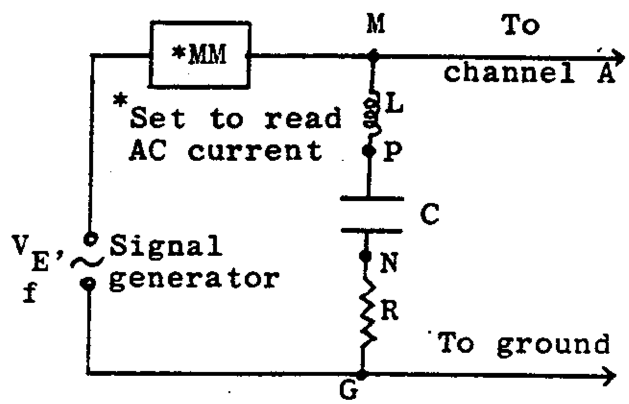

Fig. 1

If Eq. (2) is multiplied by I, we get

$$V_E = \sqrt{V_R^2 + (V_L - V_C)^2}. \quad (5)$$

In this case, the voltage leads the current by an angle given by

$$\tan\phi = \frac{X_L - X_C}{R}. \quad (6)$$

If $X_L - X_C = 0$, the circuit is purely resistive or a resonant circuit. The natural frequency f_r of a circuit having an inducatance L and a capacitance C, is given by

$$f_r = 1/2\pi\sqrt{LC}. \quad (7)$$

Obviously, resonance occurs if the frequency of the external AC voltage is equal to the natural frequency f_r of the circuit. At resonance frequency, the impedance of an R-L-C circuit is minumum (=R) and hence the current in the circuit is maximum. Further, Eq. (6) indicates that $\phi = 0$ for a resonant circuit. In other words, AA' and BB' (shown in Fig. 22-6, given on page 9-3P) will be zero at resonance. Also see Fig. 3 of this experiment.

The signals applied to channels A and B constitute 2 sine waves of the same frequency but of different amplitudes. Thus if we set the DISPLAY switch at A vs. B, signal 'A' will be applied to the vertical deflection plates and signal 'B' will be applied to the horizontal deflection plates. Thus two mutually perpendicular simple harmonic motions will be impressed upon the electron beam which will trace an ellipse on the screen (as shown in Fig. 2). This is a Lissajous figure. More complicated Lissajous figures are obtained when the ratio of the frequencies is 2:1, 3:1, 2:3, etc. In this case, however, at resonance, when the phase difference between the two signals is zero, the ellipse is reduced to a straight line.

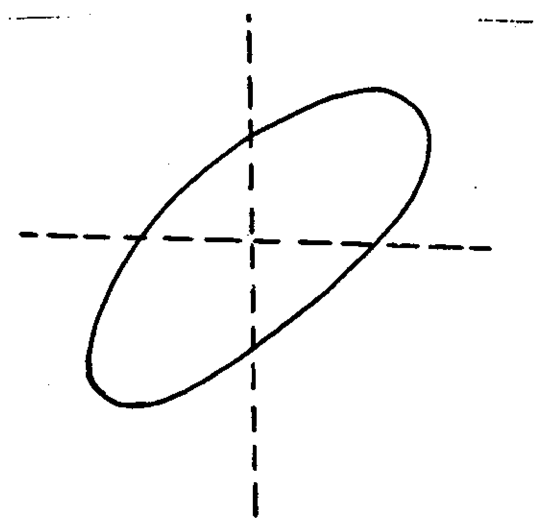

Fig. 2

In this experiment, resonance is studied by (a) obtaining the maximum current (I_{max}), (b) observing zero phase difference between V_A and V_B(the signals applied to the channels A and B), and (c) setting the DISPLAY to A vs. B and reducing the ellipse to a straight line.

Voltages and phase difference are measured by means of the oscilloscope as explained on pages 9-2P and 9-3P.

Procedure:

Unit 1. Measurement of Z and the phase difference:

(a) Make the circuit as shown in Fig. 10.3a. Do not connect the multimeter in the circuit. Switch on the signal generator. The sine wave from the signal generator provides the external AC voltage of suitable V_E and f.

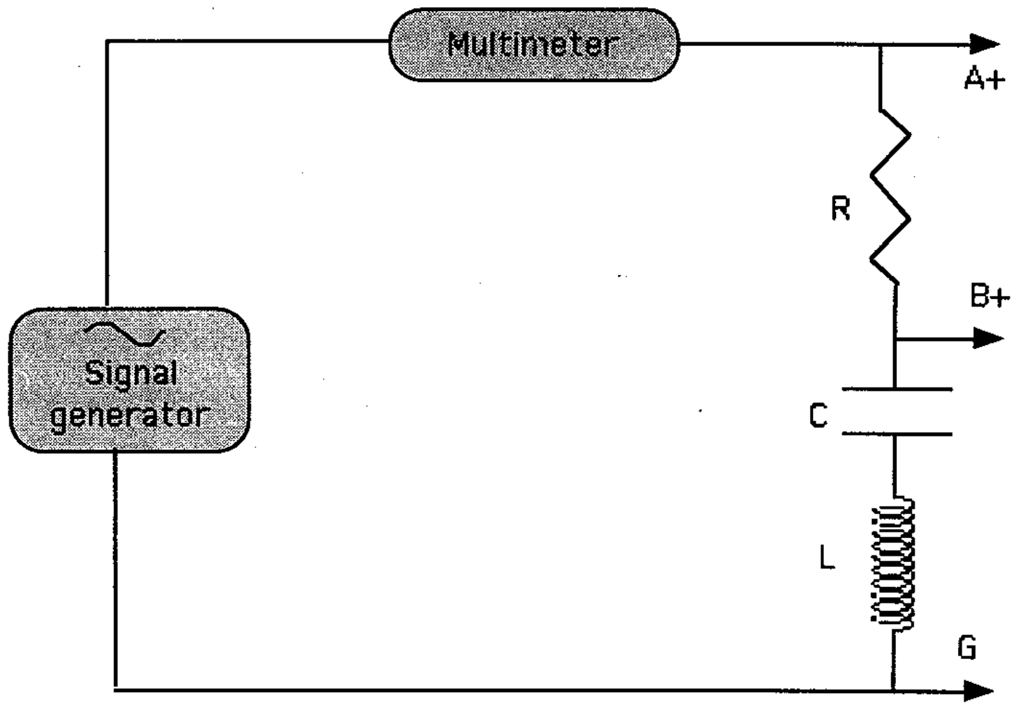

Fig. 10.3a

(b) Select the value of f between 300 Hz and 600 Hz, and the value of C between 0.1 μF and 0.06 μF. Calculate $X = |X_L - X_C|$. Keep R equal to about 1.2(X).

(c) Record the values of f, L, C, R and R'.

(d) Set the multimeter to read AC voltage. Measure the total voltage (V_E), the potential difference across R (V_R), the potential difference across L (V_L), the potential difference across C (V_C), the potential difference across L and C (V_{LC}).

(e) Set the multimeter to read AC current and insert it in the circuit as shown in Fig. 10.3a. Record the value of the current (I) in the circuit. Make sure that the current remains constant throughout the experiment.

(f) Switch on the oscilloscope.

(g) Set trigger mode to AUTO, set vertical coupling of channels A and B to AC and SLOPE to +. Display mode can be CHOP or ALT.

(h) Adjust the time/division, volt/division (channels A and B), and, horizontal and vertical positions to obtain the display as shown in Fig. 9.2.

(i) Make sure that the VAR controls (A and B) are in CAL position. Record volt/div (A and B) and time/div settings. Read the peak-to-peak voltages (in divisions) of A and B displays.

(j) Make the connections as shown in Fig. 10.3b. Adjust the volt/div (A and B) and time/div, if necessary.

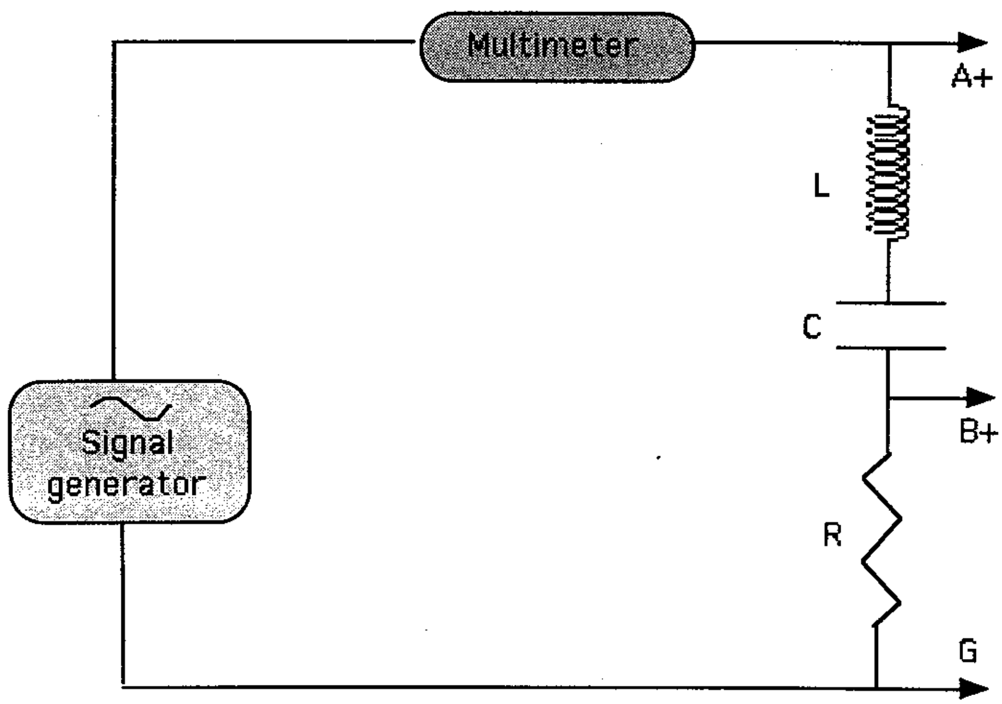

Fig. 10.3b

(k) Make sure that the curves are centered with respect to the horizontal axis. Read A_1B_1, A_2B_2, A_1A_2 and B_1B_2 (Fig. 9-6). Make a sketch of the display.

(l) If time permits, repeat the entire procedure by changing the values of f, C and R to obtain one more set of data.

Unit 2. Study of resonance:

(a) Calculate the natural frequency f_r of the circuit by using Eq. (7). Set the frequency of the signal generator near f_r.

(b) Vary the frequency of the signal generator such that the current in the circuit (as indicated by the multimeter) is maximum. Record this frequency (f_1) and current I'_{max}.

(c) Eliminate the multimeter from the circuit, set it to read AC voltage and measure V_E.

(d) Adjust the centering of A and B displays with respect to the horizontal axis, as accurately as possible. Adjust the frequency of the signal generator until there is no phase difference between the A and B displays (as shown in Fig. 9-4). Record the frequency of the signal generator (f_2).

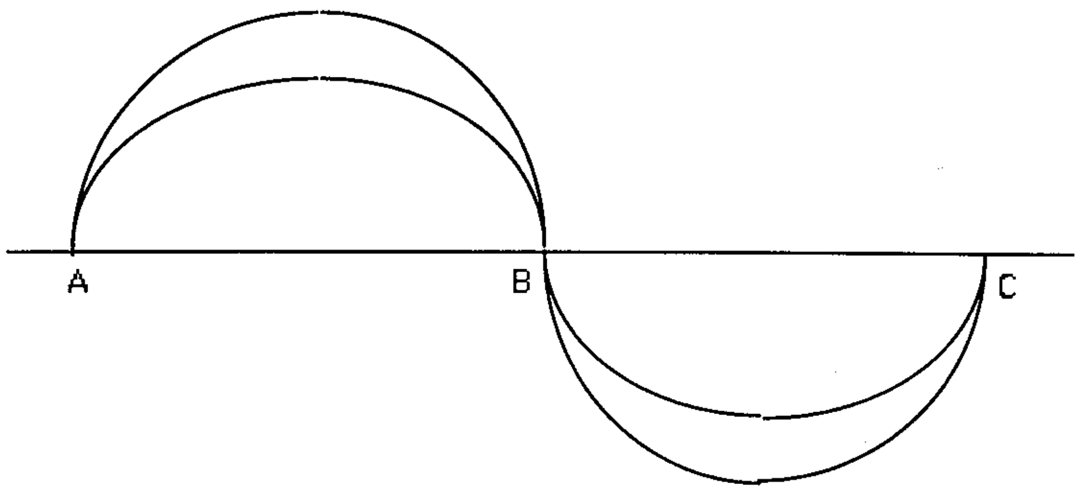

Fig. 10.4

(e) Change the display to A vs. B by selecting X-DEFL for trigger source (key [19]). In general, an ellipse will be displayed on the screen. Adjust the frequency of the signal generator until the ellipse is reduced to a straight line. Record the frequency of the signal generator (f_3).

(f) If time permits, repeat the entire procedure by changing C and/or R.

Note that volt/div (A and B) and time/div, and, vertical and horizontal VAR controls may have to be adjusted in steps (d) and (e).

Further, if the signals are weak, the displays may be distorted or other difficulties may be encountered in steps (d) and (e). In such a case, either skip these steps, or change R and C, and, start from step (a) of the procedure.

York College of The City University of New York

Physics II   Name:

Experiment No. 10: Pre-Lab Questionnaire

1. If $X_L = X_C$, what kind of circuit do we have?

2. If L 1.5 henry and C 0.06 μF, the natural frequency of the circuit is

   ____

3. Describe the methods of determining resonance frequency in this experiment.

4. In the first part of this experiment, the ________________ controls should be in calibrated position. Explain your answer.

5. Why the time/division control need not be in calibrated position while determining the phase difference between the applied voltage and current?

Experiment No. 10

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

DATA SHEET

Unit 1: AC Circuit Containing RLC:

Frequency f =

Resistance R =

Resistance of inductor R' =

Capacitance C =

Inductance L =

Multimeter readings:

I = ; V_E = ; V_R =

V_{LC} = ; V_L = ; V_C =

Oscilloscope readings:

Volt/div (A) = ; Volt/div (B) = ; Time/div =

V_A (peak-to-peak A) = ; V_B (peak-to-peak B) =

A_1B_1 = ; A_2B_2 = ; A_1A_2 = ; B_1B_2 =

Sketch of the display (label the curves voltage and current):

Unit 2: Resonance:

R = ; R' = ; C = ; L =

f_r (theoretical) =

I'_{max} (experimental) = ; V_E =

f_1 = ; f_2 = ; f_3 =

Make similar data sheets for each set.

Calculations:

Unit 1:

Set No. ____

$X_C(\text{theoretical}) = \frac{1}{2\pi fC} =$

$X_L(\text{theoretical}) = 2\pi f L =$

$X_{LC} = | X_L - X_C |$

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

$\phi(\text{theoretical}) = \tan^{-1}\left(\frac{X_L - X_c}{R + R'}\right) =$

$V_X = | V_L - V_C | =$

$V_T = \sqrt{V_R^2 + V_{LC}^2} =$

From peak-to-peak readings:

$V_E' =$

$V_{LC}' =$

$X_{LC}'(\text{experimental}) = \frac{V_{LC}}{I} =$

$Z'(\text{experimental}) = \frac{V_E}{I} =$

$\delta x = \frac{1}{2}(A_1B_1+A_2B_2) =$

$x = \frac{1}{2}(A_1A_2+B_1B_2) =$

ϕ' (expererimental) $= 180\frac{\delta x}{x} =$

Percent difference between						
V_X & V_{LC}	V_T & V_E	V'_E & V_E	V'_{LC} & V_{LC}	X'_{LC} & X_{LC}	Z' & Z	ϕ' & ϕ

Unit 2:

Set No, _____

I_{max} (theoretical) $= V_E/(R + R') =$

Percent difference between			
I'_{max} & I_{max}	f_r & f_1	f_r & f_2	f_r & f_3

Questions:

1. Why is it not necessary for the horizontal vernier to be in calibrated position in this experiment?

2. How will you measure V_L, V_R and V_C in Unit 1 of this experiment by using the oscilloscope?

3. What is the main source of error in Unit 1 of this experiment?

4. Can the current ever lead the voltage in Unit 1? Explain.

5. What will happen if in Unit 2, the resistance R is changed after the frequency has been adjusted to obtain I_{max}?