Name of the Experiment: Determination of dielectric constant of materials using parallel plate capacitor.

Theory

The electric flux through a closed surface area in vacuum is given by Gauss's law of electrostatics:

$$\oiint_s \bar{E}.d\bar{A} = \frac{Q}{\varepsilon_0} \qquad (1)$$

Where $\bar{E}$ is the electric field intensity, Q is the charge enclosed by the closed surface A, ε_0 is the permittivity constant in free space and s is a closed surface area.

If a voltage V_c is applied between two capacitor plates as shown in fig. 1, an electric field $\bar{E}$ will prevail between the plates defined by: $V_c = \int_1^2 \bar{E}.d\bar{r} = E.d$

If **E** is constant Eq. (1) gives

$$\frac{Q}{\varepsilon_0} = E.A = V_C.A.\frac{1}{d} \qquad (2)$$

The charge Q of the capacitor in terms of the capacitance of the capacitor is given by

$$Q = CV_{out} \qquad (3)$$

Where the capacitance C of the capacitor is given as

$$C = \varepsilon_0 \frac{A}{d} \qquad (4)$$

Thus, the dielectric constant is ε_0:

$$\varepsilon_0 = \frac{d}{A}.\frac{Q}{V_c} \qquad (5)$$

Equations (3), (4) and (5) are valid only approximately for parallel field lines for a small and constant distance between the plates.

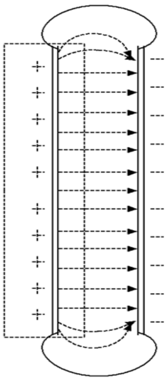

Fig. 1: Electric field of a plate capacitor with small distance between the plates, as compared to the diameter of the plates.

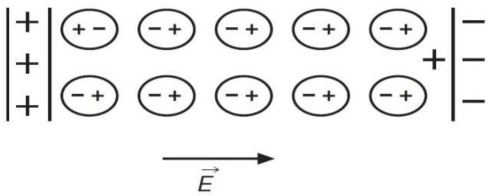

Fig. 2: Generation of free charges in a dielectric through polarization of the molecules in the electric field of a plate capacitor.

A dielectric material placed between the plates as shown in fig. 2 increases the capacitance of the capacitor. With the dielectric material of dielectric constant ε the voltage V_c will reduced as

$$V_c = \frac{V_{vac}}{\varepsilon} \qquad (6)$$

Hence the capacitance and charge of the capacitor becomes,

$$C = \varepsilon.C_{vac} \qquad (7)$$

$$Q = CV_C = \varepsilon.\varepsilon_0.\frac{A}{d}.V_C$$

$$\varepsilon = \frac{d}{\varepsilon_0 A}.\frac{Q}{V_{out}} \qquad (8)$$

For the same voltage, the amount of charge of the capacitor is significantly increased by the dielectric. If the charges obtained with and without plastic (equations [3] and [8]) are divided by each other.

Material and Apparatus

Plate capacitor (d 260 mm), Plastic plate (283×283 mm), Glass plates f. current conductors, High-value resistor (10 MΩ), Universal measuring amplifier, High voltage supply unit (0-10 kV), PEK capacitor/case (1/0.22 μF), Voltmeter (0.3-300 VDC and 10-300 VAC), Green-yellow connecting cord (100 mm), Red connecting cord (500 mm), Blue connecting cord (500 mm), Connecting cord (50 KV, 500 mm), Screened BNC cable (750 mm), BNC adapter socket (4 mm plug), T type BNC connector, BNC-plug/socket adapter (4 mm)

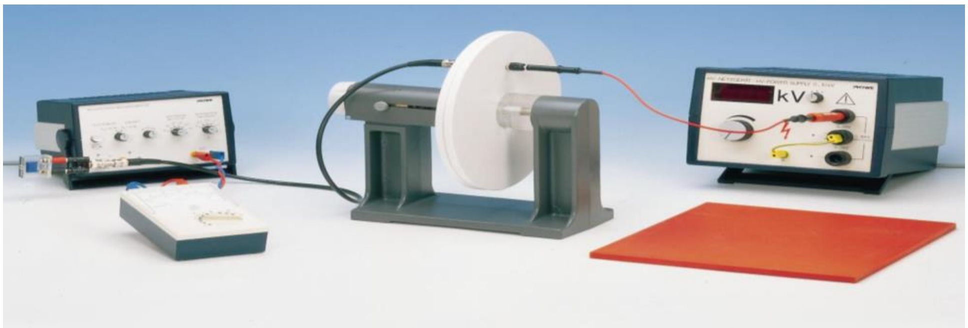

Fig. 3: Measurement set-up: Dielectric constant of different materials.

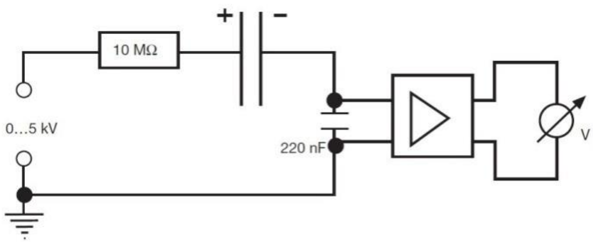

Fig. 4: Wiring diagram

Experimental Setup (Connection)

1. Calculate the surface area of the capacitor plates by means of their radius (r =13cm).
2. According to figure 4, connect the positive terminal of the high voltage (upper connector) with the high resistance (10 MΩ) key. Then connect the black connector with 10 MΩ key.
3. Connect the middle connector (yellow wire) of the high voltage to the ground. Connect ground of high voltage with the negative plate of capacitor.
4. Again, connect the 220nF capacitor to the measuring Amplifier (in left bottom knob).
5. Connect the output of the measuring Amplifier to a digital voltmeter using blue and red connector.
6. Turn on the High voltage and measuring Amplifier and set the Voltmeter into 30 volts range.
7. Keep the plate separation about 9mm.

Data Taking Procedure

8. Set the input voltage 2.5kV and distance between plates 9 mm

9. For charging the plate, connect another knob of the black connector with positive plate of the capacitor and wait for 10 sec for then remove it. Please be aware that your hand or fingers does not touch with metal knob of the connectors.

10. Now, connect the cable of 220nF to the positive plate of the capacitor for discharge and take the reading from voltmeter and write on the table.

11. In each case, after taking the reading push the Toggle Switch (left arrow button) of the measuring amplifier.

12. For Table 2, set the input voltage of the HV-power supply at 0.5 kV and plate distance 9mm.

13. Repeat the following procedure for 0.5, 1.5, 2.5, 3.5, and 4.5 kV and write data on Table 2.

14. Plot a graph for charge *Q* of a plate capacitor as a function of the inverse distance between the capacitor plates d^{-1}(V_c= 1.5 kV) (Take data for Table 1).

15. Again, plot a graph charge Q of a plate capacitor as a function of the applied voltage V_c, between the plates (d = 0.98 cm) (take data from Table 2).

16. Calculate Q by following equation (3) for each case and plot in a graph and take a slope for permittivity constant ε_0 of the air.

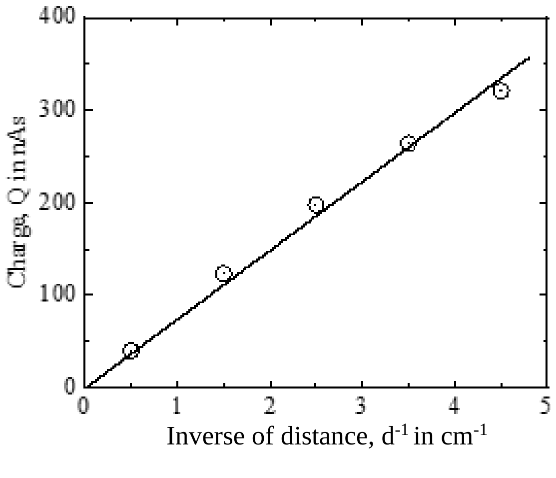

Fig.5: Electrostatic charge Q of a plate capacitor as a function of d^{-1} cm^{-1}

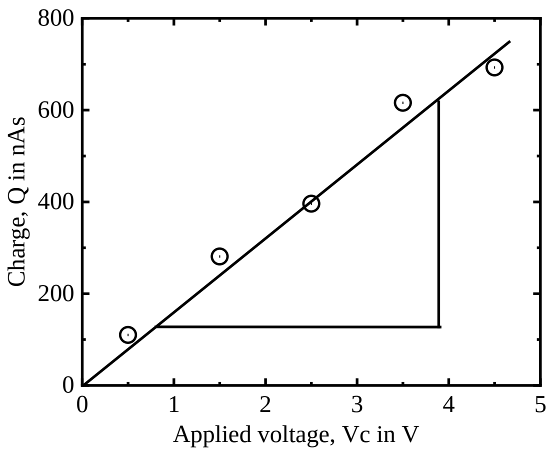

Fig. 6: Electrostatic charge Q of a plate capacitor as a function of the applied voltage V_c, with air between the plates (d = 9 mm)

Measurement results

Table 1: Measurement of the electric constant at various separation

A = 0.0531 m^2 V_c = 2.5kV C = 220 nF

Distance between Plates	d^{-1}	Output voltage dropped in the opposite plate, V_{out}		Mean Voltage, V_{out}	Charge, Q
[cm]	[cm^{-1}]	[V]		[V]	[nAs]
0.5					
1					
1.5					
2					
2.5					

Table 2: Measurement of dielectric constant for Air

A = 0.0531 m^2 d = 9 mm C = 220 nF

Applied voltage, V_c	Output voltage dropped in the opposite plate, V_{out}		Mean Voltage, V	Charge, Q	Dielectric constant, ε_0
[V]	[V]		[V]	[nAs]	[pAs/Vm]
0.5					
1.5					
2.5					
3.5					
4.5					

Calculation:

Thus, the dielectric constant of air is ε_0:

From the slope of graph 2, $\frac{Q}{V_c} =$ …………..

$$\varepsilon_A = \frac{d}{A} . \frac{Q}{V_c} = \quad ………..$$

Result: The dielectric constant of air is…………

Discussions: