Experiment 2

Plotting the Electric Field Using Equipotentials

Equipment needed: 2 sheets of graph paper (either 5 squares per inch, or 4 squares per inch), pencil, your cell phone (or other device) to make an electronic copy of the graph drawings

This experiment utilizes the PhET simulation called “Charges and Fields” located on the University of Colorado, Boulder website: phet.colorado.edu in the “Physics” category of the drop down menu: “simulations”.

Looking at a single, positively charged particle it seen to generate an electric field. The direction of the electric field is radially outwards from the particle.

Va

Vb

The illustration to the right shows the direction of the electric field about the positively charged particle. The equation for the electric field generated by a point charge shows the relationship between the strength of the electric field with the charge Q and the distance r. The letter k represents the Coulomb constant.

When a test charge (particle with very small charge) is placed in the electric field of this positively charged particle it will result in a force applied to the test charge.

Work can be done in moving the test charge along the line of the electric field. This equates to traversing through different electric potential (voltage) values as you change r. For a point charge the electric potential follows this relationship:

As you traverse outward along one of the electric field lines you will see that the nearby field lines separate farther and farther apart. This illustrates that the electric field is getting weaker.

For a point charge, traversing radially outward by the same distance r in any direction will result in the electric potential changing by the same amount. Each of the dashed lines on the represent positions about the charged particle having the same electric potential. This dashed line is then called and equipotential, meaning “same, or equal potential”. Notice that the electric field lines traverse across the equipotential lines at a 90° angle. This relationship between equipotential lines and electric field lines is always true.

Prior to opening the website (phet.colorado.edu) you will need to place small registration marks onto both graph paper sheets to make it easier to plot the equipotential lines.

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Determine the approximate center of your graph paper and place a small cross at this center point, as shown in the above illustration. This will be the origin of the graph from which the measurements will be taken. Every 5 squares, both vertical and horizontal, place a small dot (these are colored green in the above illustration). The above illustration is more like the graph sheet that has 4 squares per inch. A graph sheet that has 5 squares per sheet will have more registration marks.

**Part 1:**

**Electric Field Configuration about Two Charged Particles, One Positively Charged, the Other Negatively Charged.**

Once you have reached the screen with the various physics simulations download and open the “Charges and Fields” simulation.

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In the box (upper right corner of your screen) uncheck “Electric Field”, and check “Grid”. A grid pattern will appear showing heavier lines drawn every 5 blocks. The points where these heavier lines cross each other correspond to the registration marks that you made on your graph sheets. There is no “origin” mark on the grid in the simulation. Just pick a point near the middle of the grid where two heavy lines cross each other. That will be your “origin”.

In this first configuration place a single, 1 nano-Coulomb, positively charged particle, 5 lines to the left of the origin; and place a single, 1 nano-Coulomb, negatively charged particle, 5 lines to the left of the origin (as shown in the above illustration). Make sure that you center these charges on the grid lines (vertical and horizontal) as you see in the illustration. You are able to “Click and Drag” each particle using your computer cursor.

In this configuration 8 separate equipotential lines will be drawn using the device which reads Voltage. It is colored blue and has a cross-hair attached at the top of it. Click and Drag this “Voltage Meter” and drag it around the grid. You will see the Voltage Meter display various voltages dependent on the position. Also notice, that as soon as you started moving the Voltage Meter around the grid that an eraser symbol and a pencil symbol became available on the Meter.

**Displaying Equipotential Lines on the Grid**

The first equipotential value that you will use is +19 volts. Move the Voltage Meter over near the positively charged particle and find a spot the reads +19 volts. If you cannot get a perfect reading of +19 volts, find a spot that comes as close as you can to +19 volts. Once you have found this position, let go of the mouse button. Move the cursor onto the pencil symbol and click once. A green line will show. If you Click and Drag the center of the cross-hair over this green line you should get the same voltage value that you chose. This green line represents an equipotential line. Repeat this process for the following voltage values.

9 volts, 4 volts, 1.5 volts, -1.5 volts, -4 volts, -9 volts, -19 volts.

This will result in 4 equipotential lines “circling” around the positively charged particle, and 4 equipotential lines “circling” around the negatively charged particle. They really are not circles as you can see. When finished placing the equipotential lines onto the simulation’s grid place the Voltmeter back in its box.

(continued on next page)

**Mapping the Equipotential Lines onto Your Graph Sheets**

For each of the green equipotential lines on the simulation’s grid you will map enough points onto your graph sheet so that you can hand draw the equipotential lines.

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In the above illustration selected points from one of the equipotential lines of the simulation are transferred to the graph sheet. Then, a smooth curve is fitted to the selected points. This represents one of the equipotential lines. Complete the other 7 equipotential lines onto your graph sheet.

**Drawing the Electric Field Lines**

As you saw in the first illustration showing the electric field traversing radially outward from the positively charged particle (or point charge), these electric field lines crossed the equipotential lines at a 90° angle. Now, with two charged particles, one positively charged and the other negatively charged, draw several electric field lines emanating from the surface of the positively charged particle and terminating onto the surface of the negatively charged particle. These lines should be drawn continuously, making sure that you curve these electric field lines so that they cross the equipotential lines properly.

Make sure that you draw arrow heads on the electric field lines to show which direction the field is flowing. Direction should be from positive charge to negative charge, or from higher electric potential to lower electric potential.

**Determining the Electric Potential using Superposition**

On the simulation use the Voltage Meter to “measure” the electric potential corresponding to the point (x=15 squares, y=10 squares) and record this on the Excel spread sheet associated with this experiment.

Then, using the equation for electric potential of a point charge, determine the electric potential caused by the + 1 nano-Coulomb charged particle at this same point, and determine the electric potential caused by the -1 nano-Coulomb charged particle at this same point. Once you have determined these two potentials add them together. You are superimposing the two electric potentials by adding them together. Compare your calculated total electric potential to the one you measured in the simulation. Use the percent error equation to determine how close your calculation is to the measured value.

**Calculate the magnitude and direction of the Electric Field at a Point**

Using the same point that you determined the electric potential, determine the electric field. The electric field is a vector quantity, so the electric field generated by the positively charged particle at a point can be vectorially added to the electric field generated by the negatively charged particle at the same point to determine the resultant electric field vector.

The direction of the electric field, at a particular point in space, generated by a positively charged particle is directed radially away from the positively charged particle. The direction of the electric field, at a particular point in space, generated by a negatively charged particle is directed radially in towards the negatively charged particle.

Determine the magnitudes and the angles of the individual electric fields generated by each charged particle at the point in question. Call one, E+, for the electric field generated by the positively charged particle. Call the other, E-, for the electric field generated by the negatively charged particle. Determine the x- and y- components for each, and from these determine the resultant electric field’s magnitude and direction. Use the Excel spread sheet to do your calculations.

(continued on the next page)

**Part 2:**

**Electric Field Configuration between Two Lines of Charged Particles, One Positively Charged, the Other Negatively Charged.**

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The two lines of charges will consist of overlapping point charges. Start with the two point charge positions from Part 1. Add 5 charges up the graph, in a line, ending with the fifth charge centered exactly 10 squares from the initial charge. Add 5 charges down the graph, in a line, ending with the fifth charge centered exactly 10 squares from the initial charge. Add a second layer of charges along the top of this line of charges, such that they overlap the charges below them. You should have a total of 21 charges for one line of charges. Repeat for the other oppositely charged line of charges. The two lines of charges are both vertical on the graph and they are 10 squares apart from each other, on center. Please refer to the illustration above.

As you did in Part 1, hand draw the equipotential lines and the electric field lines for this configuration. Use the following electric potential values: +130 volts, + 80 volts, + 30 volts, -30 volts, -80 volts, -130 volts.

Make sure on both of your equipotential lines and electric field lines drawings (part 1 and part 2) that you show the positions of the charges (part 2 can just be drawn as long rectangles), designate which is positively charged and which is negatively charged (only one + and one – sign to be used for the long rectangles in part 2), the equipotential lines, and the electric field lines with arrow heads showing proper directions.

Results

State here a comparison of the measured electric potential and the calculated electric potential from part 1, stating how well they compare using the percent error found. State the magnitude and direction of the electric field found in part 1.

Questions for Discussion

1. In part 2, how are the electric field lines between the two lines of charge oriented with respect to each other near the “origin”? What happens to the electric field lines between the two lines of charge, but near the ends of the lines of charge?
2. Using the simulator you saw that the equipotential lines did not cross each other. Is it possible for equipotential lines to cross each other? Explain your answer.
3. A 10 centimeter diameter solid sphere made of a conducting material has 10 micro-Coulombs of charged placed upon it. What is the potential difference between a point on one side of the sphere to a point on the exact opposite side of the sphere? What is the magnitude of the electric field at the center of the sphere?
4. Describe how the lines of electric field are oriented with respect to each other for a region having a uniform electric field. What electric circuit device generates a uniform electric field?