Lab #3 – Charge on Tape

OBJECTIVES

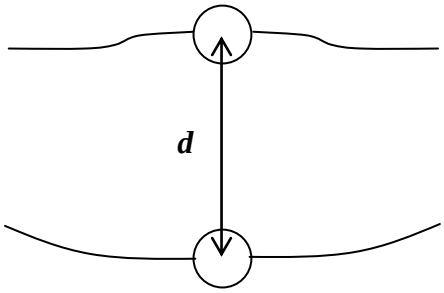
In this lab you will:

- Design an experiment to calculate the amount of charge on a piece of tape
- Make physical measurements and modeling assumptions
- Calculate physical quantities based on the above measurements
- Verify your results to be physically reasonable

1) Warm-Up Problems

The following problems are intended to motivate a possible experimental design for measuring the charge on a piece of invisible tape. After you have taken all necessary data (for your experiment) you will do calculations similar to those you are about to do in these problems. Therefore, to save your group a great deal of time in this lab, we advise that you **SOLVE THE PROBLEMS BELOW ENTIRELY SYMBOLICALLY**. This symbolic approach will provide you with a formula in which to enter your experimental data.

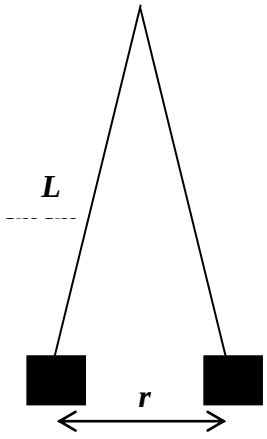
Problem (1) Two small plastic balls (of mass $m = 2\ g$) are rubbed all over with fake fur – both acquiring the same amount of charge. Attached to each ball are insulating nylon strings, which are arranged so that the balls may only move up or down in the vertical direction. When one ball is held above the other as shown, the top ball "floats" a distance $d = 0.5\ cm$ above the lower ball, and the strings attached to the top ball become slack (i.e. they exert no vertical force on the top ball.)



(a) What is the approximate amount of charge on each ball?

(b) Can you determine the sign of the charge, or only the absolute value?

Problem (2) Two small hollow glass cubes, of mass $m = 1.4\ g$, are each rubbed with silk, and acquire a positive charge. The cubes hang motionless from strings, as shown in the diagram below. The length of each string is $L = 8.0\ cm$, and the cubes are separated by a distance $r = 3.0\ cm$



(a) What is the approximate amount of charge on each cube? (Express your answer in terms of L, r, m, and physical constants)

(b) What simplifying approximations did you have to make to get this answer?

CHECKPOINT 1: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

2) The Tape Experiment Design

You will now design and carry out an experiment to determine, approximately, how much charge is on a piece of charged invisible tape. In designing your experiment, reflect on the problems you just worked to give you some ideas.

Available equipment: *Invisible tape and a meter stick*
We have measured the mass of 1 m of tape ***(0.00125 kg per meter)***

a) In your work space,
- **i. Make a detailed and understandable diagram of your experimental setup**
- **ii. Show and label all objects**
- **iii. Show and label any quantities that you will need to measure. (Make sure to consider what approximations are necessary)**
- **iv. Show all vector quantities (e.g. Electric Forces, gravitational forces) with labeled arrows**

From your diagram it must be evident what quantities are being measured. Another person should be able to replicate your experiment from analyzing your diagram.

CHECKPOINT 2: You must have your experimental design approved by an instructor before moving onto the next section

3) The Tape Experiment

a) Conduct your experiment.

b) Clearly record all measurements you make in your lab workspace. Make sure you measure all relevant distances.

c) Answer the following questions:

- **i. What is the amount of charge on one of your pieces of tape, in Coulombs. Show every step in your work, starting from fundamental physics principles (e.g., the momentum principle).**
- **ii. How many excess electrons produce this charge? Show your work.**
- **iii. What approximations did you make in your analysis? State these clearly.**
- **iv. To establish a lower bound on reasonable answers, answer the following question: What is the smallest (non-zero) amount of charge that could possibly be on a charged tape? Explain briefly. Is your answer larger than this number?**

v. If you assume the tape is made entirely of carbon atoms (atomic mass 12), estimate the largest amount of charge that could possibly be on a charged tape. Show all steps in your calculation – with clear reasoning. Is your answer smaller than this number?

vi. If the electric field near the surface of a charged object exceeds $\sim 3 \times 10^6$ N/C (which is the E-Field required to ionize air), then a spark is possible. Did you observe or feel a spark when handling your charged piece of tape? If not, then calculate the charge necessary to produce an E-Field of $\sim 3 \times 10^6$ N/C. This also serves as an upper bound, is your answer smaller than this number?

Recall: The E-Field near the surface of an object is $= \frac{Q/A}{2\varepsilon_0}$

vii. Calculate the fraction of the molecules on the surface of the tape which gained or lost one electronic charge. (see p. 589 (3rd edition) for a discussion of how to estimate the number of molecules on the surface of the tape). Show all your work clearly.

CHECKPOINT 3: Ask an instructor to check your work for credit.