Laboratory Report 1 – Ryan White (44990392) - PHYS1002

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Introduction:

It has been defined that electric fields create forces on charges in their vicinity, where various apparatus are designed to create fields and test this. A Van de Graaff generator could be used to create an imbalance of charge on a sphere by transferring positive charges to the exterior surface of an attached metallic sphere. In doing this, a positive, radiating electric field is created, with the surface of the attached sphere as the source. In doing this, and defining the electric field and charges, the theoretical force on a conducting ball could be calculated given a predetermined distance from the sphere's surface. The aim of the experiment was to determine the force on a conducting ball at a distance 'd' from a charged sphere as the result of an electric field.

Specifically in this investigation, a conducting ball was weighed and situated on scales and a field created. The field, based on prior theory [1], was defined to induce an attractive force on the polarised conducting ball, implying a 'negative' weight on the scales as downward force is lessened in the presence of an upwards force.

Theory:

Coulomb's Law is described as the relationship between charge and distance, and is given by [1]

$$F_{on\ q} = K\frac{|q_1||q_2|}{r^2}$$

Where, $F_{on\ q}$ is the resultant force on a charge in the influence of an electric field as a product of charges q_1 and q_2 and at a distance r from the charges. The constant K is defined as

$$\frac{1}{4\pi\epsilon_0}$$

Using Coulomb's Law, the force on a charged (or polarised) object may be calculated given defined variables. While the distance r is controlled, the charges of the two analysed spheres are not known.

To obtain values for force from raw data of force, the force equation must be calculated with obtained values for mass and known values of attraction (Earth's gravity of $9.8 m/s^2$):

$$F = ma$$

Since the conducting ball will be polarised under a non-uniform electric field of a sphere, the ball will be attracted to the electric field source [1], and thus a negative weight (force in the upwards direction, countering gravity's downward force) is expected to be seen.

To ultimately test Coulomb's Law, the obtained values for force must be plotted against values for r. The theory predicts that an inverse square relationship is present, where the field is stronger in close proximity to the source.

Experimental Arrangement:

A metallic grounding ball was suspended via a retort stand directly above an acrylic tube. The grounding ball was connected to the Van de Graaff generator via a wire, so that the grounding ball would be directly charged. The acrylic tube was situated upon scales, with a funnel atop the tube with a conducting ball held securely in the funnel. The scales were zeroed after the ball was placed atop, and the distance between the grounding ball and conducting ball was measured with a ruler and recorded. The Van de Graaff generator was then charged using a uniform clockwise rotation, and any weight change in the scales were recorded. This process was completed multiple times with varying distances between the grounding ball and the conducting ball.

Results and Discussion:

With a constant conducting ball mass, beginning at zero before every data entry, the distance (d, measured in metres) was changed with every data iteration. Values in table 1 show the observed change in ball mass in relation to the change in distance between the conducting ball and the source of the field.

A value of uncertainty for each measurement of distance was defined as ±2mm (or ±0.002m) due to difficulties in observing marked increments in the ruler used. In conjunction with this, the spherical shape of each of the measured balls made it difficult to accurately define exact starting and ending points for each measurement.
A degree of ±0.001g of error was decided upon for the observed mass due to acute fluctuations of the maximum mass value. Instead of the mass plateauing at a singular value, it ranged between two values about a central point. Given the scales accuracy to within a thousandth of a gram, this was the agreed upon uncertainty.

Table 1: Summary of Obtained Data

Distance (m) (+/- 0.002m)	Mass (g) (+/-0.001g)	Force (N) (+/-0.00981N)
0.094	0.002	0.01962
0.092	0.004	0.03924
0.078	0.012	0.11772
0.067	0.002	0.01962
0.045	0.053	0.51993
0.038	0.053	0.51993
0.016	0.1	0.981
0.015	0.098	0.96138
0.004	0.45	4.4145

Values for the force were calculated with the observed values of mass and the known value of gravity($9.8m.s^{-2}$). Take, for example, the calculation of the first data entry

$$F = ma = 0.002\times 9.81 = 0.01962N$$

As the error in the mass calculation was one one-thousandth of a gram, the error in the force is as follows

$$\Delta F = \Delta m \times g = 0.001\times 9.81 = 0.00981$$

In an effort to accurately depict a linear relationship of an inverse square relationship, the values for force and distance were calculated as natural logarithms, where the original values were multiplied by 1000 each to return positive logarithm values. The new data entries may be seen in table 2.

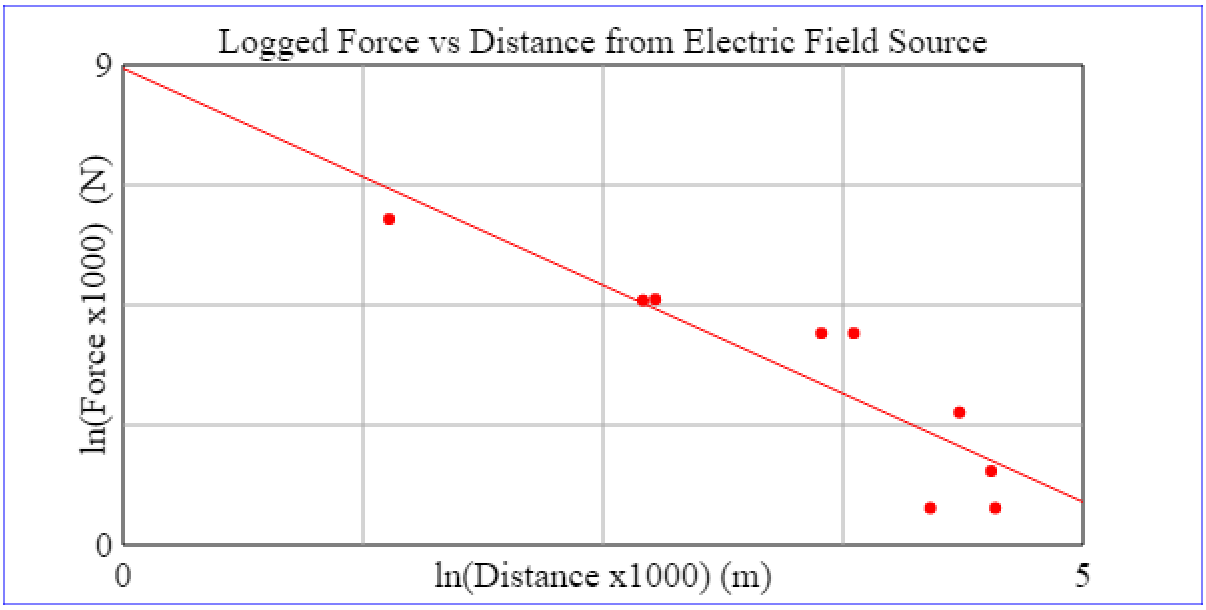
Table 2: Log Data

Distance (m)	Force (N)	$\log_e$(Distance x 1000)	$\log_e$(Force x 1000)
0.094	0.01962	4.543294782	2.976549454
0.092	0.03924	4.521788577	3.669696635
0.078	0.11772	4.356708827	4.768308923
0.067	0.01962	4.204692619	2.976549454
0.045	0.51993	3.80666249	6.253694187
0.038	0.51993	3.63758616	6.253694187
0.016	0.981	2.772588722	6.88857246
0.015	0.96138	2.708050201	6.868369752

0.004	4.4145	1.386294361	8.392649856

Linear regression of the data yields a line of best fit with the equation:

$$y = -1.63(\pm 0.3)x + 8.9(\pm 1.1)$$



As can be seen, the line of best fit (obtained by linear regression) only very loosely follows the theorised relationship – although a scattered trend may be seen.

Conclusion:

The calculated relationship between distance between an electric field source and a charge and the resultant force due to the field was not as expected. Although a log graph shows a loose correlation, the results are far from definitive and as such, a valid conclusion may not be made as to the validity of Coulomb's Law based solely on the results of this experiment.
Future experiments, with more defined and controlled variables would be recommended in an effort to justify the validity of the model.

References:

1. Knight, R.D (2015) *Physics for Scientists and Engineers with Modern Physics*, Pearson.