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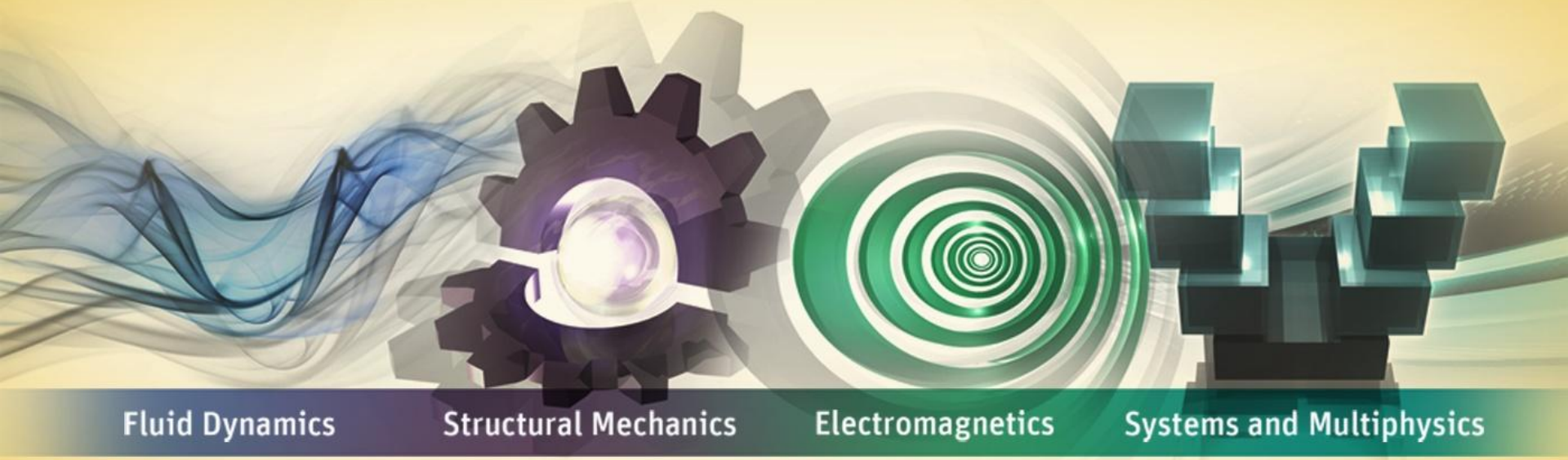
Workshop 4 :
Basic DC Conduction Analysis



ANSYS Maxwell 3D V16

About Workshop

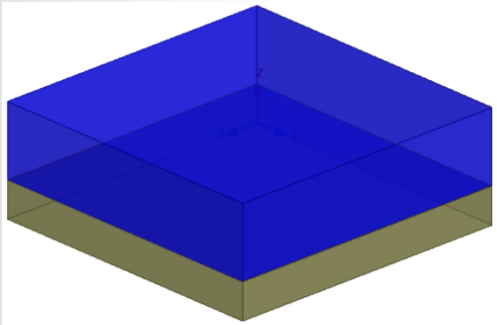
- **DC Conduction Solver**
  - This workshop introduces the DC conduction solver. Only conductors are considered in the process i.e. without including insulator fields.
  - Following Two Examples will be solved in this workshop

Example 1 : Parallel Plates with Non-uniform media

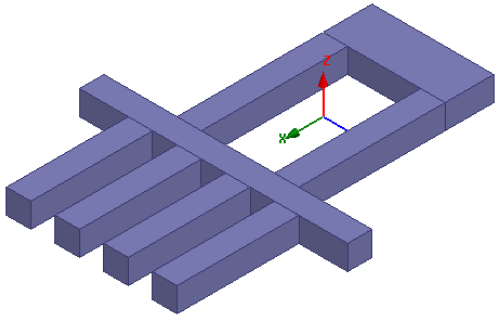
- In this example, we want to determine the DC resistance between two plates with a non-uniform media made of graphite and sea water. We do not need to draw the plates; we just need to draw the two media regions.

Example 2: DC current flow in conductors

- In this example, we illustrate the capability of the DC current solver to reconstruct the current paths flowing in different conductors



Example 1



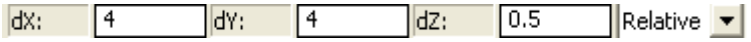
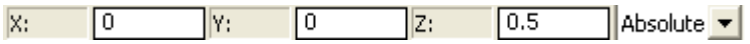
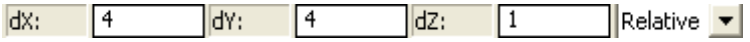
Example 2

Example 1: Parallel Plates with Non-uniform media

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 3D Design***, or click on the  icon
  - Change the name of the design to **Plates**
- **Set the Solution Type:**
  - Select the menu item ***Maxwell 3D → Solution Type***
  - Solution Type Window:
    1. Choose DC Conduction
       - Include Insulator Field : ☐ **Unchecked**
    2. Click the **OK** button

Create Geometry

- **Create Solid**
  - 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: 4, dY: 4, dZ: 0.5**, Press the **Enter** key 
  - Change the name of the Object to **Solid** and material to **graphite**
- **Create Liquid**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0, Y: 0, Z: 0.5**, Press the **Enter** key 
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 4, dY: 4, dZ: 1**, Press the **Enter** key 
  - Change the name of the Object to **Liquid** and material to **water_sea**

Assign Excitations

- **Assign Excitation for Top**
  - Select the menu item ***Edit → Select → Faces*** or press **F** from the keyboard
  - Select the top face of the Object Liquid
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **10 V**
    2. Press **OK**
- **Assign Excitation for Top**
  - Select the bottom face of the Object **Solid**
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **-10 V**
    2. Press **OK**

Note: We have not drawn the conductor plates which are at the assigned voltage. Instead we applied voltages to top and bottom faces of region between two plates

Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 3D → Analysis Setup → Add Solution Setup***
  - Solution Setup Window:
    1. Click the **OK** to accept default settings
- **Start the solution process:**
  - Select the menu item ***Maxwell 3D → Analyze All***

Compute the DC Resistance

Note: The DC resistance is not directly computed by Maxwell3D. However, we already know the applied voltage. We need the DC current that flows through the media. The current is obtained by taking the integral of Z component of J on a cross section of the region. To define any cross section, we define a local coordinate system, and use the planes defined by this local CS.

- **Create Local Coordinate System**
  - Select the menu item ***Modeler → Coordinate System → Create → Relative CS → Offset***
    1. Using the coordinate entry fields, enter the origin position
       - **X: 0, Y: 0, Z: 1**, Press the **Enter** key
  - The total current going through the media will be the integral of the current density J on the plane XY of this local CS.

Compute the DC Resistance (*Contd…*)

- **Calculate Resistance**
  - Select the menu item ***Maxwell 3D → Fields → Calculator***
  - In Field Calculator window:
    1. Select **Input > Quantity > J**
    2. Select **Vector > Scal? > ScalarZ**
    3. Select **Input > Geometry**
       - Select **Surface**
       - Select **RelativeCS1:XY** from the list
       - Press **OK**
    4. Select **Scalar >**  **(Integrate)**
    5. Press **Eval**
  - The total current is close to **-1.28A**. The value is very low because the conductivity of medium is very low. The negative sign is just a matter of sign convention due to the CS orientation.
  - The DC resistance is given by R = Voltage / Current. The difference of potential between the two plate is 20 V. We obtain **R = 15.625 Ohm**

Compute the DC Resistance (*Contd…*)

- **Analytical value of Resistance**
  - The analytical value of the resistance is given by the following formula

    $$\mathbf{R = \sigma_2 h_1 + \sigma_1 h_2 / (\sigma_1 \sigma_2 A)}$$

    where σ_1, σ_2 are the conductivity of the two medium, h_1,h_2 the thickness of the two medium and A the surface of the plates.
  - If we take below values,
    - σ_1 = **70000 Siemens/m,**
    - h_1= **0.5e-3 m (ferrite);**
    - σ_2 = **4 Siemens/m,**
    - h_2 = **1e-3 m (sea water) ;**
    - A = **16e-6 m^2.**
  - The value of resistance comes out to be:

    R = 15.625 Ohm
  - The values are similar to what we obtained using Maxwell

Example 2: DC current flow in conductors

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 3D Design***, or click on the  icon
  - Change the name of the design to **Conductors**
- **Set the Solution Type:**
  - Select the menu item ***Maxwell 3D → Solution Type***
  - Solution Type Window:
    1. Choose DC Conduction
       - Include Insulator Field : ☐ **Unchecked**
    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 Conductor**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 1, Y: -0.6, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 1, dY: 0.2, dZ: 0.2**, Press the **Enter** key
       - Change the name of the Object to **Conductor**
- **Duplicate Conductor**
  - Select the object **Conductor** from the history tree
  - Select the menu item ***Edit → Duplicate → Along Line***
    1. Using coordinate entry fields, enter the first point of duplicate vector
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using coordinate entry fields, enter the second point
       - **dX: 0, dY: 0.4, dZ: 0**, Press the **Enter** key
    3. Total Number: **4**
    4. Press **OK**

Create Geometry (*Contd…*)

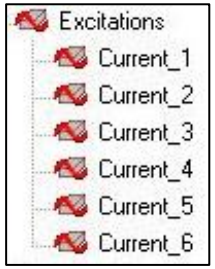
- **Create Conductor_4**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0.8, Y: -1, Z: 0**, Press the Enter key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 0.2, dY: 2.2, dZ: 0.2**, Press the Enter key
       - Change the name of the Object to **Conductor_4**
- **Create Conductor_5**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0.8, Y: -0.4, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: -1.2, dY: 0.2, dZ: 0.2**, Press the **Enter** key
       - Change the name of the Object to **Conductor_5**

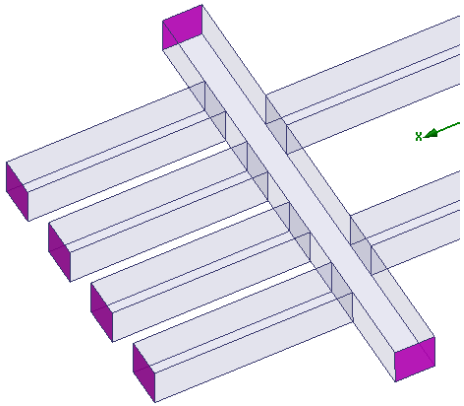
Create Geometry (*Contd…*)

- **Duplicate Conductor_5**
  - Select the object **Conductor _5** from the history tree
  - Select the menu item ***Edit → Duplicate → Along Line***
    1. Using coordinate entry fields, enter the first point of duplicate vector
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using coordinate entry fields, enter the second point
       - **dX: 0, dY: 0.8, dZ: 0**, Press the **Enter** key
    3. Total Number: **2**
    4. Press **OK**
- **Create Conductor_Sink**
  - Select the menu item ***Draw → Box***
    1. Using the coordinate entry fields, enter the box position
       - **X: -0.4, Y: 0.6, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: -0.4, dY: -1, dZ: 0.2**, Press the **Enter** key
       - Change the name of the Object to **Conductor_Sink**

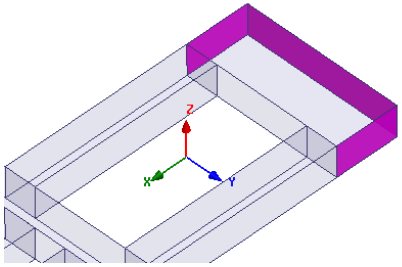
Assign Excitations

- **Assign Excitation Current**
  - Select the menu item ***Edit → Select → Faces*** or press **F** from the keyboard
  - Select the top faces of the Objects **Conductor, Conductor_1, Conductor_2, Conductor_3** and **Conductor_4** as shown below
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Current***
  - In Current Excitation window,
    1. Set Value to **1 A**
    2. Press **OK**
  - Maxwell creates 6 current excitations of 1A.



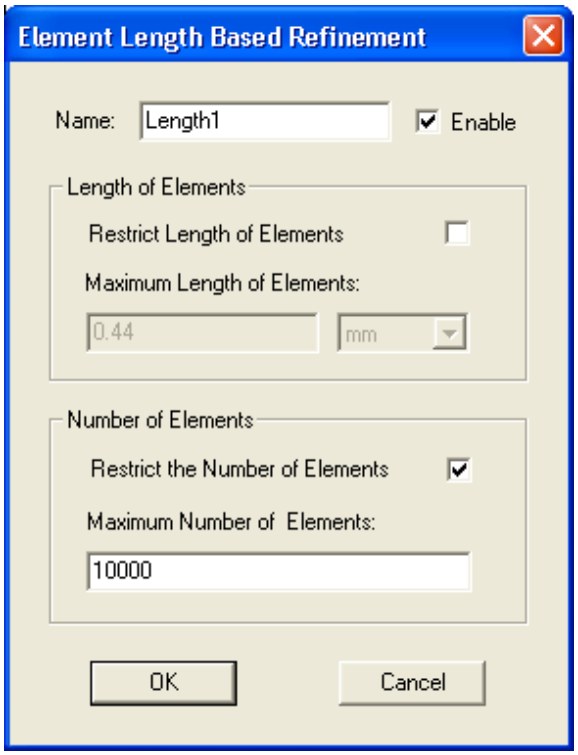


- **Assign Excitation for Top**
  - Select the faces of **Conductor_Sink** as shown in the image
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Sink***
  - Press **OK**



Assign Mesh Operation

- **Assign Mesh Operation**
  - Select the menu item ***Edit → Select → Objects*** or press **O** from the keyboard
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Maxwell 3D → Mesh Operations → Assign → Inside Selection → Length Based***
  - In Element Length Based Refinement window,
    1. Restrict Length of Elements: ☐ **Unchecked**
    2. Restrict the Number of Elements: ☑ **Checked**
    3. Maximum Number of Elements: **10000**
    4. Press **OK**



Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 3D → Analysis Setup → Add Solution Setup***
  - Solution Setup Window:
    1. Click the **OK** to accept default settings
- **Start the solution process:**
  - Select the menu item ***Maxwell 3D → Analyze All***
- **Plot J Vectors**
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Maxwell 3D → Fields > Fields → J → J_Vector***
  - In Create Field Plot window, Press **Done**

Modify Plot

- **Modify Plot Attributes**
  - Double click on the legend to change plot properties
  - In the window
    1. **Scale** tab
       - User Limits: ☑ **Checked**
         1. Min: **0**
         2. Max: **9e+7**
    2. **Marker/Arrow** tab
       - **Arrow** Options
         1. Size: **One space from right**
         2. Map Size: ☐ **Unchecked**
         3. Arrow tail: ☐ **Unchecked**
    3. **Plots** tab
       - Plot: **Vector_J1**
       - Vector Plot
         1. Spacing: **Set to Minimum**
    4. Press **Apply** and **Close**