4.

Study of Resistors, Capacitors and Inductors with an AC Source

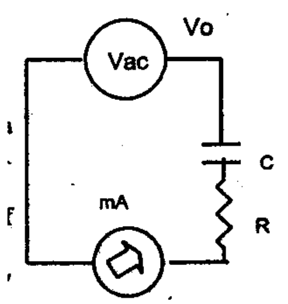
Experiment 4 : STUDY OF RESISTANCE, CAPACITOR AND INDUCTOR BY AC SOURCE

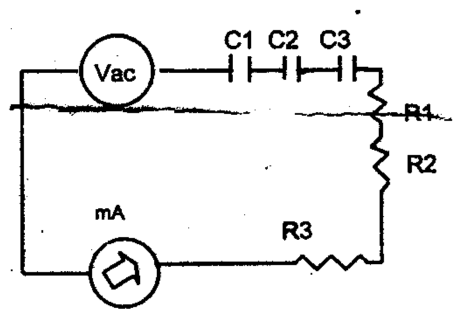
1.0 AIM :

A. To study simple RC circuit and to show that currents are in quadrature. Determine the effective ac resistance.
B. To represent the deviation in the behaviour of an actual capacitor by adding a shunt resistance.
C. To determine the effective series resistance for a capacitor corresponding to a shunt across it and verify it experimentally.
D. To determine equivalent power loss resistance of an inductor as a function of resistance and input voltage.

2.0 : DETAILED PROCEDURE AND CALCULATION :

A. To study simple RC circuit





Experimental procedure:

Make the electrical circuit as shown below (Fig.) Measure the voltages across capacitor V_c and Resistor V_R and current I flowing in the curcuit. Select another capacitor of different value and adjust R such that the current I remains the same. Repeat the procedure for atleat five different values of capacitors.

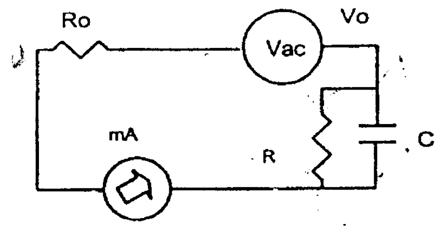
Make another circuit Fig. In which three resistors are connected in series with three series connented capacitors and apply voltages. Measure voltage across each componens.

Calculations:

1.Compare the measured value of current I with the calculated one from the formula $V_R = IR$ and $V_c = I / \omega c$ in each case.

1. Plot V_c verses $1 / c$ and determine the value of frequency f.
2. Determine the impedance of the circuit by formula $Z = V_o / I$ and verify theoretically.
3. From the vector diagram between V_R, V_c and V_o, show that $V_o^2 = V_R^2 + V_c^2$ in all the cases.
4. Show that the sum of resistive voltage and the sum of capacitive voltage are in quadrature in circuit b.

B1. To represent the deviation in the behaviour of an actual capacitor by adding a shunt resistance.



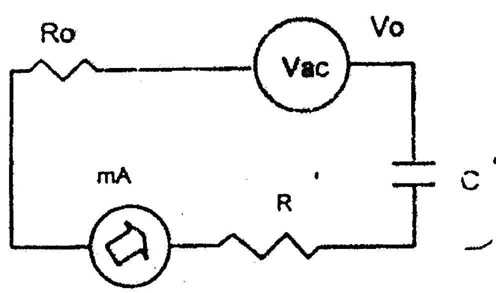
Expcuimental procedure:

Connect the circuit as shown below. Measure voltages V_o, $V_{cR}$and V_{R0}. Increase the value of R in five steps from a low value to a very high value. Measure the current flowing through the circuit, I_o, current through R, I_R and current through C, I_c for each value of R.

Calculations:

1. Draw five voltage vector diagrams to evaluate the effect of increasing R on the performance of capacitor.
2. Draw five current vector diagrams and show that I_R and $I_c$are in quadrature.

B2 : To detemine the effective series resiostance for a capacitor corresponding to a shunt across it.



Experimental Procedure :

Connent a resistor R in parallel to a capacitor C as shown in the figure below. Meaqsure the voltages V_{CR}, V_{RO}, and V_O and current to flowing through them. Take minimum tree sets.

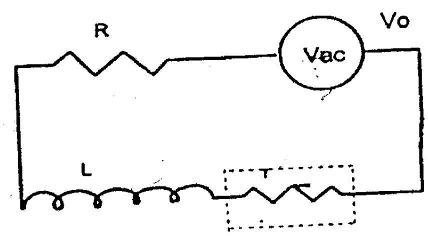
Calculations:

1 Draw vector diagrams and measure $V_{R'}$ and $V_{C'}$. Determine R' and C' from the triangle and using the relation given below.

$$R' = V_C^2 / (R\, I_O^2)$$

3. Show that the same current flows in the circuit byt connenting R' and C' in series.

C. To study the equivalent power loss resistance of an inductor.



Experimental procedure:
Connect the LR circuit as shown in figure below (where r is the power loss resistance of inductor). Measure voltage across inductor V_L, voltage across resistance V_R' and source voltage V_O. Keeping R and L constant , take five sets with different V_O and L, by selecting five different values of R.

Calculations :

1. Calculate r for all the observations from vector diagrams.
2. Draw graphs between r vs V_O and r vs R.

2.0 : DETAILED DISCUSION :

A capacitor C and a resistance R are connected in series to the source along with the current meter. Measure I, V_c, V_R and V_{RC}, the last one being the voltage across R and C together.
Verify the relations

$V_R = IR$ and $V_C = I / \omega C$

where ω is the angular frequency (i.e. $\omega=2\pi$ times the frequency f of the a-c supply). From Equation (5.1) can you say what would happen to the relative values of V_R and V_C at very low and very high frequencies?

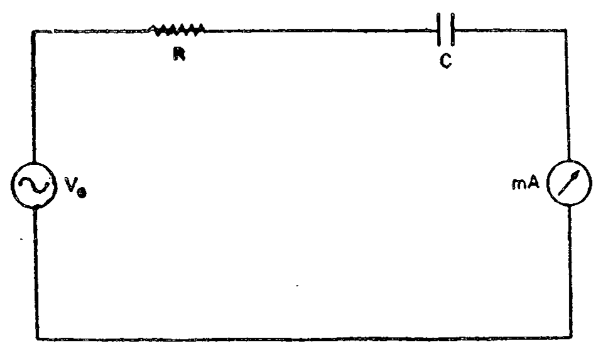


FIGURE 5.2

Use different values of C and adjust R in each case to obtain the same current. Draw a graph between V_C and $1/C$.

EXPERIMENT 5-C *To study the vectorial addition of voltages across the capacitor and the resistor in an RC circuit.*

Connect some capacitors and some resistors in series to the source (Fig. 4.11). Establish the relation

$$V_{C_1}\,\omega C_1 = V_{C_2}\,\omega C_2 = \ldots\ldots = \frac{V_{R1}}{R_1} = \frac{V_{R2}}{R_2} = \ldots\ldots = I \quad \ldots (5.4)$$

As far as rms values of currents and voltages are concerned, the impedance $1/\omega C$ plays the same role as the resistance R.

Notice that the voltages V_R and V_C do not add algebraically. For example, for just one capacitor and one resistor in series,

$$V_R + V_C > V_0$$

(V_0 being the source voltage). Do you see that

$$V_R^2 + V_C^2 = V_0^2$$

Explain this on a vector diagram. Also check for a series of resistors and capacitors that

$$V_{R1} + V_{R2} + V_{R3} = V_{R123}$$

and

$$V_{C1} + V_{C2} + V_{C3} = V_{C123}$$

where V_{R123} is the voltage across all the three resistors in series and V_{C123}, the voltage across all the three capacitors.

EXPERIMENT 5-D *To study the deviation in the behaviour of an actual capacitor from an ideal one.*

With a constant source voltage V_0, connect a resistor and a capacitor in series and measure V_R and V_C. For different values of R and C (keeping source voltage fixed), construct the vector triangles of sides V_R, V_C and V_0; the best way is to draw all the triangles with the same base V_0. Then, for different values of V_R and V_C, we ought to obtain right-angled triangles with V_0 as hypotenuse. Thus, the vertices of the triangles ought to be on a semi-circle. In reality it may not be so. Can you guess the reason?

EXPERIMENT 5-E *To represent the deviation in the behaviour of an actual capacitor by a series resistance.*

From the foregoing experiment you have probably learnt the difference between an ideal and an actual capacitor. The latter always has some leakage across it which can be represented by a leakage resistance, in series or in parallel with it. This would imply that its reactance is not purely capacitive. This and the next experiment will help you to understand these remarks better.

Connect a capacitor and a number of equal resistors in series with the source [Fig. 5.3(a)]. Measure the potential differences in pairs V_{C0} and V_{04},

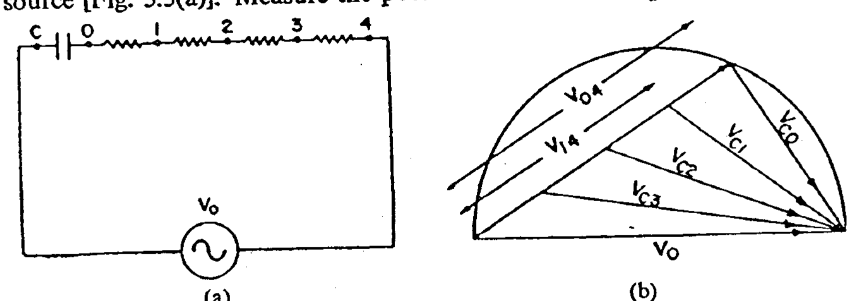


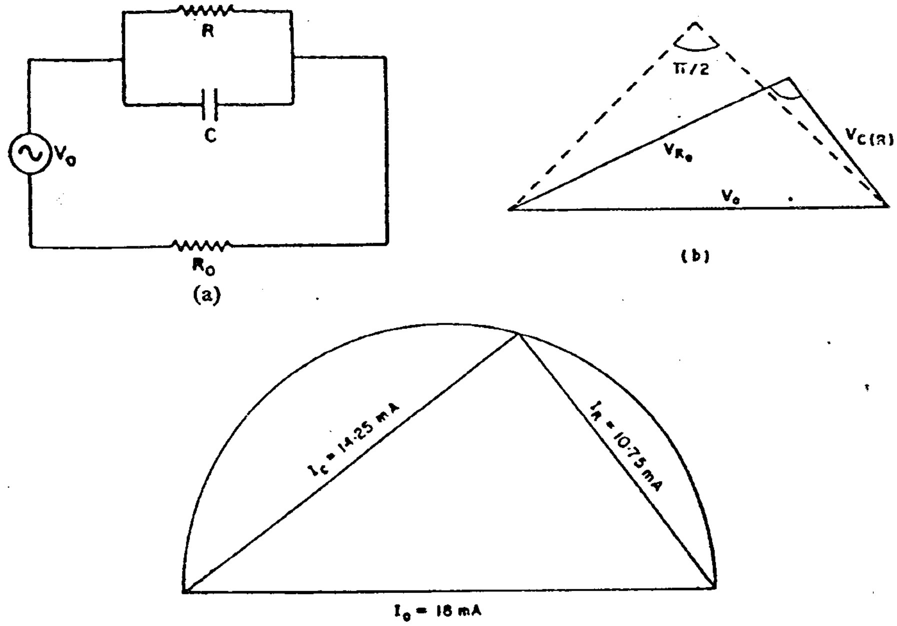
FIGURE 5.3

V_{C1} and V_{14}, V_{C2} and V_{24}, V_{C3} and V_{34}. With the source voltage V_0 as base, construct triangles for each of these pairs [Fig. 5.3(b)].

Determine (from the diagram) the phase difference between constituents of each of the above pairs, for example, between V_{C0} and V_{04} and so on. You will find that whereas the phase difference between V_{C0} and V_{04} is almost $\pi/2$ with the vertex of the triangle nearly touching the semi-circle, the same is not true of the pairs V_{C1} and V_{14}; V_{C2} and V_{24} etc. The phase difference in these cases is quite different from $\pi/2$ and the vertices lie well inside the semi-circle. Thus, when you measure V_{C1}, V_{C2} etc. what you are effectively doing is to associate some resistance with the capacitor and then measure the voltage across the combination which makes the vertex move inwards. This is an *exaggerated* picture of an actual capacitor. In this sense, you can represent the behaviour of a non ideal capacitor by treating it as a combination of a small series resistance and an ideal capacitor of a slightly higher capacitance. (see Experiment 5H).

EXPERIMENT 5-F *To represent the leakage resistance of a capacitor by a shunt.*

Connect a resistor R in parallel with a capacitor C (Fig. 5.4a) and then this combination in series with another resistor R_0 and the source of power.



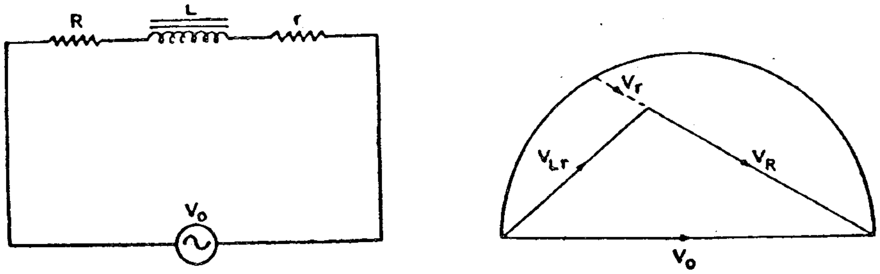
(c)
FIGURE 5.4

Measure $V_{C(R)}$, V_{R_0} and V_0 (the source voltage). Draw a vector diagram for these voltages (Fig. 5.4b). You will notice that the phase difference between $V_{C(R)}$ and V_{R_0} is not $\pi/2$. By varying R you will also notice that the phase difference approaches $\frac{\pi}{2}$ as R is increased. In fact, if you remove the shunt R and draw the vector diagram afresh (dotted) you will find the phase difference to be nearly $\pi/2$.

This means that a real capacitor (as opposed to an ideal one) can also be treated as having a large resistance as a shunt with it. However, the capacitors you have been using are not very far from ideal at least under the conditions used.

EXPERIMENT 6-D *To determine the equivalent power loss resistance of an inductor.*

Connect the circuit of Fig. 6.15, where r is the resistive part of the inductor and is to be determined. Measure V_L, V_R, V_0 (the applied voltage) and draw the voltage triangle. You will find that the triangle is not a right angled one. Draw a semi-circle with V_0 as diameter and extrapolate the V_R line until it intercepts the semi-circle. You can now estimate the equivalent power loss resistance (from V_r) of the inductor since $r/R = V_r/V_R$. Compare



(a) (b)

FIGURE 6.15

it with the d-c resistance of the coil (measure it directly with a meter). You will find that there is a difference—the equivalent power loss resistance r is not just the d-c resistance. This is because the power loss in an inductor is due to its d-c resistance plus the hysteresis and eddy losses in the core. Measure this equivalent resistance for different values of the a-c voltage. Why may it vary?