Objective

In this lab, we will learn about electric fields by using different electrode configurations to create electric fields, then calculating the strength of the fields and observing their various shapes and patterns.

Procedure

Please see pages 149-151 in the lab manual for the complete procedure.

Data

<table>
<thead>
<tr>
<th>Measurement Points</th>
<th>Distance Δd Between Points (m)</th>
<th>Voltage at Measurement Points (V)</th>
<th>Voltage Change AV Between Points (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A (5,0)</td>
<td>(3,0) and (7,0)</td>
<td>0.04</td>
<td>5.3 @ (3,0), 7.3 @ (7,0)</td>
</tr>
<tr>
<td>Point B (2, -5)</td>
<td>(1, -5) and (3, -5)</td>
<td>0.02</td>
<td>4.5 @ (1, -5), 5.4 @ (3, -5)</td>
</tr>
</tbody>
</table>

*Table 1: Data for the parallel electrode configuration, used to calculate electric field strength*

<table>
<thead>
<tr>
<th>Measurement Points</th>
<th>Distance Δd Between Points (cm)</th>
<th>Voltage at Measurement Points (V)</th>
<th>Voltage Change AV Between Points (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 2: Data for the ring-shaped, / point electrode configuration, used to calculate electric field strength*

Please see the attached sheets in Appendix 1 for graphs of the equipotential and electric field lines for the two electrode configurations.

Calculations

To calculate the electric field strength for the parallel electrode configuration, choose a point in the electric field, then measure the voltage at two points just to the left and right of the chosen point. After measuring the distance between the left and right points, use the following equation to find the strength of the electric field at the chosen point:
\[ E = \frac{\Delta V}{\Delta d} \Rightarrow E = \frac{V_{\text{Left}} - V_{\text{Right}}}{|D_{\text{Left}} - D_{\text{Right}}|} \]

A similar method can be used to calculate the electric field at a chosen point for the ring-shaped / point electrode configuration. Please see Appendix 2 for complete, written calculations.

**Final Results**

<table>
<thead>
<tr>
<th></th>
<th>Electric Field Strength (V m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Point A (5,0)</strong></td>
<td>5.0E+01</td>
</tr>
<tr>
<td><strong>Point B (2,-5)</strong></td>
<td>4.5E+01</td>
</tr>
</tbody>
</table>

*Table 3: Parallel electrode configuration*

<table>
<thead>
<tr>
<th></th>
<th>Electric Field Strength (V m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Point A (5,0)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Point B (2,-5)</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Ring-shaped / point electrode configuration*

**Discussion and Observations**

In this experiment, we studied electric fields by arranging electrodes in different configurations, then observing the resulting field patterns with a multimeter and calculating the field strengths. The first configuration consisted of two parallel plate electrodes placed 0.1m apart. When the probe was placed in between the electrodes, it was observed that moving the probe parallel to the orientation of the electrodes caused almost no change in the voltage, while motion perpendicular to the electrodes resulted in significant voltage changes. Regarding these voltage changes, the voltage increased the most as the probe was moved perpendicularly from the positive electrode toward the negative electrode, and decreased the most when moved perpendicularly from negative to the positive; the voltage increased and decreased the least when the probe was moved parallel to the electrodes. The probe was then placed in direct contact with each electrode to measure the electrical potential; for the negative electrode, the potential should have been zero, but a very small potential of ≈0.03V was detected (due to the slight ionization of the water between the electrodes, which allowed some electricity to flow). The potential on the positive electrode was 7V. Additionally, the probe was used to measure the potential around the outside of the parallel electrodes, and the potential was constant, indicating that the electric field was confined to in-between the electrodes and that the electric field strength outside of them was zero.

The second configuration was comprised of a ring-shaped electrode (connected to ground) with a positive
point electrode inside it, slightly offset from the center. This configuration was explored in the same manner as
the first: after placing the probe within the ring electrode, it was noted that moving the probe inward radially—
from the outer edge toward the point electrode in a straight line—caused the voltage to increase the most, while
the voltage decreased the most when moved in the reverse direction. When the probe was moved in a circle at a
constant distance from the point electrode, the voltage did not change at all (increased and decreased the least).
The voltage was also measured outside of the ring and was found to be constant, again indicating that the electric
field was confined to in-between the ring and point electrodes and that the electric field strength on the outside
was zero.

Questions

1. If the electric potential is the same everywhere on the conducting electrodes, then the electric field
   strength is zero, because the strength of the electric field is related to the change in electrical potential
   across the field: if the change in potential is zero (the potential is constant), then the strength of the field is
   also zero.

2. \( \text{Volt} = \frac{J}{C}, \text{then} \Rightarrow \frac{N}{C} = \frac{V}{m} \Rightarrow \frac{N}{C} = \frac{V}{C \times m} \Rightarrow \frac{N}{C} = \frac{N \times m}{C \times m} \Rightarrow \frac{N}{C} = \frac{N}{C} \)

3. It is not possible for two equipotential lines to cross because by definition, all points on an equipotential
   line must have the same value for the electrical potential; if two equipotential lines were to intersect, then
   they would have the same potential at that point and for one of the lines, that value for the potential would
   be different from all the other points on the line, causing that line to no longer be equipotential.

4. The electric field between the electrodes of a parallel plate will only be perfectly uniform if the electrodes
   are infinitely long; otherwise, “fringe effects” will distort the field near the ends of the electrodes and
   cause it to be non-uniform.

5. The question states that the electric field lines are perpendicular to the surface of a conductor, “since the
   charges are free to move on a conductor.” Because the electric field lines and the equipotential lines must
   be orthogonal to each other, the equipotential lines must therefore be parallel to the conductor's surface.