ELEC 1908
The Electric Potential (V)

~~March 28, 2013~~

$\boxed{\text{March 24 2017}}$

Abstract

The objective of this lab is to solve numerically Laplace's equation in order to obtain the electric potential distribution in different electric structures. To solve Laplace's equation we use a finite element solver called "Maxwell 2D Field Simulator". This software will enable us to visualize the electric field lines and equipotential lines in cross sections of structures consisting of conductors and insulators. The lab will run in the Department of Electronic undergraduate computer network room in ME 4128.

1 Running Maxwell 2D Field Simulator

1.1 Access the Maxwell Control Panel

To access the Maxwell 2D field simulator you must first access the Maxwell Control Panel. Double click the left mouse button on the **Maxwell SV** icon or choose **Start/Programs/Ansoft/Maxwell SV**

1.2 Creating the Project

Create a Project Directory:

- Choose **Projects** in the Maxwell Control Panel
- In the **Project Directories** menu choose **Add**
- In the Alias box enter **1908lab1** then click on the Make New Directory circle and hit **OK**

Add a new Project in the Directory previously created:

- Choose **New** in the Projects menu, then enter a Name (for example each problem will have its own project in the 1908lab1 directory)
- Change **Type** to be: "Maxwell SV Version 9"
- Ensure "open project upon creation" is checked, click **OK**

1.3 Define Model

Specify Solver Type:

- Select **Electrostatic**

Specify Drawing Plane:

- Select **XY Plane**

Set Up Drawing Region:

- Choose **Define Model / Draw Model**
- Choose **Model / Drawing Units / mm**
- choose **Model / Drawing Size** and set the Minima to **(0,0)** and the Maxima to **(100,100)**
- Choose **Window / Grid** and set dU and dV smaller if necessary for less space between each point (2 mm is recommended)

Create Geometry:

- Choose **Object** and use the tools offered to draw the object [Note: don't spend too much time matching all of the dimensions exactly, the point of the lab is to analyze the models and understand]
- When the model is complete then save and exit

1.4 Defining Materials and Sources

Set Up Materials:

- Choose **Setup Materials**
- Note: throughout the lab the conducting material used is **copper**, the dielectric is **air** or **Teflon**, and the background is **vacuum**
- Select an object and material and press **Assign**
- When all objects are assigned a material then exit and save

Set Up Boundaries / Sources:

- Choose **Set Up Boundaries / Sources**
- Choose **Edit/Select / Object / By Clicking** and left click on an object so it is highlighted. Then right-click anywhere in the display area to stop selecting objects
- Choose **Assign / Source / Solid** then select **Voltage** and **Assign** a corresponding voltage to the conductor
- Note: throughout the lab the voltage values for the conductors are either 10 V or 0 V
- For the background once it is highlighted choose **Assign / Boundary / Balloon** then select **Charge** and **Assign** it. Selecting the **Charge** option for the balloon boundary models an electrically insulated system. That is, the charge at infinity balances the charge in the problem region, forcing the net charge to be zero. [The **Voltage** option models an electrically grounded system, i.e. the voltage at infinity is zero, but the charge at infinity may not exactly balance the charge in the problem region]
- When all objects are assigned their source or boundary then **exit** and **save**

1.5 Generating a Solution

Setup Solution:

- Choose **Setup Solution / Options**
- Set the Percent refinement per pass to **15**, the Number of requested passes to **10**, and the percent error to **1** then click **OK**

Solve:

- Choose **Solve** and wait for the "Solution Process is Complete" message'

1.6 Analyzing the solution

Plotting:

- Choose **Post Process...** and wait for a "2D Post Processor" window
- To **Zoom** or **UnZoom** if needed, use the magnifying glass with the "+" or "-" sign respectively and select the new area
- To plot the E Vector and the Voltage together for best display do the following: choose **Plot/Field...**
- Then select **E Vector/Surface -all-** and press **OK**
- In the arrow options select Type **2D** and press **OK**. Since the pattern of arrows is not too consistent, go to **Plot/Modify...** and in Arrow Options change **Size** and **Spacing** to approximately 10 and 1 respectively then press **OK**. You may want to iterate this step a few times until you get a nice arrow pattern.
- While having the consistent plot of the arrows choose **Plot/Field...**
- Select **Phi/Surface -all-** and press **OK**. In the next screen, **unselect "filled"** and press **OK**
- To change the contour divisions choose **Plot/Modify**, select **Phi** and change the number of Divisions (choose a value between 50 and 100)

Show your results to the TA on the screen and save the images to your w: drive [can save images using **File / Print / Active View** then choosing **Setup** and change the Printer to **PDF Creator**]

- Note: You may **Remove** or **Modify** the Plot area in the following way: Select **Plot/Delete or Modify/** select Phi (or E) and press **OK**.
- If you need to modify a problem, close the Post Processor window for that problem and go back to step 1.3. Make sure to open the structure in "Modify" mode. If at some point your window says on top "Read-Only" while trying to modify the problem structure, get assistance from the TA.

2 Problems

2.1 Field at a raised point

This problem models the electric field in the vicinity of a triangular tip. The tip has a 10 V source and the rest of the rectangular plate has a 0 V source. The material of both plates is copper. The material around the plates is vacuum. To draw the structure on can use the **Polyline**.

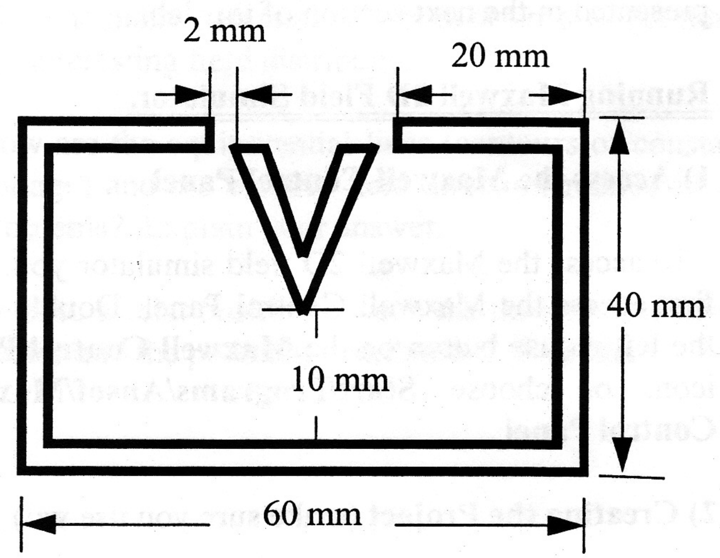

Figure 1: Field at a raised point

The plates are 2mm thick.

1. Plot the equipotential lines (contour of constant voltage), and the electric field lines.

2. Where is the location of the maximum electric field strength ? (Use the coloured electric field intensity plot- Mag E)
   What is the value of the maximum field strength ?

3. Calculate an estimate of the field strength at that point by using the equation $E = \frac{\Delta V}{\Delta d}$, where ΔV is the change in potential and Δd the distance.

2.2 Field in a trough

This problem models the electric field distribution in a trough. The plate on the right has a 10 V source and the rest of the structure has a 0 V source. The material around the plates is air or vacuum. The thickness of the plates is 2mm. To draw the structure one can use **Polyline** once more.

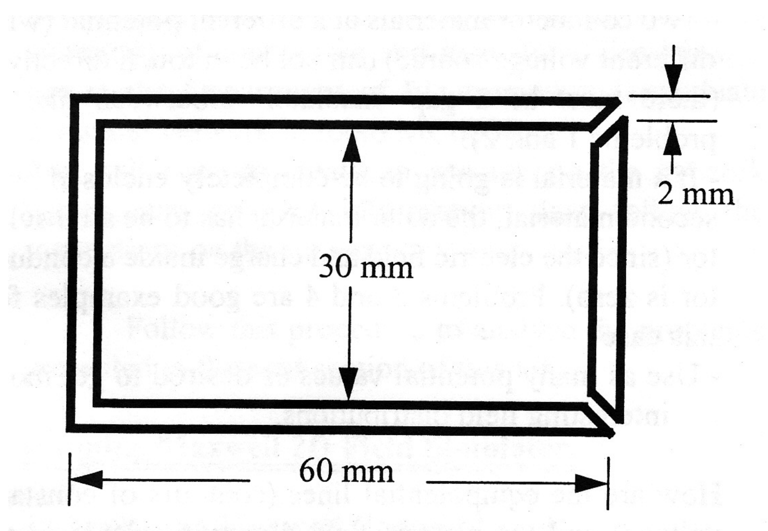

Figure 2: Field in a trough

1. Plot the equipotential lines (contours of constant voltage), and the electric field lines.
2. How does the electric field in the gap compare to that in the surrounding regions ? Why ?
3. Calculate the electric field strength near one of the gaps and compare your result with that predicted numerically.
4. What is the Electric Field inside of the metal ? Is this always the case for electro-static problems ? Explain.

2.3 Field in a coaxial cable (square)

This problem models the electric field distribution around a coaxial cable with a square conductor and a circular insulator.

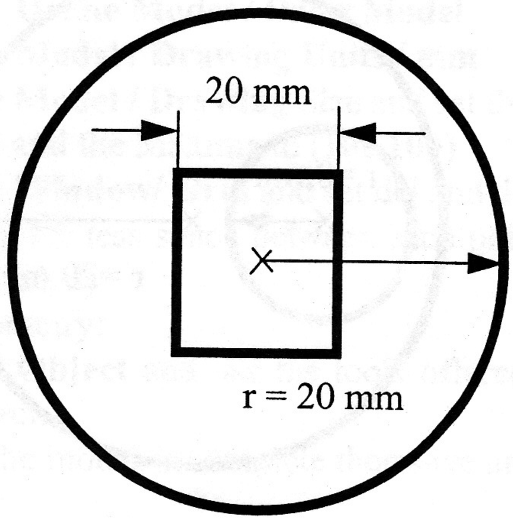

Figure 3: Field in a coaxial cable

The inner material is a 20x20 mm square. It is made of copper and has a source of 10 V. The outer material is a circle of radius = 20mm, it has a source of 0 V and is made of **Teflon**.

1. Plot the equipotential lines (contours of constant voltage), and the electric field lines.
2. Calculate the electric field strength at one of the corners and compare your value with that obtained from the simulation.
3. In which direction do you have to move the conductor (square material) in order to get a maximum electric field at the right-bottom corner ? Draw an arrow with the right angle.
4. Move the conductor in that direction (as much as you want) and recalculate the electric field at that point. Compare your result with that predicted by the simulation as you did before.
5. Can there be a non-zero electric field in the insulator/dielectric ? What happens to an electric field in a dielectric ?

2.4 Field in a coaxial cable (circular)

This problem is a variation of the previous structure.

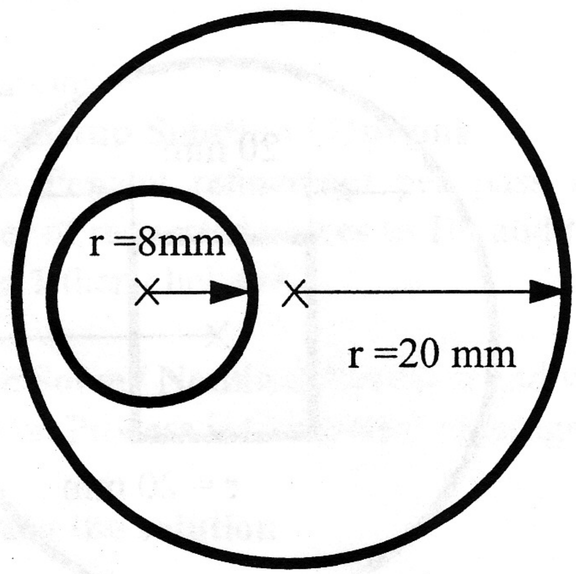

Figure 4: Field in a coaxial cable 2

1. Plot the equipotential lines (contours of constant voltage), and the electric field lines.

2. Identify the regions (two points or draw a line) that correspond to the maximum and to the minimum electric field in this structure. Answer this question before looking at the simulation results and explain how you found the points.

3. Calculate the electric field strength at these points and compare your results with those obtained from the simulations.

4. If you wanted to reduce the electric field strength at these points by half while preserving the structure (not necessarily the dimensions), what would you have to do ? Hint: There are several ways, try to find and explain them all.

5. Simulate and verify one of the options you came up with in the previous question.

6. How are the equipotential lines (contours of constant voltage) and the electric field related in all problems ? As well, in what direction are the Electric Field lines pointing with respect to the Electric Potential (Voltage) ?

3 Due Date

Svetlana

Email your report in PDF format to ~~nick.stupich@gmail.com~~ by ~~Friday April 5^{th}, 2013~~. March 23 at Midnight