ILLINOIS INSTITUTE OF TECHNOLOGY - PHYS 221 L03

Lab Report - Lab 01: Coulomb's Law

September 15, 2020

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Lab 01
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Coulomb's Law

Introduction

The purpose of Lab 01 was to examine Coulomb's Law. There were two targets for Lab 01. The first was to analyze the transfer of charge between different rods charged with different materials. This was achieved through the usage of pith balls and rods. The second target was to design and carry out an experiment to determine the charge of the other rods when rubbed with different materials (silk, plastic, wool, mystery fur) based on how an acrylic rod gains a positive charge when rubbed with silk.

Equations:

1. $F = k\frac{q1q2}{r^2}$

   F = force
   k = constant: 9×10^9
   q1,q2 = charges
   r = radius

Experimental Methods

1. Get some colored pith balls (each weighing 0.04g), mirror scales, and conduction rods
2. For part 1, take the mass of the pith ball and the length from center of the pith ball to the pivot. Charge 2 conduction rods with several different materials by rubbing them, and see how the pith balls react. The materials are: wool/felt, silk, plastic bag sheet (polyethylene), hair, and mystery fur.
3. Drag the rod across the metal support where the string is tied to when pith balls are charging.
4. Estimate the separation distance and calculate the angle where the pith balls have maximum separation when using the scale mirror.
5. Repeat part 1 with different rods.
6. For part 2, charge the pith balls with the different rods by rubbing them with silk and observe the reaction when the lucite/acrylic rod is placed near the pith balls. Find the kind of charge the rods have by observing how the pith balls react. Also record how the pith balls move.

Results and Discussion

Below is the Table 1 that contains the data recorded.

Table 1:

Rod	Material	Separation (m)
Lucite/acrylic	polyethylene/plastic	0.07
Lucite/acrylic	silk	0.04
Lucite/acrylic	wool	0.02
Lucite/acrylic	mystery fur	0.01
hard rubber	mystery fur	0.05
hard rubber	wool	0.04
hard rubber	silk	0.02
hard rubber	polyethylene/plastic	0.01

The data table is organized from left to right, the type of rod rubbed by a certain material, and the separation of the pith balls measured in meters. The most notable separations were with the lucite/acrylic rod rubbed by polyethylene/plastic with a separation of 0.07m, hard rubber rubbed by mystery fur with a separation of 0.05m, and lucite/acrylic rubbed by silk as well as hard rubber rubbed by wool having a separation of 0.04m. This shows that there was more electric charge transferred to separate the pith balls by a marginally bigger amount than the other trials. The rest showed very little separation, ranging from 0.01m to 0.02m.

Below is Table 2 pertaining to part 2 of the experiment, which has some qualitative data about the experiment.

Table 2:

Scenario	Separation	Observation	Charge of Rod
Pith balls charged with the nylon rod rubbed with silk	moderate separation of pith balls	pith balls deflect away from the acrylic rod rubbed with silk	positive
Pith balls charged with the acetate/rayon rod rubbed with silk	little to no separation of pith balls	pith balls deflect slightly towards the acrylic rod rubbed with silk	negative
Pith balls charged with the hard rubber rod rubbed with silk	moderate separation of pith balls	pith balls deflect towards the acrylic rod rubbed with silk	negative
Pith balls charged with the PVC/vinyl rod rubbed with silk	large separation of pith balls	pith balls deflect towards the acrylic rod rubbed with silk	negative
Pith balls charged with the nylon rod rubbed with plastic	moderate separation of pith balls	pith balls deflect away from the acrylic rod rubbed with plastic	positive
Pith balls charged with the acetate/rayon rod rubbed with plastic	little to no separation of pith balls	pith balls deflect slightly away from the acrylic rod rubbed with plastic	positive
Pith balls charged with the hard rubber rod rubbed with plastic	little to no separation of pith balls	pith balls deflect slightly towards the acrylic rod rubbed with plastic	negative

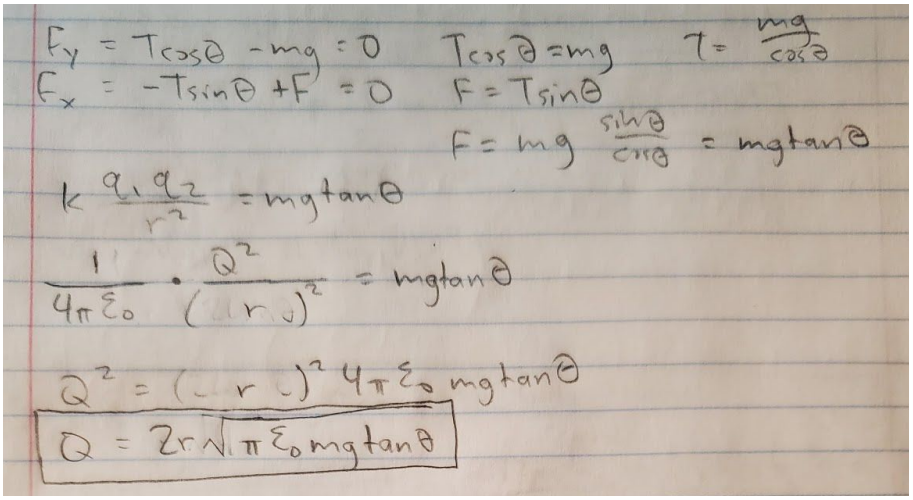
Pith balls charged with the PVC/vinyl rod rubbed with plastic	moderate separation of pith balls	pith balls deflect towards the acrylic rod rubbed with plastic	negative

Based off of figure 2 of the lab manual that shows electronegativity ranking of the materials, and the information of a negative charge is found when rubbing a PVC rod with silk, we were able to determine the charges of the rods and the magnitudes of the charges by looking at the behavior of the pith balls and the separation of the pith balls respectively. A trend that was found was that the pith balls deflect away from the rod when the charge of the rod was positive, and when the pith balls deflect slightly towards the rod, then the rod charge was negative.

Some errors that could have caused erroneous results could be a rod and material not discharging the pith balls fully. Another error that may have caused no separation between a rod and a material could have been due to not rubbing the rod with the material long enough.

Questions

1. Using the free body diagrams of Figure 3, derive an expression for the charge in terms of the pith ball mass *m*, and the separation distance "r".



2. Calculate the charge on the pith balls for each rod/soft material combination. How many millions or billions of electrons reside on each pith ball?
    a. Using the equation derived from the first question, we can calculate the charge of the pith balls, and then find the number of electrons by dividing the charge by the electron charge of 1.6 x 10^{-19}C. To find tan(θ) since we don't know the value of θ, we found y and x since tan(θ) = y/x. tan(θ) = $\frac{(1/2)r}{\sqrt{L^2-(1/4)r^2}}$.

Rod charged with Material	Charge (C)	# of e
lucite/acrylic charged with polyethylene/plastic	0.000000006087067085	38044169284
lucite/acrylic charged with silk	0.000000002616239475	16351496720
lucite/acrylic charged with wool	0.0000000009233211728	5770757330

lucite/acrylic charged with mystery fur	0	0
hard rubber charged with mystery fur	0.000000001168951483	7305946771
hard rubber charged with wool	0.0000000008353009793	5220631120
hard rubber charged with silk	0.000000000294793763	1842461019
hard rubber charged with polyethylene/plastic	0.0000000001041787741	651117338

3. Compare the extremely small gravitational attraction between the two pith balls with the repulsion of the electrostatic force.
    a. The gravitational attraction is a lot weaker than the electrostatic force. Since small masses equal weaker gravitational attraction, even though electrostatic force is small, the gravitational attraction would be almost negligible in comparison.
4. Develop a way to determine if the mystery fur is from a rabbit or cat. If you have time, try your method out, to see if it works. If time is short, or humidity is too high, describe how one could carry out the method in conditions with lower humidity.
    a. Rub the rod with the mystery fur and human hair separately. Measure the r length between the pith balls. According to the equation derived from question 1, greater r length equals a greater charge, which means more charge was transferred to the pith balls from the rod. If the length of the experiment with the mystery fur is greater than the length of the experiment with the human hair, then it is the rabbit fur because rabbit fur is more electron-donating than human hair. Otherwise, if the length of the experiment with the mystery fur is less than the length of the experiment with the human hair, then it is the cat fur since cat fur is less electron-donating than human hair.

Conclusion

In this lab, we observed the effects of Coulomb's Law through the pith balls, rods, and materials. From the data gathered from the experiment, it was evident how Coulomb's Law works and how it is applied in certain scenarios, one being the experiment done in this lab. By selecting different combinations of rubbing different rods with different materials and recording the separation distance between the pith balls, we were able to find the amount of electrons transferred and the charges of the balls, showing through our quantitative and qualitative observations how Coulomb's Law works.