Name: **Stream:** **Sec:** **Roll No.:**

EXPERIMENT NO. **Date:**

TITLE : DETERMINATION OF DIELECTRIC CONSTANT OF NON-CONDUCTING SOLIDS & LIQUIDS

Course Outcome: Understand the basic strategy to find capacitance and hence dielectric constant with the help of capacitance meter. .

APPARATUS:

a. **Capacitance measuring unit**
b. **Circular parallel plate probe of diameter 50.0 mm**
c. **Circular parallel plate probe of diameter 10.0 mm**
d. **Coaxial Cylinder Set up(CCS)**
e. **Solid samples of Lead Zirconate Titanate pellet (PZT), Bakelite sheet, Glass plate and Teflon plate.**
f. **Liquid sample of Carbon Tetrachloride(CCl_4)**.

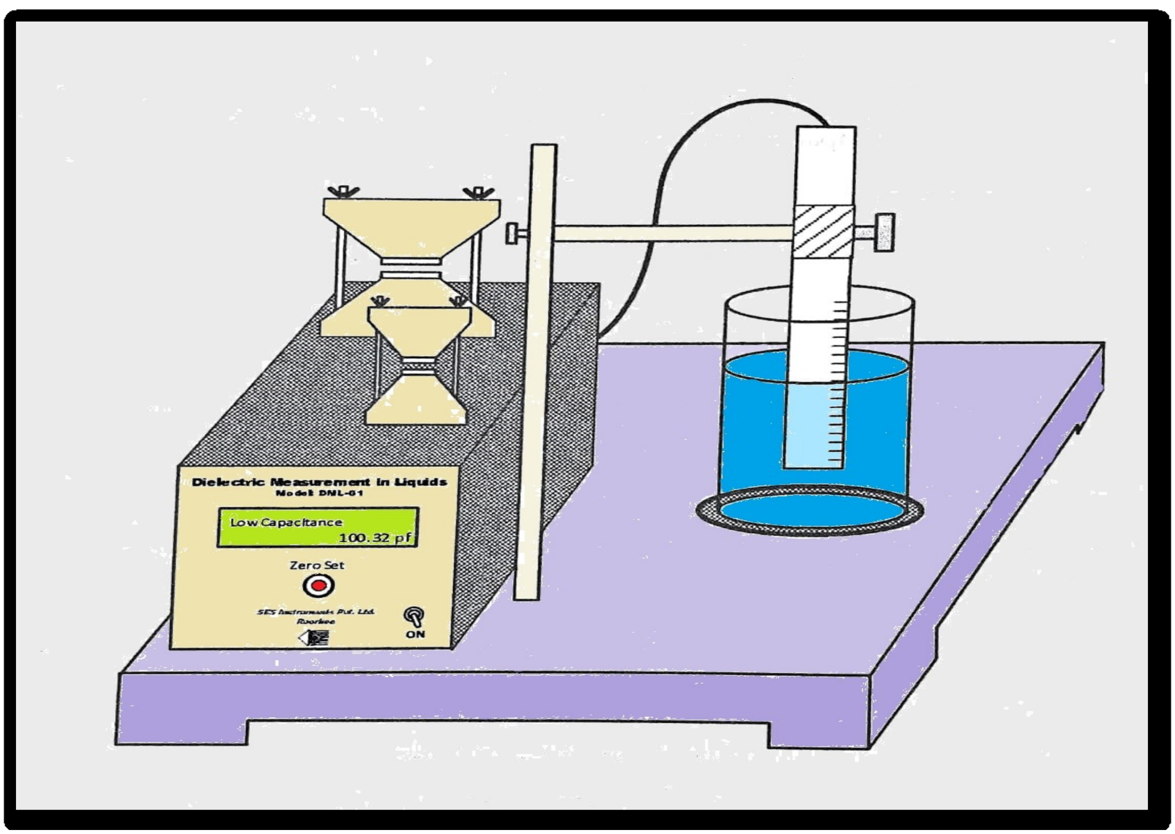


Figure 1: Instrument for Dielectric measurement in solid and liquids

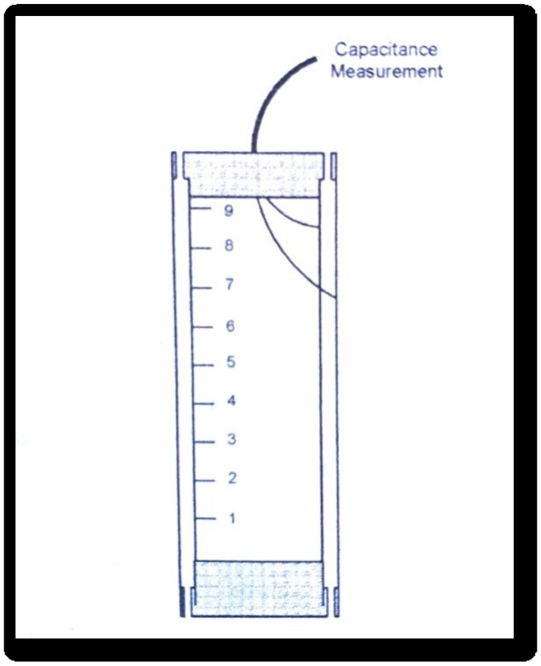


Figure 2: Coaxial Cylinder Set-up (CCS) For measuring capacitance of liquids.

BASIC THEORY:

Dielectric materials are special kind of insulators that can be polarized and can store electric charges under electric potential.

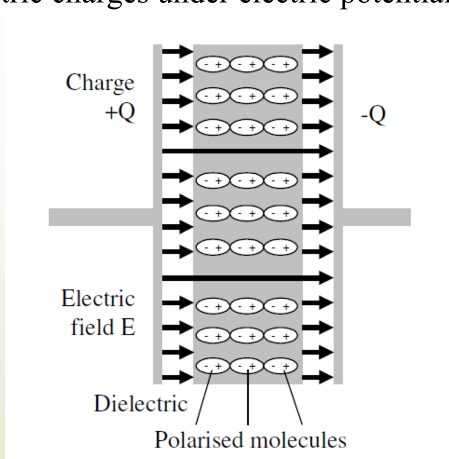


Figure 3

Polarization is a technique of creating or inducing dipoles in a dielectric material by applying an external electric field.

In an atom, positive charges stay at the centre and negative charges revolve around keeping the centroid at the centre. But if the atom is placed in an external electric field, positive and negative charges are displaced slightly and hence their centroids no longer coincide. Electric dipoles are thus generated by polarization of dielectric atoms.

INTRODUCTION

Dielectric or electrical insulating materials are the substances in which electrostatic field can persist for long times When a dielectric is placed between the plates of a capacitor and the capacitor is charged, the electric field between the plates polarizes the molecules of the dielectric (Figure 3). This produces concentration of charge on its surface that creates an electric field which is antiparallel to the original field (which has polarized the dielectric). This reduces the electric potential difference between the plates. Considered in reverse, this means that, with a dielectric between the plates of a capacitor, it can hold a larger charge. The extent of this effect depends on the dipole polarizability of molecules of the dielectric, which in turn determines the dielectric constant of the material.
The electrons in the molecules shift toward the positively charged plate. The molecules then create a leftward electric field that partially annuls the field created by the charged plates. (The air gap is shown for clarity; in a real capacitor, the dielectric is in direct contact with the plates.)
The method for determination of dielectric constants of liquids consists in the successive measurement of capacitance, first in a vacuum, and then when the capacitor is immersed in the liquid under investigation. A cylindrical capacitor (figure 2) has been used for liquid samples and different size parallel plate capacitors for solid samples.

Working formula

Parallel Plate Capacitor:

The capacity of a parallel plate capacitor is given by

$$\boxed{C = \kappa \frac{\varepsilon_0 A}{d} \text{ Farad}} \qquad (1)$$

where A is plate area and d is distance between the plates. It is assumed that the dielectric completely fills the space between the capacitor plates.

Cylindrical Capacitor:

The capacitance per unit length of a long cylindrical capacitor immersed in a medium of dielectric constant κ is given by

$$C' = \kappa \frac{2\pi\varepsilon_0}{\ln(r_2/r_1)} \text{ Farad/m} \qquad (2)$$

Here $\varepsilon_0 = 8.854\times10^{-12}$ $C^2 m^{-2} N^{-1}$ is permittivity of free space, r_1 is external radius of the inner cylinder and r_2 is internal radius of the outer cylinder.

In actual practice, there are errors due to stray capacitances at the ends of the cylinders and the leads. In any accurate measurement, it is necessary to eliminate these. It has been done in the following way:
Consider a cylindrical capacitor of length L (in meter) filled to a height h (<L) of dielectric constant κ. Its total capacitance is given by

$$C = \frac{2\pi\varepsilon_0}{\ln(r_2/r_1)}[\kappa h + \kappa_0(L-h)] + C_s \qquad (3)$$

Here κ_0 is the dielectric constant of air and C_s, is sum total of stray capacitances. A simplification of equation (3) leads to

$$C = \frac{2\pi\varepsilon_0}{\ln(r_2/r_1)}(\kappa-\kappa_0)h + C_0 \ , \qquad (4)$$

where $C_0 = C_s + \frac{2\pi\varepsilon_0}{\ln(r_2/r_1)}\kappa_0 L$.
Eq. (3) shows that the measured capacity C is a linear function of h (the height up to which the liquid is filled in the capacitor). If we vary the liquid height h and measure it, together with the corresponding capacitance C, the plot of the data should be a straight line. The slope

$$\boxed{\frac{dC}{dh} = \frac{2\pi\varepsilon_0}{\ln(r_2/r_1)}(\kappa - \kappa_0) \text{ Farad/m}} \qquad (5)$$

Will yield a value of κ, if κ_0, r_1 and r_2 are known. The uncertainty due to C_s has thus been eliminated.

PROCEDURE:

Solid sample

1. Connect the bigger *sample holder* to the digital capacitance meter
2. Keep a little space among two plates of the *sample holder* and switch the capacitance meter 'ON' **without keeping any sample in between**.
3. Press "ZERO ADJ" switch for 2-3 seconds, until the meter shows "Zero Cal". The capacitance meter is calibrated now. Switch off the meter.
4. Put glass plate inside parallel plate capacitor and lower the upper plate by turning the top screw clockwise till the capacitor plates touch the sample surface.
5. Switch the meter on and take readings. Also do the same for Bakelite and Teflon plates one by one.
6. Now connect the smaller sample holder and repeat steps 2-5 for Lead Zirconate Titanate pellet (PZT)

Liquid sample

7. Fill the glass container with experimental fluid up to a height of about 12 cm and place it below the Coaxial Cylinder set-up(CCS).
8. Lower the CCS until the liquid touches the zero mark on the scale.
9. Press "ZERO ADJ" switch for 2-3 seconds, until the meter shows "Zero Cal".
10. Now lower the CCS in steps of 1 cm up to 8 cm and take the readings on the capacitance meter.
11. Plot liquid level on x axis and Capacitance on Y axis. In this linear graph find slope dC/dh and hence find dielectric constant (κ) of the fluid.

OBSERVATIONS:

Solid sample

Diameter of the bigger capacitor plates: 50.0 mm
Diameter of the smaller capacitor plates: 10.0 mm
$\varepsilon_0 = 8.854\times10^{-12}\ C^2\ m^{-2}\ N^{-1}$ is = permittivity of free space

Capacity measurement:

Sl. No.	sample	Thickness (mm)	Capacitance (pF)
1.	**Glass**	1.5	
2.	**Bakelite**	1.5	
3.	**Teflon**	1.0	
4.	**PZT**(Lead Zirconate Titanate)	2.55	

Liquid sample

Sample: Carbon Tetrachloride (CCl_4)
Dielectric Constant of free air(κ_0) = 1.0059
External radius of the inner cylinder: 25.4 mm
Internal radius of the outer cylinder: 30.6 mm

Capacity measurement:

Sl. No.	Liquid level (cm)	Capacitance (pF)
1	0.0	
2	1.0	
3	2.0	
4	3.0	
5	4.0	
6	5.0	
7	6.0	
8	7.0	
9	8.0	

CALCULATIONS:

Solid Sample: Dielectric constant $\kappa = \frac{C\,d}{\varepsilon_0 A}$

$\kappa_g =$

$\kappa_{Bak} =$

$\kappa_{Tef} =$

$\kappa_{PZT} =$

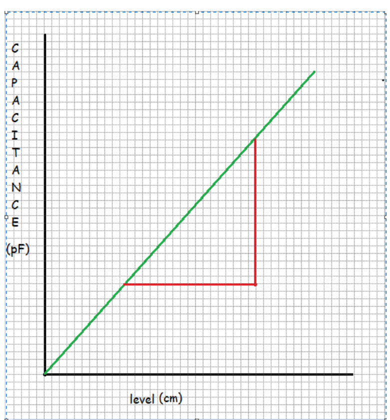
Liquid Sample:

Slope = $\frac{dC}{dh}$ = pF/cm = F/m

$\kappa = \kappa_0 + \frac{dC/dh}{2\pi\varepsilon_0} \ln(r_2/r_1)$=

PRECAUTIONS, CONCLUTIONS AND DISCUSSIONS:

SAMPLE GRAPH:



PROVOKING THOUGHTS:

From this instrument you can also measure

Dielectric constant of other non conducting liquids such as acetone, ethyl alcohol, methanol, glycerol etc.