Visualizing Electric Potential: Mapping Equipotential Lines in a Conductive Water Tray

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***Abstract*—The goal of this experiment was to study the distribution of electric potential around conducting wire configurations and identify the corresponding equipotential regions. Using a water tray with a saline solution as the conductive medium, we measured the potential difference at defined points on a coordinate grid by connecting the wires to a power supply and using a multimeter to record voltages at various locations. Our observations indicated that equipotential regions were centered somewhat equidistantly between the voltage sources, with a mostly consistent rate of potential change along paths parallel to the sources. Some discrepancies between expected and observed values were noted, likely due to limitations in the measurement equipment and procedural inconsistencies. Despite these challenges, the experiment successfully demonstrated the properties of electric potential and equipotential lines, providing a clear visual representation of their relationship with the electric field.**

***Index Terms*—electric potential, equipotential lines, electric fields, saline solution, conductive medium, voltage mapping, potential gradient**

I. Introduction

ELECTRIC FIELDS arise from the presence of electric charges and describe the force that a charge would experience within the region of influence [1]–[3]. The strength of the electric field is determined by the magnitude and distribution of charges, as well as the distance from the source. Electric potential, on the other hand, represents the potential energy per unit charge at a point in the field and is related to the electric field through the equation [1]:

$$V = -\int E \cdot dr. \tag{1}$$

(1) shows that electric potential is the integral of the electric field along a path, with the negative sign indicating that electric potential decreases in the direction of the field. Equipotential lines are defined as contours where the electric potential remains constant. These lines are always perpendicular to electric field lines, reflecting the fact that no work is required to move a charge along an equipotential surface. This property makes equipotential mapping a useful tool for visualizing the distribution of electric fields and potential in various setups.

In this experiment, we used a polypropylene container filled with a saline solution as a conductive medium to simulate the behavior of electric potential and field in a simplified, accessible environment. Salt was added to enhance the conductivity of the water, ensuring a stable field for measurement. By placing conducting wires connected to a power supply in the tray, we created an electric field and measured the potential at various points using a multimeter. This allowed us to map the equipotential regions and explore their relationship with the electric field. The results gave us insights into how equipotential lines and their relationship to electric fields are critical in applications such as designing capacitors, grounding systems, and electrical shielding.

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II. Methods and materials

To study electric potential and equipotential regions, we used a 3-cup polypropylene food container (EasyFind; Rubbermaid; Atlanta, GA) containing approximately $500\,\mathrm{mL}$ of a weak saline solution prepared using ordinary tap water plus a pinch of sea salt. The polypropylene container acted as a prototype simulating the final electrophoresis rig. The aqueous salt solution acted as a stable conductive medium for electric field visualization, allowing the electric field to propagate more effectively and improving the consistency of voltage measurements across the tray. Container dimensions were approximately $15\,\mathrm{cm} \times 15\,\mathrm{cm}$, ensuring sufficient space for accurate mapping of the potential. A small amount of blue food coloring (about five drops) was added to the water to improve visibility during the setup and ensure uniform distribution of the solution.

Voltage was applied using a $12\,\mathrm{V}$ DC power supply (model PS-28A), and the potentials were measured using a digital voltmeter (model HSPE-051 AC). A piece of graph paper beneath the container allowed for repeatably locating the measurement points, which were on $1\,\mathrm{cm} \times 1\,\mathrm{cm}$ grid squares. The circuit was set up by attaching one alligator lead to the positive terminal of the power supply and submerging it at one end of the tray, while the other was connected to the negative terminal and submerged at the opposite end. This configuration created an electric field across the tray. We placed the wires parallel to the graph paper's grid lines for consistency in measurements. Points of measurement (labeled 1 through 9) were marked at specific coordinates on the grid, spaced uniformly to facilitate data collection.

Using a multimeter set to measure voltage, we started at a reference ground point ($0\,\mathrm{V}$) and systematically recorded the voltage at each grid intersection, moving outward from the ground point. Measurements were taken at incremental voltage settings of $3\,\mathrm{V}$, $6\,\mathrm{V}$, $9\,\mathrm{V}$ and $12\,\mathrm{V}$ adjusted at the power supply. This allowed us to observe how potential varied across the tray for different input voltages. Data collected at these points were

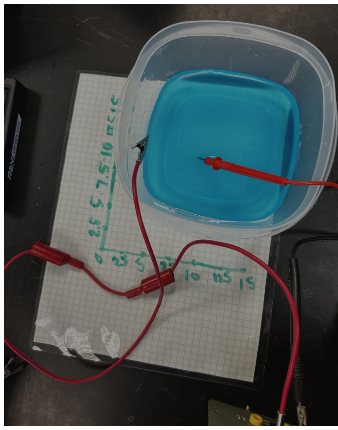

Fig. 1. Image of experimental setup

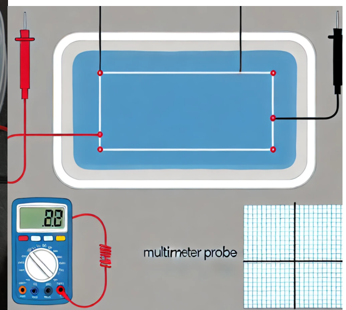

Fig. 2. Diagram of experimental setup

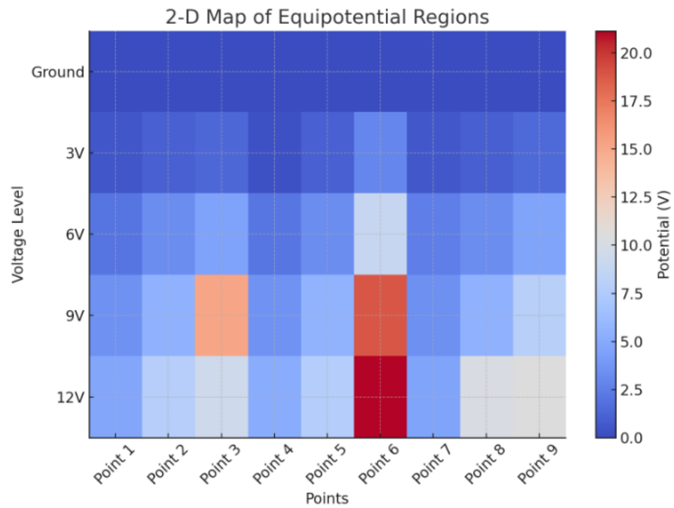

Fig. 3. Equipotential map of data in Table I

TABLE I
RECORDED VOLTAGE (V) AT DIFFERENT POINTS

	measurement point								
V	1	2	3	4	5	6	7	8	9
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.53	1.02	1.35	0.28	1.05	2.95	0.63	0.98	1.48
6	2.02	3.27	4.48	2.08	3.28	8.97	2.48	3.29	4.55
9	3.47	5.52	15.2	3.63	5.57	18.9	3.45	5.47	7.87
12	4.79	7.78	9.47	5.12	7.72	21.15	4.55	10.2	10.53

used to plot a 2D map of the tray using the Matplotlib library in Python [4], [5].

III. Results

As shown in Table I, the data collected at input voltage levels of 3 V, 6 V, 9 V and 12 V consistently showed an increase in potential as the distance from the ground point increased. For example, at 3 V, the potential ranged from 0.53 V at Point 1 to 1.48 V at Point 9. At 9 V, the potential rose from 3.47 V at Point 1 to 7.98 V at Point 9. However, there were outliers, such as a value of 15.2 V at Point 3. This suggests either variations in field uniformity or higher concentrations of salinity in that region. It is also unclear how we observe voltages higher than the power supply output (e.g. point 6).

The data from Table I are plotted in Fig. 3, which visually represents the regions of equal electric potential across the water tray. Though Fig. 3 does not depict level curves of equal potential, we hypothesize that equipotential lines are more tightly packed near the electrodes, indicating steep potential gradients and stronger electric fields. As the distance from the electrodes increases, the equipotential lines become more widely spaced, reflecting weaker electric fields and more gradual potential changes.

IV. Discussion

The potential changes most rapidly near the electrodes, where the electric field strength is highest. This is evident in the tightly packed equipotential lines close to the voltage sources in Fig. 3. Farther from the electrodes, the potential change becomes more gradual, as reflected in the broader spacing between lines. This indicates a diminishing electric field strength as distance from the source increases.

The electric field radiates outward from the positive terminal and converges at the negative terminal. The regions with steeper potential gradients correspond to stronger electric fields, while flatter potential regions indicate weaker fields. This relationship reflects the fundamental correlation between electric fields and the rate of change of potential. From our observations, we infer that electric field lines would radiate outward from the positive terminal and converge at the negative, crossing equipotential surfaces perpendicularly. This pattern aligns with the theoretical relationship [1], [3] between electric fields and equipotentials.

V. Conclusion

The experiment effectively demonstrated the idea of equipotential lines. The electric potential along a theoretical equipotential line stayed somewhat constant, proving how electric potential is the same along an equipotential line. Even with this, the experiment could have been improved. The voltmeter at some points seemed to not be very precise, and the power supply may have been supplying a slightly incorrect voltage due to wear and tear. In addition, human error in terms of correct probe placement would have caused some incorrect readings with the voltage. If this experiment were to be conducted again, more modern technology could be used, along with more precise measuring.

VI. Acknowledgement

We thank several anonymous reviewers whose comments helped our manuscript. All authors did data collection. RC did data analysis and wrote the discussion. SM wrote the conclusions. JH plotted the results. EH wrote the introduction. NP plotted the results and wrote materials. DG analyzed results and wrote the abstract. NG wrote the methods.

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