EE 735 Assignment 1

Solving Laplace Equations for Parallel Plate Capacitor Systems

Non Extendible Deadline: 21 Jan 2025 11:59 pm(100% Penalty for Late Submission)

Implement all codes using Python

Hints, assumptions, and instructions:

1. Please define all input variables at the beginning of your code and use proper comments while developing the code. Your code must work for other input values too.
2. Assume that all the capacitors are enclosed in a big box whose boundaries are maintained at 0 V.
3. Assume that everywhere the thickness of the plate is t=1 nm.
4. The entire dielectric region is charge-free, and $\epsilon_r = 1$ unless mentioned in the problem.
5. It is mandatory to submit your code along with the report (in pdf) in a single zip file. Name the file `EE735_A1_RollNo_Name` for this assignment.
6. Reference for the assignment: `https://www.youtube.com/watch?v=DWCNVF9oMkw`.

Problems

Question1

Consider a system of two parallel plates as shown in Figures 1 and 2. (Parameters values are d = 20nm, L = 500nm, V = 5V)

A. Plot the electrostatic potential and equipotential surfaces.

B. Plot the 2D electric field profile.

C. Find out the capacitance (per unit width) of the structure by numerically solving the 2D Laplace equation.

D. Compare the simulated capacitance with the theoretical value ($C_{th} = \frac{\epsilon L}{d}$). Which one is larger and why?

E. Now the right half of the region is replaced with another dielectric material as shown in Figure 2; repeat parts A, B, C, and D for this system.

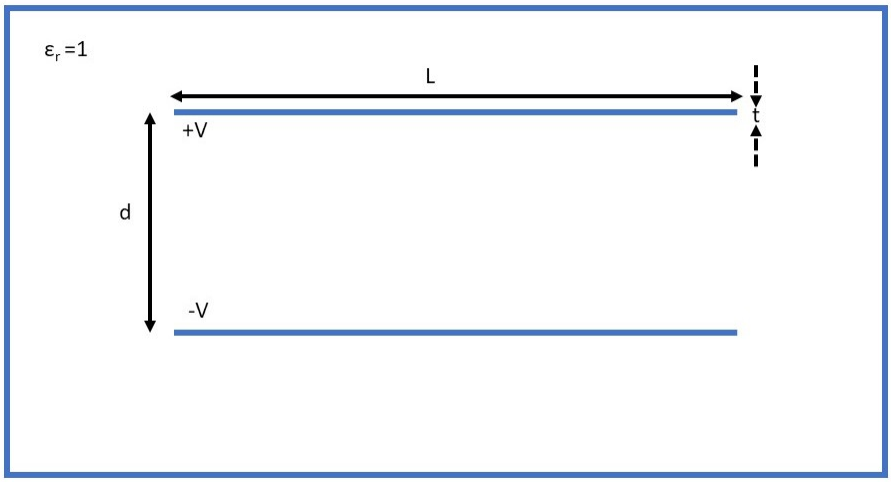

Figure 1: Structure for Q1 Parts A, B, C, D and Q2

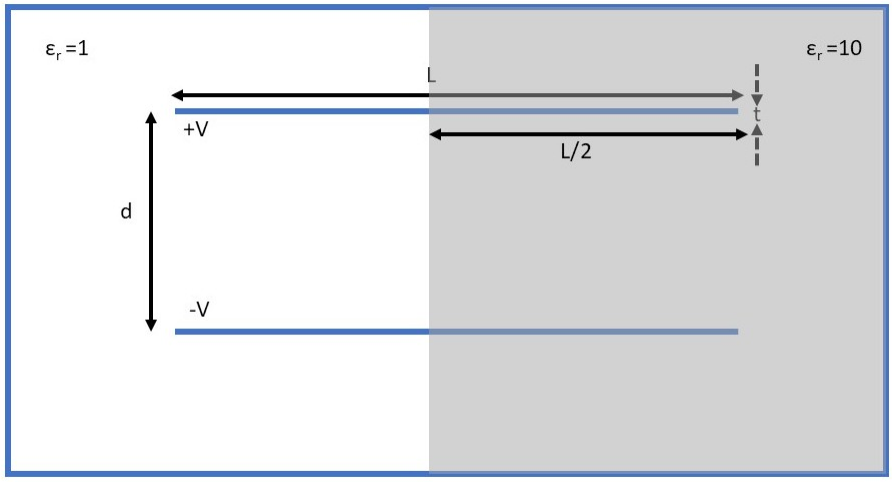

Figure 2: Structure for Q1 Part E

Question2

For the structure in Figure 1

A. Vary L from 50 nm to 1000 nm. Plot C as a function of L.

B. Calculate the parasitic capacitance $C_p(L) = C(L) - C_{th}(L)$ and plot it as a function of L. Qualitatively explain the nature of the plot.

Question3

Now consider the system shown in Figure 3.
Four plates are placed in the middle of the two parallel plates such that they form a square with length a ($a \leq d, L$). All the plates are at a constant potential of V_1 Volts. Vary the value of a as 4, 8, and 12nm. Vary the value of V_1 as -5, 0 and 5V. For all 9 cases, carry out the following:

A. Plot the electrostatic potential and equipotential surfaces.

B. Plot the 2D electric field profile.

C. Find out the charge on the parallel plates and the capacitance (per unit width) of the structure by numerically solving the 2D Laplace equation.

D. Note and explain the observations from your simulation results of A, B, and C.

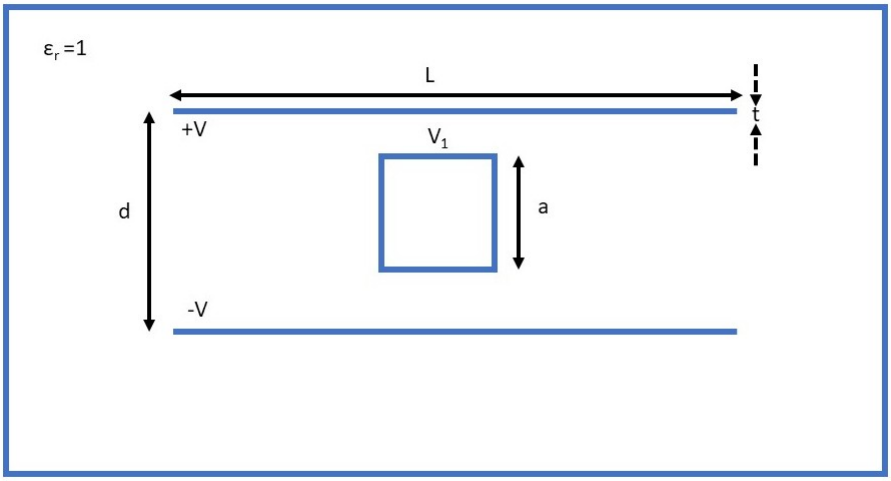

Figure 3: Structure for Q3