Electromagnetic Fields - Computer Project

Semester A - 2019-20

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Introduction

In this project you will solve the potential problem in the structure shown in figure 1, using finite difference method. The structure is infinite on the z axis, so this is a 2-dimensional problem. Thus, you will be characterizing the structure per unit length (in z). The dimensions of the structure in x and y axes are $1m$ X $1m$. In each section, you will need to solve the Laplace equation numerically to find the potential and electric field in the entire structure, under the given conditions.

Question 1

The structure to analyze, should you accept the mission, is uniform with finite conductivity $\sigma_0 = 3\,S/m$, with vacuum outside of it. On the sides $x = 0$ and $x = 1$ two electrodes are placed on the interval $[y_L, y_H]$ as shown. The right electrode is set to $1V$ and the left electrode is grounded. In this section: $[y_L, y_H] = [0, 1]$.

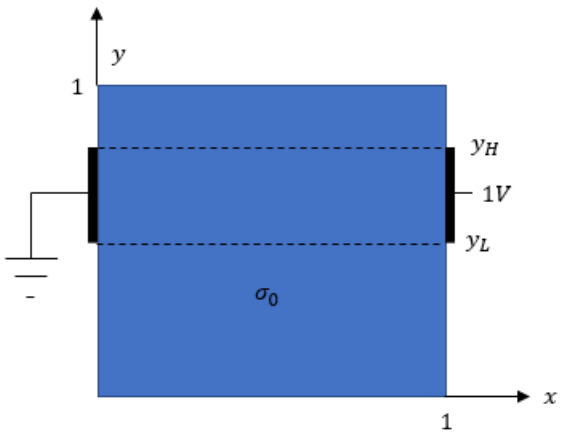

Figure 1: Structure for sections 1+2

a. Write explicitly the boundary conditions on the potential.

b. What is the expected behavior of the potential and electric field in the structure? Explain.

c. Solve the Laplace equation using finite difference method and display the results:

- Draw the potential map in the structure. Plot the equi-potential lines.
- Draw the electric field in the structure (magnitude and direction).
- Plot both components of the electric field as a function of x on the lines $y = 0.5$ and $y = 0.3$.

d. Calculate (numerically) the effective conductivity and capacitance of the structure per unit length as seen by the electrodes. Normalize the capacitance by ϵ_0. Explain the calculation.

Question 2

Now the width of the electrodes is reduced.

a. Solve the Laplace equation to find the potential and electric field for $[y_L, y_H] = [0.2, 0.8], [0.3, 0.7], [0.45, 0.55]$. For each case, plot the same figures as in 1c.

b. Explain the differences observed in the fields between different electrode widths.

c. Calculate the effective conductivity and capacitance (normalized by ϵ_0) of the structure per unit length as seen by the electrodes.

Question 3

In this section $[y_L, y_H] = [0.3, 0.7]$. Now it is given that inside the structure there is a strip of material with different conductivity σ_1, see figure 2. The strip is located between points x_R and x_L. To determine the values of x_R and x_L, sum the last digit in the id of all group members (call it N).

- If $N \leq 9$: $[x_L, x_H] = [0.2, 0.4]$.
- If $10 \leq N \leq 15$: $[x_L, x_H] = [0.3, 0.6]$.
- If $N \geq 16$: $[x_L, x_H] = [0.4, 0.8]$.

Solve the potential problem under the new conditions:

a. What are the boundary conditions now?

b. Calculate the potential and electric field and plot the same figures as in 1c for $\sigma_1 = 0.1, 10, 100$. Denote the boundaries of the strip in all figures.

c. Explain the results observed for low and high values of σ_1. What is the physical meaning?

d. Calculate the effective conductivity and capacitance (normalized by ϵ_0) of the structure per unit length as seen by the electrodes.

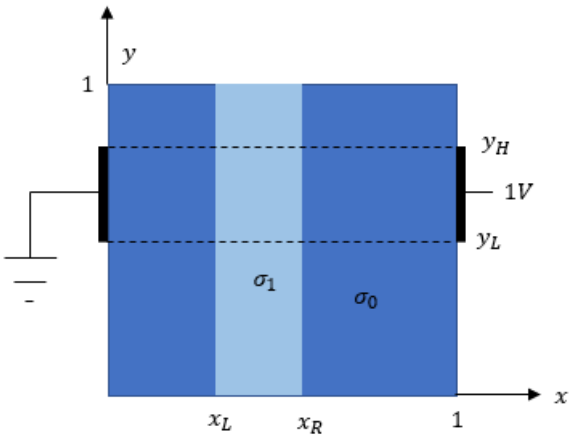

Figure 2: Structure for section 3

Submission Instructions

- It is recommended to read all questions before you start working.
- Submission is in groups of 2 or 3.
- Submission date: 21/01/20
- Submission is not obligatory. The grade will be 13% of the final grade (MAGEN).
- The project should be submitted as a pdf file containing all required figures and explanations for every section. Please type all your answers, do not submit any hand-written pages. The code should be written in MATLAB.
- The project may be submitted in Hebrew or in English.
- In addition to the document, submit 3 m files containing the code for every question named **Q1.m, Q2.m, Q3.m**. The codes should perform all required calculations extract all figures. You may use auxiliary functions in nested format only.
- All four files should be compressed to a zip file named **id1_id2_id3.zip** and submitted via Moodle.
- **Important!** It is your responsibility to check that your code runs without errors. Ten points will be deducted automatically from every file that prompts an error.
- Needless to say, copying is not allowed and can be easily checked. Please don't do that.
- Useful functions in MATLAB: meshgrid, contourf, quiver.

Good Luck!