NATIONAL UNIVERSITY OF TECHNOLOGY

COMPUTER ENGINEERING DEPARTMENT

Applied physics Lab (PHY13002)

Experiment No:3

Title: Experiment to investigate Dielectric constant of different materials.

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Objectives:

1. The relation between charge and voltage is to be measured using a plate capacitor.

2. The electric constant is to be determined from the relation measured under point 1.

3. The charge of a plate capacitor is to be measured as a function of the inverse of the distance between the plates, under constant voltage.

4. The relation between charge and voltage is to be measured by means of a plate capacitor, between the plates of which different solid dielectric media are introduced.

Apparatus:

1. Voltmeter
2. Plate capacitor
3. Plastic plate
4. Glass plates
5. Connecting cord
6. Adapter
7. Screened cable
8. Capacitor.

Theoretical explanation:

Electrostatic processes in a vacuum are governed by Maxwell's equations. When voltage V is applied to a capacitor, a uniform electric field E forms between the plates, and the capacitor's charge Q is proportional to V, with capacitance C inversely proportional to the plate distance d. The electric constant ε_0 can be experimentally determined using small d.

Inserting a dielectric between the plates modifies the field, as the material's dipoles align with E, weakening it by a factor equal to the dielectric constant ε. This reduces V and increases C, allowing the capacitor to store more charge. The dielectric constant ε depends on the material, e.g., plastic (ε=2.9) and glass (ε=9.1). Maxwell's equations incorporate ε for dielectrics, describing the influence of polarization and free charges on the electric field.

Dielectrics enhance a capacitor's ability to store charge by reducing the effective electric field through polarization, leading to increased capacitance. This property is critical in designing capacitors for various applications. The relationship between charge, voltage, and capacitance underscores the fundamental role of material properties like the dielectric constant in influencing electrostatic behavior and energy storage efficiency.

Procedure:

- Assemble the plate capacitor setup, connecting it to a voltage source and a charge-measuring device.
- Fix the distance d between the capacitor plates to a constant value.
- Gradually increase the voltage from 0.5V to in small steps and record the corresponding charge Q on the plates.
- Plot Q versus V to verify the linear relationship and calculate the electric constant ε0\varepsilon_0ε0 using equation (4).
- Insert a plastic dielectric plate between the capacitor plates, ensuring no air gap, while keeping d constant.
- Repeat the voltage variation and measure the charge Q plastic for each voltage.
- Compare $Q_{plastic}$, and Q_{vacuum} for the same voltage to analyze the effect of dielectrics.
- Calculate the dielectric constants of plastic and glass using the ratios $Q_{plastic}/Q_{vacuum}$.

Observations and Calculations:

1.Measurements:
The experiment was conducted at asending voltages from 0.5V to 2.5V. For each result, the distance was kept constant,and the voltages were varied. The voltage decreased as the distance decreased, as expected.

2.Graphing the Results:
Graph was plotted for Voltage(U) vs Charge(Q).As Voltage increases charge increases and the increase is linear.

3.Observation:

The experiment demonstrates that inserting a plastic dielectric between the capacitor plates significantly increases the charge stored for the same applied voltage. The measured charge ratio $Q_{plastic}/Q_{vac}$ is approximately 3.0, indicating that the plastic dielectric enhances the capacitance by a factor of three compared to the vacuum. This effect is due to the polarization of the dielectric, which reduces the effective electric field inside the capacitor. The results validate the relationship between the dielectric constant and increased capacitance, consistent with theoretical predictions.

Task1:

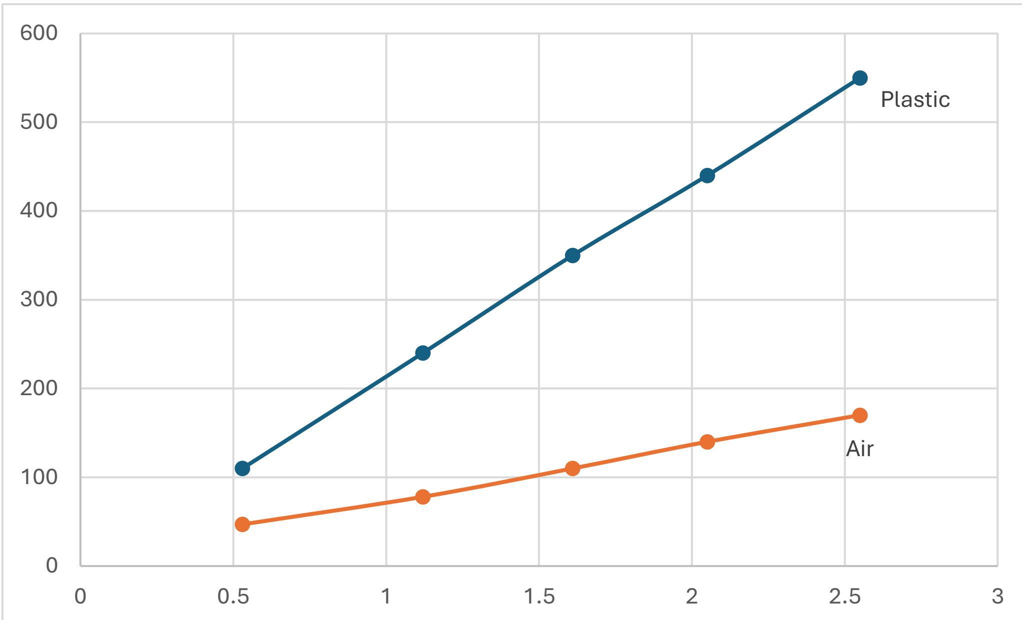
U_c (kV)	0.5	1.0	1.5	2.0	2.5	Average Values
U (V)	0.53	1.12	1.61	2.05	2.55	
Q(nAs)	110	240	350	440	550	≈ 330
U_{vac} (V)	0.22	0.36	0.54	0.69	0.78	
Q_{vac} (nAs)	47	78	110	150	170	≈110
Q/Q_{vac}	2.34	3.07	3.18	2.93	3.23	≈3

Result and Analysis:

$$\varepsilon r = \frac{47}{110} = 2.34 \text{ (for the first measurement)}$$

- The measured charge ratios $Q_{plastic}/Q_{vac}$ for the plastic dielectric are: 2.34, 3.07, 3.18, 2.93, and 3.23.
- **The average dielectric constant calculated from these ratios is approximately 3.0**, indicating that the plastic dielectric increases the capacitor's charge storage capacity by a factor of three compared to the vacuum.
- The experiment demonstrates how the dielectric material affects the capacitor's performance by polarizing under the influence of the electric field. This polarization reduces the effective electric field inside the dielectric, allowing the capacitor to store more charge for the same applied voltage.
- Charge Behavior: In the vacuum, the charges Q_{vac} measured were lower due to the absence of dielectric-induced polarization. With the plastic plate, the charges Q were significantly higher because the plastic dielectric aligned its dipoles along the electric field, effectively enhancing the capacitor's ability to store charge.
- The plastic dielectric improves the capacitor's performance by increasing its capacitance, as indicated by the calculated dielectric constant. This result is consistent with typical properties of plastic materials used as dielectrics, confirming the validity of the experiment.

Graph of Voltage(U_c) vs Charge(Q):



This graph shows how the charge stored in a capacitor (Q) change as the applied voltage (Uc) increases for two different materials between the plates:

Plastic and air:

- Plastic Dielectric: The slope (216 nAs/kV) means plastic allows the capacitor to store much more charge because it has a higher ability to resist the electric field (higher dielectric constant).
- Air (Vacuum) Dielectric: The gentler slope (63.6 nAs/kV) means air stores less charge since it has a lower ability to resist the electric field (lower dielectric constant).

This shows that using plastic as a dielectric increases the capacitor's charge storage significantly compared to air.

Precaution:

- Ensure that the distance between the capacitor plates remains constant while varying the voltage to avoid measurement errors.
- Avoid physical proximity to the capacitor during measurements to prevent distortion of the electric field.
- Use properly calibrated equipment to measure charge and voltage for accurate results.
- Ensure there is no external interference or stray electric fields affecting the setup.
- Handle the capacitor and dielectric materials carefully to avoid damage or contamination.

Comments:

- The experiment demonstrates the relationship between charge and voltage, highlighting the role of dielectric materials in enhancing the capacitor's performance.
- The plastic dielectric significantly improves charge storage, as indicated by the steeper slope compared to air.
- Small variations in measurements could occur due to environmental factors or limitations of the equipment used.
- This experiment effectively validates the theoretical equations relating charge, voltage, capacitance, and dielectric constants.

Conclusion:

This experiment shows that the charge stored in a capacitor increases linearly with the applied voltage. The presence of a dielectric material, such as plastic, significantly enhances the charge storage capability of the capacitor, as indicated by its higher dielectric constant compared to air. The calculated gradients confirm the influence of dielectrics, with plastic storing more charge due to its better insulating properties. This illustrates the practical application of dielectrics in improving capacitor performance.