PHY152H1S – Practical 2: Electrostatics

Don't forget:

- List the NAMES of all participants on the first page of each day's write-up. Note if any participants arrived late or left early.
- Put the DATE (including year!) at the top of every page in your notebook.
- NUMBER the pages in your notebook, in case you need to refer back to previous work.

Note that the activities below have numbers which refer to numbers in the Electricity and Magnetism Module 1 at http://faraday.physics.utoronto.ca/Practicals/ . We are skipping some of the activities there, so some activity numbers are missing.

Activity 1 (20 minutes)

A. Press a length of sticky tape 10 – 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 the tape hanging over the edge onto itself. Do this for a second length of sticky tape. Peel one of the tapes off the table and hang it from the edge of the cupboard. Peel the second tape off the table and holding its handle bring it near the first tape. Try to keep your hand holding the second tape far away from the tapes that are hanging down. What happens? How does the distance between the tapes affect the interaction between them?

B. 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, 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 cupboard at least 50 cm away from each other. Pull the second pair of strips off the surface and separate them. Describe the interaction between two top strips when they are brought toward one another. How does the strength of the interaction depend on the distance between the tapes? Caution: if the two tapes come into contact with each other the charges on them may change.
In the lab notebook describe the interaction between two bottom strips when they are brought toward each other. How does the strength of the interaction depend on the distance between the tapes?
Describe the interaction between a top strip and a bottom strip when they are brought toward each other. How does the strength of the interaction depend on the distance between the tapes?

C. Rub the supplied plastic rod with the fur, hold the rod horizontally and bring it near but not touching the hanging bottom and top strips. Describe what you observe. Caution: if the tape touches the rod the charge on the tape can change.
Again being careful not to touch the hanging strips, bring the *fur* near them. What do you observe?
Rub the supplied glass rod with the polyester cloth, hold the rod horizontally and bring it near but not touching the hanging bottom and top strips. Describe what you observe.

D. Following Benjamin Franklin, we arbitrarily call the charge on the glass rod after being rubbed with polyester *positive* and the charge on the plastic rod after being rubbed by fur *negative*. For the sticky tape, what type of charge is on the top strip? What type of charge is on the bottom strip?

What type of charge is on the fur after rubbing the plastic rod? Devise and carry out an experiment to test your answer. Describe the experiment and the result in the lab notebook. Predict what type of charge is on the polyester after rubbing the glass rod? Devise and carry out an experiment to test your prediction. Describe the experiment and the result in the lab notebook.

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

Activity 2 (30 minutes)

Blow up the two balloons, tie them off, and tie each to the end of one of the supplied strings. Hang each balloon from the horizontal rod which is attached to the vertical rod that is clamped to the table. You will want each balloon to be as far as possible from the vertical rod, the edge of the tabletop, and any other objects. At the end of today's Practical you may keep the balloons.

Below you will also be using a small white ball of *pith*[1], which is hanging by a silk thread onto a small stand. You will also be supplied a dark gray ball hanging by a thread from a stand; these are pith balls that have been coated in Aluminum.

A. Rub the glass rod with the polyester, and slowly bring the rod near the Aluminum coated pith ball, letting the two touch. Describe what happens. Can you explain your observations?
B. What is the sign of the electric charge on the coated ball? Confirm your answer using the glass rod after rubbing with polyester and the plastic rod after rubbing with fur, being careful not to let the rods touch the ball.
C. Remove the electric charge on the Aluminum coated ball by touching it with the metal plate. Repeat Part A using the plastic rod after rubbing it with fur. Describe what happens.
D. Now what is the sign of the electric charge on the ball? Confirm your answer using both the plastic rod after rubbing it with fur and the glass rod after rubbing it with the polyester.
E. Rub the glass rod with the polyester, and slowly bring the rod near the uncoated pith ball, letting the two touch. Describe what happens. Can you explain your observations?
F. What is the sign of the electric charge on the uncoated ball? Confirm your answer using both the plastic rod after rubbing it with polyester and the glass rod after rubbing it with the polyester. Are your results the same as for Part B? Explain.
G. Rub the two balloons with the fur. Bring the balloons closer together. Describe what happens.
H. Determine whether the charges on the balloons are positive or negative.
I. As you showed in Activity 1, when you rub the fur with the plastic rod it becomes charged. Does the charging of the balloons depend on whether or not the fur is charged? Explain.

[1] Pith is an insulator found in vascular plants.

Activity 4 (50 minutes)

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

This version will only work if your browser is configured to display Flash animations directly without an html wrapper.

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?
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*.
H. We took 10 datapoints from the animation, calculated *r* and *F* and their errors, and placed the result in a dataset named `CoulombDistForce`.[2] A copy is located in the following area:

```
public:Modules/E&M/Module01/Data
```

Explore this data with the *ViewDataset* program which is on the desktop of your computer and/or a spreadsheet program such as *Excel*. As always, the datasets are tab separated, with the first row a title, the second row the names of the variables, and the rest of the rows the actual data.
How could you use a collection of force-distance, *F* versus *r*, data for different values of the distance to determine how the force depends on the distance? How many different ways can you and your partners think of? Which do you think might be best?

I. Here is a method which you may have thought of in Part I. Imagine that the force *F* varies in an unknown way with the distance *r*:

$$F = \frac{c}{r^n} \qquad (1)$$

You wish to determine *n* from data of *F* versus *r*. A good way to do this is to fit the data to Eqn. 1. However, *n* does not have a linear relation to *F* and *r*, so a non-linear fitter has to be used. We have non-linear fitters, but using them is not as simple as the *PolynomialFit* program which you may have used in other Modules.

But, if we take the logarithm of both sides of Eqn. A1, we get:

$$\ln(F) = (-n)\ln(r) + \ln(c) \qquad (2)$$

Recall that the generic equation of a straight line is:

$$y = mx + b$$

So if we take the logarithms of *F* and *r* and fit this data to a straight line:

Slope = (-*n*) Intercept = ln(*c*)

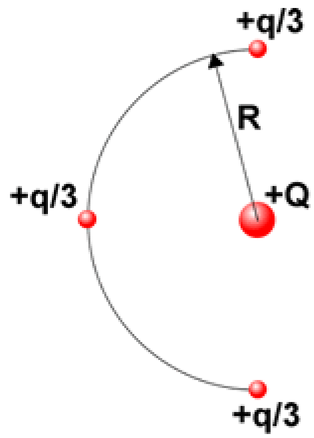
[2]Not having Coulomb-like patience, I did not do the error calculations by hand. Instead I used some error propagation routines with *Mathematica* software.

Use this method using *PolynomialFit* which is on the desktop of your computer. The following file, located in the same directory as the one you looked at in Part H, contains data of the logarithm of the force *F* versus the logarithm of the distance *r*:

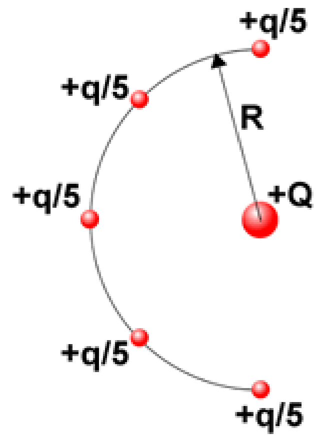
`CoulombLnDistLnForce`

Activity 9 (If You Have Time)

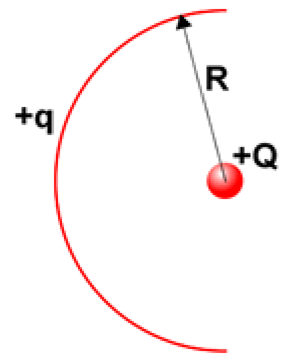
A. A point charge **+Q** is located a distance **R** away from three identical point charges, each of charge **+q/3**, equally distributed along a semicircular arc of radius **R** as shown. What is the total force, magnitude and direction, exerted on **+Q**?



B. A point charge **+Q** is located a distance **R** away from five identical point charges, each of charge **+q/5**, equally distributed along a semicircular arc of radius **R** as shown. What is the total force, magnitude and direction, exerted on **+Q**?



C. A point charge **+Q** is located a distance **R** away from a semicircular arc that is uniformly charged with a total charge of **+q** as shown. The charge per arc length λ along the semicircle is:



$$\lambda = \frac{+q}{\pi R}$$

What is the total force, magnitude and direction, exerted on **+Q**?

This 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.

Last revision: January 18, 2014 by Jason J.B. Harlow.