Experiment 1

Force Between Two Charged Particles

Equipment needed: website phet.colorado.edu

This experiment uses a simulation created by the University of Colorado at Boulder. The simulation is called “Coulomb’s Law” and can be downloaded by going to the website: phet.colorado.edu.

On the opening page you will see along the top of the page the word “SIMULATIONS”. Click on this for a drop down menu and choose “Physics”. The simulations are in alphabetical order. Click on “Coulomb’s Law”, download, and open the file. You will have a choice between Macro Scale and Atomic Scale. Choose the Macro Scale.

Here you will be able to change the charges on q1 and q2 as well as change their respective positions. With this experiment you are going to explore how the forces change when you vary q1, q2, and the distance between the two charged particles. With the data gathered you will begin to investigate the relationship between the forces between the particles and begin to derive an equation. Once you have modeled the equation you will solve for the Coulomb constant and compare it with the accepted hand book value.

Using an Excel spread sheet accompanying these instructions you will graph the data to determine how the force changes with a change in position, and a change in the charge of q2 (keeping q1 constant).

Your first table shows with the column titles that you are holding q1 at 1 micro-Coulomb of charge, while q2 takes on the values of: 1μC, 2 μC, 4 μC, 6 μC, and 10 μC. At the same time you will change the separation (r, meters) between the two charged particles. To do this, set the center of q1 at the 0 centimeter mark and move q2 to the indicated positions in the table. Only record the force values to the nearest whole number, entering them into the first table on the Excel spread sheet.

Graph the data.

This is done by first selecting all 7 columns of data (do not include the column titles, only the numerical values). The first column (r, meters) will be the x-axis of the graph, while the other six columns of Force will be plotted on the y-axis. Next, click on “INSERT” near the top of the screen and an options menu will drop down. Choose the scatter graph located in the charts box. This is the one that shows a miniature graph with just dots in it (no lines). When you click on it another drop down box will show. Click on the Scatter Chart with NO lines to graph your data. You are choosing the one with no lines because you are going to fit an equation to each of your data sets. Increase the size of the graph and place it in the grey area marked “Place graph 1 here”.

Analyze the data sets in the graph.

The x-axis shows the separation between the charged particles. You have six sets of data, each having a different value for the charge on q2. Looking at the first data set (the data points for each data set is a different color) for q2 having a charge of 1 μC what type of relationship is it forming? Is it a linear relationship? Or, is it something else? You will answer these questions in the Questions for Discussion portion of your experiment, so take notes as you go through the experiment.

Fitting a trendline and including a general equation to the data.

Look at the vertical line that represents r = 0.020 meters. You will see six data points, each a different color. Move the cursor to the topmost data point and right-click on it. A drop down menu will appear with “Add Trendline”. Click on “Add Trendline” and a Format Trendline window will open. You will notice that it defaults to a Linear Fit and shows the best fit to your data with a dotted line. Does the Linear Fit choice fit very well with your data points? If it does, then you will choose this option. If it does not, try a different option until you get the best fit to your data points. The best fit will have the dotted line go through each of the data points in that set of data, or very close to going through each of the data points. If the dotted line does not go well through each of the data points choose a different option until you get the best match. Don’t choose Moving Average for any of your choices. You are looking for the correct relationship. Once you do, go down to the bottom of the Format Trendline window and select the box by “Display Equation on Chart”. Once the equation box appears move the equation box so it is just to the left of the data point on the r = 0.020 vertical line. You may notice that in the equation you only have single digit numerical values. You will need to increase the number of decimal places to get more accurate values. To do this right-click on the equation box and choose “Format Trendline Label” from the drop down menu. Change the Category from General to Number, and increase the number of decimal places to 4.

Repeat this for the other 5 data sets.

Analyze and compare the equation fits for all 6 data sets.

Which of these general equation fits did you choose?

a) y = AeBx

b) y = Ax + B

c) y = A ln(x) + B

d) y = Ax2 + Bx + C

e) y = AxB

The x in the equation fit represents the separation r between the two charged particles. By looking at the trendline equation fit that you chose how does r vary? Looking at all 6 data sets trendline equations you can see that r varies by almost nearly the same amount. What simple numerical value does this seem to approach? You may need to take an average of this value to see that it very nearly approximates a single numerical value. What is this value?

Plot a new graph of the force values but now using the representation of r such that you get a linear fit. This will give you a slope value A which will make it a bit easier how to represent A in the final writing of the relationship for Force. Notice in Table 2 that there is a blank column with a question mark in the header/title of the column. Choose the proper representation of r and write this as the new header/title of the column.

Knowing how r varies partly solves how to determine the equation. The multiplying factor A needs to be determined. It must involve the other aspects of what was being changed in the data sets. You changed the charge on q2 while keeping q1 a constant value as you varied the separation. Now, using the simulation, set a constant separation by placing q1 on the 0 centimeter mark and q2 on the 10 centimeter mark. By doing this you will more easily see how A can be represented in the final equation.

Set q1 to 1 μC and vary q2 from 1 μC to 10 μC, recording these 10 charge values in Table 3 on the spread sheet. Graph q2 as the x-axis and F as the y-axis. What kind of relationship is seen in the graph? How does the force F vary as you vary q2? What if you reversed the roles of q1 and q2? Set q2 to 1 μC and vary q1. You don’t have to graph this one. Do you get the same relationship, or a different one? If you get the same relationship how do q1 and q2 get written into the value for A? If you get a different relationship how does this affect how q1 and q2 are written into the value for A?

To make sure that the relationship that you are forming is correctly represented try the following. Continue to have q1 and q2 separated by 10 cm in the simulation. Start with q1 and q2 both having charges of 1 μC and record the force value in Table 4. Also write in the charges for q1 and q2. For the next data set increase both q1 and q2 to each have charges of 2 μC. Record the resulting force. Keep increasing the charges on q1 and q2 in increments of 1 μC, recording the resulting force values, until you reach 10 μC for each. Plot the resulting forces on the y-axis, and the charge on q2 as the x-axis for Graph 4. Is the resulting trendline what you expected when considering your model/equation that you are generating?

Once you have your model/equation finalized you should be left with a constant factor that makes your equation an equality. This constant factor is called the Coulomb Constant. Determine the Coulomb Constant on your worksheet using Excel. Then, compare your calculated value for the Coulomb Constant with the accepted handbook value using a percent error equation.

Results

In this section of your report show your final model/equation for the force between two charged particles, and declare the value you calculated for the Coulomb Constant and how well it agrees with the handbook value. Do some research online to see what a reasonable % Error maximum would be when comparing an experimentally determined value to a Handbook value.

Questions for Discussion

1. Looking at the first data set (the data points for each data set is a different color) for q2 having a charge of 1 μC what type of relationship is it forming? Is it a linear relationship? Or, is it something else?
2. Which of the 5 general equations did you choose for the trendline fit for graph 1? What simple numerical value does the power of r seem to approach?
3. For the data you graphed in Table 3, what kind of relationship is seen in the graph? How does the force F vary as you vary q2? What if you reversed the roles of q1 and q2? Set q2 to 1 μC and vary q1. Do you get the same relationship, or a different one? If you get the same relationship how do q1 and q2 get written into the value for A? If you get a different relationship how does this affect how q1 and q2 are written into the value for A?
4. In graph 4, is the resulting trendline what you expected when considering your model/equation that you are generating?