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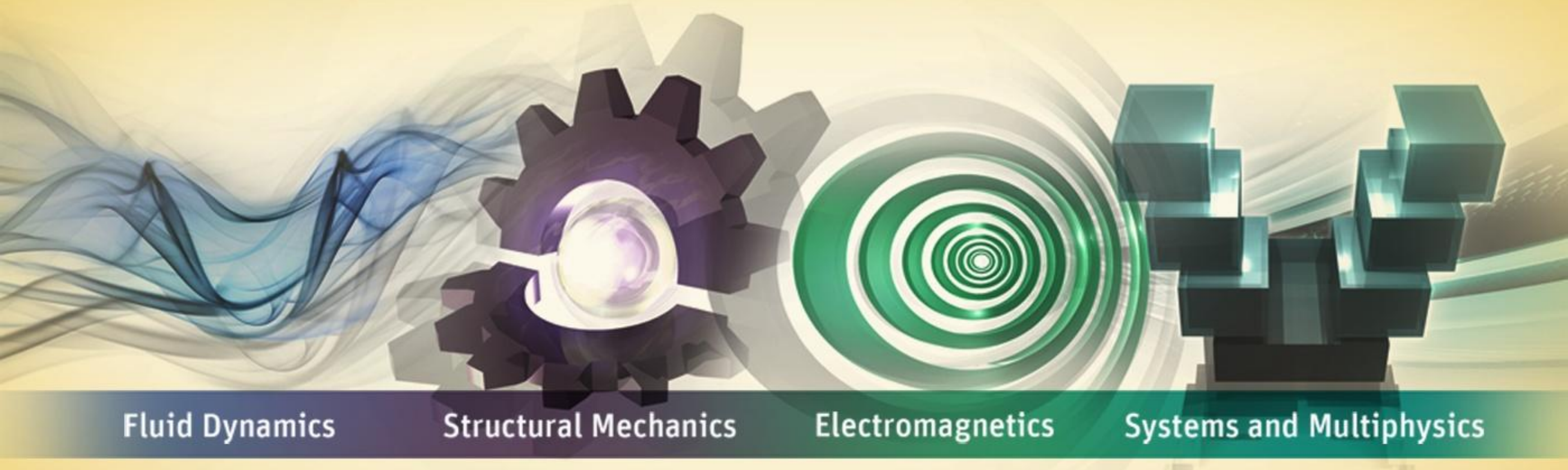
Workshop 4:
Basic DC Conduction Analysis



ANSYS Maxwell 2D 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 XY Plane

    - In this example, we want to determine the DC resistance between two plates with a non-uniform media made of graphite and sea water. The Problem is solved with 2D XY representation.

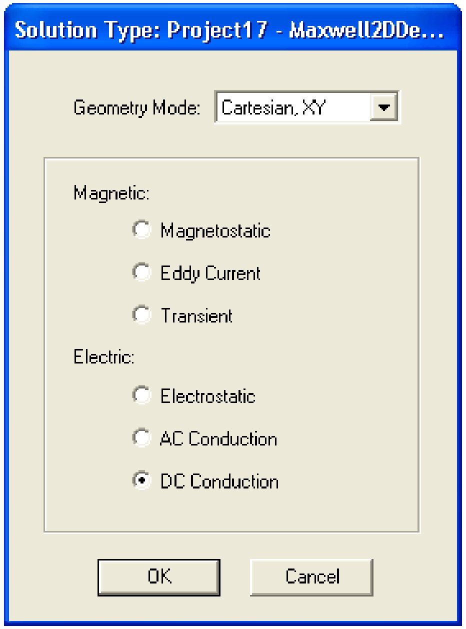
    Example 2: Parallel Plates with Non-uniform media in RZ Plane

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

Example 1 : Parallel Plates with Non-uniform media in XY Plane

Problem Setup

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

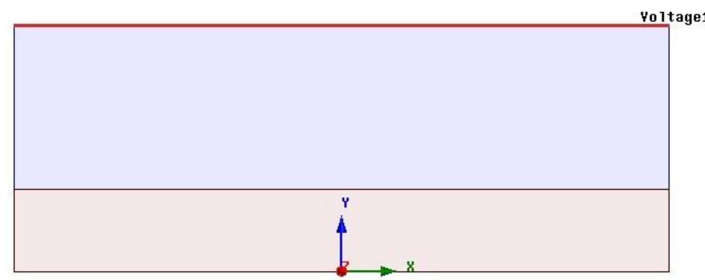


Create Geometry

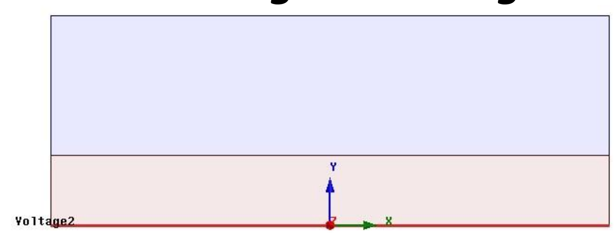
- **Create Solid**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the box position
       - **X: -2, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 4, dY: 0.5, dZ: 0**, Press the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

Assign Excitations

- **Assign Excitation for Top**
  - Select the menu item ***Edit → Select → Edges*** or press **E** from the keyboard
  - Select the top edge of the sheet Liquid
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **10 V**
    2. Press **OK**



- **Assign Excitation for Bottom**
  - Select the bottom edge of the sheet Solid
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **-10 V**
    2. Press **OK**



Note: We apply the voltage to the plates. We did not draw the plates, because we can apply a voltage to the top and bottom part of the regions.

Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 2D → 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 2D → Analyze All***

Compute the DC Resistance

Note: DC Resistance is not calculated automatically by Maxwell. But since we already know the voltages applied, Resistance can be calculated. We need the DC current that flows through the media. The current is obtained by taking the integral of Y component of J on a cross section of the region. To define any cross section, we will create a line at the middle of Liquid. The total current going through the media is the integral of the current J on the this line multiplied by depth of the model in Z direction

- **Create Line**
  - Select the menu item ***Draw → Line***
    - A massage will pop up asking if the geometry needs to be created as a non-model object, press **Yes**
    1. Using the coordinate entry fields, enter the first point
       - **X: -2, Y: 1, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the second point
       - **X: 2, Y: 1, Z: 0**, Press the **Enter** key
    3. Press **Enter** again to exit the drawing
  - Change the name of the line to **Sec_Line**

Compute the DC Resistance (*Contd…*)

- **Calculate Resistance**
  - Select the menu item ***Maxwell 2D → Fields → Calculator***
  - In Field Calculator window,
    1. Select **Input > Quantity > J**
    2. Select **Vector > Scal? > ScalarY**
    3. Select **Input > Geometry**
       - Select **Line > Sec_Line >** Press **OK**
    4. Select **Scalar > Integrate**
    5. Press **Eval**
  - The reported value is around **-320**. The total current appears, close to **1.28A**(-320*0.004) assuming dimensions of the plates in Z is 4mm.The value is very low; it makes sense 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

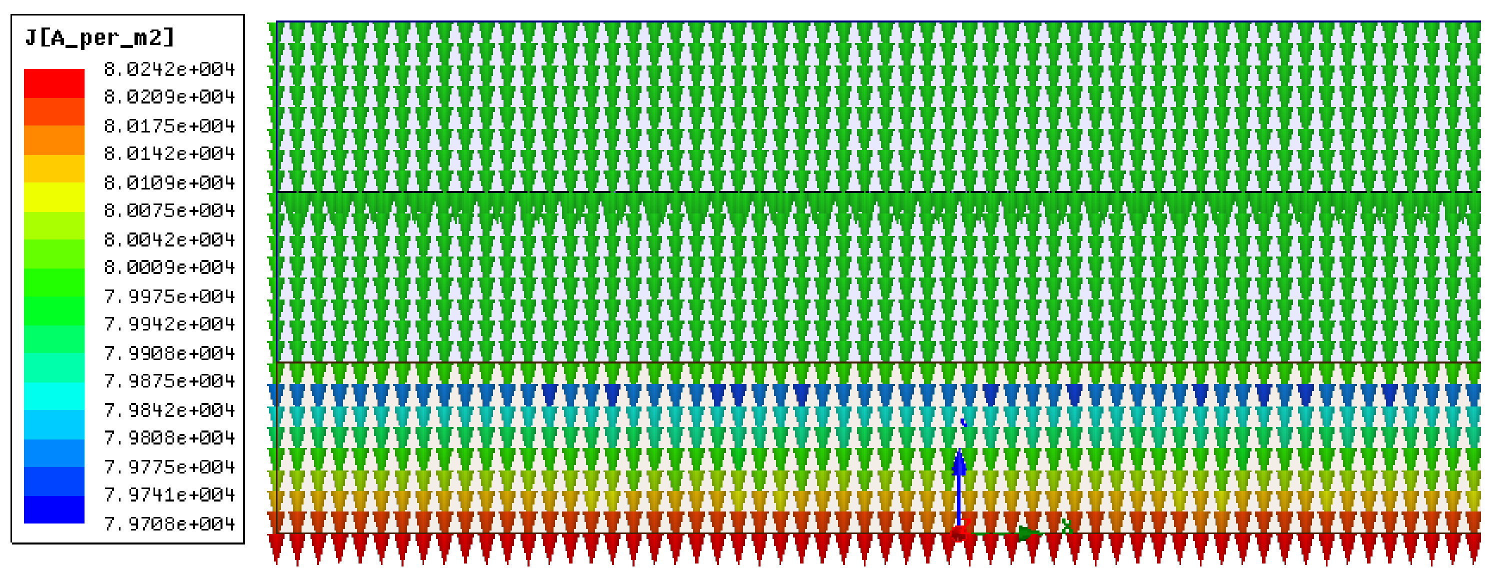
    $\mathbf{R = \sigma_2 h_1 + \sigma_1 h_2 / (\sigma_1 \sigma_2 A)}$

    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 =**16 e-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

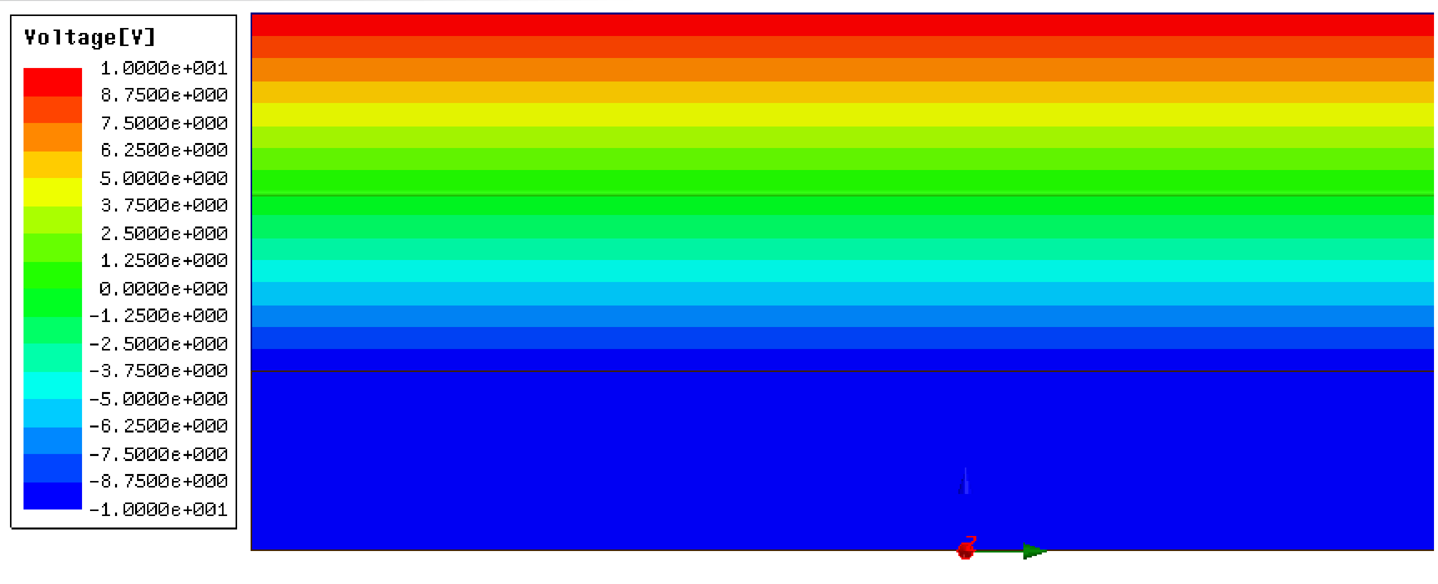
Field Plots

- **Plot Current Density Vectors**
  - 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 2D →Fields →Fields →J →J_Vector***
  - In Create Field Plot window,
    - Press **Done**
  - Modify attributes of the plot by double clicking on the legend



Field Plots (*Contd…*)

- **Plot Voltage**
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Maxwell 2D → Fields → Fields → Voltage***
  - In Create Field Plot window,
    - Press **Done**

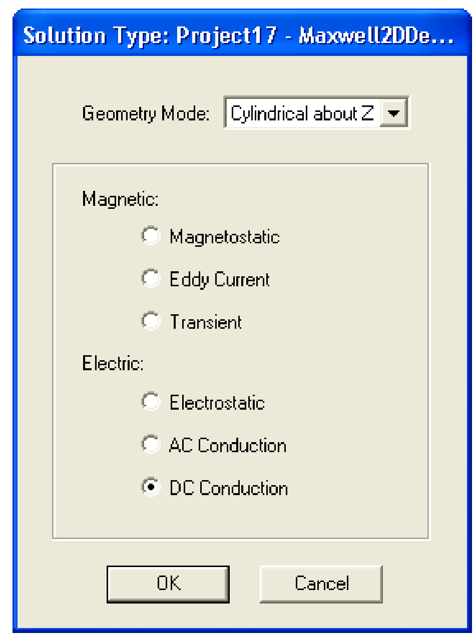


Note: Hide previous plots by selecting View → Active View Visibility → Fields Reporter and unchecking the previous plots.

Example 2: Parallel Plates with Non-uniform media in RZ Plane

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 2D Design***, or click on the icon
  - Change the name of the design to **Plates2**
- **Set Solution Type**
  - Select the menu item ***Maxwell 2D → Solution Type***
  - Solution Type Window:
    1. Geometry Mode: **Cylindrical about Z**
    2. Choose **DC Conduction**
    3. Click the **OK** button

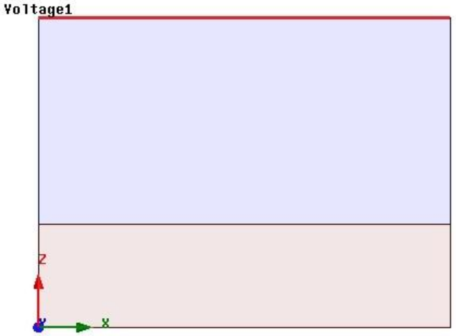


Create Geometry

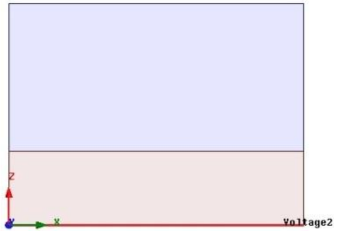
- **Create Solid**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the box position
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 2, dY: 0, dZ: 0.5**, Press the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

Assign Excitations

- **Assign Excitation for Top**
  - Select the menu item ***Edit → Select → Edges*** or press **E** from the keyboard
  - Select the top edge of the sheet Liquid
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **10 V**
    2. Press **OK**



- **Assign Excitation for Top**
  - Select the bottom edge of the sheet Solid
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Voltage***
  - In Voltage Excitation window,
    1. Set Value to **-10 V**
    2. Press **OK**



Note: We apply the voltage to the plates. We did not draw the plates, because we can apply a voltage to the top and bottom part of the regions.

Analyze

- **Create an analysis setup:**
  - Select the menu item ***Maxwell 2D → 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 2D → Analyze All***

Compute the DC Resistance

Note: We will user same approach as in Example1 to compute DC Resistance

- **Create Line**
  – Select the menu item ***Draw → Line***
    - A massage will pop up asking if the geometry needs to be created as a non-model object, press **Yes**

    1. Using the coordinate entry fields, enter the first point
       – **X: 0, Y: 0, Z: 1**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the second point
       – **X: 2, Y: 0, Z: 1**, Press the **Enter** key
    3. Press **Enter** again to exit the drawing

  – Change the name of the line to **Sec_Line**

Compute the DC Resistance (*Contd…*)

- **Calculate Resistance**
  - Select the menu item ***Maxwell 2D → Fields → Calculator***
  - The total current going through the media is the RZ integral of the current J on the line Sec_Line
  - In Field Calculator window
    1. Select **Input > Quantity > J**
    2. Select **Vector > Scal? > ScalarZ**
    3. Select **Input > Geometry**
       - Select **Line > Sec_Line >** Press **OK**
    4. Select **Scalar > Integral >RZ**
    5. Press **Eval**
  - The total current appears, close to **-1.005A.**
  - The DC resistance is given by R = Voltage / Current. The difference of potential between the two plate is 20 V. We obtain **R = 19.9 Ohm**

Note: In RZ case, Z component of J is considered unlike Y component in XY plane.

Compute the DC Resistance (*Contd…*)

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

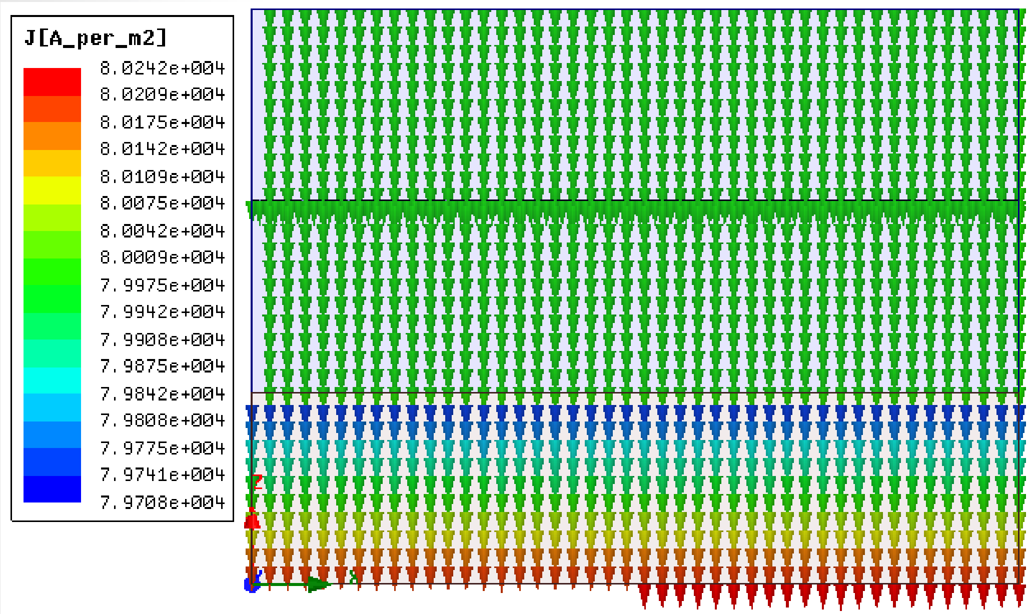
    $\mathbf{R = \sigma_2 h_1 + \sigma_1 h_2 / (\sigma_1 \sigma_2 A)}$

    where σ_1, σ_2 are the conductivity of the two medium, h_1,h_2 the thickness of the two medium R is radius of plates 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) ;**
    - R = **2e-3 m**
    - A = πR^2 =**12.566 e-6 m²**.
  - The value of resistance comes out to be:

    R = 19.9 Ohm
  - The values are similar to what we obtained using Maxwell

Field Plots

- **Plot Current Density Vectors**
  - 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 2D →Fields →Fields →J →J_Vector***
  - In Create Field Plot window,
    - Press **Done**
  - Modify attributes of the plot by double clicking on the legend



Field Plots (*Contd…*)

- **Plot Voltage**
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Maxwell 2D → Fields → Fields → Voltage***
  - In Create Field Plot window,
    - Press **Done**