Performance: Report: Total:

Physics 212-2

Potentials and Voltages

NAME: ____________________________ ☐

STUDENT ID ____________________________ ☐

LAB PARTNER(S): ____________________________ ☐

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Check the box next to the name of the person to whose report your group's data will be attached.

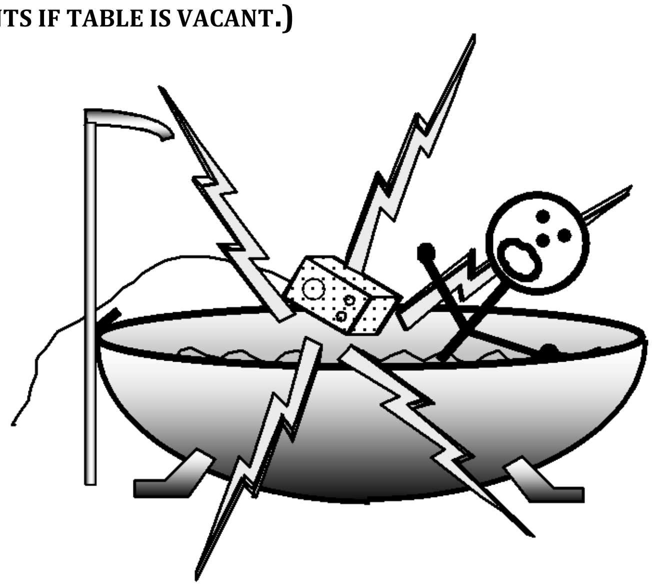
LAB SECTION: ____________________

INSTRUCTOR: ____________________

DATE: ____________________

TABLE: ____________________

(YOU WILL BE TAKEN 3 POINTS IF TABLE IS VACANT.)



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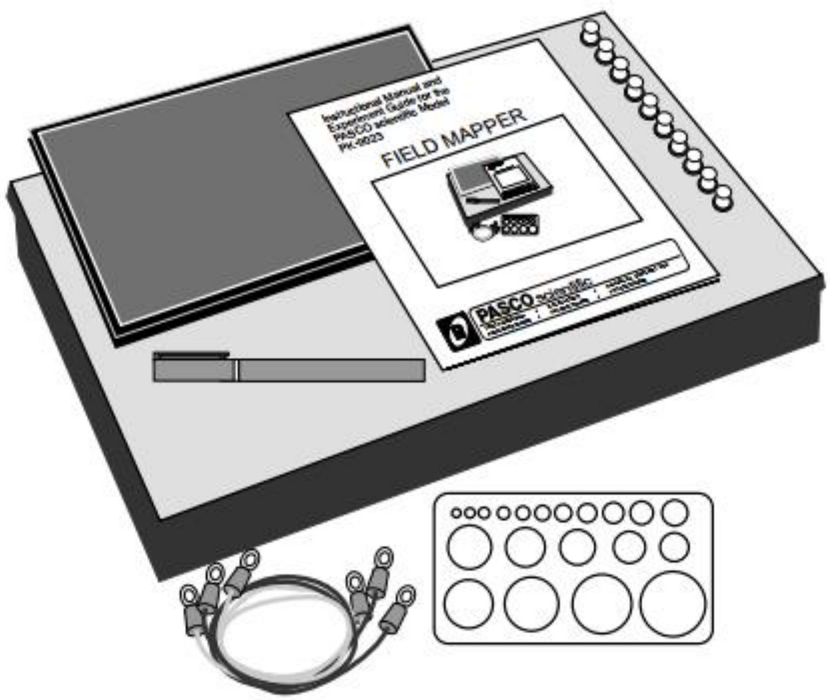
Physics Lab 212-2

Equipment List

PASCO PK-9023 Field Mapper:

A silver conductive ink pen
Conductive paper
A corkboard working surface
3 wires for connecting the conductive paths
A circle template for drawing the conductive paths
A large plastic tray for storing the paper and other supplies

Power supply
Digital Multimeter (DMM)



Potentials and Voltages

Investigation 1: Work in an Electric Field

To find out
- How to verify that the electric force is conservative

Preview
- Set up an electric field across a conductive paper using charged electrodes, and then investigate the electric potential at various points in the conductive paper.

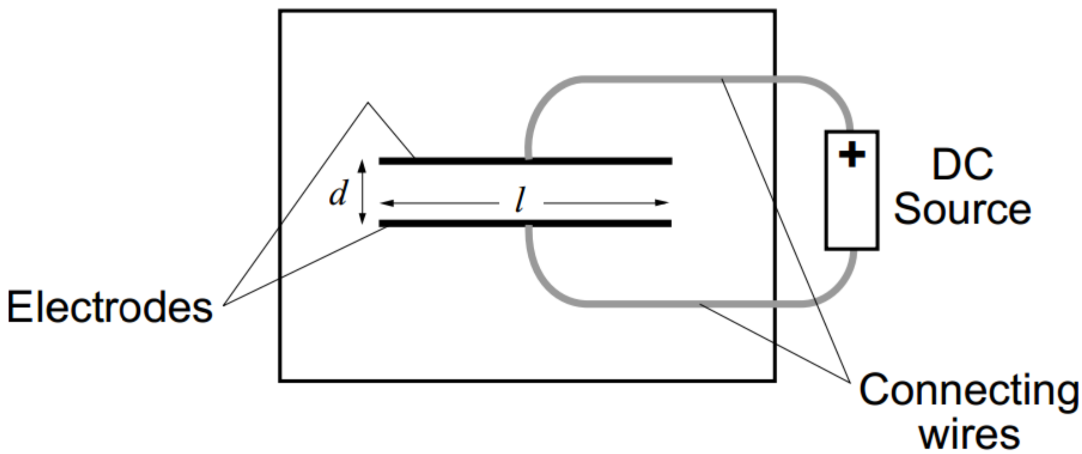


Figure 1. Diagram of a setup for mapping electric potential

In this experiment you will use a conductive paper to simulate a region in space where you can measure electrical potential. The metal electrodes (bars or cylinders) may be "charged" (by connecting them to a power supply), or left uncharged. The electrode connected to the red wire from the supply simulates a region of positive charge. The electrode connected to the black wire from the supply simulates a region of negative charge equal in magnitude to the positive charge. (In fact, the relationship between the electrical property and the wire's color depends on you).

Consider the configuration shown in Figure 1. It involves two long, separated electrodes, one positive and one negative. This experimental setup simulates the field you would find between two large parallel plates. The conductive paper permits you to measure the potential anywhere on the paper.

Activity 1 Finding Voltages

1. Set up the tank as shown in Figure 1.
    - Plan and sketch the layout (size, shape and relative spacing) at least in your mind. In this activity, you should write two parallel electrodes. **Note: the distance between the two conductive electrodes should be large enough, so that you could do the rest activities by using one conductive paper.**
    - Pick up your silver ink pen. **Shake the pen until you can hear the 'click' sound.** Press the pen's tip lightly on the conductive paper. The trace of the pen should be silver white. If you don't see it, shake the silver ink pen again. Details:
        a. Place the conductive paper, printed side up, on a smooth hard surface. **DO NOT attempt to draw the electrodes while the paper is on the corkboard (the brown board).**
        b. Shake the conductive ink pen (with the cap on) vigorously for 10-20 seconds to disperse any particle matter suspended in the ink.
        c. Remove the cap. Pressing the spring loaded tip lightly down on a piece of scrap paper while squeezing the pen barrel firmly starts the ink flowing. Drawing the pen slowly across the paper produces a solid line. Drawing speed and exerted pressure determines the path width.
        d. Once a satisfactory line is produced on the scrap paper, draw the electrodes on the black conductive paper. If the line becomes thin or spotty, draw over it again. A solid line is essential for good measurements. **The line will be air dry in 3-5 minutes at room temperature. However, the medium won't reach maximum conductivity until after 20 minutes drying time.**
        e. Mount the conductive paper on the corkboard using one of the metal push pins in each corner.

2. Set up the meter and turn on the electric field.

    - Turn on the DC power supply. Inserting the banana plug wire into the output port of the supply. Dress a banana-alligator plug onto the other tip of the banana plug wire. Thus you can use the alligator to connect. See figure 1.1

      NOTE: Check that the surface of the terminal which touches the electrode is clean. A dirty path may result in a bad contact.

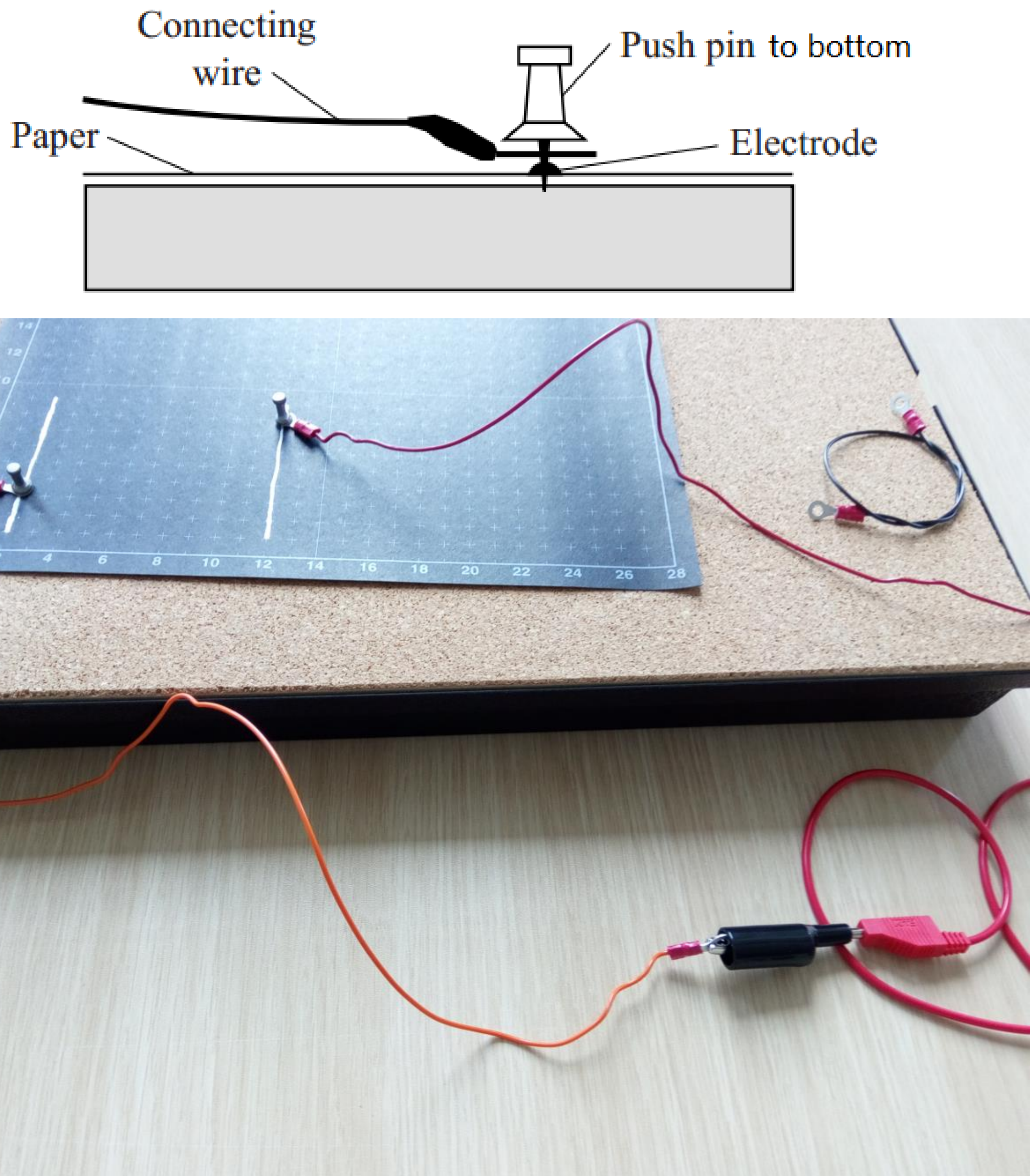


Figure 1.1

- Set the digital multimeter (DMM) to measure *DC voltage* by pressing the button (⎓V) on the front of the DMM. The multimeter has two probes, and measures the *electric potential difference* (voltage) between the point where the red probe is touching and the point where the black probe is touching. **<u>Keep placing the negative probe onto the negative electrode.</u>**
- If you now place the test probe directly on top of the positive electrode (connected to the transformer by the red wire), you will be in a position to measure the voltage difference between the electrodes.
- Turn on the power supply. Your DMM should read 4.0 V. If it does not, adjust the power supply dial a bit.

3. Try some measurements.
   - Poke the test probe (use the probe of the DMM) onto the conductive paper. Move it around a bit and get a feel for the voltage readings at different places on the paper.
   - Put the test probe half way between the two electrodes and record your reading here:

Potential in the middle: _________ [V]

Prediction	Suppose you put the test probe on the negative electrode. What do you expect the potential difference measured by the DMM will be? ____

4. Test your predictions.
   - Put the test probe on the negative electrode and record your reading here:

Potential on the negative electrode: _________ [V]

Q1 Explain why you got this reading. What is the potential difference between two points on the same conductor? Is this true for *any* two points on any conductor?

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Q2 If you put 2.0 Coulombs of charge on the negative electrode (0 V), it would be defined to have 0 Joules of potential energy. If you put the same charge *midway* between the two electrodes, how much potential energy would these same 2.0 Coulombs of charge have? (Measure the voltage difference, and then compute the energy.)

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Q3 How much work would be involved in taking these 2.0 Coulombs of (positive) charge from the midpoint between the electrodes to the positive electrode? Would it depend on the path? What is the work if you move the charge in a closed path (i.e., starting and ending points are the same)?

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Investigation 2: Equipotentials and Electric Fields

To find out

- How to map the electric potential in two dimensions for a variety of electrode configurations
- How to determine electric field lines given the equipotential surfaces, and vice versa

Preview

- Discover the equipotential surfaces for different electric fields
- Examine equipotentials and electric fields for a variety of electrode configurations

By definition, force is exerted along the direction of the field; no force is exerted along the direction *perpendicular* to the field, and no force means that no work is done. Thus, if we move a charge along a path which is everywhere perpendicular to ***E***, no work will be done. We can envision a surface perpendicular to the field by considering a given point and looking at all of the paths which pass through this point and are everywhere perpendicular to the field. By definition, ***E*** points along the direction in which the potential changes the most rapidly. Perpendicular to ***E***, the potential does not change at all. Consequently, all points on the "perpendicular" surface are at the *same* electrical potential, and the surface is called an *equipotential surface*.

You are already familiar with equipotential surfaces in a gravitational field – Figure 2 shows a common example: steps. For example, somebody on step 3 could walk anywhere along step 3, and since the gravitational field is perpendicular to the step, gravity would do no work on that person. In other words, the gravitational potential energy is the same all along step 3, so this step represents an equipotential surface. The other steps in the diagram are also equipotential surfaces.

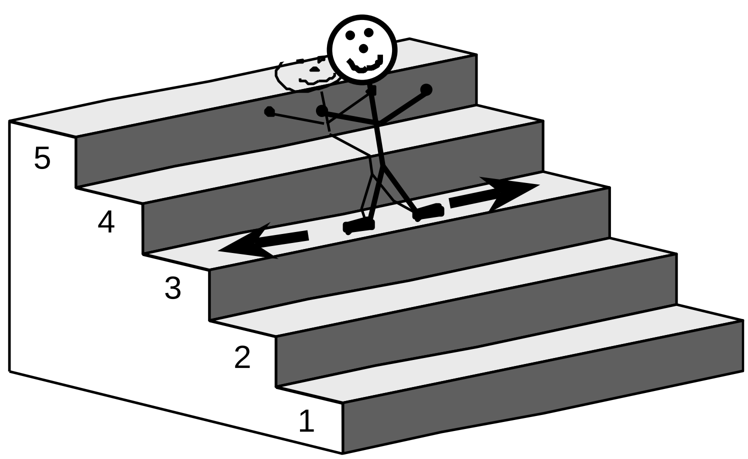

Figure 2. Equipotential steps

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Activity 2 Field of an electric dipole

One of the most common field configurations that you will encounter is that of a dipole. It is formed when two charges of equal magnitude and opposite sign are placed a distance apart from each other.

Prediction	Consider the dipole configuration of Figure 3. On the left half of the diagram, sketch *several* electric field lines you would expect to find. Use a colored pencil and be specific in your drawing. Remember that electric field lines always start and finish at a charge, so do not leave them hanging in space. Also, remember to indicate the direction of the field.

←----------------predictions----------------→←--------------measurements--------------→

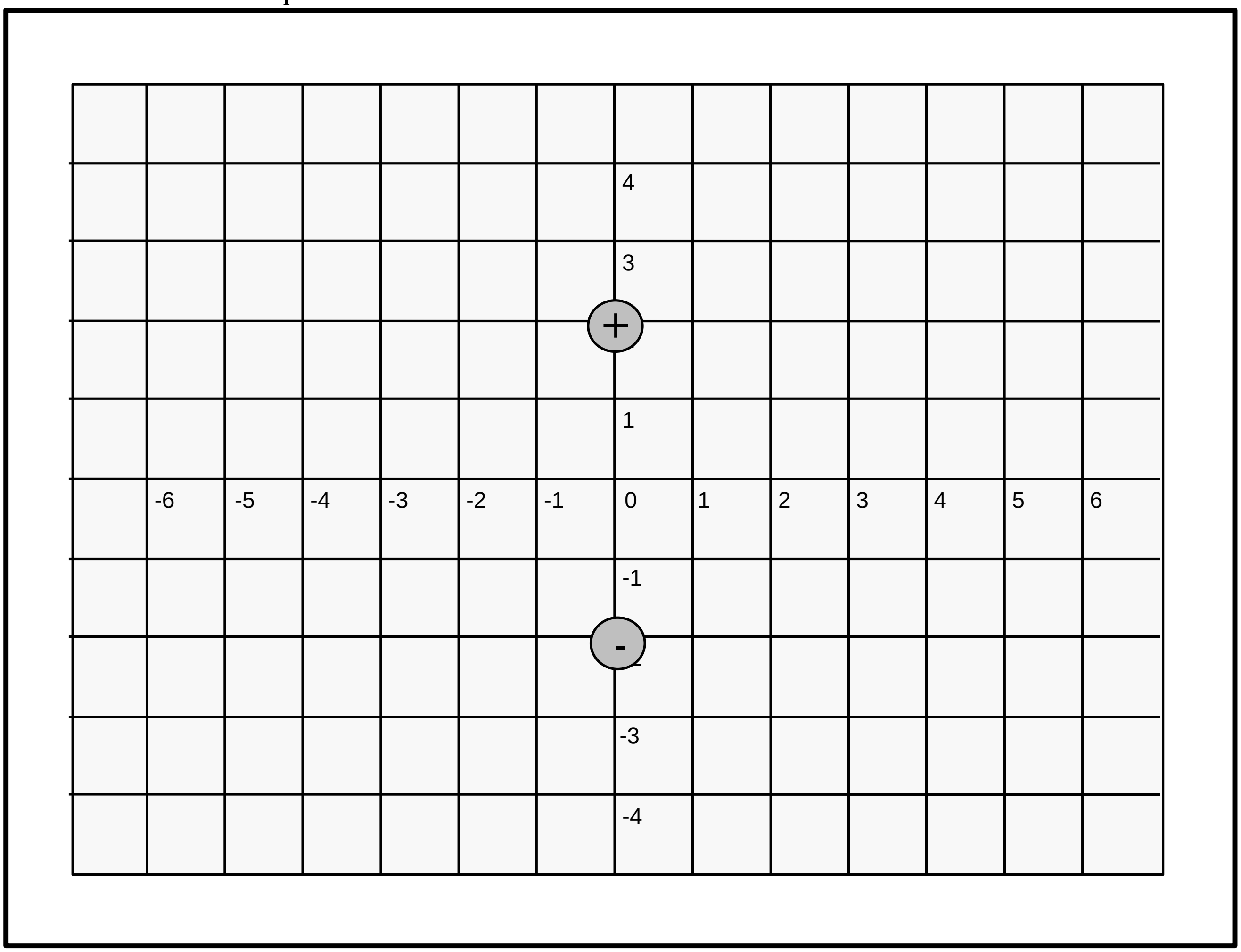

Figure 3. A dipole configuration

Since you cannot measure the actual electric field lines, you will find the equipotential lines (surfaces in 3D) and deduce the field lines from them.

Prediction	Think about the equipotential lines that would give rise to the field lines that you have just drawn. Predict and sketch *several* equipotential lines on the left half of Figure 3. Use a different colored pencil and be specific in your drawing. Remember that the equipotential lines are perpendicular to the electric field lines.

1. Set up the experiment.
   - Plot two big dots by using silver ink pen at the position as shown in Figure 3. And then use the push pin to connect them to the power supply.

2. Find several equipotential surfaces.
   - Use the test probe to plot a series of coordinates which all have the potential difference of 1.0 V with respect to the negative electrode. Record the coordinates directly on the right half of Figure 3. Use the same color as in your prediction above. Connect your points to form a continuous curve. Indicate which lines are predictions and which are the actual results.
   - Repeat this procedure for 1.5 V and at least two other potential values. Take enough data so that you can see the full pattern emerge. (Hint: Look for symmetry in this problem. Do you need to explore the whole area of the paper?)

3. Deduce the electric field lines.
   - Using the fact that electric field lines are always perpendicular to equipotential lines, sketch a set of electric field lines on the right half of your diagram in a different color than you have already used.
   - Put arrows on them to indicate the *direction* of the electric field.

Q4 What is the potential halfway between the two charges? Does this value change as you move the probe along the *horizontal* line halfway between the charges? Explain the behavior you have observed.

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Activity 3 Plates and Rings

Consider the electrode configuration of Figure 4 in which two parallel plates have (effectively) equal and opposite charges. Centered between the plates is a hollow, conducting ring.

Prediction	From your knowledge of electric fields, and of their behavior at the surface of conductors, predict and sketch *several* electric field lines on the left half of Figure 4. Be sure to include the regions inside and outside of the ring.

←--------------predictions---------------→←-------------measurements-------------→

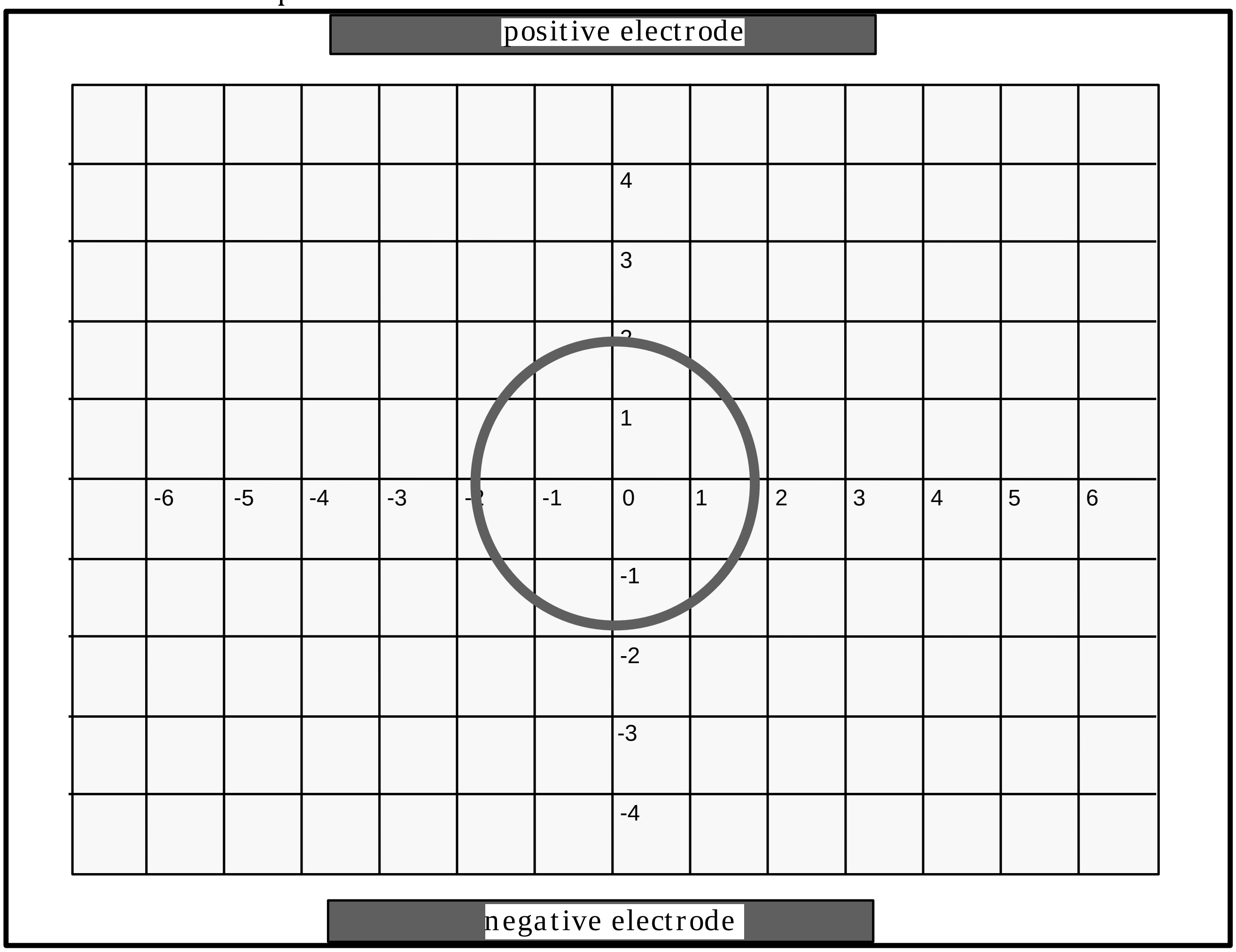

Figure 4. Two parallel plate electrodes with a conducting ring centered midway between.

Prediction	Predict and sketch *several* equipotential lines on the left half of Figure 4. Use a different colored pencil and be specific in your drawing. Be sure to include the regions inside and outside of the ring.

1. Set up.
   - Reconnect the red ("positive charge") plug to the positive electrode and the black ("negative charge") plug to the negative electrode.

2. Get busy.
   - Make a series of equipotential measurements and sketch the equipotential surfaces on the right side of Figure 4.
   - From these surfaces, deduce the electric field lines. Sketch them on the right side of Figure 4. Remember to put directional arrows on the lines.
   - Do not forget to probe the region inside the ring.

Q5 What is the potential inside the ring? What is the electric field there?

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Q6 Did your field lines outside the cylinder agree with your prediction? If not, explain any differences.

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Q7 Suppose you placed a charged object in the middle of the ring. Which way would it move?

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Activity 4 A Charged Ring and other Things

Previously we used a ring that was uncharged. This time, you will charge it "positively" and make both parallel plates "negative."

1. Set up the experiment.
   - Insert the push pin and the positive wire from the power supply to the edge of the centered ring.
   - Use an additional wire and push pin to connect the two plate electrodes to the black wire from the supply. (Of course, the colors of the cables do not *really* matter!) Make sure your electrodes have potentials that correspond to the charges in Figure 5.

Prediction	Predict and sketch several electric field lines on the left side of Figure 5. Include the region between the plates and inside the ring. Remember that the ring here is configured to act as if it contains a positive charge, and that each plate has a negative charge. Be sure to include the regions inside and outside the ring.

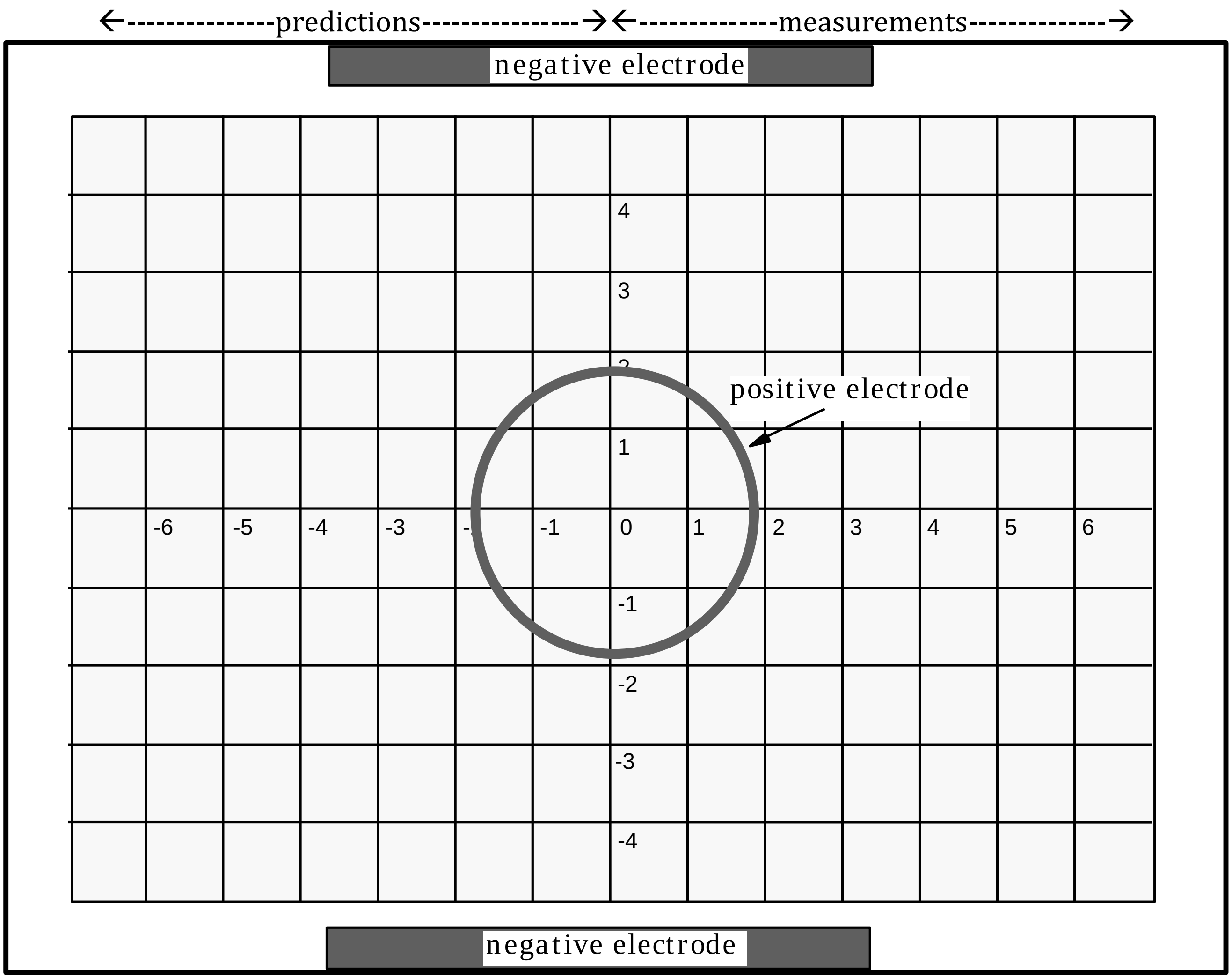

Figure 5. Two parallel "negative" plates with a "positive" hollow ring inside

2. Find some equipotentials.
   - Mark a set of equipotential points on the right side of the diagram. Do any symmetries in this problem limit the amount of work you need to do? Include the region inside the ring.
   - Connect the points, sketching your *equipotential lines* with a different color than you have used previously.
   - Pay extra attention to what happens anywhere *on the ring.*
   - Pay extra attention to what happens *inside* the ring.

3. Sketch the electric field lines.
   - Sketch a set of electric field lines on the right side of your diagram in a yet another color. Be sure to put arrows on them to indicate the direction of the electric field.

Q8 At first glance, the arrangement of conductors in this activity is similar to that from Figure 4, although the electrodes are connected differently. Do you observe any *similarities* between the equipotential lines in the two figures? How about the field lines?

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Q9 Now consider the *differences* between this setup and that of Figure 4. What features of the equipotential lines have changed? How about the field lines?

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Prediction	Suppose that instead of attaching the charge to the ring, you connected it to the centered, solid dot electrode as in Figure 6. Sketch the resulting electric field on the left side of this figure for this case. Be sure to include the regions inside and outside of the ring.

5. Make the measurement.
    - Remove the push pin and wire from the edge of the ring and insert them into the center dot electrodes.
    - Follow your own procedure now to explore the configuration with your potential probes. From that data, deduce the electric field and sketch it (in a new color) on the right side of Figure 6. Include the region inside the ring.

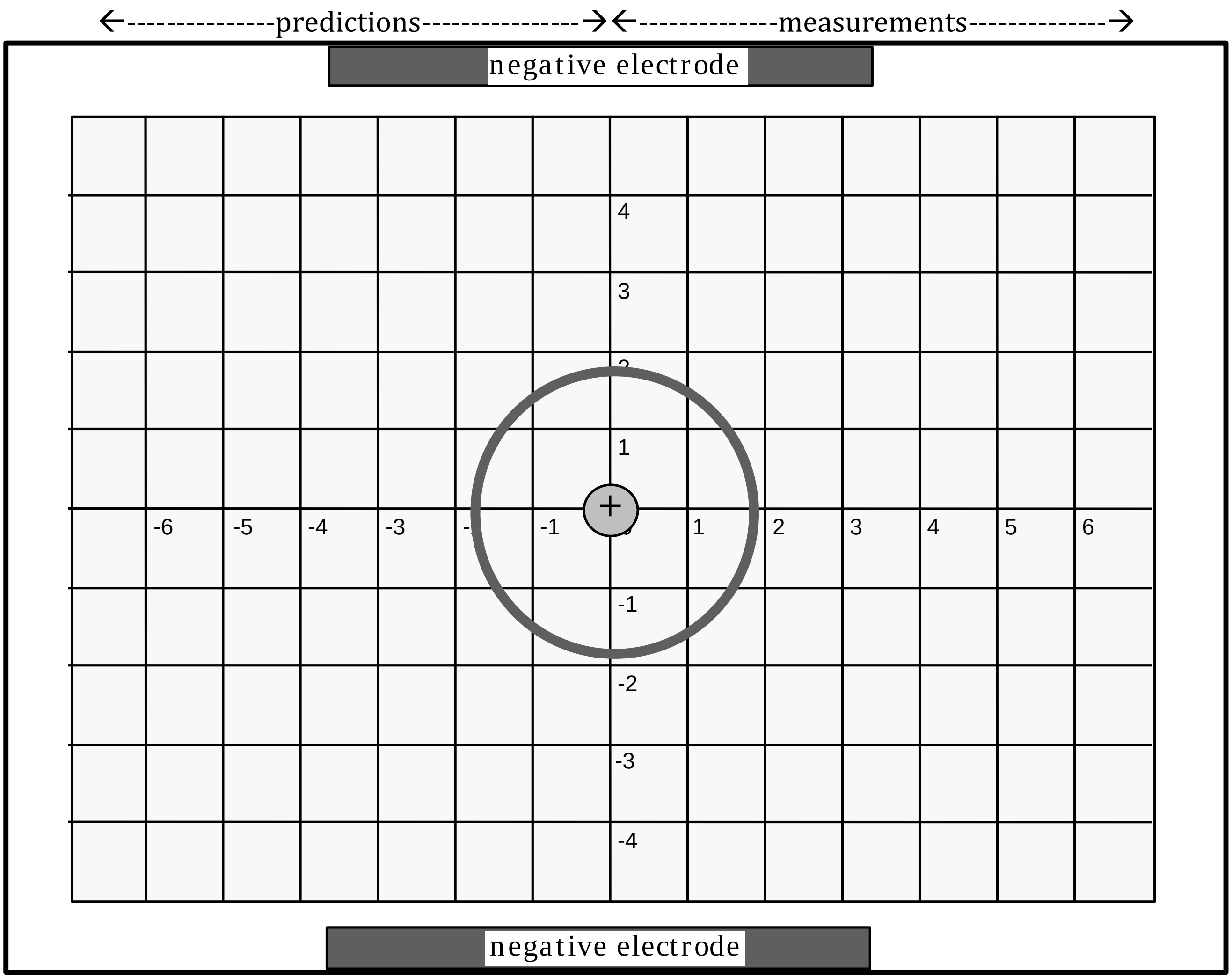

Figure 6. Centered positive electrode

Q10 Describe briefly how the central charge has affected the equipotential and field lines. What features of the new field are similar to the field in Figure 5? What has changed?

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CLEAN UP CHECKLIST

- ☐ Turn off the power supply and the digital multimeter.
- ☐ hand in the used conductive paper together with your report.
- ☐ Make your setup look neat for the next group.
- ☐ Staple everything together, make sure you have answered all the questions and done all the activities, make sure the first page is completed with lab partners' names and check boxes. Hand in your work before leaving the laboratory.