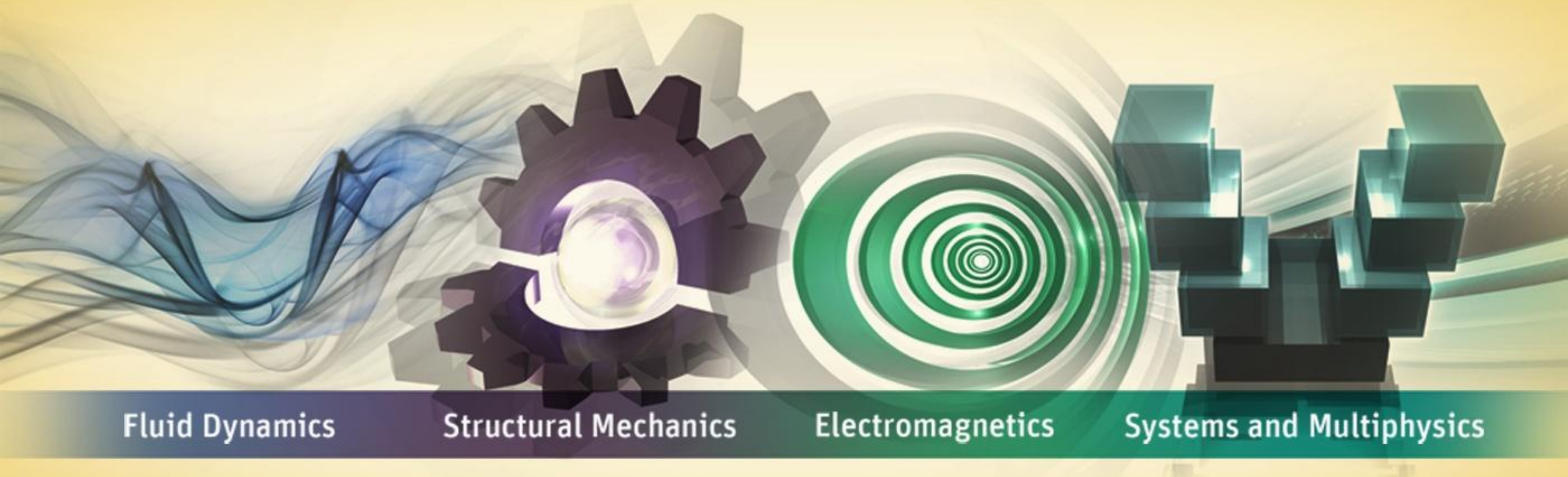
Realize Your Product Promise™

Workshop 3:
Basic Electrostatic Analysis



ANSYS Maxwell 2D V16

About Workshop

- **Introduction on the Electrostatic Solver**
  - This workshop introduces the Electro Static solver based on some simple examples. This solver is meant to solve the static electric field without current flowing in conductors (conductors are in electrostatic equilibrium). The conductors are considered perfect such that there is no electric field inside conductors.
  - The Workshop contains following three examples

    Example1: Cylindrical Capacitor in RZ

    - In this example, we will determine the electric field distribution of coaxial cable based on the potential (or the charges) that are applied on each conductor. Coaxial cable will be solved with RZ representation

    Example2: Cylindrical Capacitor in XY

    - The same problem will now solved using an XY representation

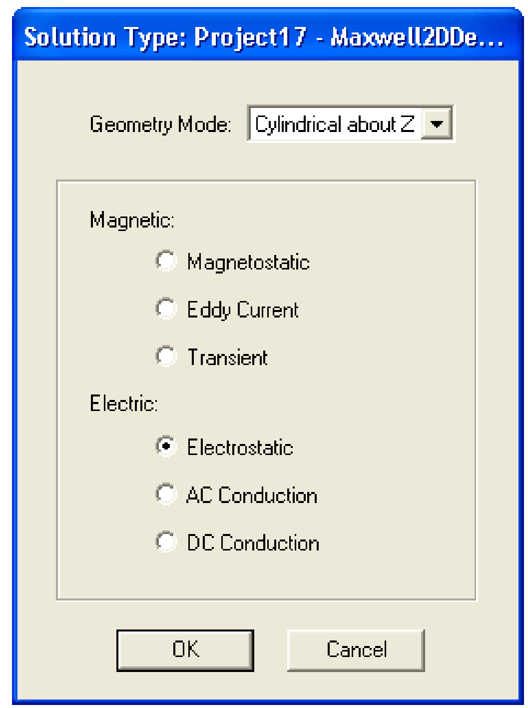
    Example3: Capacitance of a Planar Capacitor

    - In this example we illustrate how to simulate a simple planar capacitor made of two parallel plates

Example1: Cylindrical Capacitor in RZ

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 2D Design***, or click on the icon
- **Set Solution Type**
  - Select the menu item ***Maxwell 2D → Solution Type***
  - Solution Type Window:
    1. Geometry Mode: **Cylindrical about Z**
    2. Choose **Electric > Electrostatic**
    3. Click the **OK** button

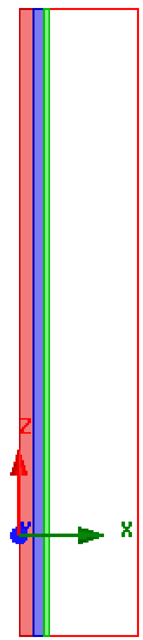


Create Model

- **Create object Inner**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0, Y: 0, Z: -4**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 0.6, dY: 0, dZ: 25**, Press the **Enter** key
  - Change the name of resulting sheet to **Inner** and color to **Light Red**
  - Change the material of the sheet to **Copper**
- **Create Air Gap**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0.6, Y: 0, Z: -4**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 0.4, dY: 0, dZ: 25**, Press the **Enter** key
  - Change the name of resulting sheet to **Air** and color to **Light Blue**
  - Change the material of the sheet to **air**

Create Model (*Contd…*)

- **Create object outer**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 1, Y: 0, Z: -4**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 0.2, dY: 0, dZ: 25**, Press the **Enter** key
  - Change the name of resulting sheet to **Outer** and color to **Light Green**
  - Change the material of the sheet to **Copper**



- **Create Simulation Region**
  - Select the menu item ***Draw → Region***
  - In Region window,
    1. Pad individual directions: ☑ **Checked**
    2. Padding Type: Percentage Offset
       - +R = **300**
       - Specify rest to **0**
    3. Press **OK**

Assign Excitations

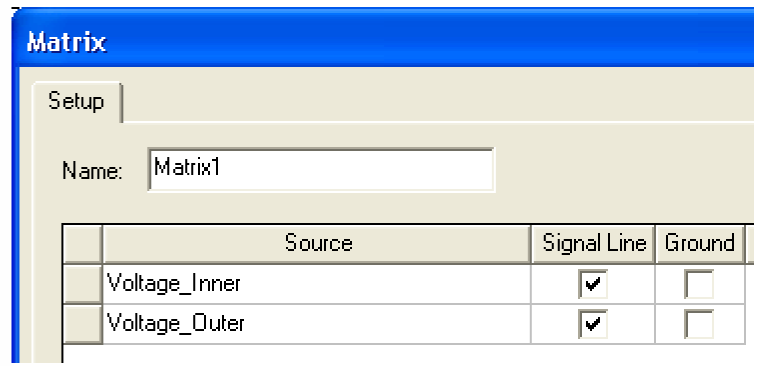
- **Assign Excitation to object Inner**
  - Select the sheet **Inner** from the history tree
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    - Name: **Voltage_Inner**
    - Value: **-1kV**
    - Press **OK**
- **Assign Excitation to object Outer**
  - Select the sheet **Outer** from the history tree
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    - Name: **Voltage_Outer**
    - Value: **1kV**
    - Press **OK**

Note: Assuming that the conductors are in electrostatic equilibrium, we assign voltage potential on the object itself. In other words, we do not solve inside conductors, we assume that all the conductor parts are at the same potential.

Assign Executive Parameters

- **Assign Capacitance Computation**
  - Select the menu item ***Maxwell2D → Parameters → Assign → Matrix***
  - In Matrix window
    1. Voltage_Inner and **Voltage_Outer**
      - Signal Line: ☑ **Checked**

    2. Press **OK**



- **Assign Force Computation**
  - Select the sheet **Inner** from history tree
  - Select the menu item ***Maxwell 2D → Parameters → Assign → Force***
  - In Force Setup window, press **OK**

Note: In addition to the fields, we are interested by the Capacitance value as well as the force applied to the inner armature. These quantities can be evaluated by assigning executive parameters.

Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 2D → Analysis Setup → Add Solution Setup***
  - Solution Setup Window:

    1. General Tab
    - Percentage Error: **0.5**

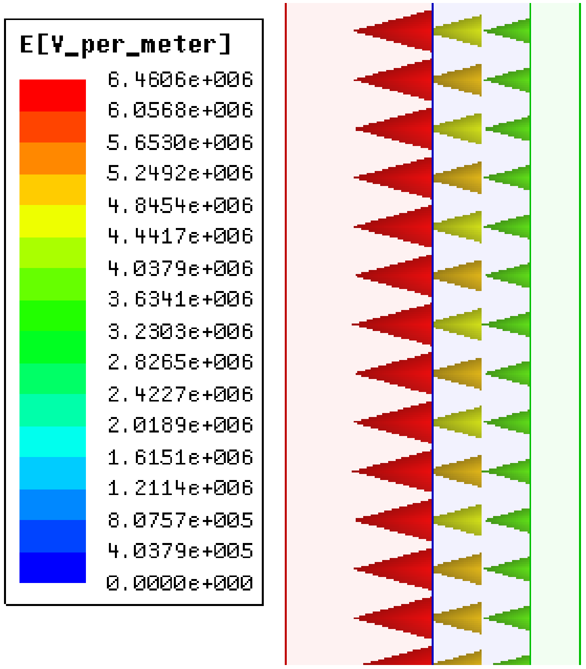
    2. Convergence Tab
    - Refinement Per Pass: **50%**

    3. Click the **OK** button

- **Start the solution process:**
  - Select the menu item ***Maxwell 2D → Analyze All***

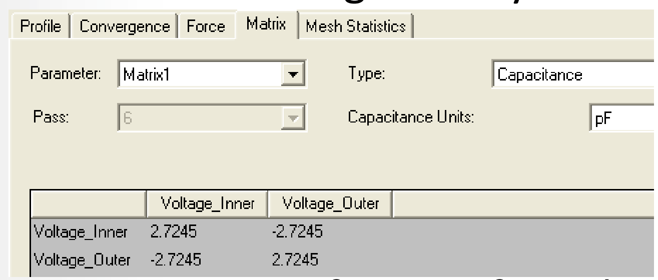
Plot Electric Field Vectors

- **Plot Electric Field Vectors**
  - Select the Plane **Global:XZ** from history tree
  - Select the menu item ***Maxwell 2D → Fields → Fields → E → E_Vector***
  - In Create Field Plot window,
    - Press **Done**
  - To adjust spacing and size of arrows, double click on the legend and then go to **Marker/Arrow** and **Plots** tabs



View Results

- **View Results**
  - Select the menu item ***Maxwell 2D → Results → Solution Data***
  - In Solutions window
    - Select **Force** tab
      - Note: The force is zero since the model is magnetically balanced.
    - Select **Matrix** tab



  - The analytical value of the capacitance per meter for an infinite long coaxial wire is given by the following formula:

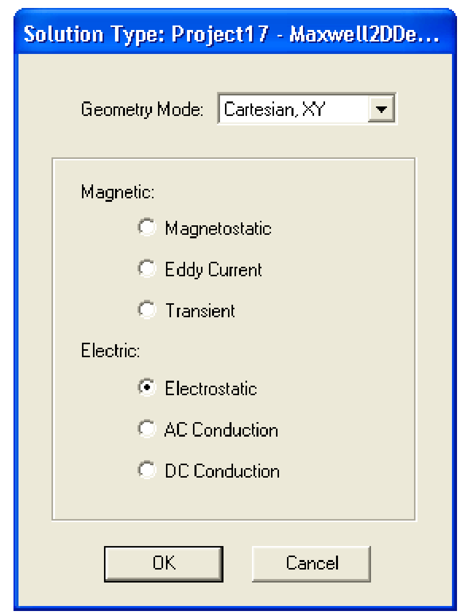
    $C = 2\pi\varepsilon_0 / \ln(b/a)$ (a and b being the inside and outside diameters)
  - The analytical value would is therefore **1.089e-10 F/m** (a =0.6mm, b=1mm)
  - In our project, length of the conductor is 25 mm, therefore the total capacitance is. **2.723pF**. We obtain a good agreement with the obtained result **2.7245 pF**.

Note: in the Convergence tab, you have access to the total energy of the system. We find 5.4489e-6 J. It is exactly 2000 times the capacitance (2000V being the difference of potential).

Example2: Cylindrical Capacitor in XY

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 2D Design***, or click on the icon
- **Set Solution Type**
  - Select the menu item ***Maxwell 2D → Solution Type***
  - Solution Type Window:
    1. Geometry Mode: **Cartesian, XY**
    2. Choose **Electric > Electrostatic**
    3. Click the **OK** button

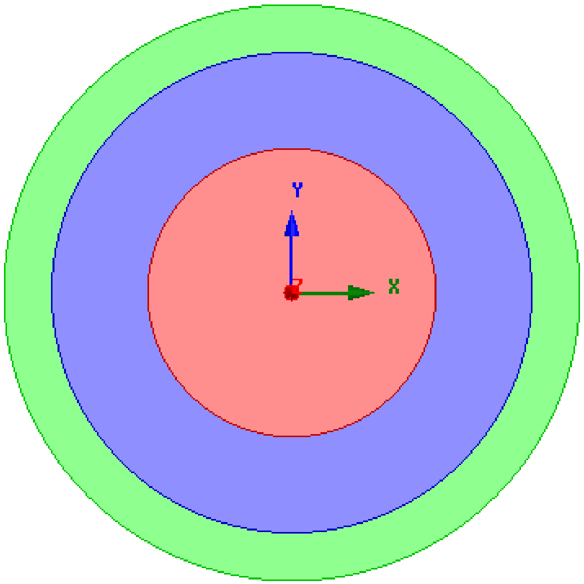


Create Model

- **Create Object Inner**
  - Select the menu item ***Draw → Circle***
    1. Using the coordinate entry fields, enter the center of circle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the radius
       - **dX: 0.6, dY: 0, dZ: 0**, Press the **Enter** key
  - Change the name of resulting sheet to **Inner** and color to **Light Red**
  - Change the material of the sheet to **Copper**
- **Create Air Gap**
  - Select the menu item ***Draw → Circle***
    1. Using the coordinate entry fields, enter the center of circle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the radius
       - **dX: 1.0, dY: 0, dZ: 0**, Press the **Enter** key
  - Change the name of resulting sheet to **Air** and color to **Light Blue**
  - Change the material of the sheet to **air**

Create Model (*Contd…*)

- **Create Object Outer**
  - Select the menu item ***Draw → Circle***
    1. Using the coordinate entry fields, enter the center of circle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the radius
       - **dX: 1.2, dY: 0, dZ: 0**, Press the **Enter** key
  - Change the name of resulting sheet to **Outer** and color to **Light Green**
  - Change the material of the sheet to **Copper**



Assign Excitations

- **Assign Excitation to object Inner**
  - Select the sheet **Inner** from the history tree
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    - Name: **Voltage_Inner**
    - Value: **-1kV**
    - Press **OK**
- **Assign Excitation to object Outer**
  - Select the sheet **Outer** from the history tree
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    - Name: **Voltage_Outer**
    - Value: **1kV**
    - Press **OK**

Note: Assuming that the conductors are in electrostatic equilibrium, we assign voltage potential on the object itself. In other words, we do not solve inside conductors, we assume that all the conductor parts are at the same potential.

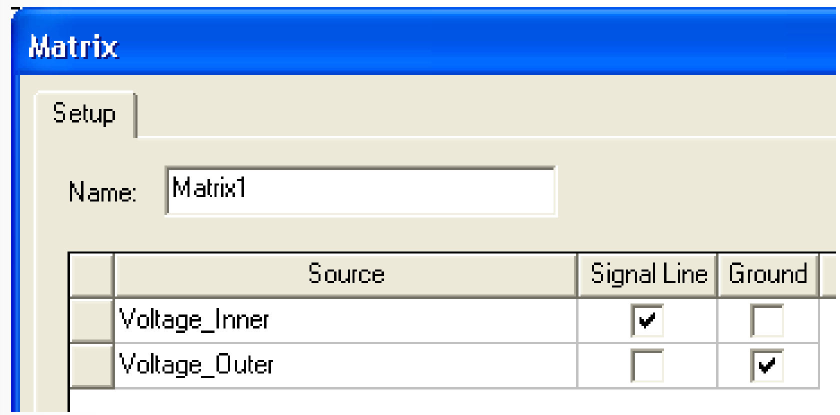
Assign Executive Parameters

- **Assign Capacitance Computation**
  - Select the menu item ***Maxwell2D → Parameters → Assign → Matrix***
  - In Matrix window

    1. Voltage_Inner
    - Signal Line: ☑ **Checked**

    2. Voltage_Outer
    - Ground: ☑ **Checked**

    3. Press **OK**



  - We ground Voltage_Outer. We will obtain just a 1 by 1 matrix.

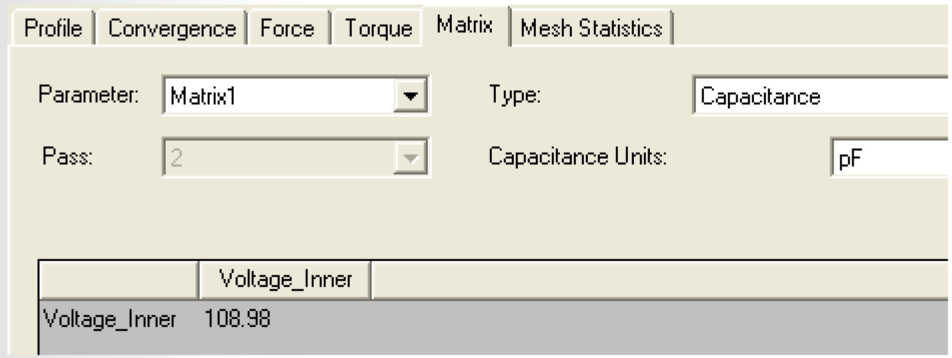
Note: In addition to the fields, we are interested by the Capacitance value as well as the force applied to the inner armature. These quantities can be evaluated by assigning executive parameters.

Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 2D → Analysis Setup → Add Solution Setup***
  - Solution Setup Window:
    1. **General** Tab
       - Percentage Error: **0.5**
    2. **Convergence** Tab
       - Refinement Per Pass: **50%**
    3. Click the **OK** button
- **Start the solution process:**
  - Select the menu item ***Maxwell 2D → Analyze All***

View Results

- **View Capacitance**
  - Select the menu item ***Maxwell 2D → Results → Solution Data***
  - In Solutions window
    - Select **Matrix** tab



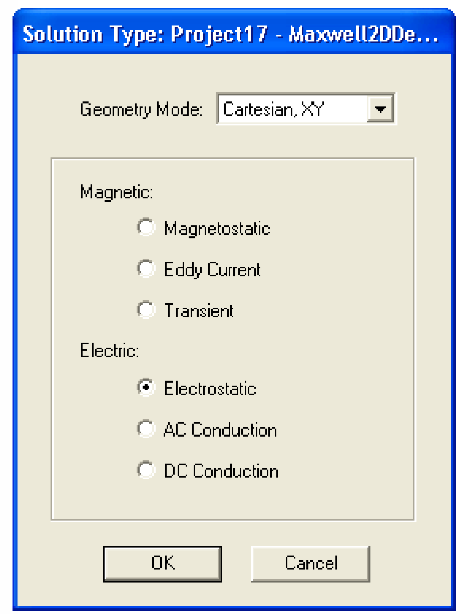
  - The analytical value of the capacitance per meter for an infinite long coaxial wire is given by the following formula:

    $\mathbf{C = 2\pi\varepsilon_0 / \ln(b/a)}$ (a and b being the inside and outside diameters)
  - The analytical value would be therefore **1.089e-10 F/m** (a =0.6mm, b=1mm)
  - This matches the obtained value.

Example3: Capacitance of a Planar Capacitor

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 2D Design***, or click on the icon
- **Set Solution Type**
  - Select the menu item ***Maxwell 2D → Solution Type***
  - Solution Type Window:
    1. Geometry Mode: **Cartesian, XY**
    2. Choose **Electric > Electrostatic**
    3. Click the **OK** button

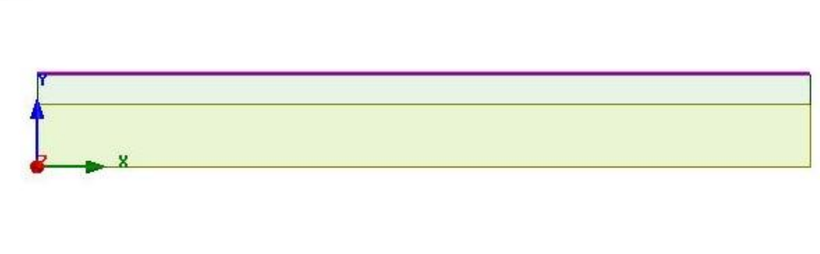


Create Model

- **Create Object DownPlate**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 25, dY: 2, dZ: 0**, Press the **Enter** key
  - Change the name of resulting sheet to **DownPlate** and color to **Yellow**
  - Change the material of the sheet to **Copper**
- **Create Object Region**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 25, dY: 3, dZ: 0**, Press the **Enter** key
  - Change the name of resulting sheet to **Region** and color to **Green**
  - Change the material of the sheet to **air**

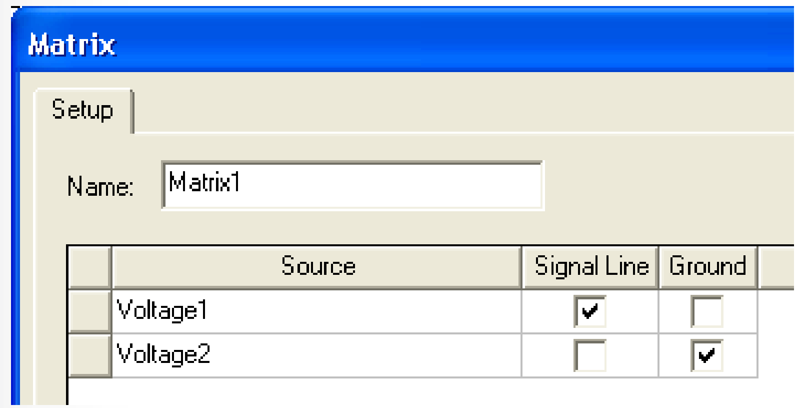
Assign Excitations

- **Assign Excitation to object DownPlate**
  - Select the sheet **DownPlate** from the history tree
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    - Value: **0 V**
    - Press **OK**
- **Assign Excitation to Region**
  - Select the menu item ***Edit → Select → Edges***
  - Select the top edge of the Region as shown in below image
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    - Value: **1 V**
    - Press **OK**



Assign Executive Parameters

- **Assign Capacitance Computation**
  - Select the menu item ***Maxwell2D → Parameters → Assign → Matrix***
  - In Matrix window
    1. Voltage1
       - Signal Line: ☑ **Checked**
    2. Voltage2
       - Ground: ☑ **Checked**
    3. Press **OK**



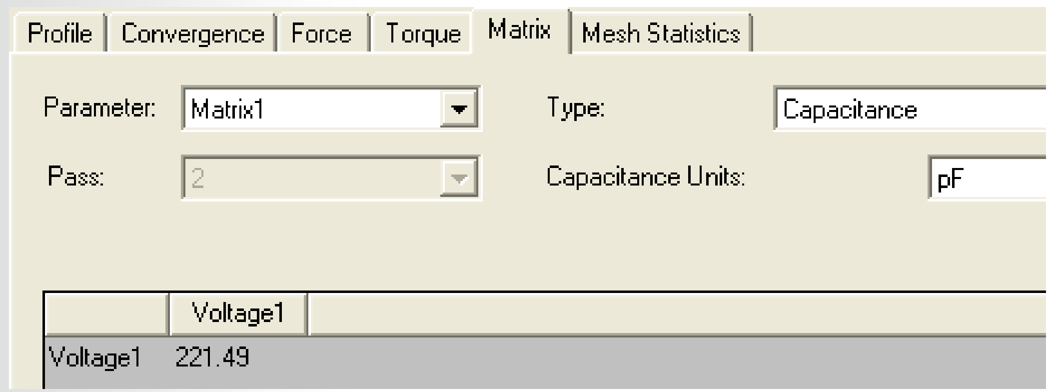
Note: In addition to the fields, we are interested by the Capacitance value as well as the force applied to the inner armature. These quantities can be evaluated by assigning executive parameters.

Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 2D → Analysis Setup → Add Solution Setup***
  - Solution Setup Window:
    1. **General** Tab
       - Percentage Error: **1**
    2. **Convergence** Tab
       - Refinement Per Pass: **50%**
    3. Click the **OK** button
- **Start the solution process:**
  - Select the menu item ***Maxwell 2D → Analyze All***

View Results

- **View Capacitance**
  - Select the menu item ***Maxwell 2D → Results → Solution Data***
  - In Solutions window
    - Select **Matrix** tab



  - The analytical value of the capacitance for two parallel plates is given by:

    $C = A/ d *\varepsilon_0$ (A is the area of the plate and d is the thickness of the di electrics)
  - If we consider the plate to be 25mm by 25 mm, using the above formula, we obtain **5.53 pF** (the dielectric is 1mm thick).
  - We obtain **221.49pF**. This value should be considered as the capacitance of the two parallel plates with a 1 meter depth. If we rescale this value by multiplying by 0.025m (25 mm) we find **5.53pF** as well.