Lab 01A: Coulomb's law: Spring 2012 R2

Charging with **electrophorus**
You will find additional information about this at the Exploratorium:
http://isaac.exploratorium.edu/~pauld/summer_institute/summer_day14electrostatic/Electrophorus.html

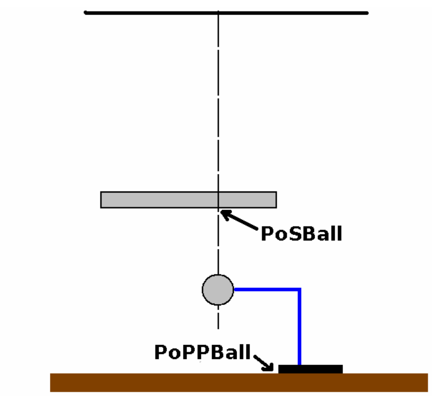
A pie pan and a Styrofoam plate can be used to charge effectively even in conditions of higher humidity. The idea is this: rub wool onto the plate for about 1 minute. Place the pie pan onto the top of the plate. Touch the pie pan (a spark will jump). Then remove your finger and separate the pie pan from the plate. We will use these again in lab01-B.

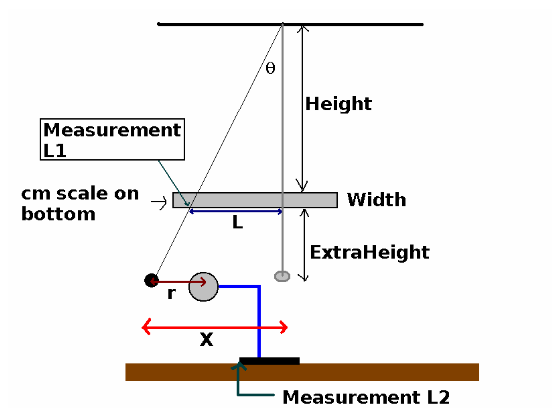
Experimental verification of the inverse square law

Without vectors, **Coulomb's law** state that the force of attraction or repulsion between charges is given by

$$F = \frac{kq_1q_2}{r^2}$$

where k is Coulomb's constant ($k=8.99 \times 10^9 Nm^2/C^2$, q_1 is the charge 1, q_2 is charge 2 and r is the distance of separation between the two charges. Incidentally, Coulomb's constant is often written $k=1/(4\varepsilon_0)$ where ε_0 is the permittivity of free space and has the value $8.854187817 \times 10^{-12}$ $C^2/(Nm^2)$. We can know the value of ε_0 to so many decimal places by measurements involving the speed of light.





These two figures show the various defined quantities. As I have tried to set things up, the initial variables should be: Height=150 cm, Width=3 cm, ExtraHeight=15 cm, PoSBall=10 cm, and PoPPBall=50 cm. You will need to check most of these but I think you should trust my measurement of 150 cm. Make sure after you finish your lab that the initial settings are returned. You will be making 10 measurements here of L1 and L2.

I

Measurement	L1 [cm]	L2 [cm]
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

The analysis of this setup is as follows: the angle θ is measured from Height+Width and L:

$$\tan(\theta) = \frac{L}{\text{Height+Width}}.$$

Assuming the angles are small,

$$\sin(\theta) \approx \tan(\theta).$$

The magnitude of the restoring force when the small ball is displaced by an angle θ is given by:

$$F = mg\sin(\theta) \approx mg\frac{L}{\text{Height+Width}}.$$

L is obtained from your measurement of L1 by:

$$L = \left|L1 - \text{PoSBall}\right|.$$

The separation between the two balls is given by:

$$r = \left|\left(\text{Height} + \text{Width} + \text{ExtraHeight}\right)\frac{\left|L1-\text{PoSBall}\right|}{\text{Height+Width}} - \left|L2 - \text{PoPPBall}\right|\right|$$

Note: Do not make measurements beyond PoPPBall.

We actually need to obtain X which is given (through trigonometry) by:

$$X = (\text{Height} + \text{Width} + \text{ExtraHeight})\frac{L}{(\text{Height+Width})}$$

If Coulomb's law is valid then we would have the following:

$$mg\frac{L}{\text{Height+Width}} = \frac{kq_1q_2}{r^2}$$

We can write this as:

$$L = \frac{b}{r^2} \text{ where } b = kq_1q_2\frac{(\text{Height+Width})}{mg}.$$

In order to verify the $1/r^2$ behavior of Coulomb's law, we take the logarithm of this:

$$\log(X) = \log(b) - 2\log(r)$$

and a linear fit of your data should be a straight line with a slope of -2.

Procedure:

Record (and verify) the following:

PoPPBall: Position of the front of the base of the ping pong ball stand: it should be about 50 cm. This is adjusted so that the string, if lowered, would pass through the center of the ping pong ball. This is read from the meter stick on the table. Record your value:

PoPPBall=____________ cm

PoSBall: Position of the small ball at equilibrium. This is read from the metal ruler. If things are set correctly it would read 10, but record your value.

PoSBall=_______________ cm

Height from the ceiling to the top of the metal ruler: this is set to be 150 cm. However if you do not believe my measurement, you may measure and record this distance. I placed a black mark on the string at the top to the ruler to keep this correct.

H=___________ 150 cm

Width of metal ruler: This is 3 cm. You can check this.

D=____________ cm

Distance between the bottom of the metal ruler to the center of the small ball: I have set this to be 15 cm but you can measure this to verify. On the spreadsheet I name this "Extra Height".

ExtraHeight=________ cm

This is the way to make your measurements the quickest way: charge the system and move the ping pong ball holder to about 10 cm from the 50 cm mark (PoPPBall) so that L2 reads 40: note that if the meterstick is backwards, this will read 60. I have arranged the system so that the front of the base reads 50 cm when the string would hang through the center of the ping pong ball and you should verify this and make adjustments as necessary. Quickly and without breathing on your system record the two numbers L1 and L2, and then move the Ping Pong base towards PoPPBall by 1 cm at a time. Do not move further than PoPPBall. This will give you 10 measurements. Do this quickly and do not breath on your system since charge will change as a result of humidity.

The analysis

Your writeup for this lab will consist of your spreadsheet, together with your data submitted as a single spreadsheet (in readable pdf format), and additionally your work should include a discussion of if your data shows a linear relationship and why and how well your experiment verifies Coulomb's law. It should also include a discussion of the procedure that you used to determine this. Also be sure to include in your discussion why it is important that the charge on the two balls stay constant while you are doing your experiment (this is, in fact, the major source of error here). Your slope should automatically be calculated for you giving the experimental error. This is done with the OpenOffice "slope" function.