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College Physics II
Lab 5: Equipotential Lines

Peter Rolnick and Taner Edis

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Introduction

You will learn how to find *equipotential lines* in a tray of tap water. (Consult section 21.5 in your textbook.) An equipotential surface is a collection of points in space where each point has the same value of electric potential as every other point. For example, the set of all points that have a potential of 4 volts is an equipotential surface.

In a shallow tray of water the equipotential surfaces are vertical surfaces in the water which can be represented as lines when viewed from above. We will map out some of these equipotential lines for three different situations:

1. Two point sources,

2. Two parallel plate sources with a circular conductor between them,

3. One more different arrangement of your choice.

Electric potential, also called *voltage,* is the potential energy of an object (in joules, J) divided by the charge of the object (in coulombs, C). The unit of electric potential (or voltage) is J/C = volts, V. Electric potential is not the same thing as electric potential energy! The letter V is used for both voltage and volts; just remember that the unit of voltage (V) is volts (V).

You should also know that *electric field lines* are imaginary lines which point in the direction a plus charge will encounter a force in an electric field.

Electric field lines are always perpendicular to the equipotential lines wherever the two cross.

Electric field lines and equipotential lines each behave in a certain way in the vicinity of a *source*—any distribution of charges which give rise to an electric field—and in the vicinity of a conducting surface:

- Near a source, the equipotential lines are parallel to the surface of the charge distribution, and the electric field lines are perpendicular to the surface of the charge distribution,

- Near a conducting surface, the equipotential lines are parallel to the conducting surface, and the electric field lines are perpendicular to the conducting surface.

Electric field lines must have arrows that point in the direction in which a free positive charge would be accelerated, that is, in the direction of the electric field. Electric fields point in the direction in which the voltage is decreasing. Therefore the arrows should point from high voltage to low voltage. For electric fields due to stationary sources, electric field lines must start and stop on a source (a "+" charge) or a sink (a "−" charge) or they can head off toward infinity in some direction.

Procedure

The source of electric potential (or voltage) is a function generator or signal generator. It will generate an adjustable alternating (AC) voltage of about 0 to 10 volts. You will measure voltage with a digital voltmeter.

1. Place a piece of graph paper under the glass tray and fill the tray with about an inch of water. Place another, identical, piece of graph paper next to the tray. You will take your measurements in the tray above the first piece of graph paper. You will draw your maps on the second piece of graph paper.

2. The function generator should produce a sine wave at a frequency of about 1 kHz with a voltage of 6 to 10 volts. (This AC voltage is what is known as a "root-mean-square" voltage, which is the sine wave amplitude divided by $\sqrt{2}$.) Set it at the maximum voltage possible (usually around 7 V), and call that value V_0.

Activity 1: Two Point Sources

1. Obtain two point source electrodes and one test electrode. Place the point source electrodes about 12 centimeters apart in the water on the line down the middle of the long axis of the graph paper. Mark these points on your own graph paper. It will be easier if you graph everything to scale.

2. Attach the positive output (+ or red) of the function generator to one point source electrode and the negative output (−, ground or black) to the other. Use banana wires and alligator clips as necessary.

3. Attach the positive input (+ or red) of the digital voltmeter to the test electrode and the negative input (−, ground or black) to the negative source electrode.

4. Mark two sheets of graph paper with the (same) positions of the two point sources, and place one sheet under the tray, and the other sheet next to the tray. Make sure the point sources are in the correct places.

5. Place the test electrode into the water (make sure you hold it straight up and down, not tilted). The voltmeter should read a value between 0 and V_0. As you move the test electrode around in the water the voltage should change. You are sampling the electric potential of various points in the water. What you are actually doing is measuring the potential difference between a point in the water and the negative source electrode. If you measure points near the negative source electrode you will get values close to 0 volts. If you measure points close to the other electrode you will get values close to V_0. Try it. (Note: Only read the volt meter to ± 0.1 V; it will fluctuate too much at the 0.01 V place.)

6. Pick about 7 voltages spread evenly between 0 and V_0, and (for each of those voltages) find enough points in the tray which are at that voltage to define a shape for that equipotential line. Remember that "at that voltage" only has to be to within ± 0.1 V.

7. Using your measurements, draw a careful map of the equipotential lines. Your map should include the sources, should show each point you

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measured, and should show about 7 equipotential lines inferred from those points. If you feel you need to take additional measurements in certain areas to make the pattern clear, then do so. Label each point, each line, and the two sources with their actual measured voltages (to within 0.1 V).

8. Draw in electric field lines. Use a different color or dotted lines to differentiate them from the equipotential lines. Include enough electric field lines for the geometry of the electric field to be clear to someone looking at your map. Your result should look very much like that in figure 21.22 in your textbook.

Activity 2: Two Parallel Plates With Circular Conductor

1. Obtain two flat long bars of metal. Remove the two source electrodes, and replace them with the plates, placed parallel and as far apart as possible. Use alligator clips to make electrical connections between the plates and the function generator and the voltmeter.

2. Place a conducting ring midway between the plates. Do not connect it to anything.

3. The test electrode will be connected to the positive input of the voltmeter and will be used to map out the lines exactly as before.

4. On two sheets of graph paper mark the (same) position of the plates and the conducting ring. Place one sheet under the tray (with the plates and the ring in the appropriate places), and place the other sheet next to the tray.

5. Proceed as in activity 1 to map out equipotential lines. Label each of the lines, the two plates, the ring, and the inside of the ring with their respective voltages.

6. Draw in the electric field lines. Note that the conducting ring can now act as a source or a sink (even though it is not connected to any voltage source) so electric field lines can start or stop on it. Note also

that electric field lines must always approach a conducting surface (the ring and the two plates are all conducting surfaces) perpendicular to that surface.

Activity 3: Additional Charge Distributions

Using the same basic technique as in activities 1 and 2, make field maps for one more charge distribution. All the charge distributions you map should be different. Here are some suggestions for additional charge distributions to try after parts 1 and 2:

- A *line* of one charge and a *point* of the opposite charge,
- Two *non*-parallel lines of opposite charge,
- A conducting *ring* of one charge, and one or more lines of the opposite charge,
- Something else you think of (check with me first).

As you do the experiment, check on the value of V_0 to make sure it hasn't drifted. If it has, readjust it accordingly.

To hand in

- A field map for each configuration you examined,
- For one of your field maps (state which one), pick two equipotential lines (state which ones) and calculate how much energy it would take to bring a charge of +1.00 C from the lower voltage line to the higher voltage line.