

Lab 200: Electrostatics - Electric Charge and Force

Name: Arsh Bhamla, Kevin Gettler,
Yosif Ismail

Group: G

Date of Experiment: 02/01/2023

Report Submitted: 02/08/2023

Course: PHYS 121A 016

Instructor: Subodh Dahal

1. INTRODUCTION

1.1 OBJECTIVES

This lab helps to reinforce understanding of charges and Coulomb's laws. We were given a variety of different materials to conduct various experiments in order to determine the existence of positive and negative charges and different ways in which charges interact with each other.

1.2 THEORETICAL BACKGROUND

Charge, like mass, is a fundamental property of objects. It emerges from the relative ratio of protons to electrons in an object. While there is nothing fundamentally different between the masses of any two objects, charges fall into two distinct groups that are arbitrarily referred to as either positive or negative.

Similar to how objects with mass apply gravitational forces to each other, objects with charge apply *electric* forces to each other. While gravity is always an attractive force, electric forces can be either attractive or repelling depending on the sign of the two charges involved. The direction of an electric force is always in line with the two charges being analyzed, and its magnitude is quantified by Coulomb's law ($F_e = k(|q_1q_2| / r^2)$).

There are three main ways that an object can be given a charge. *Tribocharging* refers to friction between two objects causing a net transfer of electrons from one object to another. *Conduction* refers to the transfer of charge between objects by direct contact, while *induction* refers to a charged object inducing an uneven distribution of charge in another object at a distance.

2. EXPERIMENTAL PROCEDURE

Tribocharging and Discharging

A PVC and acrylic rod were held over strips of paper at a distance. The rods were then rubbed with a fur hide, and once again held over the paper in order to observe any change in behavior. The rods were then rubbed over with a hand, and then held over the paper once more.

Interaction of Charged Objects

Uncharged and charged plastic and acrylic rods were variously placed on a freely rotating pivot. The remaining rods (as well a piece of metal) were then held close to the rod in the pivot to observe if any attractive or repelling force was imparted.

Identifying Charge Type

A glass, PVC, and acrylic rod were rubbed with fur and placed in the pivot described previously. A Van de Graaff generator producing a positive charge was placed near the pivot, and whether the rod was attracted or repelled was recorded. This information was used to determine the sign of the charge imparted on the rod.

Conduction and Induction

The positively charged Van de Graaff generator and a negatively charged PVC rod were held near a pith ball suspended by a thread, and moved slowly toward it. The behavior of the ball was noted as both objects moved toward it, as well as after the objects made contact with the ball.

An additional procedure was carried out where the charged PVC rod was held beneath the pith ball, and the top of the ball was touched by a human hand in order to discharge that side of the ball. The behavior of the ball towards the PVC rod was compared before and after this procedure. The behavior of the ball towards the Van de Graaff generator was also noted.

Coulomb's Law

The Van de Graaff generator and charged PVC rod were moved towards and away from the pith ball, and the acceleration of the ball was compared to the distance between the ball and both objects.

3. RESULTS

Tribocharging and Discharging

Before being rubbed with the fur, nothing notable occurred when either rod was held above the paper. After being rubbed, the paper was attracted to and clung to both rods. After the rods were rubbed by hand, the paper was no longer attracted to either rod.

Interaction of Charged Objects

See Table 1 in Raw Data for results of this experiment

Identifying Charge Type

See Table 2 in Raw Data for results of this experiment

Conduction and Induction

When either the generator or the charged PVC was brought near the pith ball, the ball was initially attracted to the stick. As soon as the ball touched either object, the ball instead became immediately repelled.

The pith ball was attracted to the PVC rod both before and after being grounded by human touch. After being ground, the ball was repelled by the generator.

Coulomb's Law

As the distance between the pith ball and either the generator or the PVC rod decreased, the acceleration of the ball appeared to increase.

4. ANALYSIS and DISCUSSION

Tribocharging and Discharging

The observed behavior aligns with understanding how charged and uncharged objects interact. Friction between the fur and the rods resulted in a net transfer of electrons between both objects. Whether the rods were positively or negatively charged, moving them near the uncharged paper strips resulted in slight dipoles within the paper leading to their attachment to the rod. Touching the rods with a human hand provided a path for the charge to dissipate into the ground, discharging the rod and stopping any attraction with the paper.

Interaction of Charged Objects

The observed behavior aligns with understanding how charged and uncharged objects interact. Uncharged objects were always attracted to charged objects, reflecting the dipole behavior explained previously. Charged objects always repelled duplicates of themselves, affirming that objects of like charge repel each other.

Identifying Charge Type

While the triboelectric series does not fully explain the observed behavior, the behavior in other parts reaffirms the results. The series lists fur before glass, acrylic and PVC, suggesting that all three rods should have been imparted with a negative charge. However, the fact that some rods were attracted to each other in Experiment 2 requires at least one of the rods to have a positive charge.

Conduction and Induction

The observed behavior aligns with understanding of conduction and induction. Whether the charged object involved was positively or negatively charged, the pith ball was initially attracted to the charge due to dipole interactions. After making contact, charge was conducted onto the ball, causing it to be repelled instead.

In the second procedure, the ball being attracted to the PVC suggests a negative charge was induced on its bottom. The ball being repelled by the generator suggests the induced positive charge on the ball's top was successfully grounded, giving the ball a permanent negative charge.

Coulomb's Law

The observed behavior corresponds to Coulomb's law, since electric force is inversely proportional to distance.

5. CONCLUSIONS

We learned about the electrical behavior for different materials. In experiment one, we proved how we can charge objects (such as the PVC and acrylic rod) to influence near neutral objects (in our case being the paper). In experiment two, we were able to see how different charges interact with one another, with both attractive and repulsive forces being shown. In experiment three, we experimented with the charge of the objects we were using by utilizing a steady positive charge, and applying our knowledge of charged interactions to determine the polarization of the materials. For

experiment four, we worked with conduction and induction. The ball experiment provided insight on how there were temporary dipole moments for conduction and permanent polarization for induction with ground. Lastly, in experiment five we noticed how Coulomb's Law worked in practice, seeing how the force applied on the ball changes as the distance was changed.

Through the conduction of the lab, we demonstrated much of what makes up electrostatics qualitatively by exploring electric charges produced by friction and their interaction, understanding conduction and induction to electrically charge an object, and qualitatively determining the electric force between charged objects. This project was an insightful one, where we learned a great deal to expand on our knowledge. This experiment raised questions for how higher charges are applied in the real world within technology and space sciences. My team agreed that we would love to learn more about the subject, and also would suggest that more experiments be added where we can use the Van der Graffe generator. Overall, this project was fun and helpful.

6. RAW DATA

Table 1. Type of Interaction Between Rods

	Uncharged plastic straw (insulator)	Uncharged metal (conductor)	Plastic straw rubbed with wool fur	Acrylic rod rubbed with wool fur
Uncharged plastic straw	no	no	attraction	attraction
Plastic straw rubbed with wool fur	attraction	attraction	repelling	attraction
Acrylic rod rubbed with wool fur	attraction	attraction	attraction	repel

Table 2. Rod Polarity With Fur

	Fur	Silk	Wool
Glass	negative	Positive	
PVC	negative		
Acrylic	positive		Positive