2.2: Activities

Equipment

- clear plastic tray containing a thin layer of water
- aluminum electrodes (one flat, one small cylinder, one large cylinder)
- multimeter with probe wire
- Pasco box and laptop
- graph paper template
- data sheet
- wires
- alligator clips

The General Idea

There are two parts to this lab. In the first part, your goal is simply to map the equipotential surfaces of integer voltages ($1\; volt$, $2\; volts$, etc.) that exist between two conductors (electrodes) – one flat, and one a small cylinder – across which a total potential difference of approximately $5\; volts$ has been created. You should show that this map is consistent with the fact that the electrodes are themselves equipotentials, and use the map to approximate the electric field lines that pass between the two electrodes.

The second part of the lab is more quantitative, and seeks to experimentally settle the following dispute: If we arrange two cylindrical electrodes coaxially, then we find that the equipotential surfaces are (unsurprisingly) circular, centered at the common axis of the electrodes. But we also notice that unlike equipotentials between parallel flat electrodes, these circular equipotentials are not equally-spaced. Both parties in the dispute agree that this reflects the fact that the electric field gets weaker as the position gets farther from the axis (measured by the radial distance r from that axis), but one group claims that the field gets weaker in proportion to $\frac{1}{r}$, while the other group claims it gets weaker in proportion to $\frac{1}{r^2}$. By making measurements of voltage at many distances from the axis, you will use graphical techniques to determine which of these assertions is correct.

Some Things to Think About

- **Warnings**
  - No, you don't have to worry about being electrocuted in this lab, though your instincts about mixing electricity and water are good ones!
  - Don't let the electrodes touch each other when the power is on, as this will short the Pasco output.
- **Setup** – You should be familiar with most of this from the Background Material:
  - Connect one wire to the flat electrode and one to the small circular electrode using the alligator clips, and the plug the other ends of the wires into the ⏚ and ∿ ports of the Pasco box.
  - Place the appropriate template face-up under the transparent tray, add a *thin* (no more than a quarter-inch) layer of water to the tray, and place the two electrodes into the tray directly above their template positions.
  - Connect the wire from the black "COM" port of the multimeter to one of the electrodes using an alligator clip, and connect the probe wire to the red "$V\Omega Hz$" port of the multimeter.
  - Put the multimeter into the $20V$ setting in the "~V" sector of the dial.
  - Make sure the laptop is connected to the Pasco box through the USB cable, start it up, and in the 9C folder on the desktop, run the "Electrostatic_Potential" application. You should *not* change any of the default settings. Turn the power on when you are ready to take data.
  - The data sheet provided has one side for transcribing points of the equipotentials in part 1, and a handy table available for recording data for part 2.

Part 1

- You should confirm that the minimum and maximum potentials are where you think they are.
- Note that while you will stick the point of the probe into the plastic below the surface of the water, it is the *water* where the potential is being measured, which means you will want to make sure that the probe tip is *vertical* when taking a measurement (you will note that in regions where the potential is changing very fast, slanting the tip of the probe can account for a substantial potential difference compared to the vertical).

- Mark several points at each integer voltage, though you will find that there are weird effects that occur near the edges of the water (edges of regions always cause issues with electric fields), so you may not want to record points too close to the edges.
- In your lab report, you should include:
  - a picture of your logged data points, along with the sketched equipotential lines they create, and a sketch of the *electric field lines* derived from these equipotentials
  - analysis of how the equipotentials and field lines "make sense"

Part 2

- The most important thing to keep in mind here is that the two prospective theories are about the electric field, but what you will be measuring is electric potentials – *these are not the same thing*, and you will need to "translate" between the two before you can even decide which graphs you need to generate! [*Reminder:* $\vec{E} = -\nabla V = -\frac{\partial}{\partial r} V \hat{r}$ *, so given the functions you are testing for* $E(r)$*, what are you testing for* $V(r)$?]
- This is the quantitative portion of the lab – you are not restricted to integer potentials, nor are you looking to sketch equipotentials. This should make the acquisition of data easier than in part 1. Nevertheless, it would be a good idea to informally confirm that the equipotentials are roughly what you expect them to be.
- As you are only looking for a functional dependence, you can use whatever units of length measurement you wish. You might find "grid squares" easier to work with than (say) centimeters.
- Use the usual online graphing calculator for the best-fit lines. Here is a reminder of how to use this tool:
  - click the "+" button in the upper-left corner and select "table"
  - enter the values you wish to graph (those that reflect the functional dependence you are testing, not the raw values you recorded!)
  - include a formula in the next box that looks like: $y_1 \sim mx_1 + b$, and a best-fit line will be drawn through the points (the subscripts are added by inserting an underscore: "y_1" is "y_1")
- In your lab report, you should include at least:
  - your table of recorded values
  - best fit line graphs for the two proposed "theories", along with a conclusion of which one fits better
  - analysis/discussion of the result
- As an extra "bonus," you can explore what is going-on *inside* the center ring. Do you expect there to be an electric field in there? From your answer to this question, what would you expect to find the potential to look like in there? Go ahead and test it! If you think you have it figured out, this is your chance to show-off to your TA – see if they confirm your brilliant conclusions.

Lab Report

Craft a lab report for these activities and analysis, making sure to include every contributing group member's name on the front page. You are ***strongly encouraged*** to refer back to the Read Me as you do this, to make sure that you are not leaving out anything important. You should also feel free to get feedback from your lab TA whenever you find that your group is at an impasse.

Every member of the group must upload a separate digital copy of the report to their lab assignment in Canvas *prior to leaving the lab classroom*. These reports are not to be written outside the lab setting.