Electric Potential Excel Activity

BACKGROUND
A point charge (Q) in space will cause an electric potential differences to exist at points surrounding it. Electric potential difference is often denoted with the letter "V". The units of electric potential (J/C), are called Volts. 1 Volt = 1J/C. Electric potential, as the term suggests, is intimately related to the concept of electric potential energy.

As with gravitational potential energy, **electric potential energy** (ELPE) is always specified relative to some selected reference point. Generally speaking, the ELPE of a charge q is taken to be zero when q is "infinitely far" from charge Q. Because our selection of a reference for measuring ELPE is arbitrary, the only thing that we can really measure is the change in a particle's ELPE, or ΔELPE, between two points as the charge moves between these two points. Therefore, we are usually more interested with a second related, but different quantity -- an **electric potential difference**. If we move charge q through space between points A and B, each of which have a different electric potential, then the electrical potential energy of q changes. If the ELPE of q changes, then work has been done on charge q as it moved through the electric field generated by charge Q. It is this work (a.k.a. this change in ELPE of q), that we can measure and can correlate to an electric potential difference. In this activity, we will refer to an electric potential difference as V_{ba}.

electric potential difference = (the change of the electric potential energy of q in moving between two different points within an electric field caused by charge Q) / q.

$$V_{ba} = \Delta ELPE/q = W_{ba}/q$$

For a given charge Q, the electric potential at a distance r from Q (relative to the potential at an infinitely far point) is given as kQ/r.

$$V_{r\infty} = kQ/r$$

Unlike the electric field **E**, electric potential is a scalar quantity. Therefore, to determine the electric potential at some point influenced by multiple point charges, simply add up the individual potentials produced by each of the charges present. If a charge is negative, be sure to include the negative sign. This is important. Here, negative potentials are okay because potential, after all, is always measured relative to an arbitrary reference point anyway. A negative potential simply means that it has less potential than other points in space.

By examining the electric potential of points in space, one can begin to understand how a charge q, when it is brought into the space conditioned by the charges establishing the existing electric field, will behave. Specifically, the electric potentials tell you what will happen to the electric potential energy of q, how it changes as q moves through the conditioned space, and the electric potential difference between locations can help determine how q will move. In this activity, you are going to generate surface plots that depict the electric potential established by various charges in two-dimensional space. These plots will aid your understanding of the somewhat abstract concept of electric potential, its relationship to the electric fields produced by charged objects, and what it means to the energies and motions of charged particles that find themselves within the conditioned space of other charges.

PROCEDURE

1. Open Microsoft Excel.

2. Click and drag to highlight columns [A] through [AD]. Then, adjust the width of one of these highlighted columns by placing the cursor over the edge of one column's header. When you adjust this column's width, all of the selected columns will adjust to the same width. Adjust the width of these columns so that each of the cells in these columns is approximately square. By doing this, you are establishing your two-dimensional space that you will model. In addition, by making your cells square, your surface plot will be less "blocky." Microsoft Excel is able to convert row numbers

and column numbers to numbers via. the ROW and COLUMN commands. This allows the spreadsheet to treat each cell as a point in space. Each cell becomes its own x-coordinate (a column number) and y-coordinate (a row number). The z-coordinate of your final plot will become the electric potential difference between a point infinitely far away from *Q* and the point represented by that cell.

3. In the top left cell A1, enter the following formula:

= 9.0E9*(charge1/SQRT((COLUMN(A1) - COLUMN(charge1))^2 + (ROW(A1) - ROW(charge1))^2))

Here, we are taking advantage of the naming capability of Excel. "charge1" will eventually be the name of the cell representing the charge's location. Since we haven't established that location yet, Excel will not be able to carry out the calculation. You may get an error message citing a circular reference -- Excel does not know yet what “charge1” is. Accept the message and continue.

4. Copy the formula into the rest of the cells of your 30 x 30 grid.

5. Click on cell R17. This cell will become your charge. Type the number “1.0E-7” in here. This cell is now the location of your *Q,* the charge that causes all other charges around it to acquire ELPE. Its magnitude is 1.0×10^{-7} C.

6. Now, name the cell R17 "charge1" (without the quote marks, without capitals, and with no spaces). The easiest way to do this in Excel is to click on the naming field to the left of the formula entry area immediately below the tool bar at the top of the page. Replace the highlighted "R17" with "charge1" and press the Enter key. You may notice a change in your spreadsheet now that Excel can actually carry out the calculation. If the cells of your grid have "##" in them, this is okay. Excel is simply telling you that the numbers in your cells are too big to display. Later, if you wish to return to your named cell, all you need to do is select "charge1" from the naming field pull-down menu and your cursor will return to this cell.

7. Now, drag from cell A1 to the opposite corner of your grid to select all the cells in it. With all your cells selected, click on the "Insert" menu in the toolbar, expand the charts option, click on the “All Charts” tab, and select the left-most surface chart type. In order to have this chart on a separate sheet, make sure your chart is selected and in the chart layout toolbar, select the “Move Chart” button. Placing the chart on a separate sheet facilitates changing your grid as necessary later. Now your chart should display on a separate sheet from your data. In order to label your chart appropriately, while viewing your chart select the “Add Chart Element” button on the DESIGN Tab of the Chart Tools Toolbars. Label the X and Y-axes as Rows/Columns using the “Axis Titles” option.

Question A: What should your Z-axis label be? Make sure to label the Z-axis (with appropriate units).

8. You have generated your potential surface. Because of the automatic scaling of the axes, you many not get a symmetric potential surface. If you would like to rearrange the angle of presentation for your plot, modify the chart settings. Experiment to get the best viewing angle for your plot.

Question B: How is the electric potential of a point on one of these curved lines related to the electric potential of a second point on the line?

Question C: If a positive charge *q* with an initial velocity (and thus initial kinetic energy) in the direction of increasing column number enters your grid along Row 14, describe its motion (including its apparent acceleration and how it changes) as it would be viewed when looking straight down on your surface (in the negative z-direction). Include a rough drawing with your description.

9. This same basic procedure can be extended to any number of charges. A two-charge system can be modeled with the following formula in cell A1 (which can be made by a quick copy, paste, and revision of the original formula):

= 9.0E9*(charge1/SQRT((COLUMN(A1) - COLUMN(charge1))^2 + (ROW(A1) - ROW(charge1))^2)) +
9.0E9*(charge2/SQRT((COLUMN(A1) - COLUMN(charge2))^2 + (ROW(A1) - ROW(charge2))^2))

If you reuse the same cell for charge1, you will not need to rename it. But you will need to name a cell "charge2" as you did before. To make your work easier, you can put your two-charge system on a new worksheet.

10. Revise your grid to model a two-charge system with two charges at R17 and F17. Make your charge at R17 = 1.0 x 10^{-7} C, and your charge at F17 = -1.0 x 10^{-7} C. Make a surface chart to graphically view the electric potential.

Question D: Assuming you are looking down on your surface (along the negative z-direction), draw equipotential lines - an equipotential line is one in which the potential at every point on the line is the same.

Question E: Describe how a positively charged particle q would move if it travels (starting from rest) from the positive Q to the negative Q. Include the particle's acceleration and how it changes in your description.

Question F: How does the particle's position relate to its rate of change of electric potential energy? You might need to think on this one a bit.

Question G: What would a positive charge do if it were placed exactly in the middle of the saddle formed between the two charges? What would a negative charge do? What is the electric field at this point for both cases?

Question H: If the electric field at the point in Question #23 is zero, does this mean that a charged particle placed here has no electrical potential energy? Explain.