# PHY132 Practicals Week 4
# Student Guide

## *Concepts of this week's Module*

- Electric Charge
- Coulomb's Law
- Addition of Electrostatic Forces

## *Background for 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.

## *Activity 1*

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.* *- - [Not done this week due to time constraints.]*

D. Do your observations in Parts A – C 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.

## Expt *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 is 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 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. - - *[Not done this week due to time constraints.]*
C. - - *[Not done this week due to time constraints.]*
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. *[If you have time.]* Calculate the error in this measurement of $r$.
H. *[If you have time.]* We took 10 datapoints from the animation, calculated $r$ and $F$ and their errors, and placed the result in a dataset named `CoulombDistForce`.[1] 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. *[If you have time.]* 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 $r$:

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

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

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*)

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`

J. *[If you have time.]* There is another file which you may wish to use to explore the relation between the force and the distance, located in the same directory as the other two data files.

`CoulbDist2Force`: *F* versus $r^2$

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. Activity 7 is from Edward F. Redish, Rachel E. Scherr and Jonathan Tuminaro, “Reverse-Engineering the Solution of a ‘Simple’ Physics Problem”, The Physics Teacher **44**, 293 (2006). Activity 8 is from Lillian C. McDermott et al. **Tutorials in Introductory Physics** (Prentice Hall, 2002), pg 75.

Last revision: February 3, 2009 by Jason Harlow