Union College Spring 2014

# Physics 121

# Lab 1 continued: Electric Force Law—the Modification

In our experimental derivation of the electric force law, we found a weaker dependence on distance than that given by the Coulomb force law. We found



where C contains the constant-in-front and the dependence on the amounts of charge on the two spheres, and r is the distance between the centers of the two balls. In class, we discussed the Coulomb force law, which says that p should equal 2. While, in lab we found p to be less than 2 by an amount greater than the uncertainty. Does this experimental result mean that Coulomb’s law does not apply to this situation or that the experiment is flawed? Aesthetically, a 1/r2 dependence is desirable, for it fits the diffusion in 3-dimensional space of the force (and of the field). So, the prudent approach to start with is to closely examine the design of the experiment for a source of systematic error.

And, indeed, there is a systematic error. And, fortunately, we can correct for it and re-analyze our results. The error occurs in our assumption that the spherical shells act like point charges located at the spheres’ centers. When the balls get relatively close, because the charges are free to move around the conducting surface, the charges on each ball move away from the ‘like’ charges on the other ball. The charges on each ball, then, are not uniformly distributed, and the effect is stronger when the balls get closer, thereby affecting the apparent distance-dependence.

Since the charges move away from the other ball, the centers of the charge distributions will be shifted farther out, and so the effective separation distance of the two collections of charge is larger than the distance between the balls’ centers. Therefore, the inferred strength of the force is smaller than expected for the measured distance, especially at the smaller distances.

We can correct for this effect by dividing the measured distances by a parameter which we label as ‘X,’ i.e.

 **rcorrected** = **rmeasured****/X.** (1)

Without explanation, a theoretical equation for X is given by

**X = SQRT[1 – 4(a3/rmeasured3)]**, (2)

where ‘a’ is the radius of the spheres. (Note that X is less than one, so dividing the measured r’s by X will yield corrected r’s that are *larger* than the measured values. This equation for X can be derived using junior/senior level physics material.)

Return, now, to the Excel table of force vs. separation distance, in a new column calculate the *corrected* value of r for each run using Equations 1 and 2. Make a new graph of log(F) vs. log(r) using the corrected r’s and find the equation for the linear fit. Do the Regression analysis with the new data and note the new slope and uncertainty. With this “correction” to the data, does the experiment now agree with the Coulomb force law?

**For your lab report (due in one week)**, turn in an abstract (following your instructor’s guidelines) and email your Excel data table and graphs. Be sure that your abstract contains all the important final quantitative results, with uncertainty. Do not list raw data, just the final results. Also make sure that your Excel table is well-labeled, with easy-to-understand column headers and units, and that the key results are also easily seen on the Excel table and graph.