T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY II
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Capacitance of metal spheres and of a spherical capacitor

PREPARED BY

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DEPARTMENT :
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TEACHING ASSISTANT :
DATE OF THE EXPERIMENT : ….. / ….. / ……….
DATE : ….. / ….. / ……….

Signature:

Experimental Procedure:

Isolated metal spheres and spherical capacitors of different radii are charged with DC voltage. The induced charges on the metal spheres are determined by means of the measuring amplifier. The capacities of the conductive metal spheres and spherical capacitors are found from the voltage and charge values.

C_i = Capacitance of isolated conductive spheres and the spherical capacitor
C_k = Capacitance of the capacitor on the measuring amplifier [10 nF=10×10^{-9} F]
U = Applied voltage
ΔV = The measured voltage determined by means of the measuring amplifier.

The voltage value ΔV, which is measured by means of the amplifier, allows to determine the corresponding charge value on the isolated conductive sphere;

$$Q = (C_i + C_k)\Delta V \qquad 1.8$$

The capacitance of the spherical conductor is too small compared to the capacitance of the capacitor, $C_i \ll C_k$; thus, it can be neglected. Under this assumption, if Equation 1.8 is rearranged, the charge on the conductive sphere has to be

$$Q = Q_k = C_k \Delta V \qquad 1.9$$

When the potential U is applied, the accumulated charge on the spherical conductor can be calculated with Equation 1.10.

$$Q = Q_i = C_i U \qquad 1.10$$

The charge has to be the same for Equations 1.9 and 1.10.

$$Q = Q_k = Q_i = C_k \Delta V = C_i U \Rightarrow \frac{\Delta V}{U} = \frac{C_i}{C_k} \qquad 1.11$$

Consequently, if Equation 1.11 is rearranged for the known C_k value and $\frac{\Delta V}{U}$ ratio, the capacitance of the isolated conductive spheres and spherical capacitor can be calculated with;

$$C_i = C_k \frac{\Delta V}{U} \qquad 1.12$$

The experiment consists of two parts:
(i) *Determination of the capacitance of two metal spheres with different diameters* and
(ii) *Determination of the capacitance of a spherical capacitor.*

I. Determination of the capacitance of three metal spheres with different diameters

The experimental set-up to determine the capacitance of spherical conductors is shown in Figure 1.3.

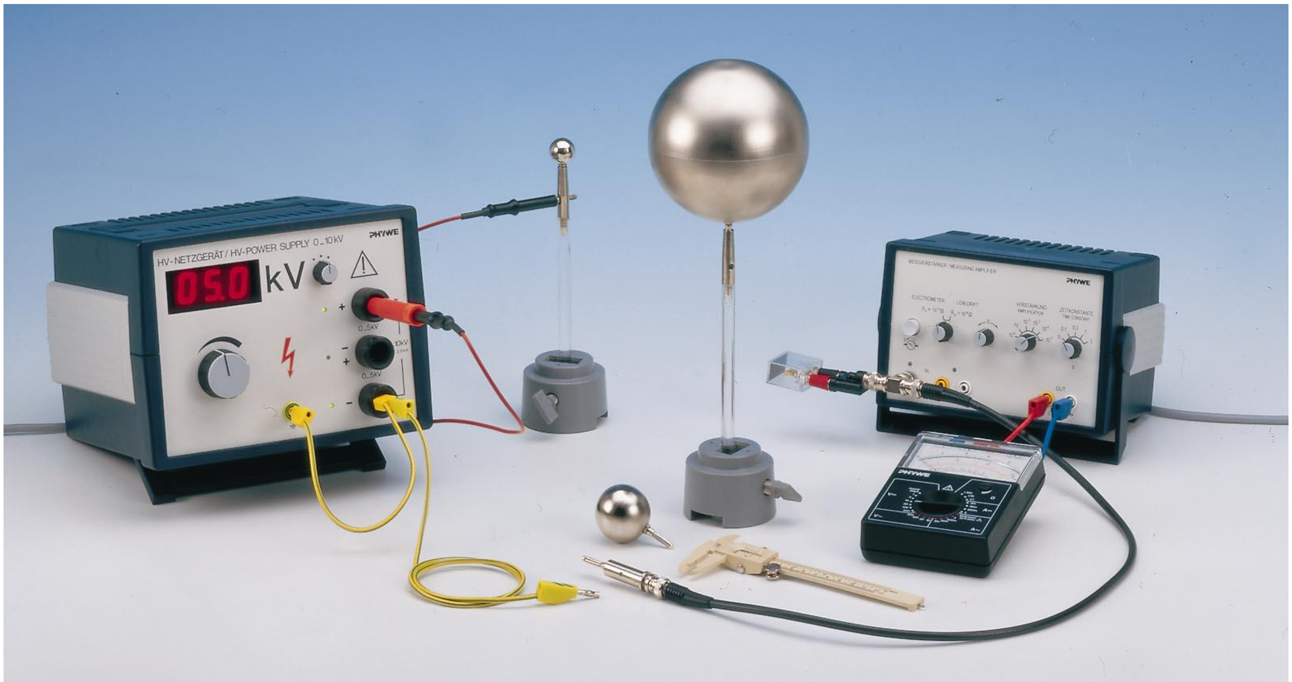


Figure 1.3: The experimental set-up used to determine the capacitance of conductive spheres.

1. Place a conductive sphere to be measured on the insulated glass feet.

2. Connect the conductive sphere held on the insulated feet to the positive terminal of the 10 kV output of the high voltage power supply by means of a high voltage cable with a protective resistance of 10MΩ. The negative pole is earthed.

3. To charge the test sphere, set the charging voltage to the desired U value via the power supply.

4. Wait for 10-15 seconds, then 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 metal spheres during measurements!***

5. 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 test sphere must be discharged through contact with the free earth connecting cable, and ensure that the amplifier is reset by pressing the leftmost button on the amplificatory.*

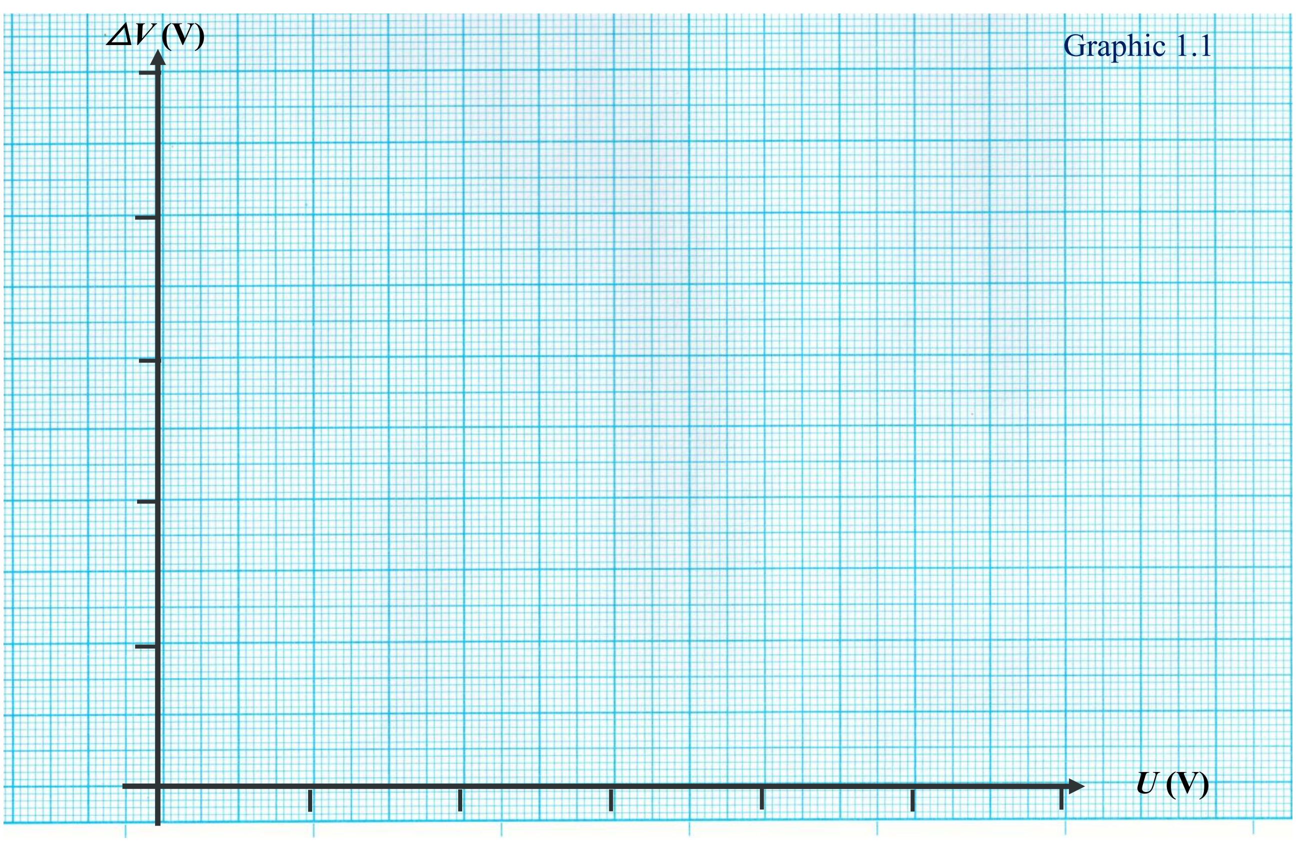
Never apply high voltage to the amplifier input.

Take your measurements for the two conductive spheres and fill the following tables. Write units of your measured values.

$2R_1 = 0.121$ m		
	U (Volt)	ΔV ( )
	0	0
1	1000	
2	2000	
3	3000	
4	4000	
5	5000	

$2R_2 = 0.041$ m		
	U (Volt)	ΔV ( )
	0	0
1	1000	
2	2000	
3	3000	
4	4000	
5	5000	

1. For each metal sphere, plot $U - \Delta V$ graphs on reserved millimetric space, where applied voltage U and read voltage ΔV are x– and y–axis, respectively. Represent the data as points on your graph. According to Equation 1.12, 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 slopes of the lines should be calculated by using the "*least squares method*" its formulae are given below. Draw the $y = mx$ lines with calculated slopes over the data points that you have marked on the graph. Are the slopes of the lines different from each other? If so, explain why?



2. Calculate the slopes of the lines that fit the data points on your $U - \Delta V$ graphs, which are plotted in the previous step. In the following formulae, the x_i's represent the U values on the x–axis, while the y_i's represent the ΔV values on the y–axis of your graphs. k is the number of data used in calculations.

i) R1

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

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

$$m_1 = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

ii) R2

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

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

$$m_2 = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

3. Substitute the slope $m = \frac{\Delta V}{U}$ values obtained from the linear fit calculations with known C_k=10nF=10×10^{-9} F in the equation $C_i = C_k \frac{\Delta V}{U} = C_k m$ and calculate the experimental capacitance values of the conductive spheres. [1 pF=1×10^{-12} F] (*Show your calculations in the blank sections below*.)

C_1=…………….... As/V = ……… pF

C_2=……….……. As/V = ……… pF

4. Calculate the theoretical capacitance of the conducting spheres using the formula $C = \frac{Q}{\Delta V} = 4\pi\varepsilon_0 R$ [ε_0= 8,86 10^{-12} As/Vm] [1 pF=1×10^{-12} F] (*Show your calculations in the blank sections below*.)

C_1=……………. As/V = ……… pF

C_2=……………. As/V = ……… pF

5. Compare experimental and theoretical values of capacitances with each other and calculate the relative percentage error.

1) $\%relative\ error = \frac{|C_{experimental} - C_{theory}|}{C_{theory}} \times 100 =$

2) $\%relative\ error = \frac{|C_{experimental} - C_{theory}|}{C_{theory}} \times 100 =$

II. Determination of the capacitance of a spherical capacitor

The experimental set-up to determine the capacitance of spherical capacitor is shown in Figure 1.4.

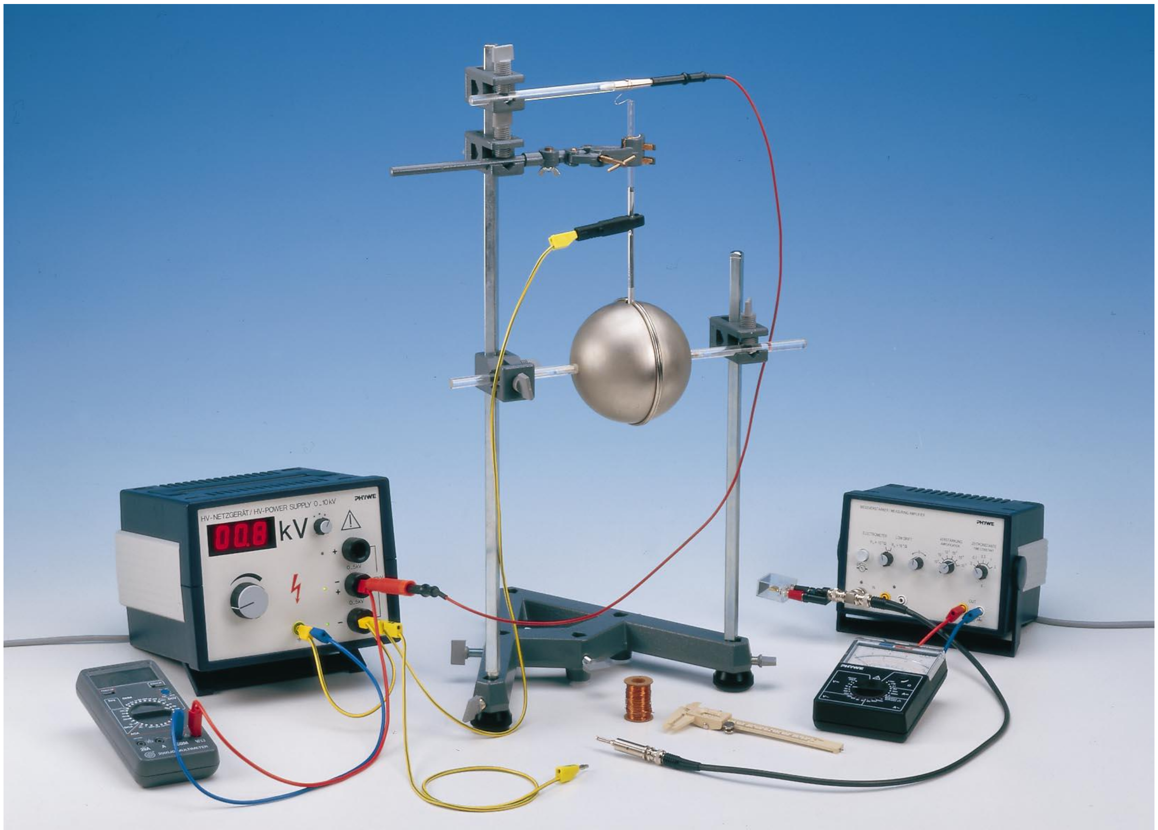


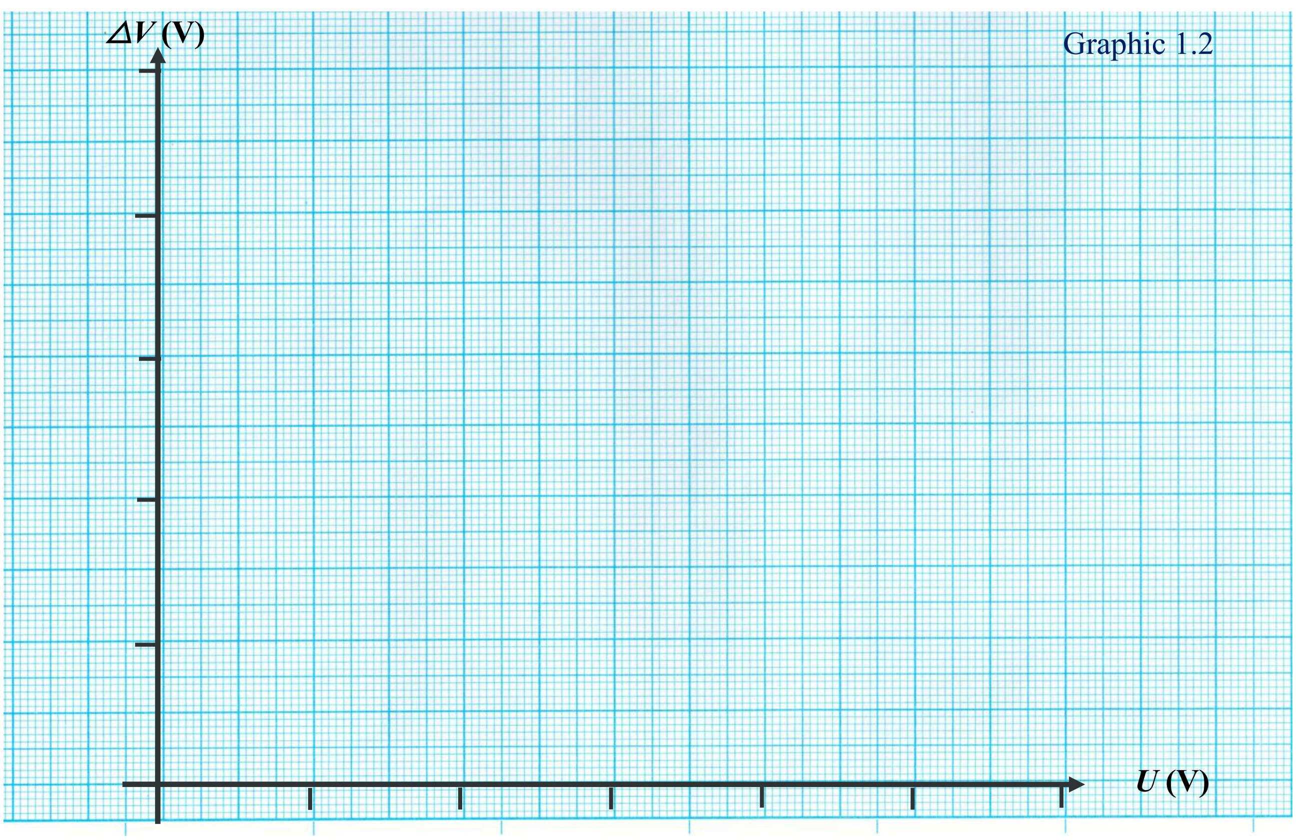
Figure 1.4: The experimental set-up used to determine the capacitance of a spherical capacitor

The experimental set-up must be altered to determine the capacitance of the spherical capacitor, as shown in Figure 1.4. The Cavendish hemispheres are put together to form a complete sphere with a small circular orifice at the top. The plastic sphere with conducting surface is suspended from a copper wire in the center of the sphere. The copper wire is lead through a glass capillary tube which is wrapped in earthed aluminum foil to neutralize stray capacitances (Fig. 1.4). The aluminum foil must not touch the hemispheres. Before connecting the 10 MΩ protective resistor, the inner sphere must be connected to the central socket of the high voltage power supply by using the crocodile clip tied to the high voltage cord. The lower socket is earthed again. Measurements for hemispheres must be taken while the hemispheres are connected to the power supply, unlike the first part of the experiment. After each measurement, the hemispheres must be discharged with the free earthling cord. Whilst doing this, it must be assured that no high voltage is induced.

For the spherical capacitor, fill the following table. Write the units of your measured values.

R_1 = 0.019 m, R_2 = 0.062 m		
	U (Volt)	ΔV ( )
	0	0
1	1000	
2	2000	
3	3000	
4	4000	
5	5000	

1. Plot $U - \Delta V$ graph on reserved millimetric space, where applied voltage U and read voltage ΔV are x– and y–axis, respectively. Represent the data as points on your graph. According to Equation 1.12, 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 using the "*least squares method*" its formulae are given below. Draw the $y = mx$ line with calculated slope over the data points that you have marked on the graph.



2. Calculate the slopes of the lines that fit the data points on your $U - \Delta V$ graphs, which are plotted in the previous step. In the following formulae, the x_i's represent the U values on the x–axis, while the y_i's represent the ΔV values on the y–axis of your graphs. k is the number of data used in calculations.

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

$$m_3 = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

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

3. Substitute the slope $m = \frac{\Delta V}{U}$ value obtained from the linear fit calculation with known C_k=10nF=10×10^{-9} F in the equation $C_i = C_k \frac{\Delta V}{U} = C_k m$ and then calculate the experimental capacitance value of the spherical capacitor. [1 pF=1×10^{-12} F] (*Show your calculations in the blank sections below.*)

C=………… As/V = ……… pF

4. Calculate the theoretical capacitance of the spherical capacitor by using the formula $C = \frac{Q}{\Delta V} = 4\pi\varepsilon_0 \left[\frac{R_1 R_2}{R_2 - R_1}\right]$ [ε_0= 8,86 10^{-12} As/Vm] [1 pF=1×10^{-12} F] (*Show your calculations in the blank sections below.*)

C=………… As/V = ……… pF

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

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

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.)

Signature:

Questions:

1. Derive the units of capacitance farad in terms of basic physical quantities of SI system.

2. Does the capacitance of a device depend on the applied voltage? What about the charge stored in it?