**Electric Fields Simulation**

# Notes:

1. ***This is a one-week lab that can be done at home.***
2. A **full report** must be submitted. Check “E&M Handout 1 - Lab Overview.docx” for more details.
3. This lab can be done in several ways. On a laptop or desktop (Win or Mac) you can download the simulation or run it in a web browser (free). You can also run it through an app on an iOS or android smartphone or tablet (but it will cost you 99 cents).
4. We strongly recommend doing the lab early in the week, rather than waiting until it is almost due. If you have trouble, you will want to have plenty of time to fix it before the deadline. No excuses!
5. Turning in your report:
   1. Collaborate with your partner(s) on data collection, analysis and report.
   2. Turn in only one report but be sure it lists all partners as authors.
   3. Lab reports should be uploaded to Canvas in pdf format by the deadline in the course calendar.
   4. You don’t need to upload or include any spreadsheets. You may want to use figures in your report that can contain screenshots of spreadsheet(s) or graphs copied and pasted from them.
6. Getting help:
   1. Your lab TA can answer questions by email or during their office hours listed in the syllabus.
   2. You should also seek advice from one another on in person or on CN.

# Objectives of this lab:

These are things you will address in your report

1. You will do some experiments in a simulated environment to measure the electric fields produced by charged objects.
2. Measure the value of the Coulomb constant, *k*.
3. Identify the errors that can occur in your experiment.
4. Identify the sources of noise in your experiment.
5. Minimize the noise in your experiment.

# What you will learn:

Please review the learning goals for the semester in lab in the “Lab Overview” document (look in the Syllabus Task on CN). In addition, this lab has several specific goals:

1. You will practice keeping lab notes in a paper notebook, computer file, or other format.
2. You will enhance the data analysis skills you learned previously, by applying them to real data.
3. You will learn to distinguish between two types of errors that occur in data: systematic errors and random errors.
4. You will enhance your understanding of how noise arises in data, and how to account for that noise when interpreting experimental results.
5. You will practice scientific communication skills by preparing graphs and writing a formal lab report.

# Equipment:

* Word or other word processor to prepare your report
* Excel, Numbers, or other graphing software
* A web browser to run the simulation. Alternatively, you can run the simulation on a smartphone or tablet.

# Background:

This lab is focused on a few equations that are central to the study of electric fields. First is the formula for the electric field produced by a point charge.

Where is the electric field produced by a charge *q* at a distance *r*, and *k* is the Coulomb constant: 8.99 x 109 N.m2/C. The field points away from *q* if *q* is positive, and towards *q* if *q* is negative.

Another important equation is the one that describes superposition.

In words, the superposition principle says that the electric field of several charges can be found by adding the fields of the individual charges using the rules for vector addition.

# ACTIVITY 1: Get comfortable with the app

To get started, you need to get the app running. Here are the options:

1. Browser: Navigate to <https://phet.colorado.edu/en/simulations/charges-and-fields>. You can use the simulation there by clicking on the image (it has a triangular play symbol like a video). If you prefer, you may download it by clicking the download link just below the image.
2. Graphical user interface, application, icon

   Description automatically generatedMobile: Download the PhET app from the App Store or Google Play (99 cents). Once you have the app, you can search for Charges and Fields. Tap on it to start. Use the “Macro Scale” first.
3. Click around in the app. Get comfortable doing things like adding charges and sensors, turning aspects of the display on and off, and measuring distances with the tape measure. The orange circle will always return the app to its original, empty, state.

When you first start, the app should look like the picture below on the left. You’re ready to start when you can easily set it up so that it looks like the one on the right.

A screenshot of a computer

Description automatically generated with low confidence Graphical user interface

Description automatically generated

# ACTIVITY 2: Measure field vs distance

* In this activity you will measure the strength of the field at various distances from the point charge.
* Put a single point charge (positive or negative, your choice) somewhere in active area, make sure no other point charges are present. Add one “sensor” at any location you like.
* Check the “Values” box so you can record the field strength. You can use the tape measure or turn on the grid (scale is shown at lower right) to measure the distance from source to sensor.
* Measure the field strength at a variety of distances (at least 8, but 10 or more would be better). Use as wide a spread of distances as you can. Note: You can use multiple sensors or just move one around. Exactly how and where you make your measurements is up to you.
* You should explain what you did in your report. You will want to include both a screen capture of your process and a graph of field vs. distance in your report.

# Analysis:

This experiment gives you an excellent opportunity to compare different ways of analyzing data. Try these two methods:

Method 1:

In Excel, calculate k for each data point you have taken. Inverting the field equation,

*k = Er2/q*.

You should find the average value of k, and the standard error of the mean. In your report, be sure to indicate if the value you get is consistent with the known value, 8.99 x 109 N.m2/C.

## Method 2:

This time, add a column for *1/r2*, and make a graph of *E* vs. *1/r2*. Add a trendline and display the trendline on your graph. Since the *x*-axis is *1/r2* and the *y*-axis is *E*, the slope of your line is *kq*, so you can calculate *k* easily from the slope.

# Discussion:

In the discussion portion of your report, you should comment on the differences between these two methods. How close are the values of *k* to the standard value? Does one method give more accurate results? The data is the same, so any differences are purely a result of how you analyzed it.

# ACTIVITY 3: Measure field vs. distance on the axis of a dipole.

* Shape, arrow

  Description automatically generatedIn this experiment, you explore how the field of a dipole changes with distance.
* First, create a dipole. Use a +1nC charge and a –1nC charge separated by a small amount (no more than 25 cm). It will be much easier if you turn on the “grid” and put the charges on a vertical line separated by 2 or 3 grid points.
* Click the electric field checkbox. Does the dipole field look like the field of a dipole should? Compare to one in your textbook. The picture shows a bit of a setup like this.
* Measure the field along the axis perpendicular to the dipole (points like the one shown in the pic). Measure the distance from the points to the center of the dipole. As usual, be sure to measure several points.
* Also as usual, be sure to take a screen picture or two to include in your report.

# Analysis:

Now, how does the strength of the electric field depend on the distance from the center of the dipole? Clearly it gets smaller with distance, but what are the details?

* Try plotting your data in various ways.
* Try looking for resources online.
* If you feel confident that you understand the data, try to determine a new value for *k* from your data.

# Discussion:

In the discussion portion of your report, you should explain how the dipole field you see compares to the ones pictured in your text, how the field along the axis depends on distance, and how your new value of *k* compares to the one from activity 2.