Experiment: 6

MEASUREMENT OF DIELECTRIC CONSTANT

AIM: To determine the dielectric constant of the dielectric medium present in a parallel plate capacitor by charging – discharging method.

APPARATUS: 5V DC power supply, digital voltmeter, timer, capacitor and resistor of known values, toggle switch

INTRODUCTION:

Relative permittivity of a dielectric medium is commonly known as dielectric constant. Relative permittivity is the ratio of the capacitance of a capacitor using that material as a dielectric (C_x), compared to a similar capacitor that has vacuum as its dielectric (C_0).

$$\varepsilon_r = \frac{C_x}{C_0}.$$

Relative permittivity is a dimensionless quantity that is in general complex-valued; its real and imaginary parts are denoted as

$$\varepsilon_r(\omega) = \varepsilon_r'(\omega) + i\varepsilon_r''(\omega).$$

A parallel plate condenser is formed by keeping two metallic plates parallel to each other. By applying a potential across the two plates an electric field is produced inside the space between the two plates. By placing an electrically insulated material within the plates the capacitance can be increased. The resulting capacitance of the parallel plate condenser is given by

$$C = \frac{K\varepsilon_0 A}{d}$$

Where, C is the capacitance in Farad.

K is dielectric constant, ε_0 is the permittivity $8.85\text{x}10^{-12}$ Fm^{-1}. A is the area of the plate

d is the distance between the plates or thickness of the dielectric material.

Charging of Capacitor

As soon as the switch is closed in position 1 (Fig 1) the battery is connected across the capacitor, current flows and the potential difference across the capacitor begins to rise but, as more and more charge builds up on the capacitor plates, the current and the rate of rise of potential difference both fall. Finally no further current will flow when the p.d. across the capacitor equals that of the supply voltage V_o. The capacitor is then fully charged.

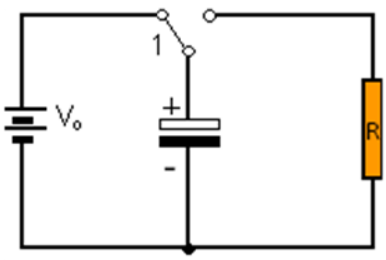


Figure 1

Discharging of Capacitor

As soon as the switch is put in position 2 a 'large' current starts to flow and the potential difference across the capacitor drops. (Fig 2). As charge flows from one plate to the other through the resistor the charge is neutralized and so the current falls and the rate of decrease of potential difference also falls. Eventually the charge on the plates is zero and the current and potential difference is also zero - the capacitor is fully discharged. The value of the resistor does not affect the final potential difference across the capacitor – only the time that it takes to reach that value. The bigger the resistor the longer the time taken.

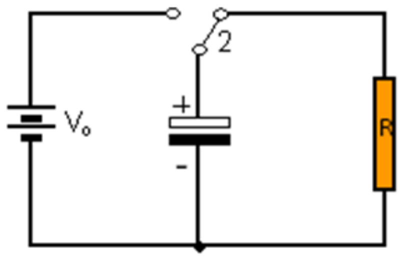


Figure 2

There are many different types of capacitors ranging from ceramic capacitors to electrolytic capacitors and silver mica capacitors to various forms of plastic (e.g. polyester) capacitors. Each capacitor type has its own advantages and disadvantages and therefore the uses of the capacitor can be different. Capacitors are used in virtually every area of electronics and they perform a variety of different tasks. Capacitors are used for coupling, decoupling, filters, for power supply smoothing, in low frequency circuits and in high frequency circuits.

FORMULA:

$$K = \frac{10^{-6} d\, t_{1/2}}{0.693\, \epsilon_0 A\, R}$$

Where,
- K is the dielectric constant of the material within the capacitor
- d is the thickness of the dielectric material in m
- A is the area of the dielectric material in m^2
- $t_{1/2}$ is the time taken by the capacitor to charge /discharge to 50% of maximum voltage in s
- ϵ_o is the permittivity of free space in $F\text{-}m^{-1}$
- R is the resistance in the circuit in Ω

NATURE OF GRAPH:

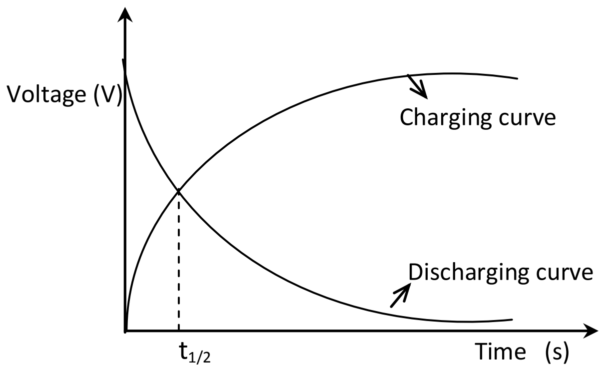
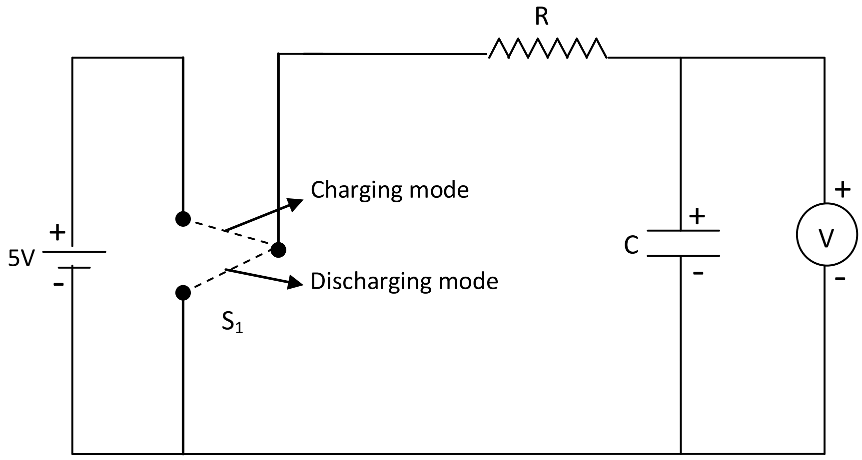


Fig: Charging and discharging curves

CIRCUIT DIAGRAM:



TABULAR COLUMN :

Time (s)	**Voltage in charging mode** (V)	**Voltage in discharging mode** (V)
0		
5		
10		
15		
20		
25		
30		
35		
40		
45		
50		
60		
70		
80		
90		
100		
110		
120		
130		
140		

150		
160		
170		
180		
190		
200		

PROCEDURE:

1. Make the connections as shown in the circuit diagram.
2. Set the timer to zero by pressing the reset button and short the capacitor so that the voltage across it is zero.
3. Keep the toggle switch in charging mode and turn on the power supply.
4. Note down the voltage V across the capacitor in the at intervals of 10s till the capacitor is completely charged (around 200s).
5. After 200s, turn the toggle switch to discharge mode and note down the voltage in intervals of 10s till the capacitor is completely discharged (around 200s).
6. Draw the charging and discharging curves for the capacitor by plotting the time't' along x-axis and voltage 'V' along y-axis.
7. Obtain the value of $t_{1/2}$ from graph (where charging and discharging curves meet) and calculate 'K', the dielectric constant of the given material using the formula.

Precautions: The electrolytic capacitor has polarities and must be connected properly as indicated in the circuit diagram.

CALCILATIONS:

R= ………..Ω

d= ………….m

$t_{1/2}$= ………..s

A= ………….m^2

ε_0= 8.854x10^{-12} Fm^{-1}

$$K = \frac{10^{-6} d\, t_{1/2}}{0.693\, \epsilon_0 A\, R}$$

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PROPORTIONAL ERROR CALCULATION:

The dielectric constant is given by the formula $K = \frac{10^{-6} d\, t_{1/2}}{0.693\ \epsilon_0 A\, R}$

Since only t is measured, the proportional error in the value of k is given by

$$\frac{\delta k}{k} = \frac{\delta t_{1/2}}{t_{1/2}}$$

where $\delta t_{1/2}$ is the least count of the stop clock.

Result**:** The dielectric constant of the given dielectric material is = k ± δk

=………………

Reference:

1. Basic Electronics, M.V.N. Rao, Wiley Eastern Publn, 3rd Edn, 1999, (Page 423-428)
2. Solid State Physics, S.O. Pillai, New Age International Publn, 6th Edition, 2006, (Page 625-626)