Luke Sill

Lab 3: Potential Mapping

Abstract

This experiment used the PhET *Charges and Fields* simulator and Microsoft Excel to model electric potential landscapes created by parallel lines of charge and by a dipole configuration. Three-dimensional topographical maps were generated to visualize equipotential regions and electric field patterns. Results confirmed that equipotential lines are perpendicular to electric field lines and that field strength increases near individual charges. Differences between simulation and spreadsheet models were analyzed to understand computational limitations and visualization accuracy.

Introduction

The purpose of this lab was to explore the relationship between electric field, electric potential, and spatial position. Understanding these relationships is fundamental to predicting the motion of free charges in electric fields and to visualizing electrostatic systems such as capacitors and dipoles. Using computational tools allows for controlled observation of potential gradients and field direction.

The two configurations examined were parallel lines of charge representing a capacitor-like field and a dipole field formed by clustered positive and negative charges. By comparing these models, the study illustrates how field strength and equipotential spacing vary across regions of differing charge density.

Materials and Methods

<u>Materials</u>

- PhET *Charges and Fields* simulation
- Microsoft Excel for data plotting and surface visualization

Procedure

- Line of charge configuration
  1. Eight positive charges were placed on the left and eight negative charges on the right, 150 cm apart.
  2. Equipotential lines were marked from +100 V to -100 V in 10 V increments.
  3. The direction of the electric field was determined visually and confirmed through potential differences.
  4. Equivalent coordinates were entered into Excel with +100 V and -100 V values to generate a 3D surface plot.
- Dipole configuration
  1. Five positive and five negative charges were clustered 150 cm apart.
  2. Equipotential lines were marked from +200 V to -200 V in 25 V increments.
  3. The same configuration was reproduced in Excel using +200 V and -200 V inputs for plotting.

Results

Equipotential spacing: Between the plates, spacing grew marginally larger; near individual charges, lines became very dense, forming closed contours around each charge.

Field direction: In the parallel plate model, the electric field vectors point from the positive to the negative plate. As shown in Figure 1, the PhET simulation visually depicts these field vectors running perpendicularly between the charged plates, with densely packed equipotential contours near the charge lines.

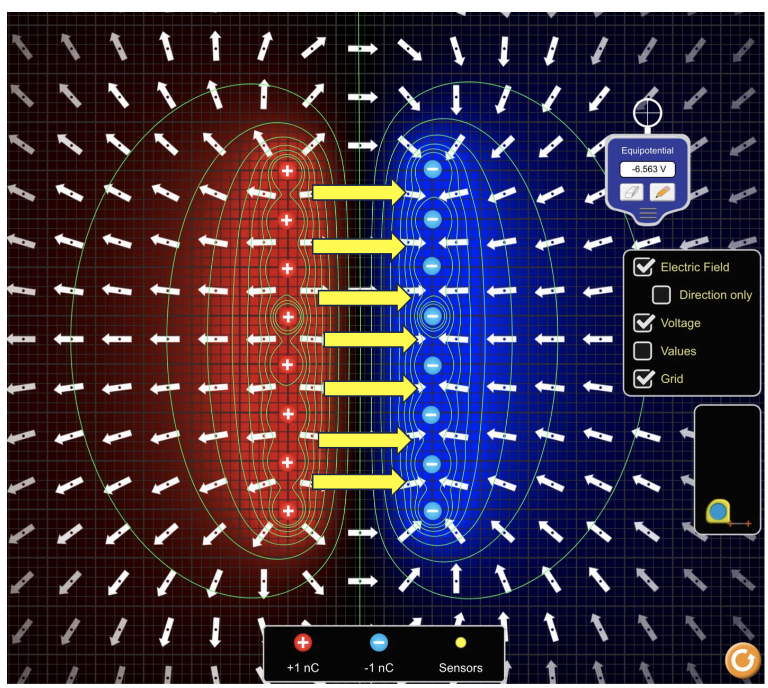

Figure 1. Electric Field and Equipotential Lines for Parallel Line Charges.

Angle between field and equipotential lines: Approximately 90°, confirming perpendicularity.

Estimated field strength: $E = \frac{\Delta V}{\Delta r} = \frac{200V}{1.5m} \approx 133.3V/m.$

Model comparison: The Excel model reproduced the overall shape but showed smoother gradients than the PhET simulation. The simulated data changed more sharply near charges, while Excel interpolation reduced this curvature. The corresponding Excel model shown in Figure 2 illustrates the same potential distribution using numerical data. The smoother gradients reflect the interpolation limits of the plotting tool while maintaining the same general voltage shape.

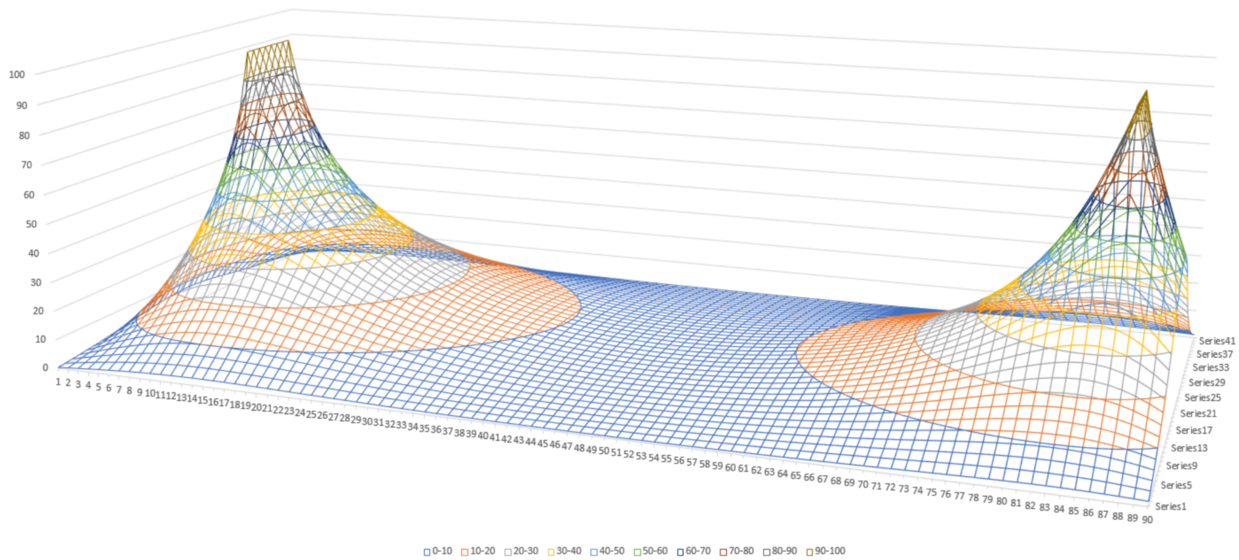

Figure 2. Excel 3D Surface Plot of Potential Between Line Charges.

Color mapping: In the Excel plots, colors represented 10 V increments between 0 V and 100 V.

Field line density: Increased near dipoles, indicating higher potential gradients.

Discussion

The experimental visualizations supported theoretical expectations for electric potential fields. A perpendicular relationship was observed between equipotential lines and electric field vectors in both configurations. Field strength was greater in regions directly between oppositely charged lines than near isolated charges, consistent with the principle of superposition.

Minor discrepancies between the simulation and Excel model are attributable to computational smoothing and step size limitations. Despite these differences, both methods conveyed equivalent qualitative trends.

The motion of a free electron was predicted correctly: it would accelerate toward the positive plate, converting potential energy into kinetic energy according to

$$\frac{1}{2}mv^2 = q\Delta V$$

Energy conservation thus explains the electron's increasing speed in the direction opposite to the electric field vector.

Conclusion

The V(x) vs. x slope illustrated the rate of potential change across the plates, representing the electric field magnitude. The field was constant between the lines of charge but varied near individual charges, decreasing with distance. The study demonstrates how computational mapping can effectively model electric potential and field relationships, reinforcing the conceptual link between voltage gradients and electric forces.

References

PhET Interactive Simulations. (n.d.). *Charges and Fields*. University of Colorado Boulder. https://phet.colorado.edu/en/simulation/charges-and-fields