NATIONAL UNIVERSITY OF TECHNOLOGY

COMPUTER ENGINEERING DEPARTMENT

Applied physics Lab (PHY13002)

Experiment No:1

Title: Experimental verification of Coulomb's law

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Objectives:

1. Establishment of relationship between active electrostatic force and charge on ball.
2. Establishment of relationship between force and distance(ball to metal plate).
3. Determination of electric constant

Apparatus:

1. Spheres hanging with plastic rods (×2).
2. Conducting ball placed on insulating stem (×2).
3. Torsion Dynamometer
4. DC supply(0-16kv)
5. Plate capacitor (283*283)
6. DC measuring amplifier
7. Digital Multimeter

Theoretical explanation:

Columb's law states that like charges repel and opposite charges attract, with a force proportional to the product of the charges and inversely proportional to the square of the distance between them. This experiment was performed to prove this law and make us understand what happens to a ball when charged by a conductor ball on a plastic stem in the presence of an electric field.

This experiment examines the relationship between electrostatic force and electric charge using a charged conducting sphere and plates. Based on Coulomb's Law, the electrostatic force between charges depends on the charge and distance. A torsion dynamometer measures the force on the sphere when charged, and the force increases with the applied voltage. The experiment involves varying voltage (10-16 kV) and distance (4-6 cm) to observe the changes in force. As the distance increases, the force weakens. The experiment confirms the relationship between electric charge, voltage, and force, validating fundamental principles of electrostatics. As the distance increases, the force weakens, and no deflection is seen at lower voltages for larger distances. The results confirm fundamental electrostatic principles, demonstrating how force depends on charge and distance.

Procedure:

a. The distance between the center of the conducting sphere and the plates was set to 4 cm.
b. The torsion dynamometer's arm was adjusted back to its starting position using the upper turning knob.
c. The high voltage (U) was set to 5 kV.
d. The conductor ball was used to charge the conducting sphere.
e. The arm of the dynamometer was returned to its starting position using the upper knob to apply counterforce.
f. Once the initial position was restored, the charge (Q) on the conducting sphere was measured, and the applied force (F) was recorded.
g. After measuring the charge, the discharging button on the DC amplifier was pressed to reset the multimeter to zero.
h. Since measuring the charge discharged the sphere, it was moved away from the plate.
i. This same process was repeated for 10, 12, 14, and 16 kV.
j. The applied force was set back to "ON," and the initial position of the discharged sphere was checked to see if it remained the same.
k. The distance was then increased to 6 cm, with measurements taken at each 1 cm step.
l. Finally a table was made to record each value

Observations and Calculations:

1.Measurements at 4-6cm:
The experiment was conducted at distances of 4 cm, 5 cm, and 6 cm. For each distance, the voltage (U) was varied from 10kV to 16 kV, and the charge (Q) and applied force (F) were recorded. The force decreased as the distance increased, as expected.

2.Graphing the Results:
Graphs were plotted for each distance with force (F) on the y-axis and voltage squared (U^2) on the x-axis. A linear relationship between force and voltage squared was observed for all distances.

3.Slope Calculation:
The slope of each graph was calculated using slope=ΔFΔU2\text{slope} = \frac{\Delta F}{\Delta U^2}slope=ΔU2ΔF, which represents the relationship between electrostatic force and voltage. The slope decreased as the distance increased, reflecting the inverse-square nature of the force.

4.Final Observations:
As the distance increased from 4 cm to 6 cm, the force became weaker. At 6 cm, deflections were minimal at lower voltages, confirming the expected decrease in electrostatic force with distance.

Task1:

Table 1: The Measurement of Charge Q and Force F for different distances.

U voltage	Distance :4cm		Distance:5cm		Distance :6cm	
	Q	F/mN	Q	F/mN	Q	F/mN
10	12	0.08	14	0.2	15	0.08
12	20	0.25	20	0.35	18	0.13
14	23	0.35	23	0.45	21	0.2
16	26	0.45	25	0.52	26	0.32

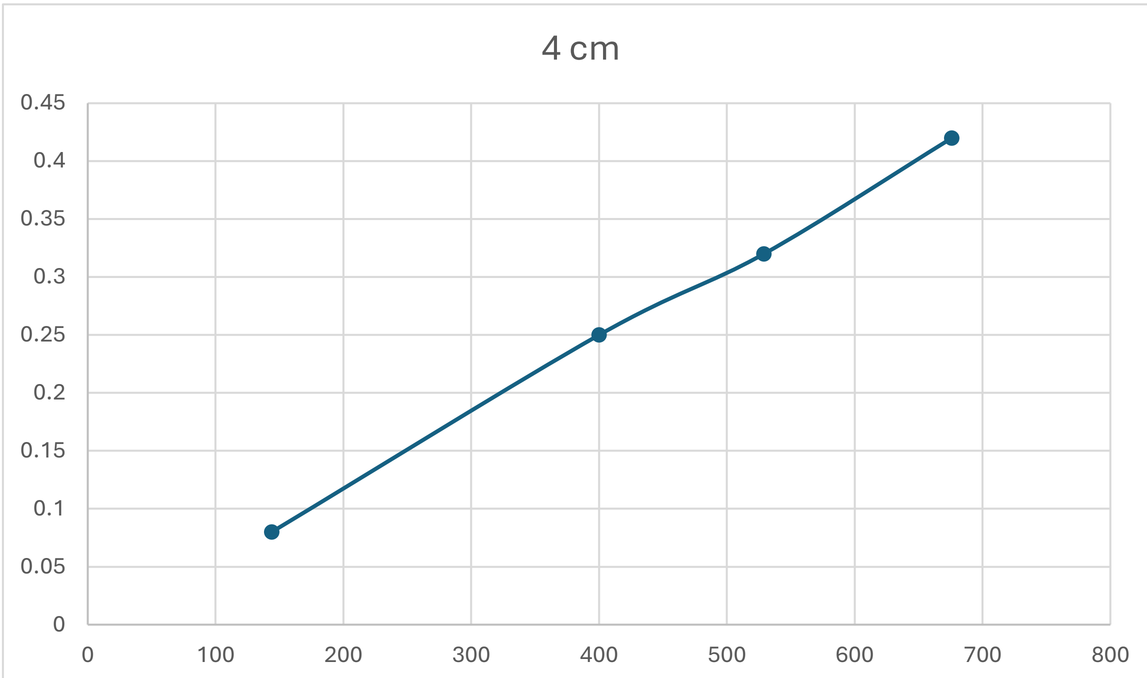
Result and Analysis:

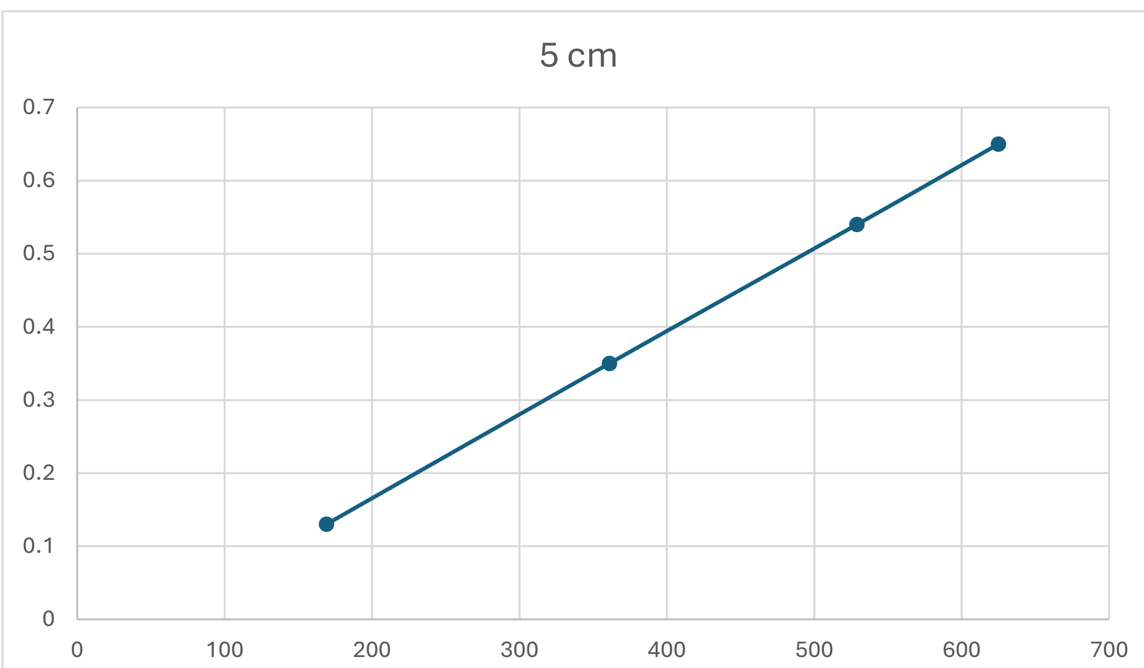
The experiment aimed to determine the value of Epsilon (ε_0) by conducting measurements at varying distances. Data was collected for distances of 4, 5, and 6 units, as represented in the table above. Graphs were plotted for each of these distances to observe the relationship between the variables involved. To calculate the slope of these graphs, a specific formula was employed. This slope is crucial, as it directly relates to the value of Epsilon not, providing insights into its behavior. The accuracy of the calculated slope plays a key role in verifying the experiment's results.

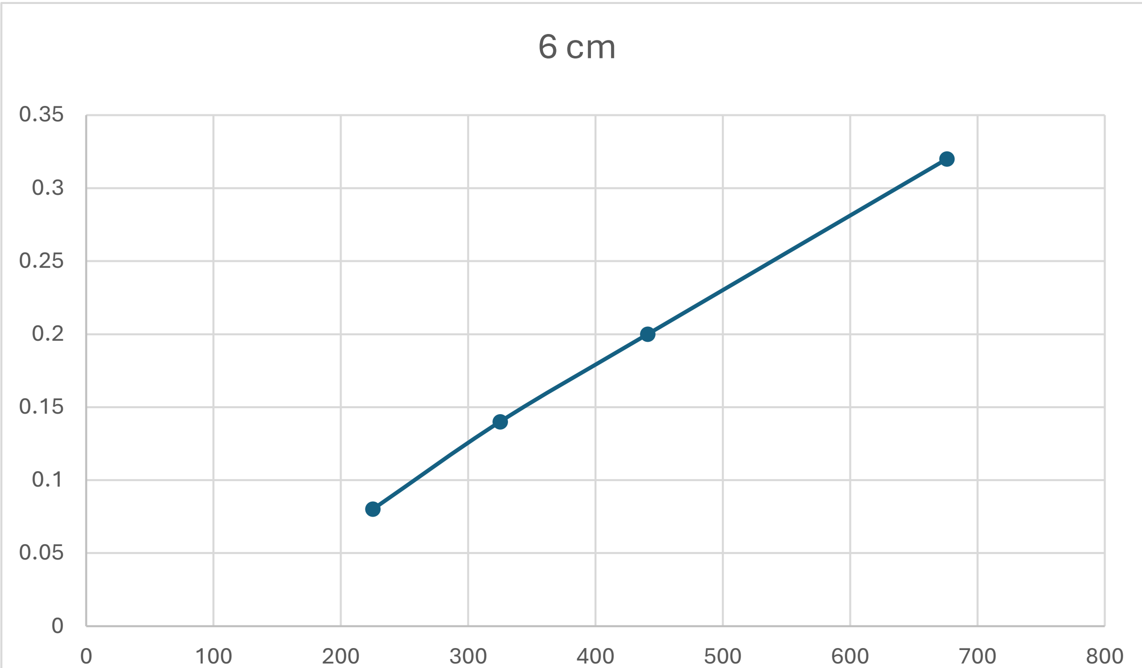
Slope of Graph formula = $\frac{y2-y1}{x2-x1}$

First Calculation of slope = $\frac{0.45-0.08}{26-12}$ =0.26×10^{11} , this is how we have calculated slope at each distance and used them to get in the next part of the experiment.

Graphs at each Distance:







Task 2:

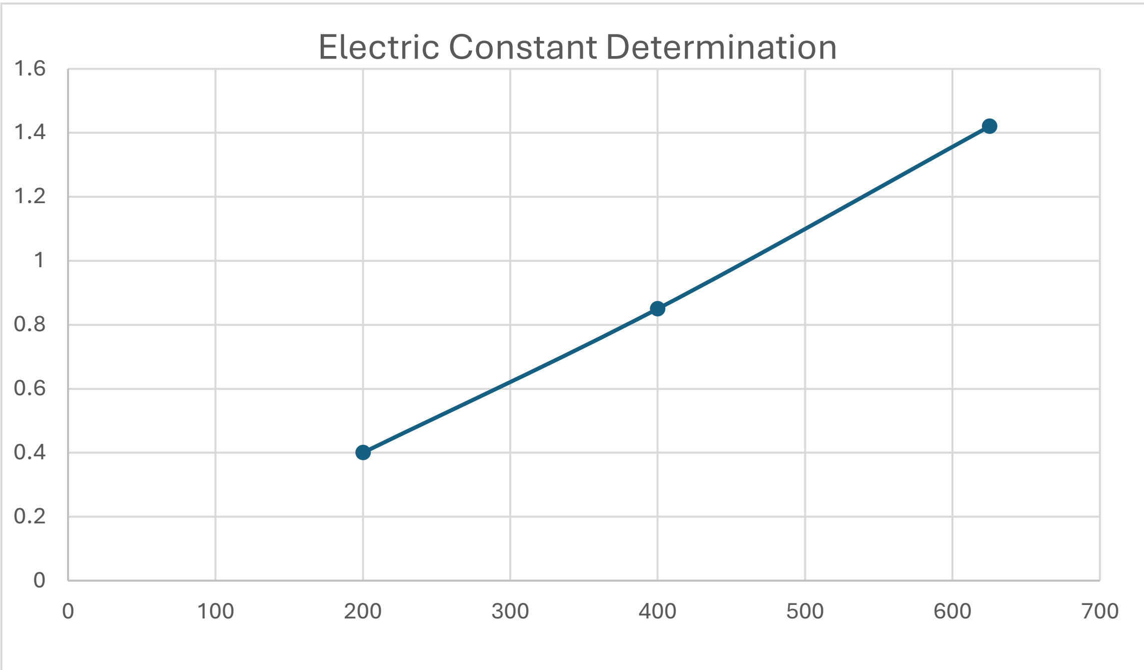
The table below shows the values for the distance between the conducting ball and the hanging ball, as well as the inverse square of the distance. Additionally, it includes the proportionality factor. The slope of the lines from the graph above has been multiplied by 10^{12}.

$$\text{Slope} = \ M \ = \frac{y2-y1}{x2-x1}$$

To find the slope we will compute the data from Table 2 as shown:

$$\text{Slope} = \frac{0.26-0.21}{625-277} = 0.0014\times10^{12}$$

Distance a (m)	$1/a^2$ (m^{-2})	Proportionality
0.04	625	0.26×10^{12}
0.05	400	0.29×10^{12}
0.06	277	0.21×10^{12}



Task 3:

The graph above can be used to calculate the experimental value of Epsilon not. To calculate the epsilon value, we need the slope of this graph which will be used in our formula.

Slope calculated in experiment: 0.0024

$$E=\frac{1}{16\pi S}$$

This will give us experimental value. Now we must compare the theoretical value and calculate our result and how much error has occurred in our experiment.

Result:

The calculated value of Epsilon not (ε_0) was 8.28×10^{-11}, while the theoretical value is 8.85×10^{-11}, resulting in a 6.44% error. This difference highlights the importance of accurately measuring the distance between the conducting ball and the hanging ball, as even small changes in distance affect the inverse square law, which plays a key role in electrostatic calculations. The slope of the graph, derived from the force and voltage measurements, is crucial for determining ε_0.

Precaution:

- Ensure that the torsion dynamometer is precisely aligned before starting the experiment.
- Avoid contact between the conducting ball and the plate, as this will introduce errors in the charge and force measurements, leading to incorrect results.
- Confirm that the suspended balls are fully stationary and stable before taking measurements.
- Handle the conducting ball with the insulated stem when adjusting its position to avoid disturbing the charge.
- Reset the charge on the hanging ball to zero before each new trial.

Comments:

- **Distance and Force Relationship:** The experiment successfully demonstrated that as the distance between the conducting ball and the hanging ball increased, the electrostatic force decreased, which aligns with theoretical expectations.
- **Graphing Consistency:** The plotted graphs showed a clear linear relationship between force and voltage squared, confirming the inverse-square nature of electrostatic forces. However, achieving precise measurements required careful control of distance.
- **Challenges with DMM Readings:** One of the key challenges was with the Digital Multimeter (DMM) readings, as each time the charge was measured, it caused the ball to discharge. This required resetting the system after every measurement, adding complexity to the process.
- **Recharging After Every Reading:** After every DMM reading, the conducting ball had to be recharged to restore accurate conditions for the next measurement. This slowed down the experiment and required meticulous care to maintain consistency.
- **Slope Sensitivity:** Calculating the slope for each graph was straightforward, but even minor errors in voltage or force measurements had a noticeable impact on the final value of Epsilon not (ε_0), showing the importance of precision.
- **Stability of Equipment:** Ensuring that the suspended balls were completely stationary before each reading was a challenge, as even slight movement could alter the measurements and affect the accuracy of the force reading