EE6506 - Computational Electromagnetics
Fall 2016
Assignment-2
Applications of Finite Difference Method

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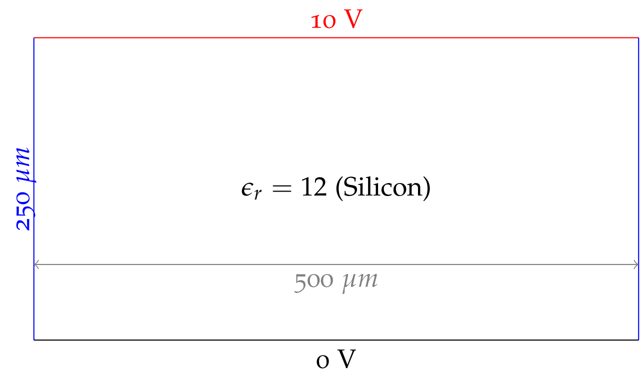
Learning Objectives from Assignment

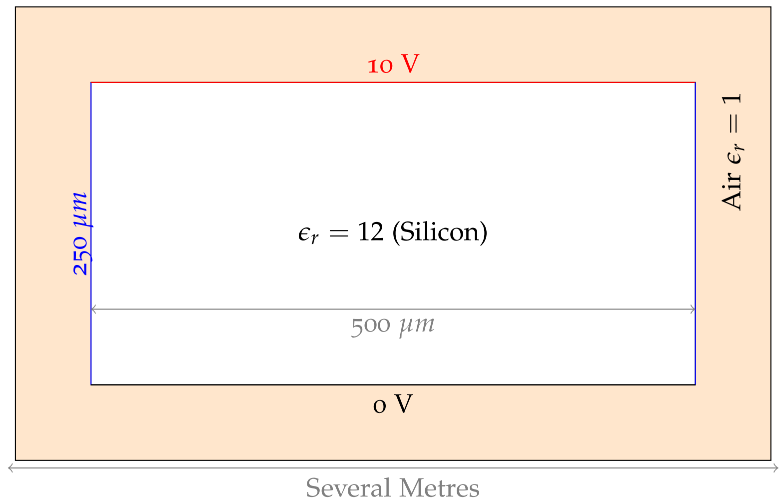
1. To apply Finite Difference Method to calculate quantities that may be needed for design or to understand functionality of a given device
2. To use the simulations and do post-processing. Post-processing may involve appropriate extended calculations from results of simulations, appropriate visualization and deriving proper conclusions.

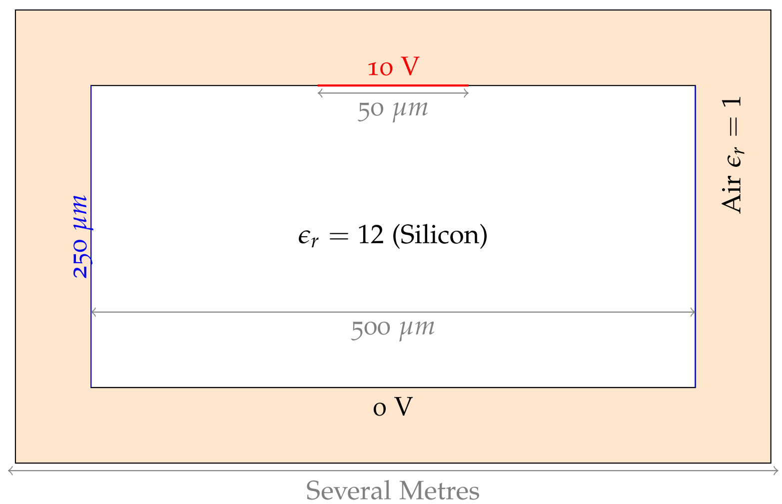
Problem - 1 - Job of an entry level Integration Engineer

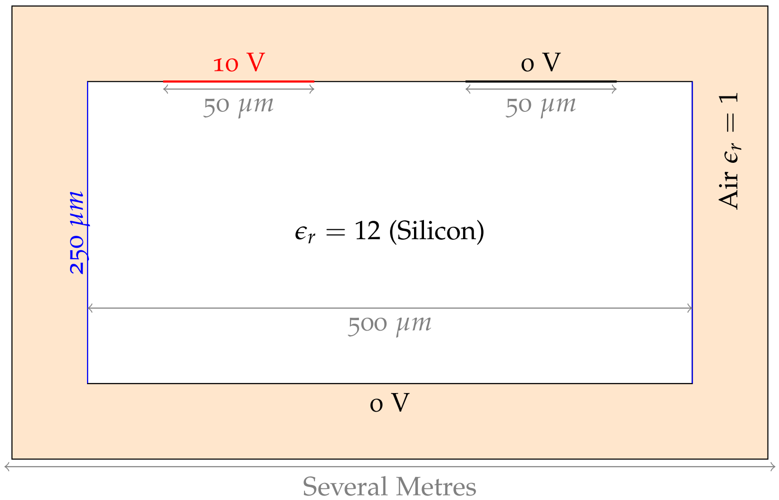
To visualize the potential distribution and electric fields in a given wafer (assuming dielectric, not semiconductor) with different positioning of contacts

Silicon has been the material of choice in the semiconductor industry due to several reasons including availability, presence of native oxide, ability to dope, decent carrier mobility and simplicity in material processing. The Device Engineer in a Fab typically focuses on how to achieve improved specifications for a particular single device. However, these designs take a very long time to be integrated into the production flow in a semiconductor fab, since the Integration Engineer has to come up with wafer level arrangement of devices. One problem often faced by the Integration Engineers is 'How can I place a number of contacts for a device like that, without having large fields or large currents between them? Can I understand what kind of potential and field distribution exist between different contacts on a semiconductor wafer? Only then will I be able to get this design into production.' Imagine that you are the Integration Engineer for this assignment. Try out the following cases by deciding appropriate boundary conditions and solving Laplace's equation using Finite Difference method. Calculate and plot the potential distribution and electric field arrow plots.

1. 
10 V
250 μm
$\epsilon_r = 12$ (Silicon)
500 μm
0 V

2. 
10 V
Air $\epsilon_r = 1$
250 μm
$\epsilon_r = 12$ (Silicon)
500 μm
0 V
Several Metres

3. 
10 V
50 μm
Air $\epsilon_r = 1$
250 μm
$\epsilon_r = 12$ (Silicon)
500 μm
0 V
Several Metres

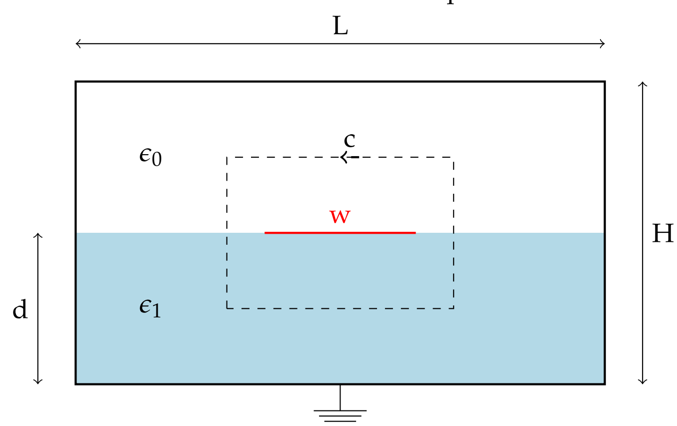
4. 

Bonus Problem - 2 - Applying the Finite Difference Method to Microstrip transmission line

Note that it is not mandatory to solve this problem. However, it will give you more insight to post-processing from calculated potentials and fields.

To visualize the potential, fields in a microstrip line and to extract the correct value of Capacitance, Characteristic Impedance using Post-Processing

Consider the cross-section of a microstrip line as shown below.



1. In the Figure, H=2, L=7, d=1, W=1, $\epsilon_1 = 9.6\ \epsilon_0$.

2. Let N denote the number of cells per unit length and I denote the number of iterations.

3. Using the Finite Difference Method and Gauss's law around the contour, calculate the charge density q_l per unit length in the perpendicular direction (Coulombs/metre).

4. Calculate the line capacitance as

$$C_0 = \frac{q_l}{V} \tag{1}$$

5. Repeat the same procedure with the entire microstrip filled with Air and calculate the capacitance C_0^{Air}.

6. Use the above values to determine the characteristic impedance and ϵ_{real}as follows :-

$$Z_0 = \frac{1}{c\sqrt{C_0^{Air}\ C_0}}; \tag{2}$$

c is the velocity of light in vacuum

$$\epsilon_{real} = \frac{C_0}{C_0^{Air}}; \tag{3}$$

7. Create a plot with x-axis as N and y-axis as Z_0 for the values of N=(6,12,18,24,30). Keep the value of number of iterations I to be fixed at 2000.

8. Create a plot with x-axis as Number of iterations (I) as (250, 500,750,... 2000) and y-axis as calculated Z_0 for a given N=20.

9. Create a table of FDM results as following

w	Z_0	ϵ_{real}
1		
1.5		
2		
2.5		

10. Write about your inferences for each of the above points in the problem. For example, how did you think 'N' affected your simulations and how 'N' actually affected the results of your program? (or) How do your results mention the role of Width of the microstrip played in determining the Line capacitance and ϵ_{real}. What can be inferred from your results and why do you think your results are correct? etc.

11. Create also plot that shows the Potential Distribution and Field diagram (arrow plots) for one particular microstrip configuration, where you think the calculations are correct.