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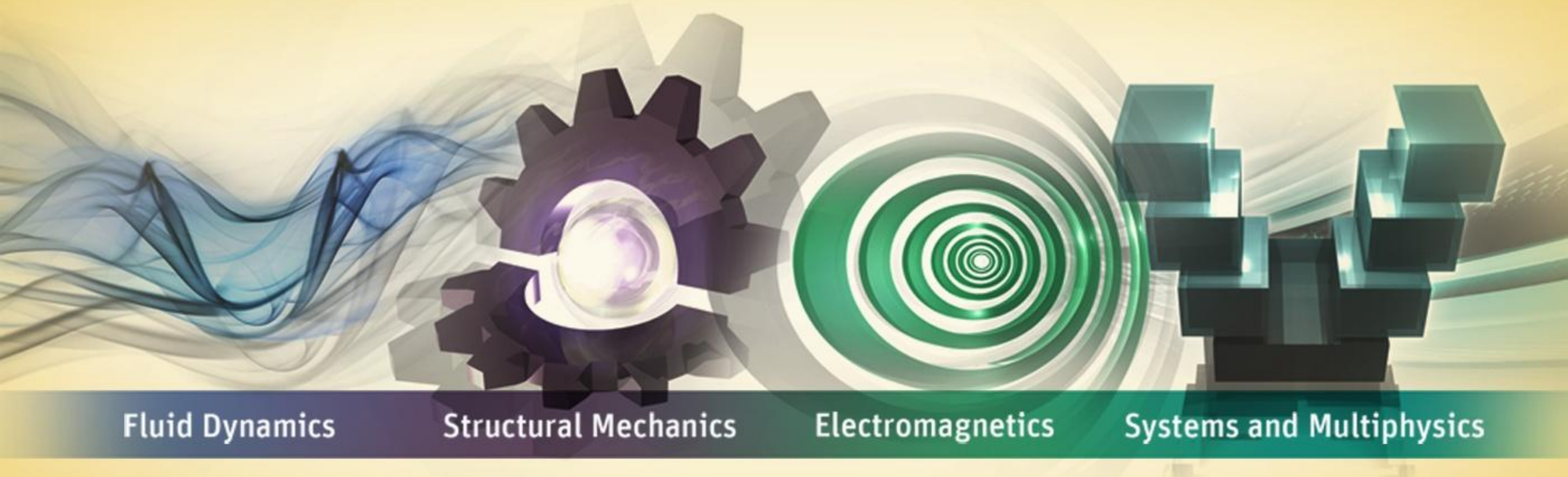
Workshop 3: Basic Electrostatic Analysis



ANSYS Maxwell 3D V16

About Workshop

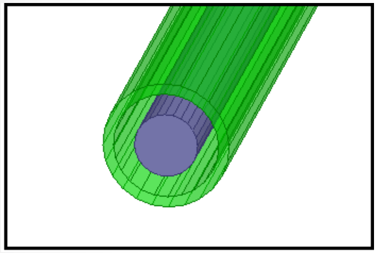
- **Electrostatic Solver**
  - This workshop introduces the **“Electrostatic Solver”.** This solver is meant to solve the static electric field without current flowing in conductors (conductors are in electrostatic equilibrium). The conductors are considered perfect such that there is no electric field inside conductors.
  - Following Two Examples will be solved in this workshop

    Example 1 : Capacitance of a Cylindrical Capacitor

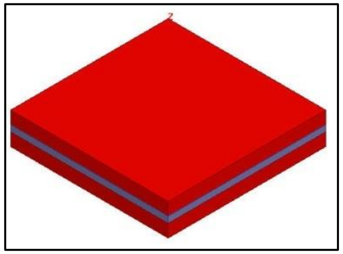
    - In this example we will solve a long coaxial line to determine the electric field distribution based on applied potential (or the charges) on each conductor. We will also evaluate the capacitance.

    Example 2: Capacitance of a planar capacitor

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



Example 1



Example 2

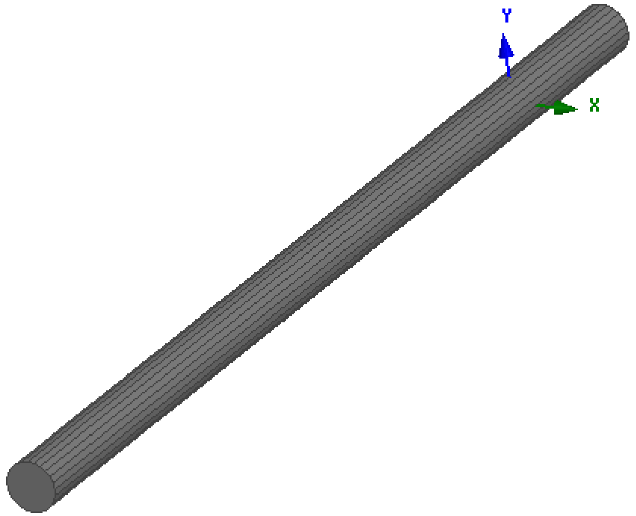
Example 1 : Capacitance of a Cylindrical Capacitor

Problem Setup

- **Create Design**
  - Select the menu item ***Project* → *Insert Maxwell 3D Design***, or click on the  icon
  - Rename design as **Coaxial Line**
- **Set the Solution Type:**
  - Select the menu item ***Maxwell 3D* → *Solution Type***
  - Solution Type Window:
    1. Choose ***Electric > Electrostatic***
    2. Click the **OK** button
- **Set the default material:**
  - Using the 3D Modeler Materials toolbar, choose **Select**
  - In Select Definition window,
    1. Type **Copper** in the Search by Name field
    2. Click the **OK** button

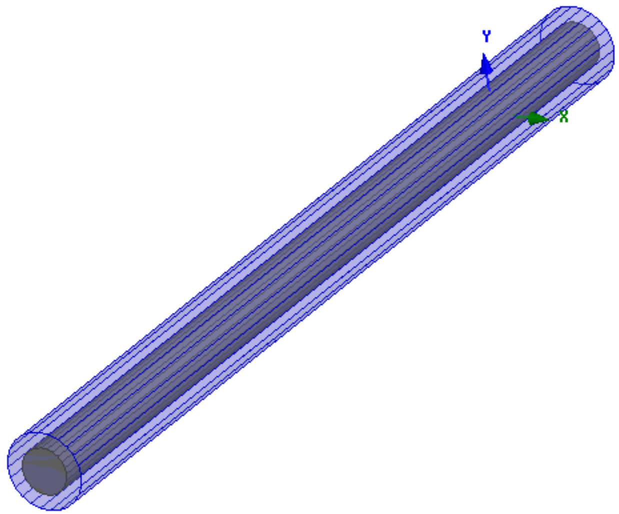
Create Geometry

- **Create Regular Polyhedron**
  – Select the menu item ***Draw → Regular Polyhedron***
    1. Using the coordinate entry fields, enter the center of the base
       – **X: 0, Y: 0, Z: -4**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the radius
       – **dX: 0.6, dY: 0, dZ: 0**, Press the **Enter** key
    3. Using the coordinate entry fields, enter the height
       – **dX: 0, dY: 0, dZ:25**, Press the **Enter** key
    4. Number of Segments: **24**
  – Change the name of the Object to **Inner**
  – Set the color of the object to **Gray**



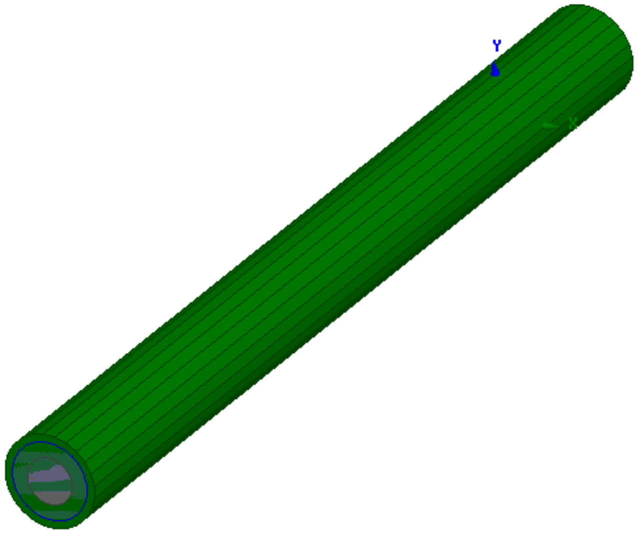
Create Geometry (*Contd…*)

- **Create Second Polyhedron**
  - Select the menu item ***Draw → Regular Polyhedron***
    1. Using the coordinate entry fields, enter the center of the base
       - **X: 0, Y: 0, Z: -4**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the radius
       - **dX: 1, dY: 0, dZ: 0**, Press the **Enter** key
    3. Using the coordinate entry fields, enter the height
       - **dX: 0, dY: 0, dZ:25**, Press the **Enter** key
    4. Number of Segments: **24**
  - Change the name of the Object to **Gap**



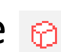
Create Geometry (*Contd…*)

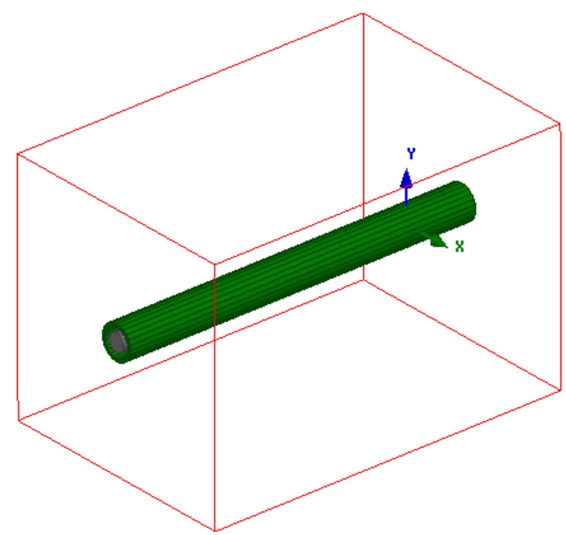
- **Create Third Polyhedron**
  - Select the menu item ***Draw → Regular Polyhedron***
    1. Using the coordinate entry fields, enter the center of the base
       - **X: 0, Y: 0, Z: -4**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the radius
       - **dX: 1.2, dY: 0, dZ: 0**, Press the **Enter** key
    3. Using the coordinate entry fields, enter the height
       - **dX: 0, dY: 0, dZ:25**, Press the **Enter** key
    4. Number of Segments: **24**
  - Change the name of the Object to **Outer**
  - Set the color of the object to **Green**



Create Geometry (*Contd…*)

- **Subtract Objects**
  – Press **Ctrl** and select the objects **Outer** and **Gap** from the history tree
  – Select the menu item, ***Modeler → Boolean → Subtract***
    1. Blank Parts: **Outer**
    2. Tool Parts: **Gap**
    3. Click the **OK** button

- **Create Simulation Region**
  – Select the menu item ***Draw → Region*** or click on the  icon
  – In Region window,
    1. Pad individual directions: ☑ **Checked**
    2. Padding Type: Percentage Offset
       – +X and -X = **300**
       – +Y and -Y = **300**
       – +Z and -Z = **0**
    3. Press **OK**



Assign Excitations

- **Assign Excitation for Inner**
  - Select the object **Inner** from the history tree
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **-1000 V**
    2. Press **OK**
- **Assign Excitation for Outer**
  - Select the object **Outer** from the history tree
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **1000 V**
    2. Press **OK**

Note: Based on the assumptions that the conductors are in electrostatic equilibrium, we assign voltage potential on the object itself (and not on the surface of the object like in the other solvers).

Assign Parameters

- **Assign Matrix Parameter to Calculate Capacitance**
  - Select the menu item ***Maxwell 3D → Parameters → Assign → Matrix***
  - In Matrix window
    1. Voltage1 and Voltage2
       - Include: ☑ **Checked**
    2. Press **OK**
- **Assign Force Parameter for Inner**
  - Select the Object **Inner** from the tree
  - Select the menu item ***Maxwell 3D → Parameters → Assign → Force***
  - In Force Setup window,
    1. Type : **Virtual**
    2. Press **OK**

Note: Parameters are assigned for calculation of Capacitance value as well as the force applied to the inner armature.

Analyze

- **To create an analysis setup:**
  - Select the menu item ***Maxwell 3D → Analysis Setup → Add Solution Setup***
  - Solution Setup Window:

    1. General Tab
      - Percent Error: **5**

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

    3. Click the **OK** button

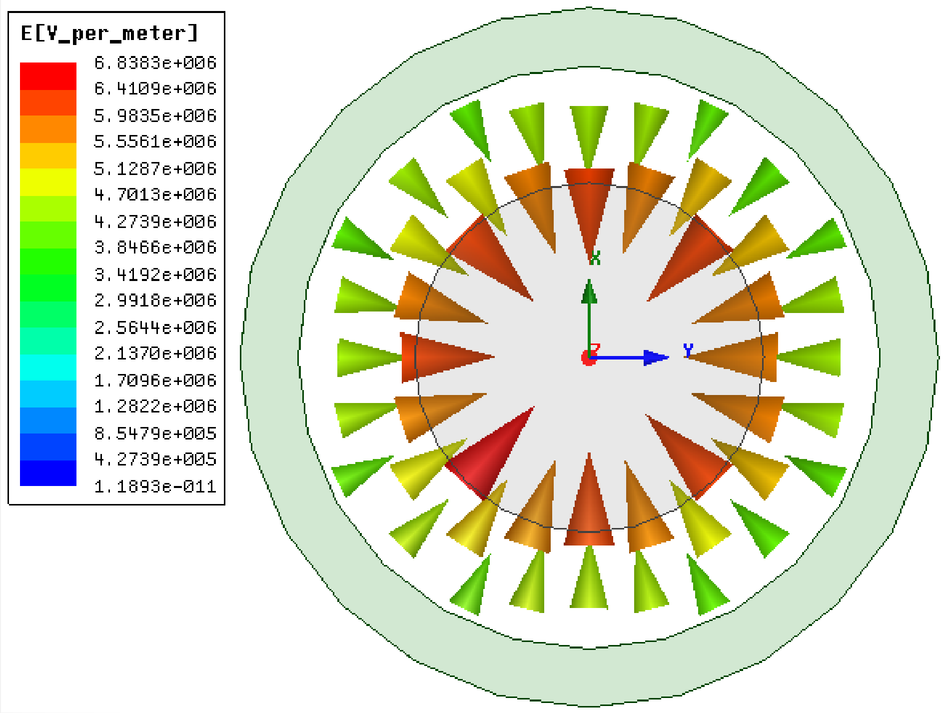
- **To start the solution process:**

  1. Select the menu item ***Maxwell 3D → Analyze All***

Note: You will need to save your project before analyzing. Note that, the project is always saved before the simulation starts.

Create Vector Plot

- **To Create Vector Plot**
  - Select the plane **Global:XY** from the history tree
  - Select the menu item ***Maxwell 3D → Fields → Fields → E → E_Vector***
  - In Create Field Plot window
    1. Press **Done**

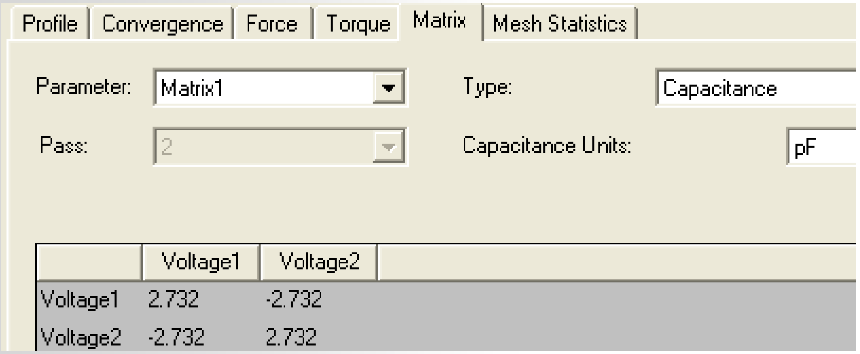


Note: Default plot may not look as shown in image. Users can modify attributes of plot to make it look better. Double click on the legend to modify plot attributes.

View Solution

- **View Capacitance**
  - Select the menu item ***Maxwell 3D → Results → Solution Data***
  - Select the **Matrix** tab
  - The analytical value of the capacitance per meter for an infinite long coaxial wire is given by the following formula:

    C = 2πε0 / 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, then length of the conductor is 25 mm, therefore the total capacitance is **2.72 pF**. We obtain a good agreement with the obtained result.

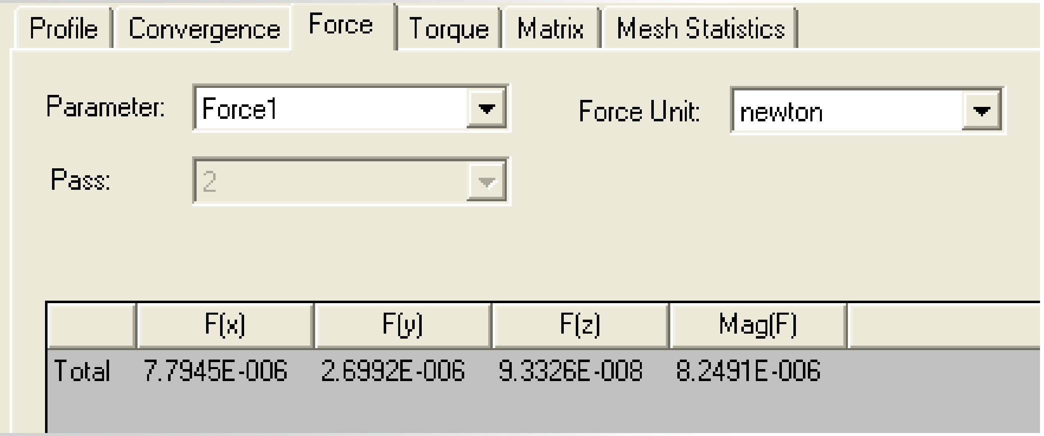


	Voltage1	Voltage2
Voltage1	2.732	-2.732
Voltage2	-2.732	2.732

Note: In our problem, we only have two conductors, therefore the capacitance values are symmetrical

View Solution (*Contd…*)

- **View Force**
  - Select the **Force** tab



Example 2 : Capacitance of a planar capacitor

Problem Setup

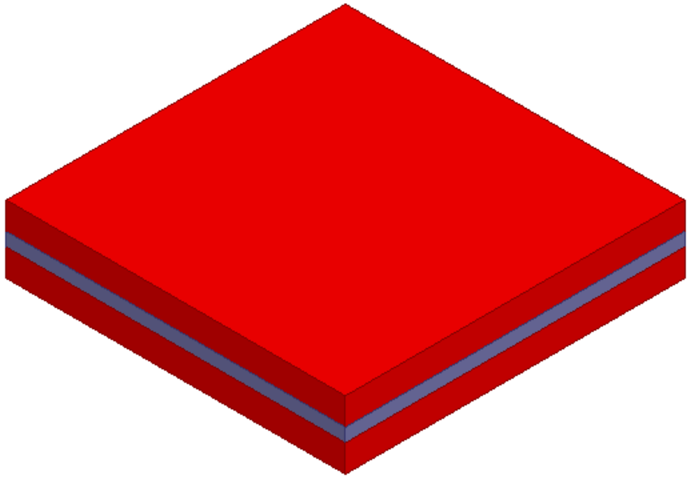
- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 3D Design***, or click on the icon
  - Rename design as **Plate**
- **Set the Solution Type:**
  - Select the menu item ***Maxwell 3D → Solution Type***
  - Solution Type Window:
    1. Choose ***Electric > Electrostatic***
    2. Click the **OK** button
- **Set the default material:**
  - Using the 3D Modeler Materials toolbar, choose **Select**
  - In Select Definition window,
    1. Type **pec** (Perfect Conductor) in the Search by Name field
    2. Click the **OK** button

Create Geometry

- **Create Box**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 25, dY: 25, dZ: 2**, Press the **Enter** key
  - Change the name of the Object to **DownPlate**
- **Create Gap**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0, Y: 0, Z: 2**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 25, dY: 25, dZ: 1**, Press the **Enter** key
  - Change the name of the Object to **Gap** and material to **Vacuum**

Create Geometry (*Contd…*)

- **Create Second Box**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0, Y: 0, Z: 3**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 25, dY: 25, dZ: 2**, Press the **Enter** key
  - Change the name of the Object to **UpPlate**
  - Change the colors of the objects if needed



Note: It is not needed to draw the plates; it is possible in this case just to apply a voltage to the surface of the gap.

Assign Excitations

- **Assign Excitation for DownPlate**
  - Select the object **DownPlate** from the history tree
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **0 V**
    2. Press **OK**
- **Assign Excitation for UpPlate**
  - Select the object **UpPlate** from the history tree
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **1 V**
    2. Press **OK**

Analyze

- **Assign Matrix Parameter to Calculate Capacitance**
  – Select the menu item ***Maxwell 3D → Parameters → Assign → Matrix***
  – In Matrix window
    1. Voltage1 and Voltage2
       – Include: ☑ **Checked**
- **Create an analysis setup:**
  – Select the menu item ***Maxwell 3D → Analysis Setup → Add Solution Setup***
  – Solution Setup Window:
    1. Convergence Tab
       – Refinement Per Pass: **50%**
       – Maximum Number of Passes: **10**
    2. Click the OK button
- **Start the solution process:**
  – Select the menu item ***Maxwell 3D → Analyze All***

View Solution

- **View Capacitance**
  - Select the menu item ***Maxwell 3D → Results → Solution Data***
  - Select the **Matrix** tab
  - The analytical value of the capacitance per meter for an infinite long coaxial wire is given by the following formula:

    $C = A/d * \varepsilon_0$ (*A* is the area of the plate and *d* is the thickness of the dielectrics)
  - Using this formula, we obtain **5.53 pF**. This value matches the value obtain using the finite elements