T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY II
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Dielectric constant of different materials

PREPARED BY

NAME AND SURNAME :

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DEPARTMENT :

GROUP NO :

TEACHING ASSISTANT :

DATE OF THE EXPERIMENT : ….. / ….. / ……….

DATE : ….. / ….. / ……….

Signature:

Experimental Procedure:

The parallel plate capacitor is charged with DC voltage. The induced charges on the parallel plates will be determined by means of the measuring amplifier.

C_p = Capacitance of the parallel plate capacitor
C_k = Capacitance of the capacitor on the measuring amplifier [220 nF=220×10^{-9} F]
U = Applied voltage
ΔV = The measured potential difference determined by means of the measuring amplifier.

The potential difference ΔV, which is measured by means of the amplifier, allows to determine the corresponding charge value on the parallel plates;

$$Q = (C_p + C_k)\Delta V \qquad 2.19$$

The capacitance of the parallel plate capacitor is too small compared to the capacitance of the capacitor $C_p \ll C_k$; thus, it can be neglected. Under this assumption, if Equation 2.19 is rearranged, the charge on the capacitor, which is connected to the measuring amplifier, should be;

$$Q = Q_k = C_k\Delta V \qquad 2.20$$

When the potential U is applied, the accumulated charge on the parallel plates of the capacitor can be calculated with Equation 2.21.

$$Q = Q_p = C_pU \qquad 2.21$$

The charge has to be the same for Equations 2.20 and 2.21.

$$Q = Q_k = Q_p \Rightarrow C_k\Delta V = C_pU \qquad 2.22$$

Consequently, the accumulated charge on the parallel plate capacitor can be measured by means of a capacitor whose capacitance value is already known.

The experiment consists of two parts:

(i) *The electric constant ε_0 is to be determined from the relation between charge Q and voltage U.*
(ii) *Determination of dielectric constant of the dielectric (plastic) medium introduced between the plates of a capacitor.*

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I. Measurement of electric constant ε_0 (vacuum permittivity)

The experimental set-up is shown in Figure 2.3 and the corresponding wiring diagram in Figure 2.4.

Figure 2.3: Experimental set-up

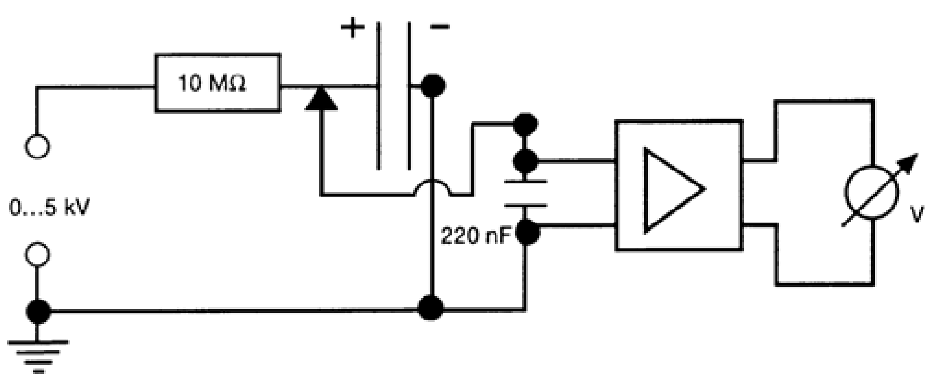


Figure 2.4: Bonding diagram

The highly insulated capacitor plate is connected to the upper connector of the high voltage power supply over the 10 MΩ protective resistor. Both the middle connector of the high voltage power supply and the opposite capacitor plate are grounded over the 220nF capacitor. The measurement amplifier is set to high input resistance, to amplification factor 1 (10^0) and to time constant 0. Correct measurement of the initial voltage is to be assured by the corresponding adjustment of the toggle switch on the unit. The electrostatic induction charge on the parallel plate capacitor can be measured over the voltage on the 220 nF capacitor, according to Equation 2.20.

1. Construct the experimental setup by using Figures 2.3 and 2.4.

2. Adjust the distance between the plates to 2 mm by using the calipers on the plate capacitor.

3. Connect the glass-insulated plate of the parallel plate capacitor to the positive terminal of the 10kV output of the high-voltage power supply by means of a high voltage cable with a protective resistance of 10MΩ and ground the other plate.

4. To charge the parallel plate capacitor, set the charging voltage to the desired U value via the power supply.

5. Wait for 10-15 seconds. At the end, remove the high voltage cable and quickly read the ΔV value from voltmeter by touching the adapter connected to the BNC test cable on the amplifier. ***Do not touch the plates during measurements!***

6. Record the measured values on the voltmeter in the corresponding tables.

Warning 1: *There will be a voltage drop on the 10 nF capacitor because of electric discharges. Therefore, the first maximum value seen on the voltmeter should be taken at each measurement.*

Warning 2: *It is important to note that before each measurement, the parallel plate capacitor must be discharged through contact with the free earth connecting cable, and ensure that the amplifier is reset by pressing the leftmost button.*

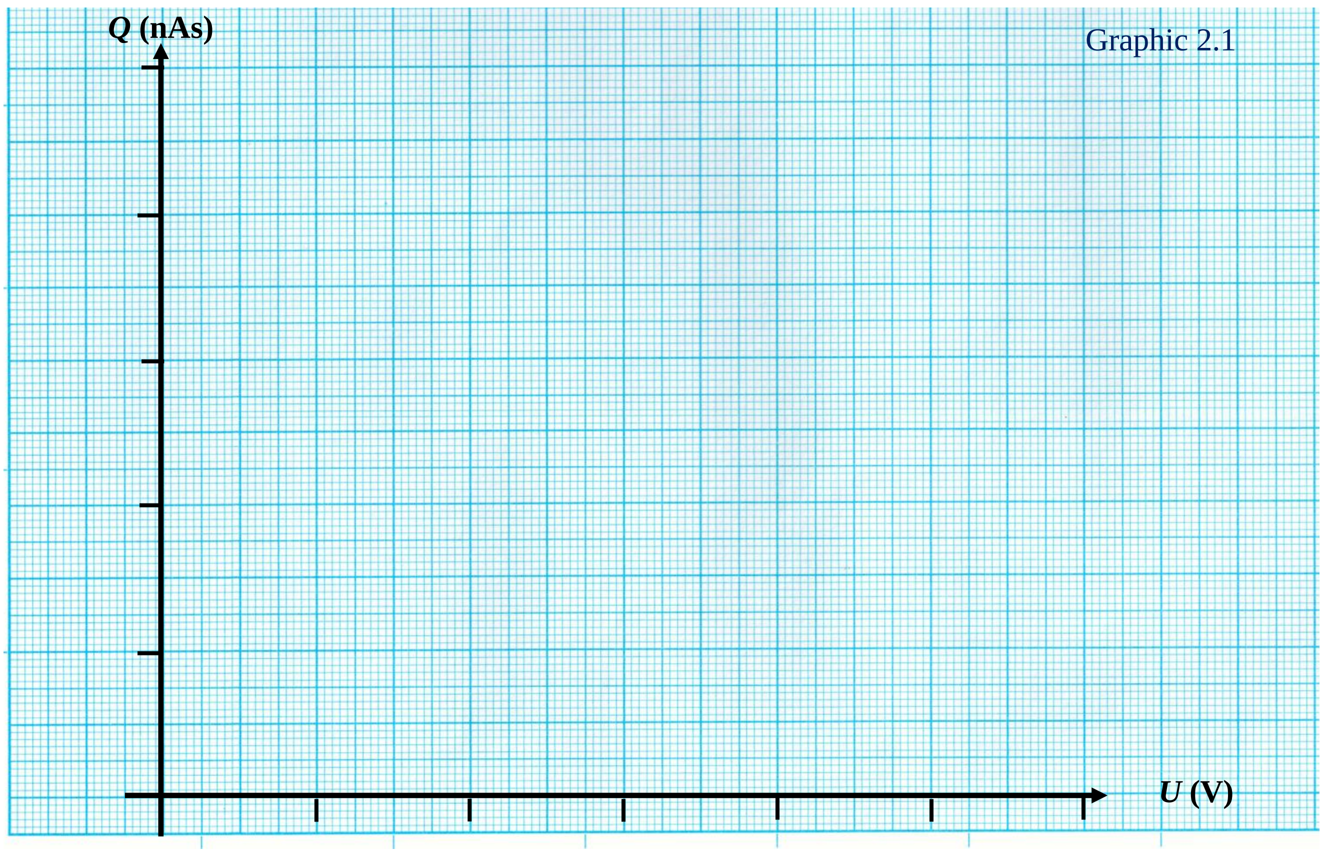
Warning 3: *Be sure not to be near the capacitor during measurements, as otherwise the electric field of the capacitor might be distorted and may cause unexpected errors in your measurements.*

Table 2.1: Record your measurements to the following table by setting the distance between the plates to d = 2 mm.

$A = 0.0531\ m^2$ $d = 2\ mm = 2\times10^{-3}\ m$ $C_k = 220\ nF = 220\times10^{-9}\ F$					
U [V]	500	1000	1500	2000	2500
ΔV [V]					
Q [nAs]					

1. Calculate the values of Q by using the equation $Q = C_k \Delta V$ and fill in Table. 2.1

2. To verify that the charge is directly proportional to the capacitor voltage, plot $U - Q$ graph on reserved millimetric space, where applied voltage U and charge Q are x– and y–axis, respectively. Represent the data as points on your graph. From our previous theoretical explanations, we expect a line in the form of $y = mx$ passing through the data points and the origin, where m is the slope of the line. In the next step, the slope of the line should be calculated by means of the statistical fitting method called "*least squares method*" whose formulae are given below. Draw the $y = mx$ line with calculated slopes over the data points that you have marked on the graph.



3. Calculate the slope of the line that fits the data points on your $U - Q$ graph, which is plotted in previous step. In the formulae, the x_i's represent the U values on the x–axis, while the y_i's represent the Q values on the y–axis of your graphs. k is the number of data used in calculations.

$$\sum_{i=1}^{k} x_i \, y_i =$$

$$m = \frac{\sum_{i=1}^{k} x_i \, y_i}{\sum_{i=1}^{k} x_i^2} =$$

$$\sum_{i=1}^{k} x_i^2 =$$

4. Calculate the electric constant (*vacuum permittivity*) ε_0 by substituting the ***m*** value, which is the slope of the graph and calculated by means of linear fitting procedure above, with known ***A*** and ***d*** parameters into Equation 2.7, $\left[\varepsilon_0 = \frac{Q}{U}\frac{d}{A} \Rightarrow m\frac{d}{A}\right]$ Compare the calculated (*experimental*) value of electric constant ε_0 and its theoretical value 8.85×10^{-12} As/Vm. (*Show your calculations in the blank section below.*)

ε_0 = ……………………… As/Vm

5. Compare experimental and theoretical values of electric constant ε_0 with each other and calculate the relative percentage error. Discuss the causes of the error.

$$\%relative\ error = \frac{|\varepsilon_{experimental} - \varepsilon_{theory}|}{\varepsilon_{theory}} \times 100 =$$

II. Measurement of dielectric constant

The dependence of the electrostatic induction charge on the voltage is measured in the space between the plates at the same distance, with a dielectric plastic slab (without air gap) and without the slab. As shown in Equation 2.17, the ratio between the electrostatic induction charge helps us to determine the dielectric constant ε of the plastic.

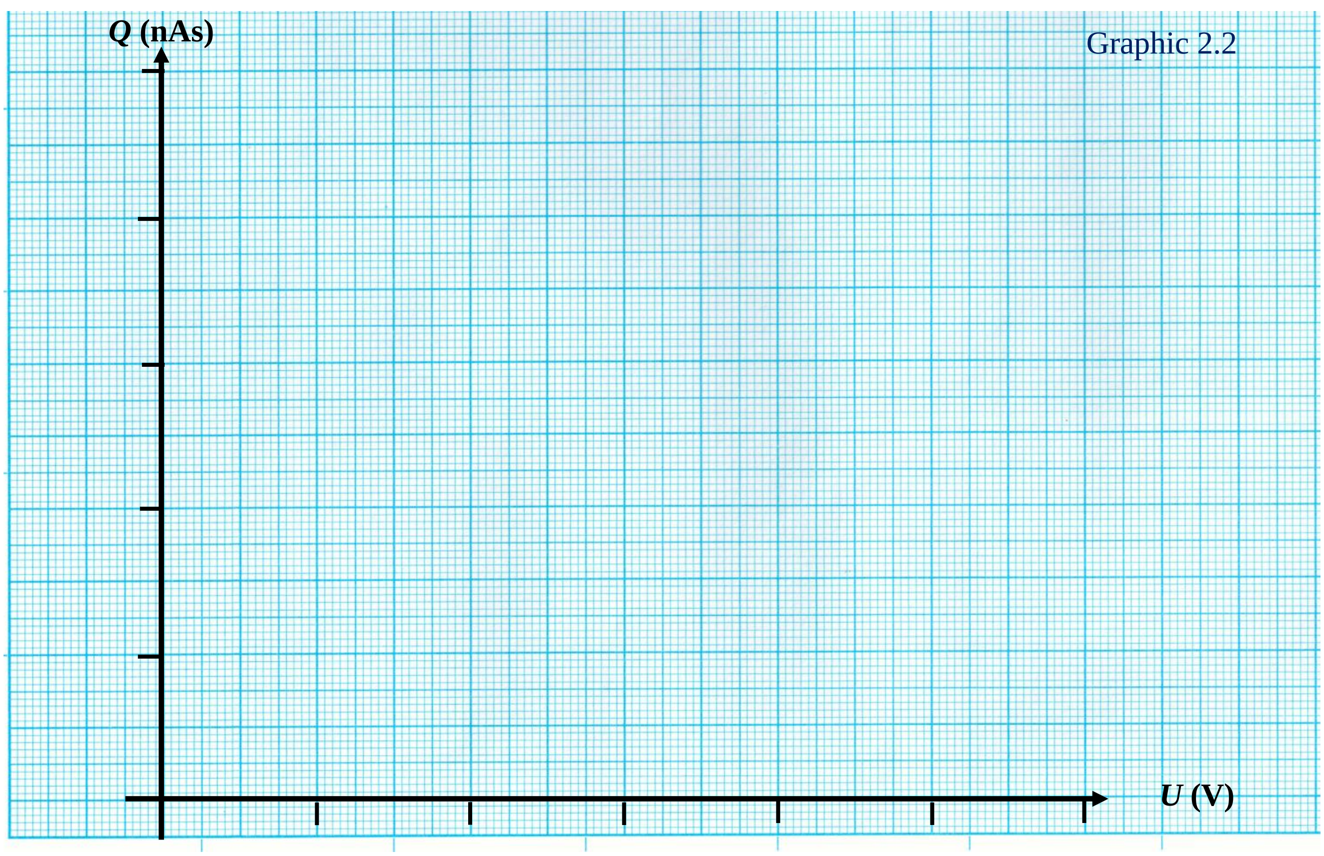
Fix the distance between the plates of the capacitor at 10 mm and apply voltage in the absence of any dielectrics (*air*) between the plates and then insert the plastic slab and increase the voltage from the high voltage source in steps of 1000 V. Record your measurements from voltmeter and fill the ΔV_{air} and $\Delta V_{plastic}$ rows of Table 2.2, respectively.

Table 2.2: Fill the relevant sections of the following table for d = 10 mm, with and without the plastic between the plates of the capacitor.

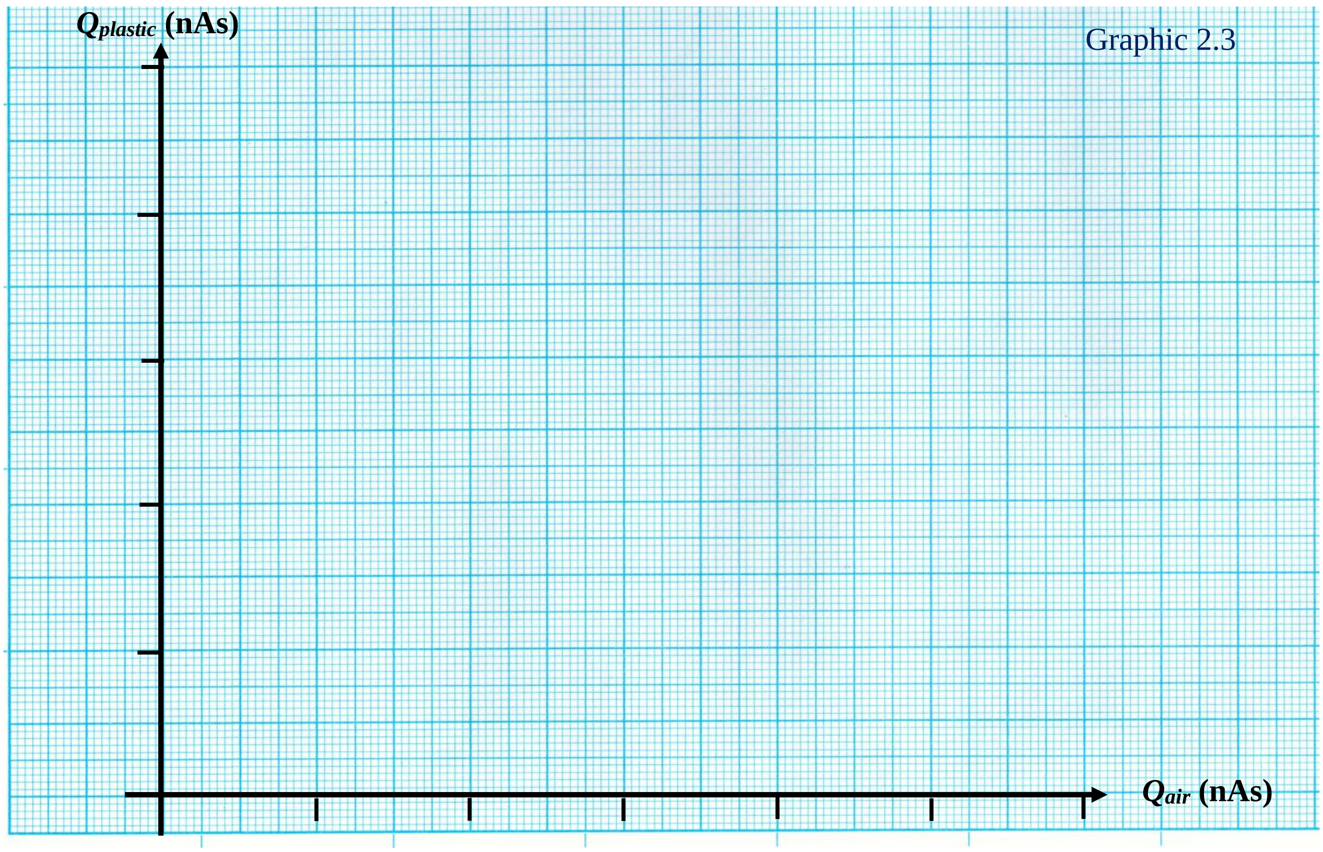
$A = 0.0531$ m^2 $\quad d = 10$ mm $= 10\times10^{-3}$ m $\quad C_k = 220$ nF $= 220\times10^{-9}$ F					
U [V]	1000	2000	3000	4000	5000
$\Delta V_{plastic}$ [V]					
ΔV_{air} [V]					
$Q_{plastic}$ [nAs]					
Q_{air} [nAs]					

1. Calculate the $Q_{plastic}$ and Q_{air} values using the equation $Q = C_k \Delta V$ and fill the rows in Table 2.2.

2. Use the data from Table 2.2, plot both of the U– $Q_{plastic}$ and U – Q_{air} graphs on reserved millimetric space, where applied voltage U and induced charges $Q_{plastic}$ and $Q_{air,}$ are x– and y–axis, respectively. (*Draw with different symbols or colors and show them on the same chart. Do not fit the points for these graphics!!! Draw the most appropriate straight line that passes through the origin and fits best to your data points by crude eye estimation.*) Are the slopes of the lines different from each other? If so, explain why.



3. Plot the $Q_{\text{plastic}} - Q_{\text{air}}$ graph on reserved millimetric space, as x-axis Q_{air} and y-axis Q_{plastic}. Represent the data as points on your graph. Calculate the slope of the $Q_{\text{plastic}} - Q_{\text{air}}$ graph by using the linear fit formulae are given below. Draw the line $y = mx$ where its slope is determined in the following step.



4. Calculate the slope of the line that fits the data points on your $Q_{\text{plastic}} - Q_{\text{air}}$ graph with the help of linear fitting procedure. In the formulae, the x_i's represent the Q_{air} values on the x–axis, while the y_i's represent the Q_{plastic} values on the y–axis of your graphs. k is the number of data used in calculations.

$$\sum_{i=1}^{k} x_i\, y_i =$$

$$m = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

$$\sum_{i=1}^{k} x_i^2 =$$

According to Equation 2.17 the dielectric constant of the material equals to the slope of the $Q_{\text{plastic}} - Q_{\text{air}}$ graph.

$\varepsilon_{plastic} =$ ....

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Conclusion, Comment and Discussion:

(Tips: Explain your general observations and experimental findings objectively and scientifically with your original sentences. Please give detailed explanations about what you have learned from the experiment and also explain the possible errors and their reasons.)

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Questions:

1. Write down the definitions of electric constant (vacuum permittivity) and dielectric constant (relative permittivity)

2. Write down the definition of dielectric material and list the dielectric constants of some materials: vacuum, air, plastic, glass and paper, etc.

3. If you were asked to design a capacitor where small size and large capacitance were required, what factors would be important in your design?

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4. Use the characteristics of the Coulomb force to explain why capacitance should be proportional to the plate area of a capacitor. Similarly, explain why capacitance should be inversely proportional to the separation between plates.

5. Give the reason why a dielectric material increases capacitance compared with what it would be with air between the plates of a capacitor. What is the independent reason that a dielectric material also allows a greater voltage to be applied to a capacitor? (The dielectric thus increases C and permits a greater V.)

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