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ECE 3712 - 001

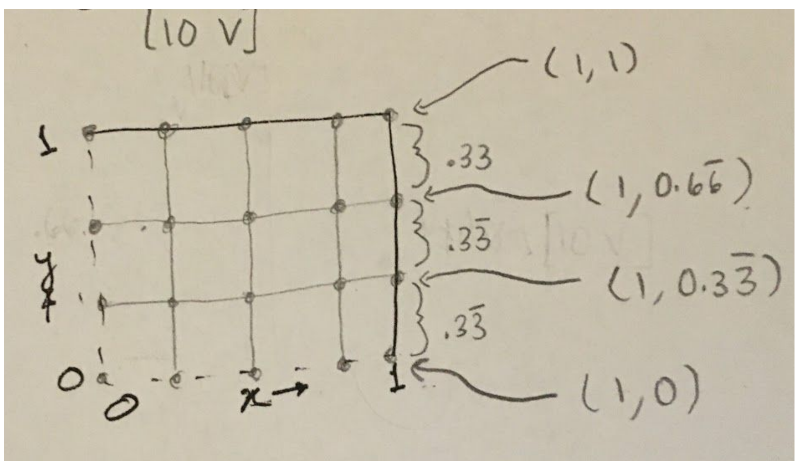
EMF Project 1

Introduction

In this project, we used Matlab along with our knowledge of laplace equations and forward/backwards difference formulas to calculate the electric potential and electric field at all grid points in a given domain. These values were then used to make plots of the equipotential lines and field intensity, as well as calculating energy and capacitance of the device. In the following section, I discuss the methods and equations used, as well as the results that they produced. Interpretation of the data and final thoughts are discussed in the conclusion.

Method & Results

To begin the problem, our first step was to determine the number 'N' of grid points used, as well as the distance between each point. We decided to use 20 grid points, which resulted in a distance of 0.33 units between each point.



Aftering determining the distance between each point, we then used forwards and backwards difference formulas, to determine E and V. These formulas were placed inside nested for loops to iterate through calculations for each grid point. The following formulas were used for these calculations:

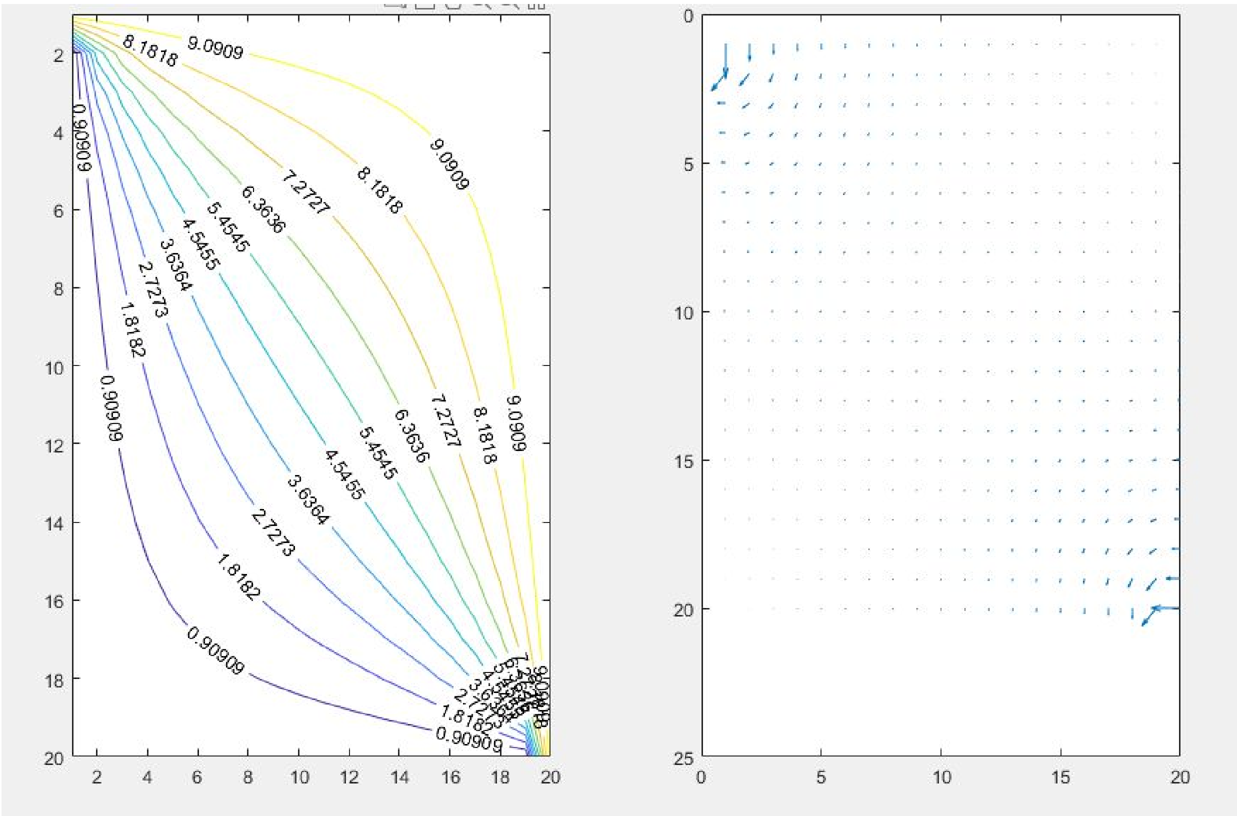
$$Ei,j \ = \ \frac{-V\,i{+}1,j - V\,i{-}1,j}{2\Delta x}Ax \ + \frac{-V\,i,j{+}1 + V\,i,j{-}1}{2\Delta y}Ay$$

$$\Delta x \ = \ 0.33$$

$$\Delta y \ = \ \Delta x \ (since\ this\ is\ a\ square)$$

$$V\,i,j \ = \ \frac{V\,i{+}1,j + V\,i{-}1,j + V\,i,j{+}1 + V\,i,j{-}1}{4}$$

After the conclusion of the for loop, a quiver plot was used to plot electric field lines, or the negative gradient of V. A contour plot was used to show the equipotential lines. The resulting graphs are shown below (contour on left, quiver on right). An interpretation of these graphs is done in the conclusion section.



The final step of this process was to calculate the energy stored and the capacitance of this device. Energy stored 'W' was calculated as a sum of E for each grid point, multiplied by the change Δ in each direction. Since there was no vertical variation in V or E, Δz was ignored. This calculation was done inside the main for loop, and the final result was multiplied by epsilon. C was calculated using this value of W, along with the total applied voltage of 10V. The equations used, along with their results are below:

$$W = \varepsilon \sum_{i=1}^{N} \sum_{j=1}^{M} Eij^2 \Delta x \Delta y \Delta z = 6.5782e-05$$

$$\varepsilon = 8.856e-12$$

$$C = \frac{2W}{V^2} = 1.3156e-06$$

Conclusion

Based on the information received from our results, the device we were given stores approximately 6.6 microJoules of energy, and its capacitance is 1.3 microFarads. The contour plot above shows that the equipotential lines of this device are being generated from the top left and bottom right corners, which is where the boundaries of the applied voltage begins. The equipotential lines then spread out in a symmetrical elliptical shape towards the center of the square before converging into each corner again. This is a similar shape to the equipotential lines of an electric dipole, and suggests that there is a positive charge on one corner of the square, and a negative charge on the other. The plot of the electric field intensity shows the field lines radiating around the top left and bottom right charges. The field intensity elsewhere in this domain is non-existent since voltage is only coming from the corner boundaries, and not within the square itself.