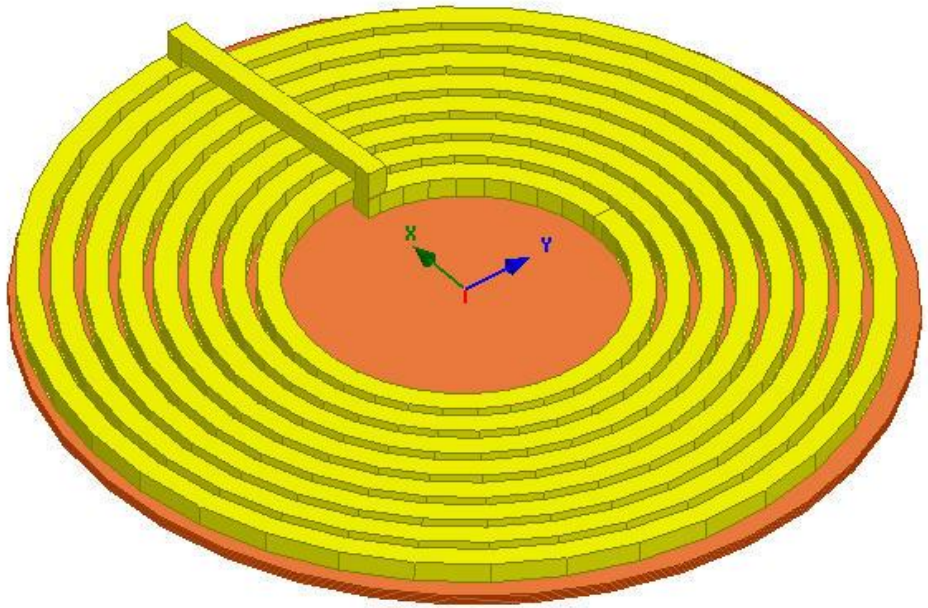
Ansys Maxwell Getting Started

Workshop 2.3: 3D Eddy Current analysis

Release 2020R2

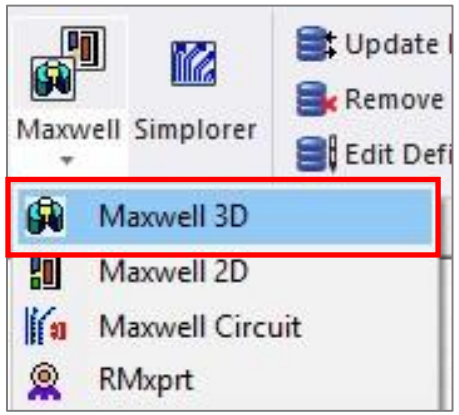
Overview

- **Introduction to the Eddy Current Solver**
  - **This workshop introduces the Eddy Current solver based on a simple example with a disk above a coil. This solver calculates the magnetic fields at a specified sinusoidal frequency. Both linear and nonlinear (for saturation effects) magnetic materials can be used. Also, eddy, skin and proximity effects are considered.**
- **3D Geometry: Iron Disk above a Spiral Coil**
  - **A sinusoidal 500 Hz current will be assigned to an eight turn spiral coil underneath of a cast iron disk. The coil induces eddy currents and losses in plate.**

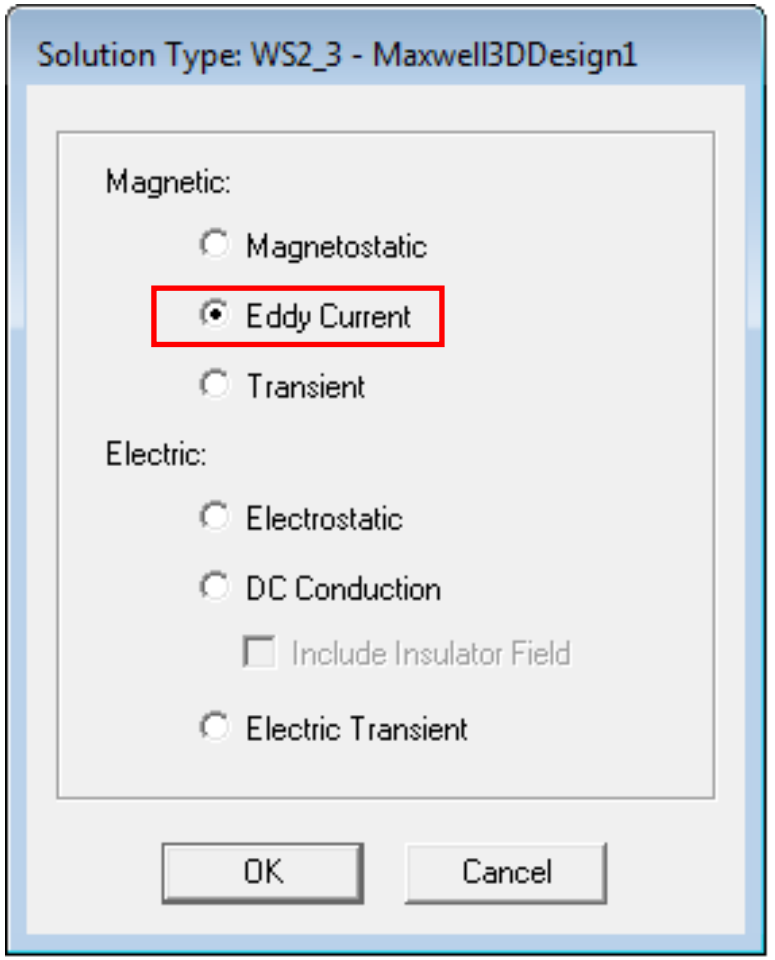


Model Setup

- **Insert Design**
  - **Select the menu item *Project → Insert Maxwell 3D Design*, or click on the icon in drop down list Maxwell on panel Desktop**

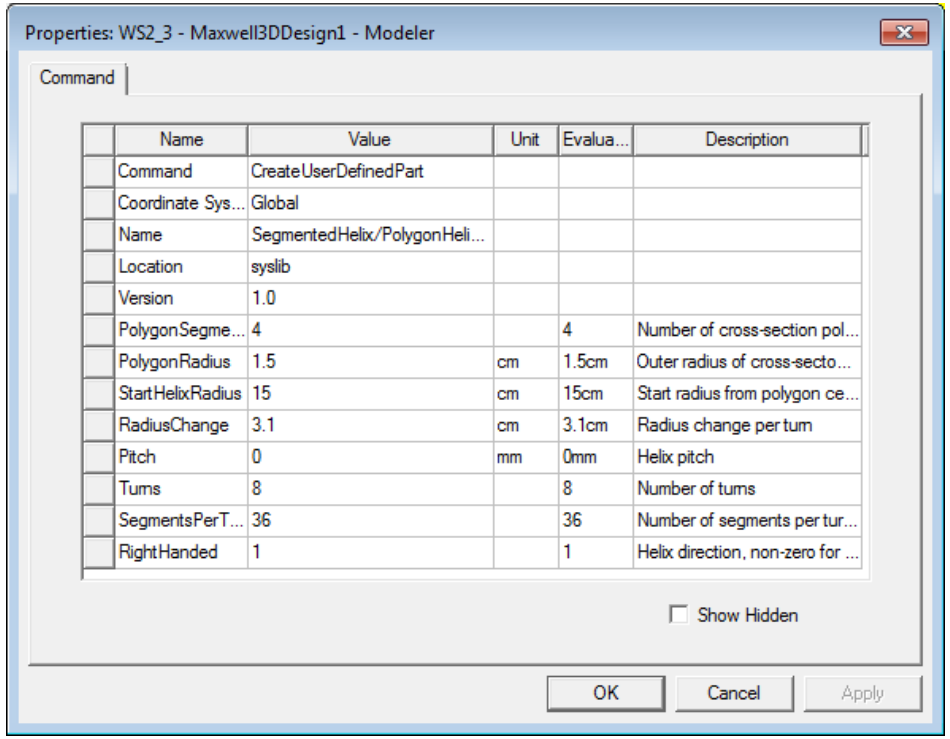


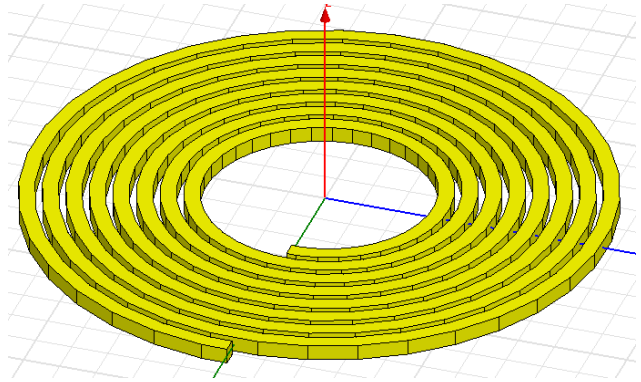
- **Set Solution Type**
  - **Select the menu item *Maxwell 3D → Solution Type***
  - **Choose *Magnetic → Eddy Current***
  - **Click the OK button**
- **Set Model Units**
  - **Select the menu item *Modeler → Units***
  - **In Set Modeler Units window,**
    - **Select units: cm (centimeters)**
    - **Press the OK button**



Create Coil1.5

- Draw Spiral
  - Select the menu item *Draw → User Defined Primitive → SegmentedHelix → PolygonHelix*
  - In User Defined Primitive Operation window,
    - PolygonRadius: 1.5 cm
    - StartHelixRadius: 15 cm
    - RadiusChange: 3.1 cm
    - Pitch: 0 cm
    - Turns: 8
    - Press OK
  - Change the name of object to Coil
  - Change the color to Yellow
  - Change the material to Copper





Note: Above operation creates a planar spiral when pitch is set to 0.

Create Coil

- **Draw Box**
  - Select the menu item ***Draw → Box***
    - **Using the coordinate entry fields, enter the box position**

      X: 14, Y: 0, Z: -2, Press the *Enter* key

    - **Using the coordinate entry fields, enter the opposite corner**

      dX: 2, dY: 2, dZ: -2, Press the *Enter* key

- **Draw another Box**
  - Select the menu item ***Draw → Box***
    - **Using the coordinate entry fields, enter the box position**

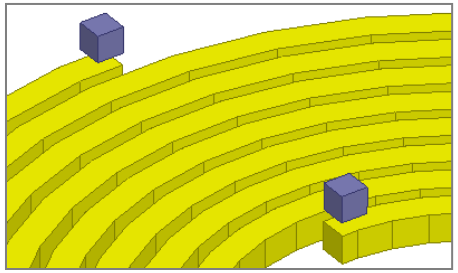
      X: 40.5, Y: 0, Z: -2, Press the *Enter* key

    - **Using the coordinate entry fields, enter the opposite corner**

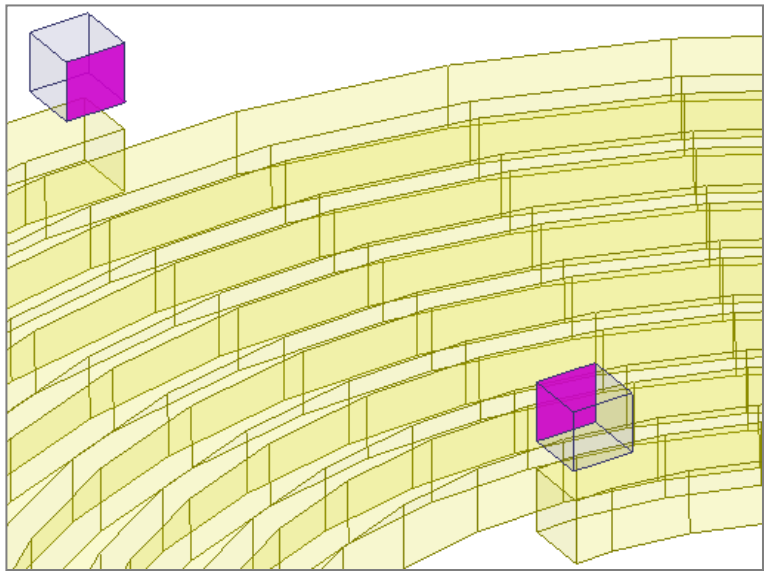
      dX: -2, dY: -2, dZ: -2, Press the *Enter* key

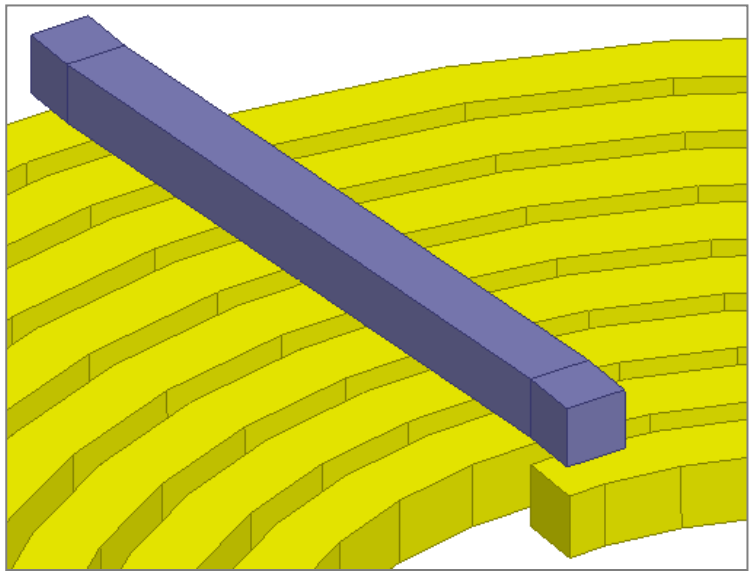
      



Create Coil

- **Connect Surfaces**
  - **Select the menu item *Edit → Select → Faces***
  - **Select the faces of the box as shown in image below**
  - **Select the menu item *Modeler → Surface → Create Object from Face***
  - **Select the resulting sheet objects from the history tree**
  - **Select the menu item *Modeler → Surface → Connect***





Note: The boxes created in last step and object created in this step will represent end connection of the coil

Create Coil

- Duplicate Boxes
  - Select **Box1** and **Box2** from the history tree
  - Select the menu item ***Edit → Duplicate → Along Line***
    - Using the coordinate entry fields, enter the first point of duplicate vector

      X: 0, Y: 0, Z: 0, Press the ***Enter*** key

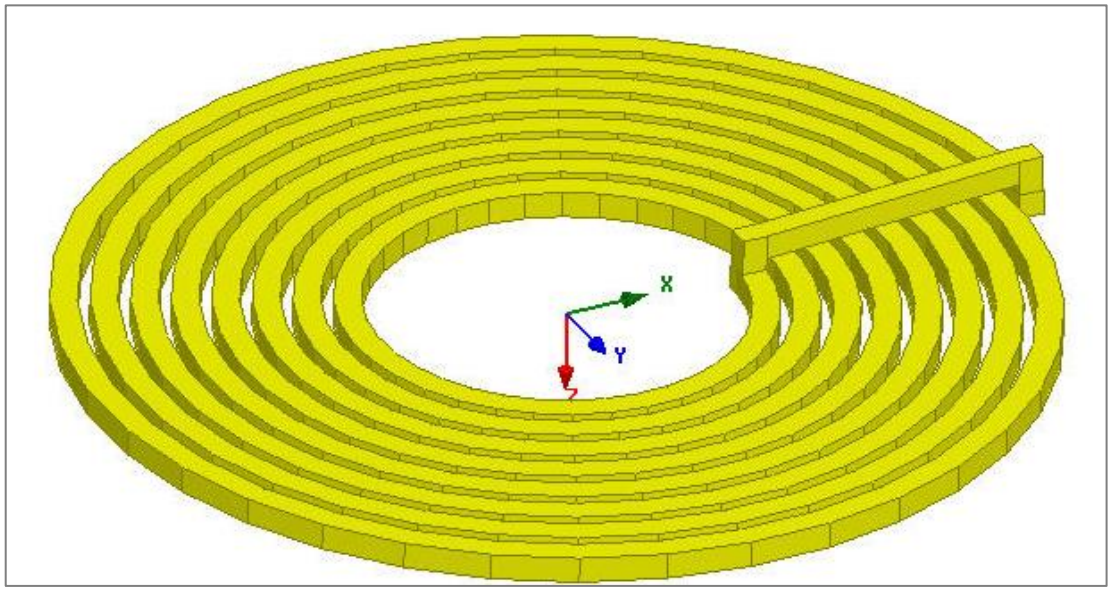
    - Using the coordinate entry fields, enter the second point

      dX: 0, dY: 0, dZ: 1, Press the ***Enter*** key

  - Total Number: 2
  - Press OK

- Unite Objects
  - Select the menu item ***Edit → Select → Objects***
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Modeler → Boolean → Unite***



Create Disk

- To Create Disk
  - Select the menu item *Draw → Regular Polyhedron*
    - Using the coordinate entry fields, enter the center of the base

      X: 0, Y: 0, Z:1.5, Press the *Enter* key

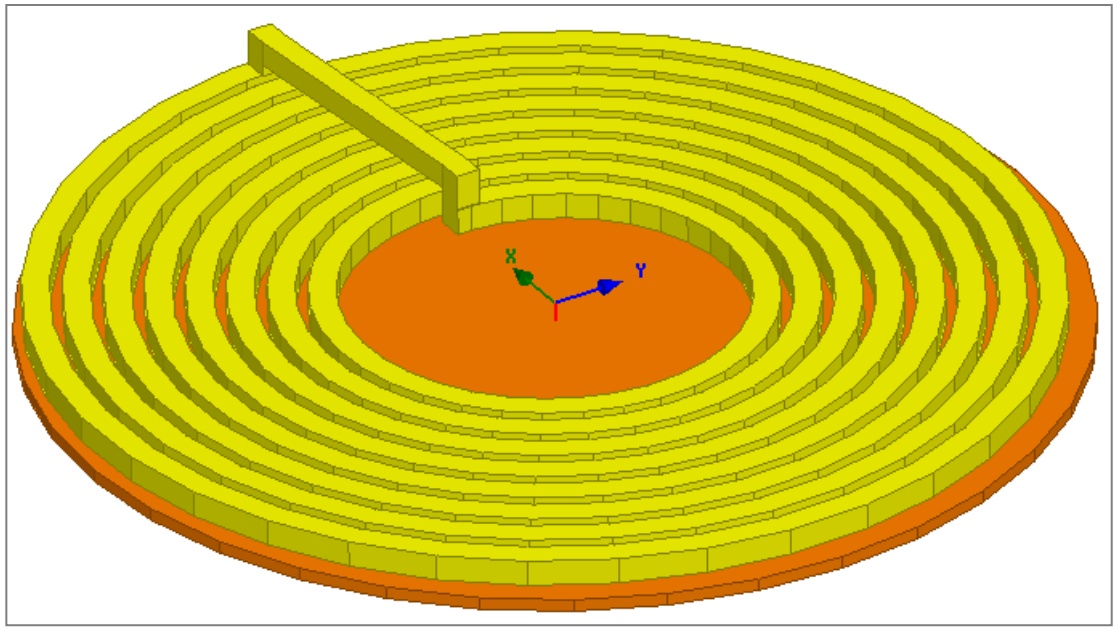
      

    - Using the coordinate entry fields, enter the radius and height

      dX: 41, dY: 0, dZ:1, Press the *Enter* key

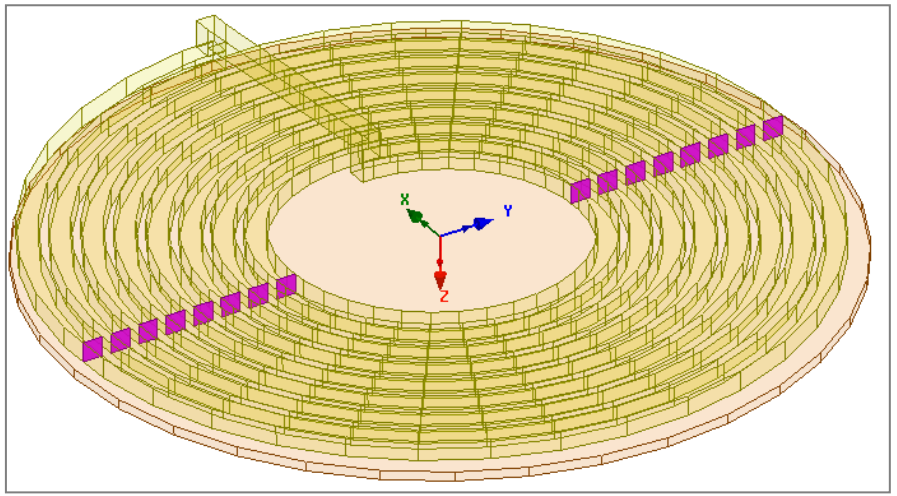
      

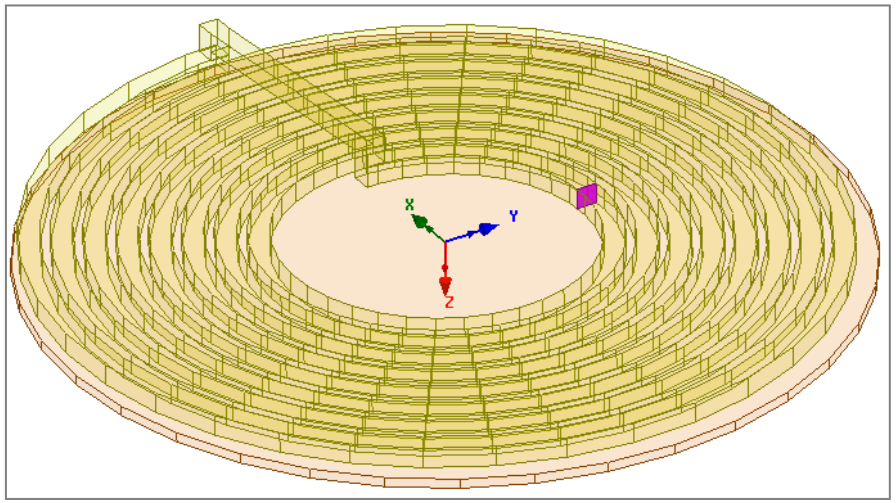
  - Number of Segments: 36
  - Change the name of the Object to Disk and color to Orange
  - Change the material of the object to cast_iron



Excitations

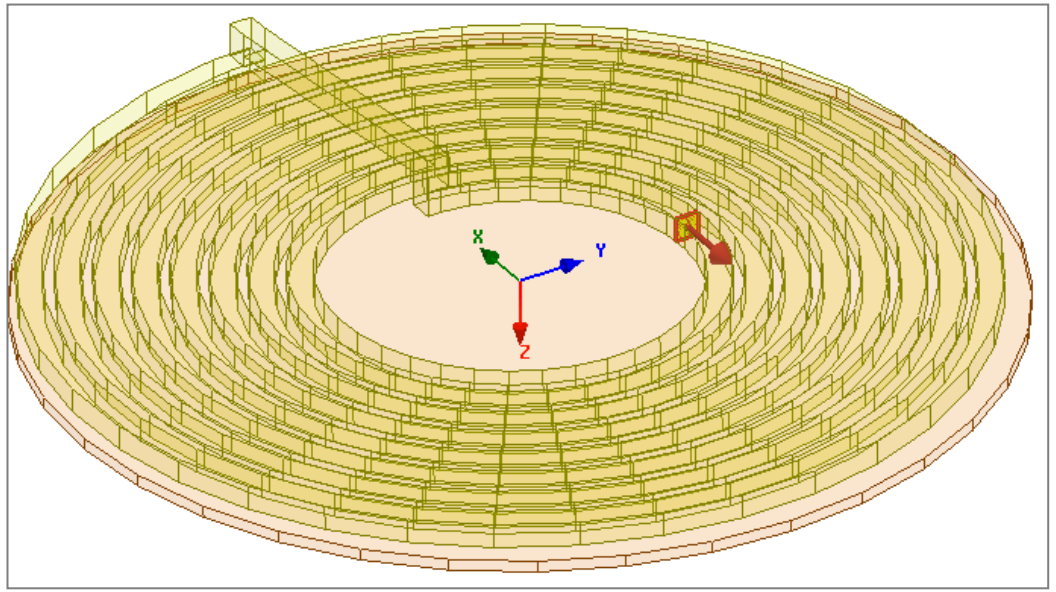
- Create Coil Terminal
  - Select the object Coil from the history tree
  - Select the menu item *Modeler → Surface → Section*
  - In Section window,
    - Section Plane: YZ
    - Press the OK button
  - Change the name of the resulting object to Coil_Terminal
  - Select the sheet Coil_Terminal from the history tree
  - Select the menu item *Modeler → Boolean → Separate Bodies*
  - Delete all the resulting sheets apart from Coil_Terminal

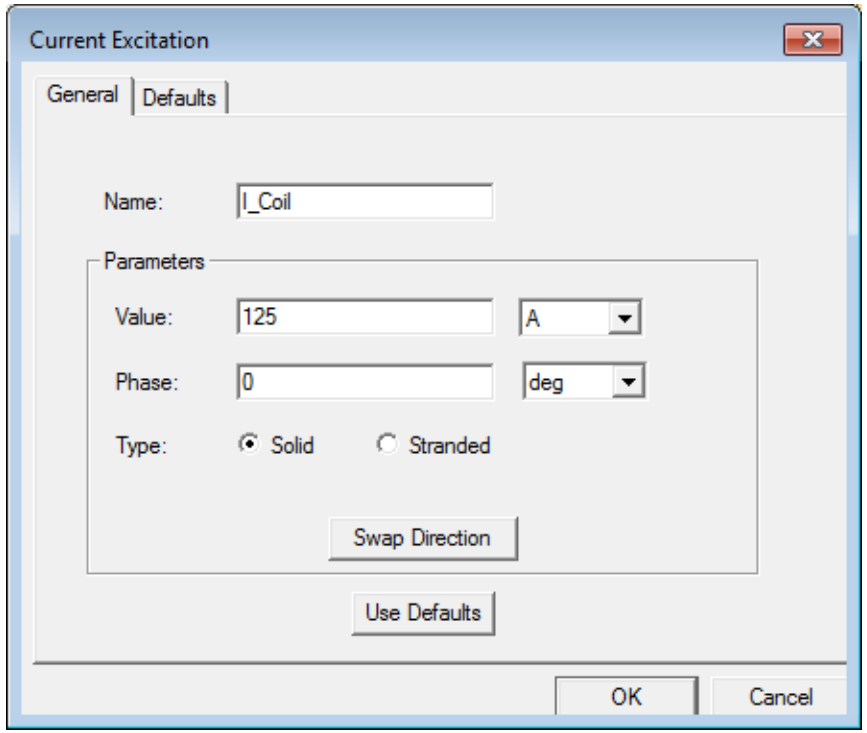




Excitations

- **Assign Excitation**
  - Select the object **Coil_Terminal** from the history tree
  - Select the menu item ***Maxwell 3D → Excitations → Assign → Current***
  - In Current Excitation window,
    - **Name: I_Coil**
    - **Value: 125 A**
    - **Type: Solid**
    - **Press OK**





Note: The current value assigned for static solvers is in Amp-Turns. Users should multiply the current value by number of turns in winding and specify resulting value in Current Excitation window.

Skin Depth

- **Compute the Skin Depth**
  - **Skin depth is a measure of how current density concentrates at the surface of a conductor carrying an alternating current. It is a function of permeability, conductivity and frequency**
  - **Skin depth δ in meters is defined as follows:**

$$\delta = \sqrt{\frac{2}{\omega \mu_0 \mu_r \sigma}}$$

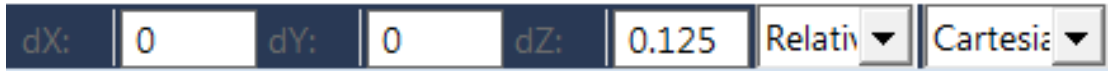
    - **ω is the angular frequency, which is equal to 2πf. (f is the frequency - in this case is 500Hz)**
    - **σ is conductor's conductivity; for cast iron it is 1.5e6 S/m**
    - **μr is conductor's relative permeability; for cast iron it is 60**
    - **μ0 is permeability of free space, which is equal to 4*π*1e-7 H/m**
  - **For the cast iron plate the skin depth result is approximately 0.24 cm**
  - **After three skin depths, the induced current will become almost negligible**

Skin Depth

- Create Surface layers to Assist with the Skin Depth Meshing
  - Select the menu item *Edit → Select → Faces*
  - Select the face on the disk that is closest to the coil
  - Select the menu item *Modeler → Surface → Create Object from Face*
  - Select the resulting sheet objects from the history tree
  - Select the menu item *Edit → Arrange → Move*
    - Using the coordinate entry fields, enter the reference point of move vector

      X: 0, Y: 0, Z: 0, Press the *Enter* key
    - Using the coordinate entry fields, enter the target point

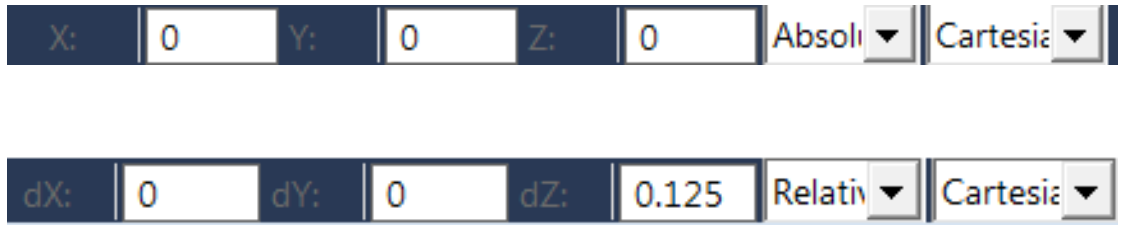
      dX: 0, dY: 0, dZ: 0.125, Press the *Enter* key

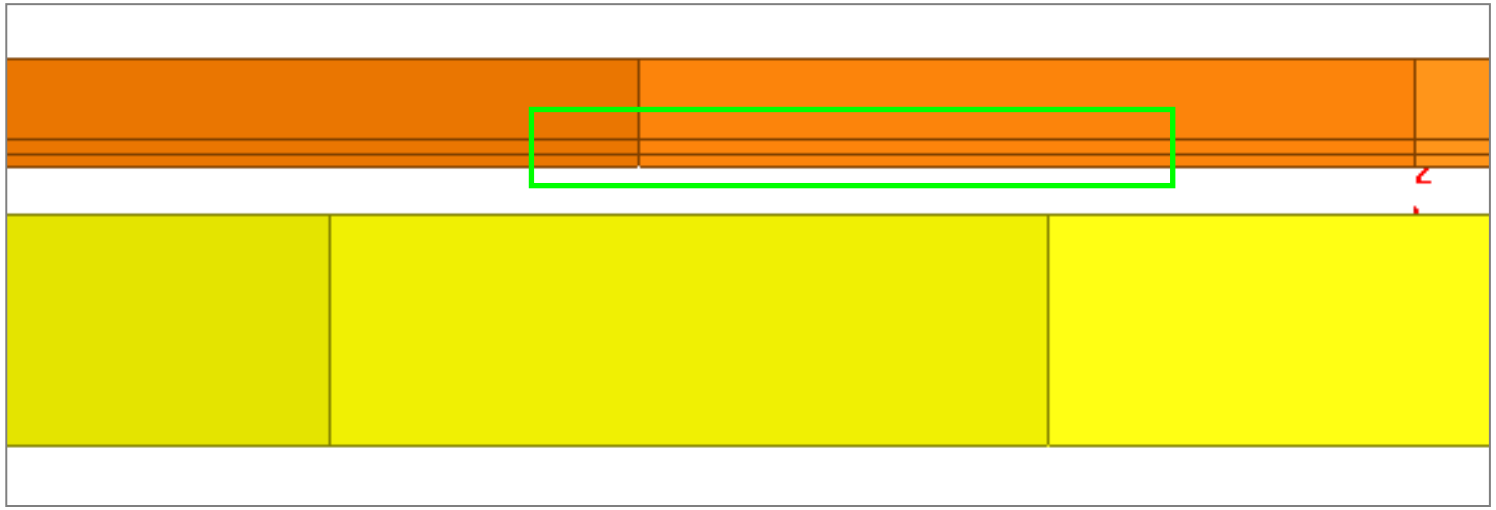


Note: we need to resolve a skin depth of 0.24 mm. Assigning mesh operations to resolve such a small skin depth region can lead to large mesh size. To resolve the skin depth effectively without need of too many elements, we create surfaces at a depth of 0.125 mm. This ensures that there are at least two elements in skin region

Skin Depth

- Duplicate Sheet
  - Select the moved sheet Disk_ObjectFromFace1
  - Select the menu item *Edit → Duplicate → Along Line*
    - Using the coordinate entry fields, enter the first point
      X: 0, Y: 0, Z: 0, Press the *Enter* key
    - Using the coordinate entry fields, enter the second point
      dX: 0, dY: 0, dZ:0.125, Press the *Enter* key
    - Total Number: 2
    - Press OK





Create Region

- Create Simulation Region
  - Select the menu item *Draw → Regular Polyhedron*
    - Using the coordinate entry fields, enter the center of the base

      X: 0, Y: 0, Z:-50, Press the *Enter* key

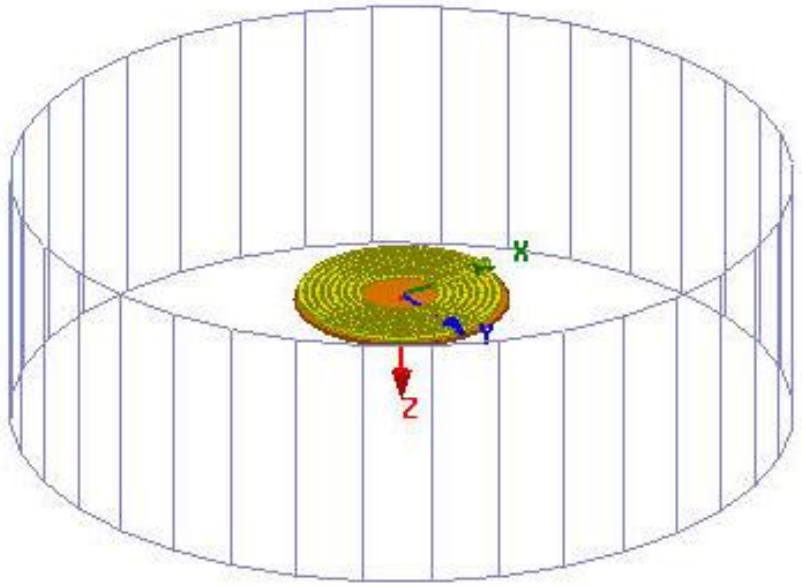
      

    - Using the coordinate entry fields, enter the radius

      dX: 150, dY: 0, dZ: 100, Press the *Enter* key

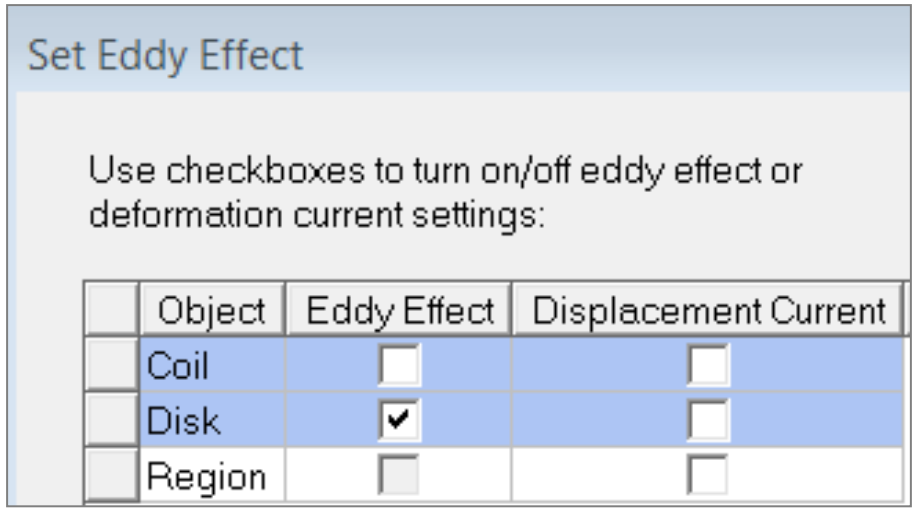
      

  - Number of Segments: 36
  - Change the name of the object to Region
  - Change Display Wireframe: ☑ Checked



Set Eddy Effect

- **Set Eddy Calculation for Disc**
  - **Select the menu item *Maxwell 3D → Excitations → Set Eddy Effects***
  - **In Set Eddy Effects window,**
    - **Coil**
    - **Eddy Effects: ☐ Unchecked**
    - **Disk**
    - **Eddy Effects: ☑ Checked**
    - **Displacement Current: ☐ Unchecked**
    - **Press OK**

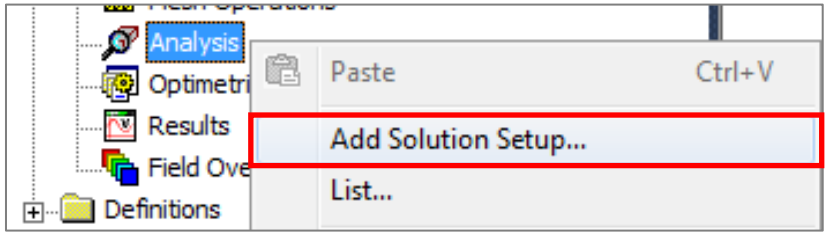


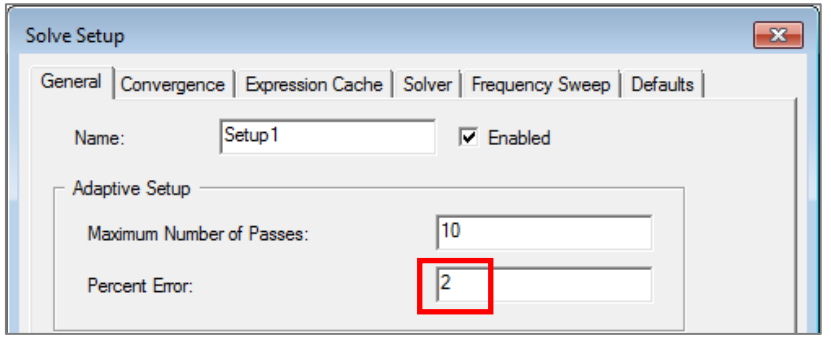
Note: Set Eddy Effects option enables users to turn on/off induced eddy current calculation in conducting objects. When a coil terminal is defined as Stranded in current definition, eddy effects are not calculated for the coil. But if coil terminal is defined as solid, users will have to turn off eddy effects manually if induced eddy current calculation in coil is not required

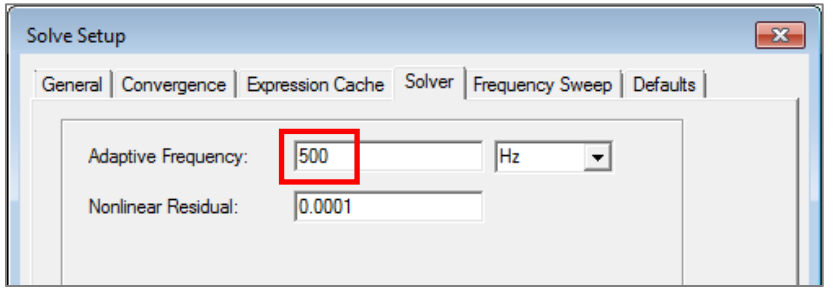
Analyze

- Create an analysis setup:
  - Select the menu item *Maxwell 3D → Analysis Setup → Add Solution Setup*
  - General Tab
    - Percent Error: 2
  - Convergence Tab
    - Refinement per pass: 20%
  - Solver Tab
    - Adaptive Frequency: 500 Hz
  - Press OK

- Start the solution process:
  - In the Project Manager window *RMB on Setup1 → Analyze*

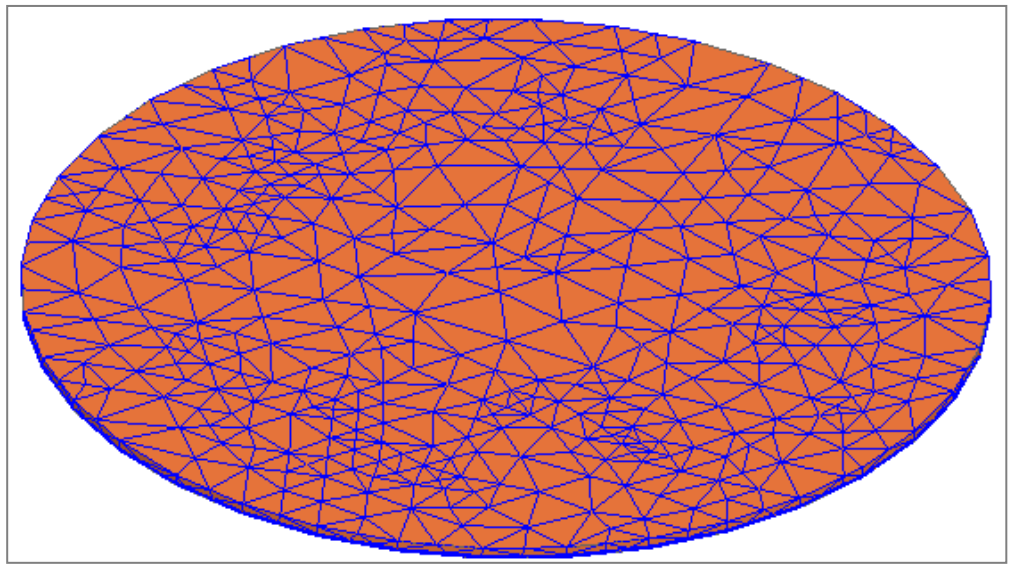




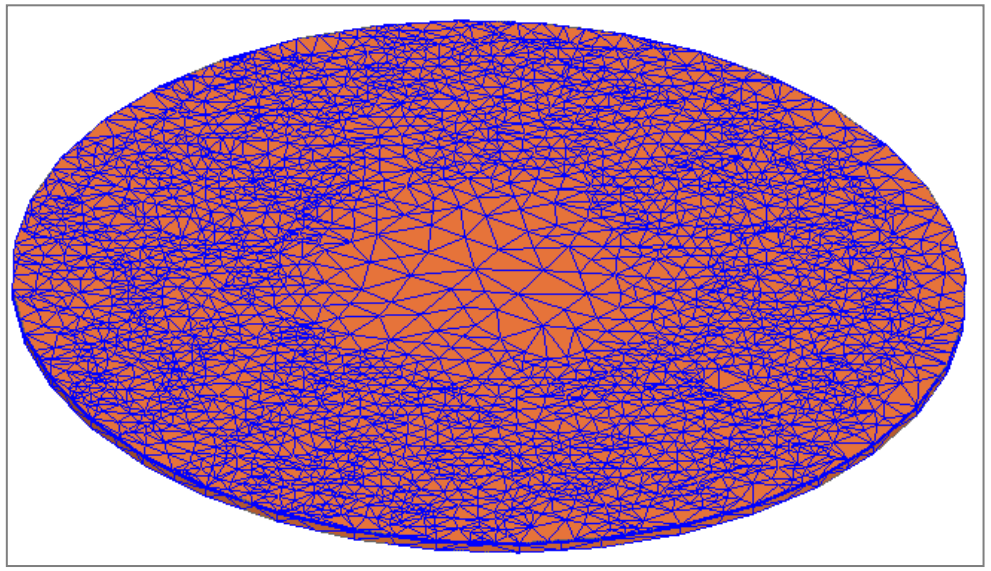


Plot Mesh

- Plot Mesh on Disk
  - Select the object Disk from the history tree
  - Select the menu item *Maxwell 3D → Fields → Plot Mesh*
  - In Create Mesh Plot window,
    - Press Done



Top View



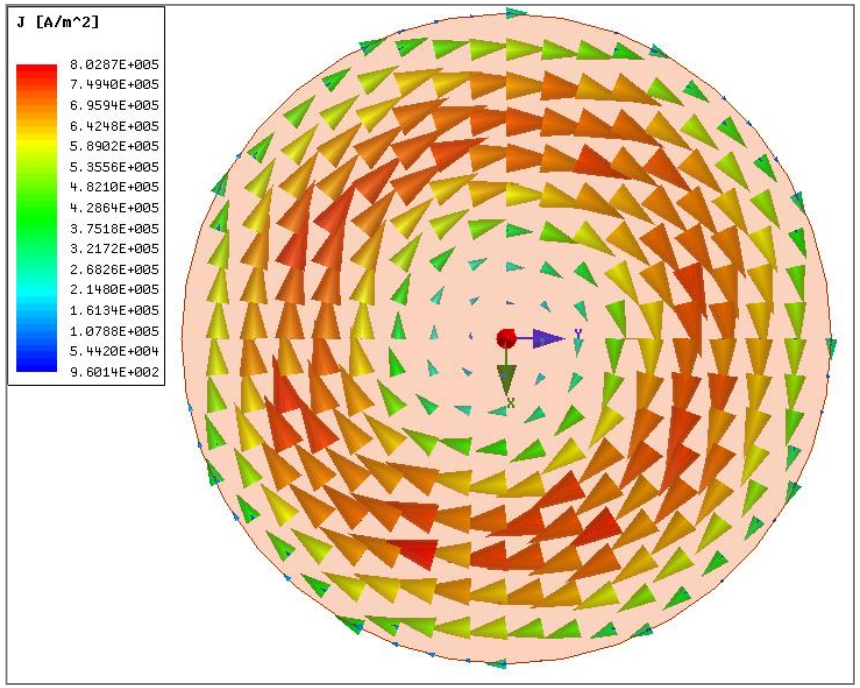
Bottom View: Notice the effect of the automatic adaptive meshing

Calculate Total Ohmic Loss

- Calculate Ohmic Losses in Disk
  - Select the menu item *Maxwell 3D → Fields → Calculator*
  - In Fields Calculator window,
    - Select Input > Quantity > OhmicLoss
    - Select Input > Geometry
    - Select Volume
    - Select Disk from the list
    - Press OK
    - Select Scalar >  Integrate
    - Select Output > Eval
  - The evaluated value of losses in the Disk should be around 270.48 W

Plot Current Density Vectors

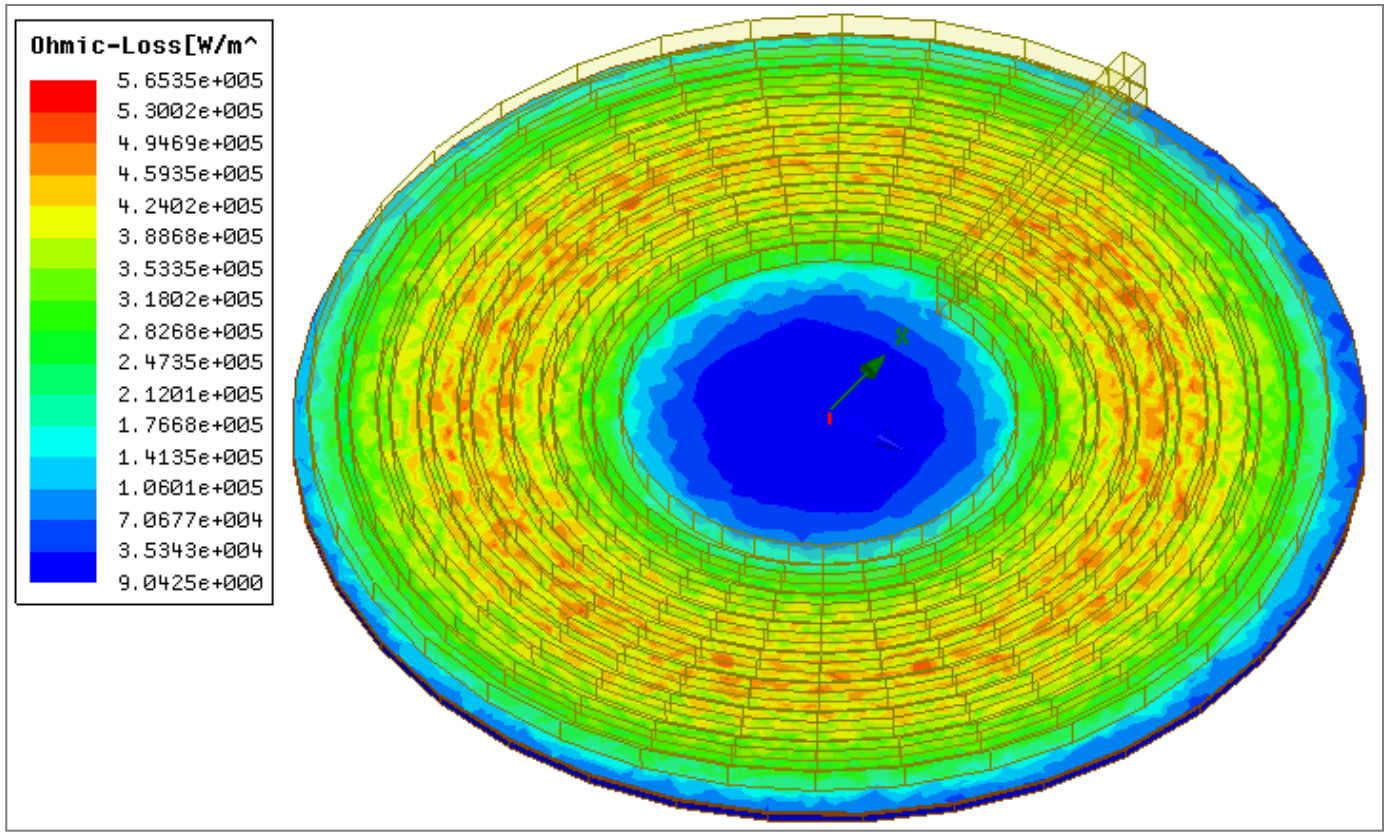
- Plot Current Density Vectors
  - Select the object Disk from the history tree
  - Select the menu item *Maxwell 3D → Fields → Fields → J → Vector_J*
  - In Create Field Plot window,
    - Plot on surface only: ☑ Checked
    - Press Done



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.

Plot Ohmic Loss Distribution

- Plot Ohmic Losses on Disk
  - Select the object Disk from the history tree
  - Select the menu item *Maxwell 3D → Fields → Fields → Other → Ohmic_Loss*
  - In Create Field Plot window,
    - Plot on surface only: ☑ Checked
    - Press Done



Saving the Project

- This completes the workshop
- Save the file with the name Workshop_2_3 in the working folder

End of Presentation