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 in fig.(1). Measure the voltage across capacitor \( V_C \) and Resistor \( V_R \) and current I following in the circuit. Select another capacitor of different value and adjust R such that the current I remains the same. Repeat the procedure for at least five different values of capacitor.

Make another circuit fig. (2), In which three resistors are connected in series with three series connected capacitors and apply voltages. Measure voltage across each components.

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 \( V_C \) versus \( 1 / \omega C \) and determine the value of frequency \( f \).
2. Determine the impedance of the circuit by formula \( Z = V_0 / I \) and verify theoretically.
3. From the vector diagram between \( V_R, V_C \) and \( V_0 \), show that \( V_0^2 = V_R^2 + V_C^2 \) in all the cases.
4. Show that the sum of resistive voltage and the sum of capacitive voltage are in quadrature in circuit b.
Experimental Procedure:

Connect the circuit as shown in figure (3). Measure voltages $V_o$ and $V_{RO}$. Increase the value of $R$ in five steps from a low value to a very value. Measure the current flowing through 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.
Experimental Procedure:

Connect a resistor R in parallel to a capacitor C as shown in fig.(4). Measure the Voltages $V_{CR}$, $V_{RO}$ and $Vo$ and current to following through them. Take minimum three set.

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.
   \[ R' = \frac{V_C'^2}{(R\cdot I_0^2)} \]
2. Show that the same current flows in the circuit by connecting $R'$ and $C'$ in series.
where \( \omega \) 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?

![Circuit Diagram]

\[ V_C \times C \times \omega = V_C \times C \times \omega = \frac{V_R}{R} = \frac{V_C}{R} \]

As far as rms values of currents and voltages are concerned, the impedance \( /\omega C \) 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

\[ V_R^2 + V_C^2 = V_0^2 \]

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. 4.1). Establish the relation

\[ V_{C_1} + V_{C_2} + \ldots = V_{R_1} = \frac{V_R}{R_1} = \frac{V_R}{R_2} = \ldots \]

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

\[ V_{R_1} + V_{R_2} + V_{R_3} = V_{R123} \]

and

\[ V_{C_1} + V_{C_2} = V_{C12} \]

where \( V_{R123} \) is the voltage across all the three resistors in series and \( V_{C12} \) 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 $V_{CO}$ and $V_{RE}$, $V_{CB}$ and $V_{RB}$, $V_{CA}$ and $V_{RA}$. 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 $V_{CO}$ and $V_{RE}$ and so on. You will find that whereas the phase difference between $V_{CB}$ and $V_{RB}$ is almost $\pi/2$ with the vertex of the triangle nearly touching the semi-circle, the same is not true of the pairs $V_{CA}$ and $V_{RA}$ 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 $V_{CO}$, $V_{RE}$ 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.

![Diagram](a)

![Diagram](b)

![Diagram](c)

**FIGURE 5.4**

Measure $V_0(R)$, $V_{R0}$ 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 $V_{R0}$ 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 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?