PHY132 Practicals Day 5
Student Guide

Summer 2009

Concepts of today's Module

- Electric Charge
- Coulomb's Law for the Electric Force

Background for Electricity and Magnetism Module 1, Activity 1:

Here are four hypotheses about electric charge:

> *Hypothesis 1*: The interaction between objects that have been rubbed or separated is due to a property of matter we call *charge*. There are two types of electric charge.
>
> *Hypothesis 2*: The strength of the interaction between electric charges increases as the distance between the charges decreases.
>
> *Hypothesis 3*: The strength of the interaction between electric charges increases as the quantity of charge increases and decreases as the quantity of charge decreases.
>
> *Hypothesis 4*: Excess charge moves readily on certain materials, known as conductors, and not on others, known as insulators. In general, metals are good conductors while glass, plastic, and rubber tend to be insulators.

Expt *Electricity and Magnetism Module 1, Activity 1*

A. *Two lengths of identical tape peeled directly off the table.*

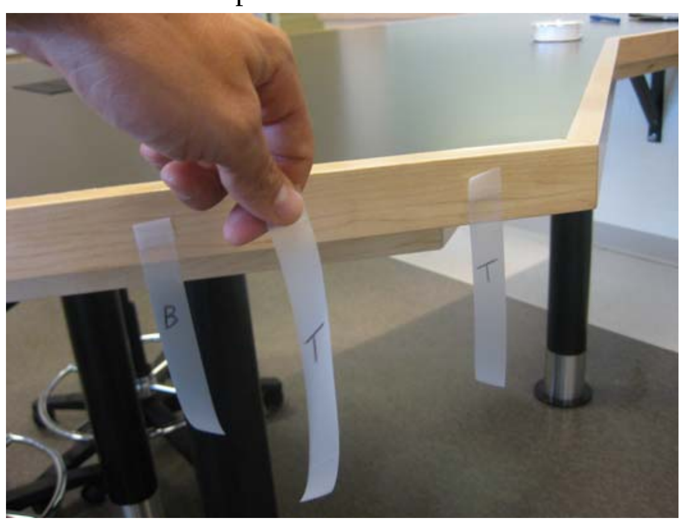
- Press a length of sticky tape 15 – 20 cm long firmly on the table top or other unpainted surface, with a few cm hanging over the edge. Form a non-sticky handle by looping about 1 cm of the tape hanging over the edge onto itself.
- Repeat for a second length of sticky tape on a different part of the table.
- Peel one of the tapes off the table and hang it from the edge of the table with the folded-part up.
- Peel the second tape off the table and, holding its handle, slowly bring it near the first tape.
- What happens? How does the distance between the tapes affect the interaction between them?

B. ***Two lengths of identical tape, one peeled off the top of the other.***

- Place a length of sticky tape 15 – 20 cm long on the table top or other unpainted surface sticky-side down, with a few cm hanging over the edge. Form a non-sticky handle by looping about 1 cm of the tape hanging over the edge onto itself.
- Press another strip of tape of equal length directly on top of the first length of tape, also sticky-side down, also with the 1 cm folded handle.
- Peel the bottom strip off the table, which will bring the top strip along with it.
- With your hands and all other objects far from the hanging pair of tapes, carefully separate them, keeping them both hanging down.
- Hang one of the tapes from the edge of the table with the folded-part up.
- Holding the other tape from the handle, slowly bring it near the first tape.
- What happens? How does the distance between the tapes affect the interaction between them?

C. ***Interactions of two top-bottom pairs of tape.***

- Place two more strips of sticky tape on the surface as in Part A. Using a pencil or ball point pen (but not a rollerball pen as the ink runs on this tape), mark the tapes with *B* for bottom.
- Press another strip of tape on top of each of the *B* strips; label these strips *T* for top.
- Pull one pair of strips off the surface, separate them, and hang them from the edge of the table with the folded-parts up at least 50 cm away from each other.
- Pull the second pair of strips off the surface and separate them.
- Bring two T-strips near each other. What happens? How does the distance between the tapes affect the interaction between them? [Caution: if the two tapes come into contact with each other the charges on them may change.]



- Bring two B-strips near each other. What happens? How does the distance between the tapes affect the interaction between them?
- Bring a B and a T-strip near each other. What happens? How does the distance between the tapes affect the interaction between them?

D. ***Glass rubbed with "silk", "amber" rubbed with fur.***

- Rub the supplied black plastic rod with the fur, hold the rod horizontally and bring it near but not touching the hanging B and T-strips. Describe what you observe. Caution: if the tape touches the rod the charge on the tape can change.

- Rub the supplied glass rod with the polyester cloth [we couldn't afford silk..], hold the rod horizontally and bring it near but not touching the hanging B and T-strips. Describe what you observe. [Be careful not to break the glass rod – if you do, find a technologist to help clean up the glass fragments.]

E. Do your observations in Parts A – D support the hypotheses? Which hypotheses are supported and which are not by your observations? Please explain in the lab notebook using complete sentences. You should not just state results that you may have learned about in class or from the textbook. Rather we wish you to devise a sound and logical set of reasons based on your observations.

F. Following Benjamin Franklin, we arbitrarily call the charge on the glass rod after being rubbed with silk or polyester *positive* and the charge on a piece of amber or plastic after being rubbed by fur *negative*. For the sticky tape, what type of charge is on the T-strip? What type of charge is on the B-strip?

Please remove all the sticky tapes from the table top when you have completed this Activity.

Expt ***Electricity and Magnetism Module 1, Activity 4***

In the late eighteenth century Coulomb used a torsion balance and a great deal of patience of discover how the electric force between small spherical charged objects depends on the distance between the objects. A modern implementation of his apparatus is shown on the next page; using it also requires considerable patience.

It is also possible to do a similar determination using the charged balls that you may have used in Activity 3, and these experiments have also been done. However, in practice this method is even more difficult than Coulomb's. An animation which side-steps these difficulties by simulating the experiment is available at:

http://www.upscale.utoronto.ca/PVB/Harrison/Flash/EM/Coulomb/Coulomb.html

The above link is to a fixed size animation which works nicely if only one person it viewing it. For use in the Practical itself a version which can be resized to be larger so that the entire Team can see it is better. Here is a link to such a version:

http://www.upscale.utoronto.ca/PVB/Harrison/Flash/EM/Coulomb/Coulomb.swf

A. Open the animation and explore how it works.
B. Move the right hand charge with the slider to some distance between the support points of the strings, move it to a new position, and then return it to the same original distance. You will notice that the measured angle the strings make with the vertical usually has a slightly different value for the same distance. Under what circumstances would a *real* apparatus exhibit this behavior?
C. If you had the patience of Coulomb and repeated the process of Part B a large number of times and made a histogram of the measured angles, what would you predict the shape to be? How would you characterize the width of the shape?
D. Set the right hand charge to any position that you like and record the distance and the angle. Calculate the value of the electric force F exerted on the left hand charge by the right hand charge. What is the direction of that force?

[***STOP!*** Please go back and take a second look at what you have recorded in your notebook for the mandatory activities. Is there anything missing? Can anything be improved? Does your TA have advice on what you might be able to do better? Please do not attempt this "If you have time" activity until you feel confident that the other activities are completed to the best of your ability, and you have obtained permission from one of your TAs.]

If you have time:

E. What is the error in this experimental determination of the value of the force? You may find one or more of the following error relations useful:

$$\Delta \sin(\theta) = \left| \cos(\theta)\Delta\theta \right|$$

$$\Delta \cos(\theta) = \left| \sin(\theta)\Delta\theta \right|$$

$$\Delta \tan(\theta) = \left| \frac{\Delta\theta}{\cos^2(\theta)} \right|$$

Note: in the above equations the error in the angle must be expressed in radians.
F. For this same position of the left hand charge calculate the distance *r* between the centers of the two 1 gram masses.
G. Calculate the error in this measurement of *r*.

Last revision to this write-up: July 8, 2009 by Jason Harlow.

This E&M Module 1 Student Guide was written in October 2007 by David M. Harrison, Dept. of Physics, Univ. of Toronto. Activities 1- 3 are based on Priscilla W. Laws et al., **Workshop Activity Guide**, Module 3, Unit 19, (John Wiley, 2004), pg. 531-533.