Created in COMSOL Multiphysics 5.6

Electric Shielding Comparison

Introduction

The electric shielding boundary condition is meant to approximate a thin layer of highly conductive material that provides an additional current path tangential to a boundary. This example compares the electric shielding boundary condition to a full-fidelity model and discusses the range of applicability of this boundary condition.

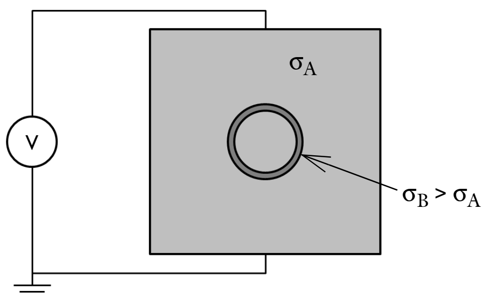


Figure 1: A square 2D domain of conductive material, with a circular inclusion. The wall of the inclusion are made of a material with higher conductivity.

Model Definition

The situation being modeled is shown in Figure 1. A 1 m square two-dimensional domain of conductive material has a DC voltage difference applied to it. Within the square domain, there is a circular inclusion of radius 0.25 m. The 0.01 m thick walls of this inclusion are modeled two ways, first using a full fidelity model that includes the thickness of the walls, and also using the electric shielding boundary condition. The inside of the inclusion has the same properties as the bulk.

The location of the electric shielding condition is at the centerline, midway between the inner and outer radii of the full fidelity model. Note that, when using the electric shielding condition, the total volume of the surrounding material is slightly larger, since the thickness of the wall is not being explicitly modeled. The conductivity of the wall of the inclusion is varied.

Results and Discussion

The voltage distribution and the electric field strength is plotted in Figure 2 for the case where the electric conductivity is one thousand times greater in the wall of the inclusion than in the bulk. This represents a thin walled object that allows significant current flow along its surface, that is, it shields whatever is inside the inclusion from the electric fields and current flow. The current can be observed to flow toward the inclusion, and then along the surface. The solutions for the full fidelity and electric shielding model agree well for the cases where the conductivity is greater than the surrounding medium.

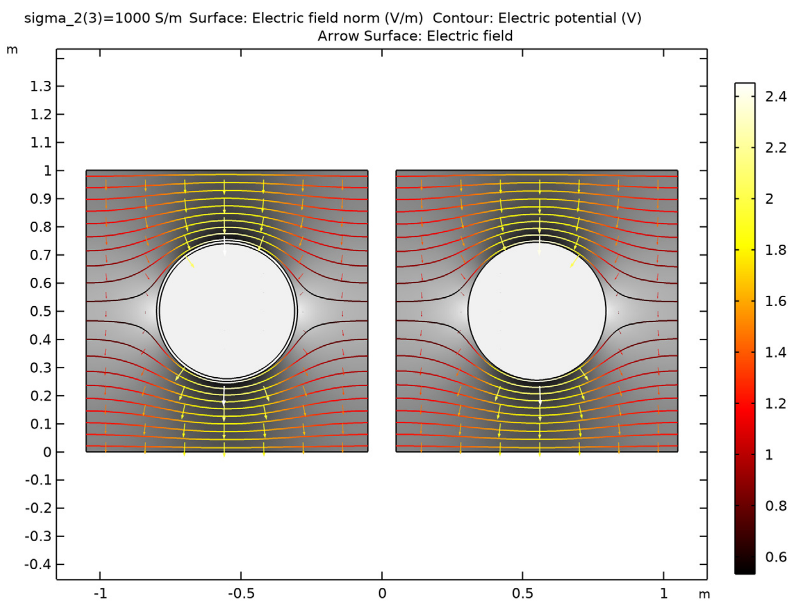


Figure 2: Isolines of the voltage field, arrow plot of the current flow, and a grayscale plot of the electric field for the case of a thin layer of material that has high conductivity. The full fidelity (left) and electric shielding (right) solutions are almost identical.

Figure 3 shows the case where the electric conductivity in the wall of the inclusion is only ten times greater than the surroundings. The electric shielding condition still agrees well with the full fidelity model.

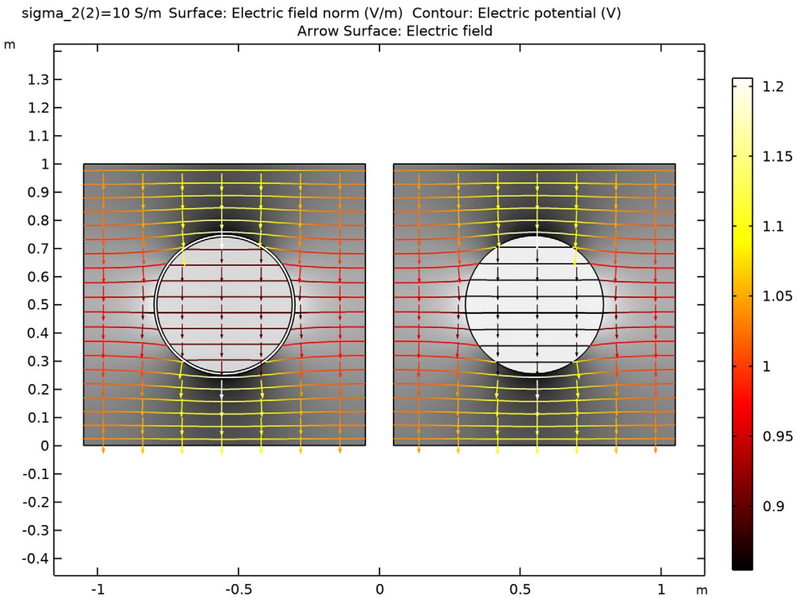


Figure 3: For the case of a thin layer of material that has conductivity ten times greater than the surrounding material.

Figure 4 shows the case where the electric conductivity in the wall of the inclusion is ten times less than the surroundings. The electric shielding condition no longer agrees with the full fidelity model. Although an additional conduction path has been added tangential to the boundary, the magnitude of this conduction path is less than in the surrounding material, thus it does not noticeably alter the current flow. The electric shielding boundary condition also does not impede the current flow normal to the boundary, which is the case, as can be seen in the full fidelity model. The Contact Impedance boundary condition would be more appropriate for this case.

The electric shielding boundary condition can be used in cases where the thickness of the boundary being approximated is much smaller than the characteristic size of the model domain, and when the conductivity of the layer is greater than the surrounding medium.

When this boundary condition can be used, the resulting mesh size is much smaller, saving solution time and memory.

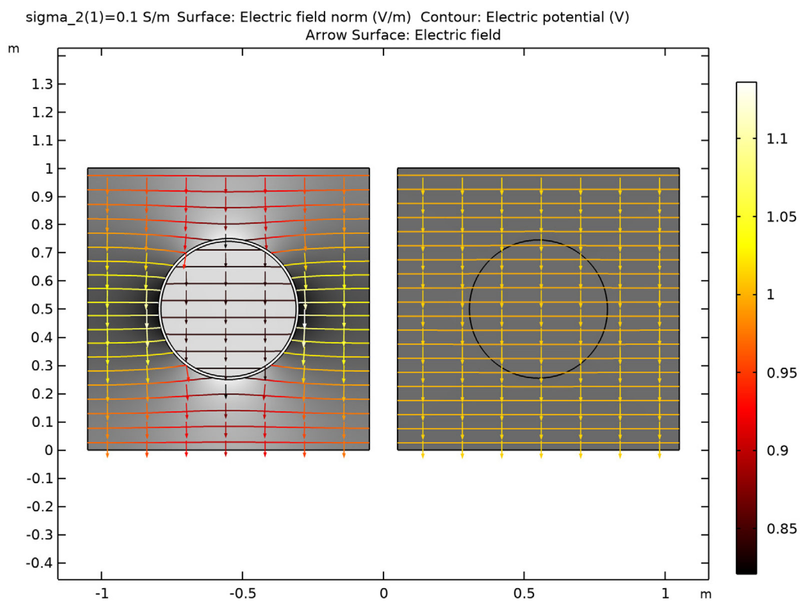


Figure 4: For the case of a thin layer of material that has conductivity ten times less than the surrounding material. The solutions do not agree for this case.

Application Library path: `ACDC_Module/Resistive_Devices/electric_shielding_comparison`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **2D**.

2 In the **Select Physics** tree, select **AC/DC>Electric Fields and Currents>Electric Currents (ec)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **General Studies>Stationary**.

6 Click **Done**.

GLOBAL DEFINITIONS

Parameters 1

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
sigma_1	1[S/m]	1 S/m	Conductivity, material 1
sigma_2	1[S/m]	1 S/m	Conductivity, material 2

GEOMETRY 1

Square 1 (sq1)

1 In the **Geometry** toolbar, click **Square**.

2 In the **Settings** window for **Square**, locate the **Position** section.

3 In the **x** text field, type `0.05`.

Square 2 (sq2)

1 In the **Geometry** toolbar, click **Square**.

2 In the **Settings** window for **Square**, locate the **Position** section.

3 In the **x** text field, type `-1.05`.

Circle 1 (c1)

1 In the **Geometry** toolbar, click **Circle**.

2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.

3 In the **Radius** text field, type `0.245`.

4 Locate the **Position** section. In the **x** text field, type `0.55`.

5 In the **y** text field, type `0.5`.

Circle 2 (c2)

1 In the **Geometry** toolbar, click **Circle**.

2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.

3 In the **Radius** text field, type `0.25`.

4 Locate the **Position** section. In the **x** text field, type `-0.55`.

5 In the **y** text field, type `0.5`.

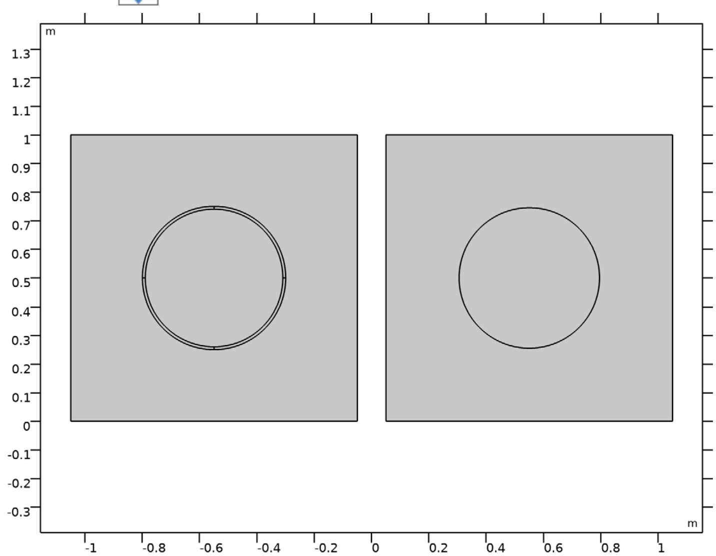
6 Click to expand the **Layers** section. In the table, enter the following settings:

Layer name	Thickness (m)
`Layer 1`	`0.01`

Form Union (fin)

1 In the **Geometry** toolbar, click **Build All**.

2 Click the **Zoom Extents** button in the **Graphics** toolbar.



The geometry on the left side describes the full fidelity model. The geometry on the right side replaces the thin layer with a boundary in order to use the **Electric Shielding** feature.

Create a set of selections for use before setting up the physics. First, create a selection for the wall of the inclusion.

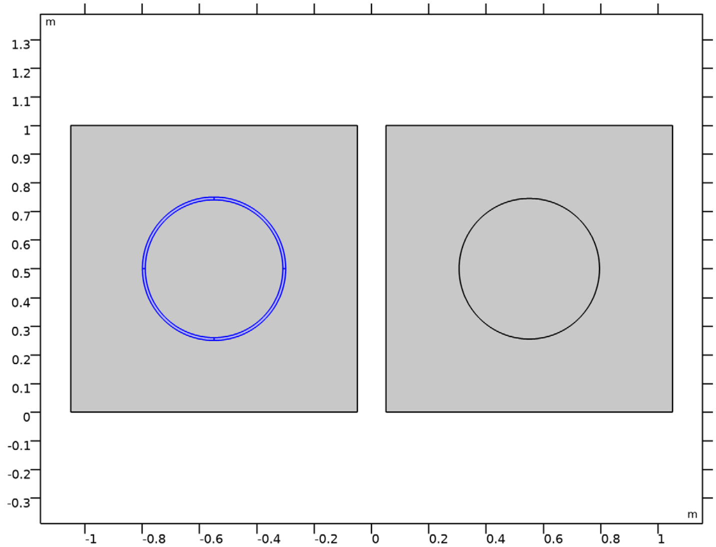
DEFINITIONS

Full fidelity

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domains 2–5 only.

3 In the **Settings** window for **Explicit**, type `Full fidelity` in the **Label** text field.



Next, add a selection for the electric shielding boundaries.

Electric shielding

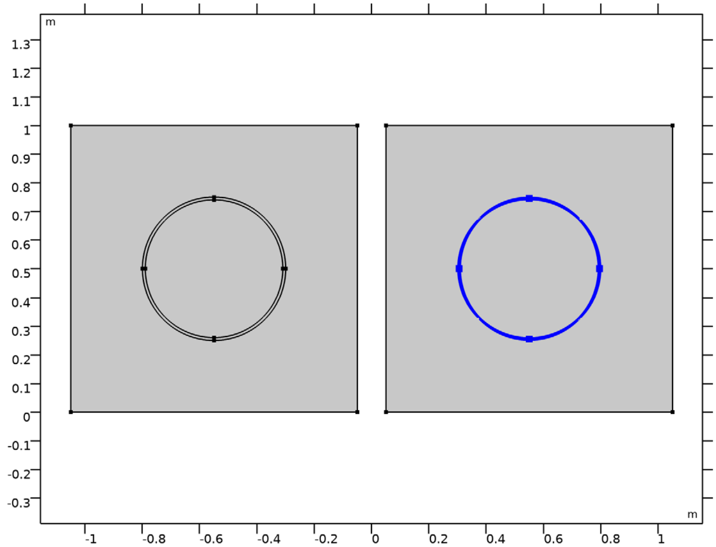
1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 Select Boundaries 21–24 only.

5 In the **Label** text field, type `Electric shielding`.



Bulk

1 In the **Definitions** toolbar, click **Complement**.

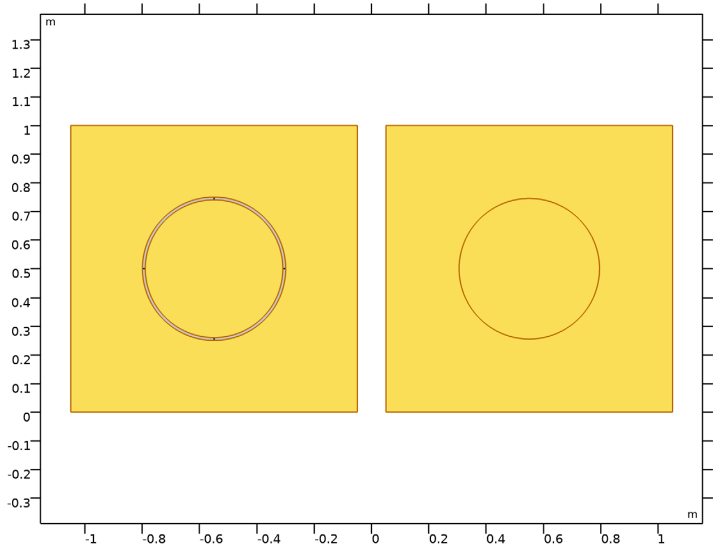
2 In the **Settings** window for **Complement**, locate the **Input Entities** section.

3 Under **Selections to invert**, click **Add**.

4 In the **Add** dialog box, select **Full fidelity** in the **Selections to invert** list.

5 Click **OK**.

6 In the **Settings** window for **Complement**, type `Bulk` in the **Label** text field.

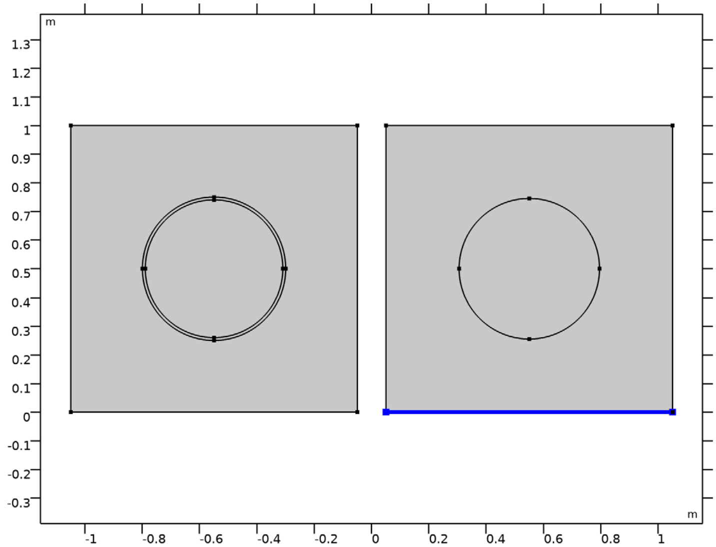


ELECTRIC CURRENTS (EC)

Ground 1

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Electric Currents (ec)** and choose **Ground**.

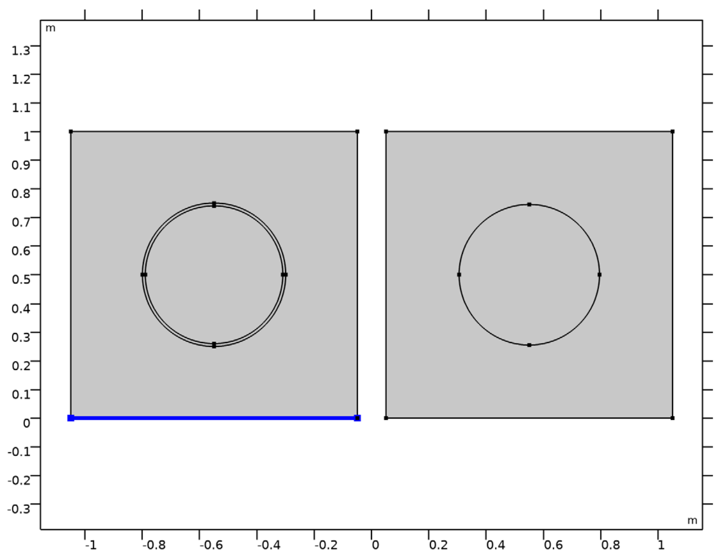
2 Select Boundary 10 only.



Ground 2

1 In the **Physics** toolbar, click **Boundaries** and choose **Ground**.

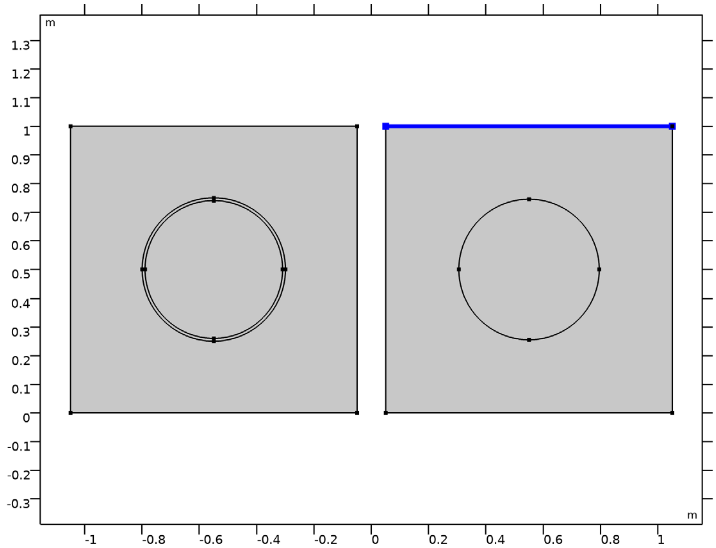
2 Select Boundary 2 only.



Terminal 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Terminal**.

2 Select Boundary 11 only.



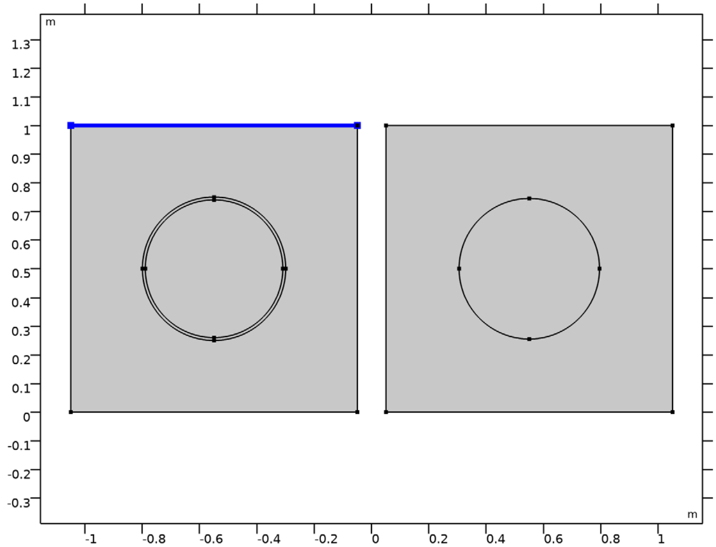
3 In the **Settings** window for **Terminal**, locate the **Terminal** section.

4 From the **Terminal type** list, choose **Voltage**.

Terminal 2

1 In the **Physics** toolbar, click **Boundaries** and choose **Terminal**.

2 Select Boundary 3 only.



3 In the **Settings** window for **Terminal**, locate the **Terminal** section.

4 From the **Terminal type** list, choose **Voltage**.

Electric Shielding 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Electric Shielding**.

2 In the **Settings** window for **Electric Shielding**, locate the **Boundary Selection** section.

3 From the **Selection** list, choose **Electric shielding**.

MATERIALS

Material 1 (mat1)

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Materials** and choose **Blank Material**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Bulk**.

4 Locate the **Material Contents** section. In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Electrical conductivity	sigma_iso ; sigmaii = sigma_iso, sigmaij = 0	`sigma_1`	S/m	Basic
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic

Material 2 (mat2)

1 Right-click **Materials** and choose **Blank Material**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Full fidelity**.

4 Locate the **Material Contents** section. In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Electrical conductivity	sigma_iso ; sigmaii = sigma_iso, sigmaij = 0	`sigma_2`	S/m	Basic
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic

Material 3 (mat3)

1 Right-click **Materials** and choose **Blank Material**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

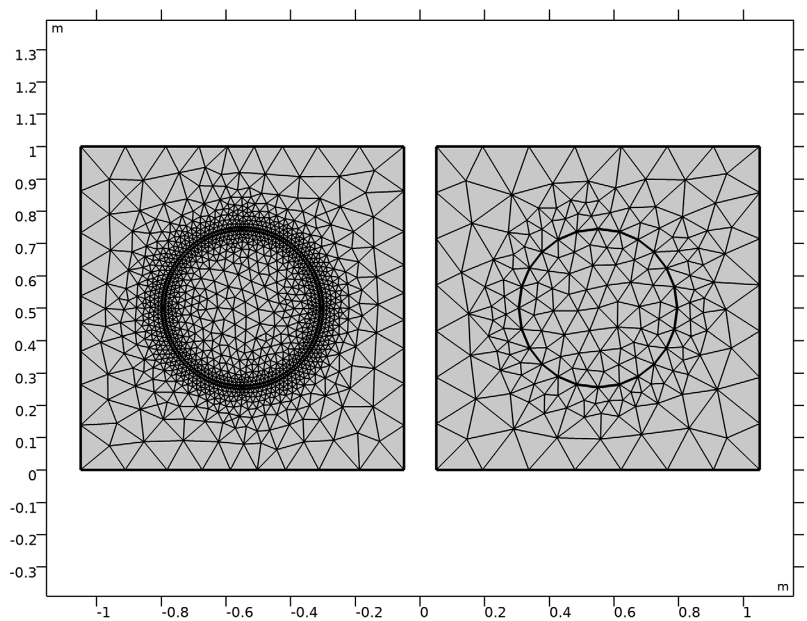
4 From the **Selection** list, choose **Electric shielding**.

5 Locate the **Material Contents** section. In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic
Electrical conductivity	sigma_iso ; sigmaii = sigma_iso, sigmaij = 0	`sigma_2`	S/m	Basic

MESH 1

In the **Model Builder** window, under **Component 1 (comp1)** right-click **Mesh 1** and choose **Build All**.



STUDY 1

Parametric Sweep

1 In the **Study** toolbar, click **Parametric Sweep**.

2 In the **Settings** window for **Parametric Sweep**, locate the **Study Settings** section.

3 Click **Add**.

4 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
sigma_2 (Conductivity, material 2)	1e-1 1e1 1e3	S/m

5 In the **Study** toolbar, click **Compute**.

RESULTS

Study 1/Solution 1 (sol1)

Begin the result analysis by excluding the interior of the wall from the selection. The walls interior is not of interest in this comparison.

1 In the **Model Builder** window, expand the **Results>Datasets** node, then click **Study 1/ Solution 1 (sol1)**.

Selection

1 In the **Results** toolbar, click **Attributes** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Domain**.

4 From the **Selection** list, choose **Bulk**.

The default plot shows the surface plot of the electric potential. Change the expression to show the norm of the electric field.

Surface 1

1 In the **Model Builder** window, expand the **Results>Electric Potential (ec)** node, then click **Surface 1**.

2 In the **Settings** window for **Surface**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)>Electric Currents> Electric>ec.normE - Electric field norm - V/m**.

3 Locate the **Coloring and Style** section. From the **Color table** list, choose **GrayPrint**.

4 Clear the **Color legend** check box.

5 Select the **Reverse color table** check box.

Electric Potential (ec)

Next, add a contour plot showing the electric potential.

Contour 1

In the **Model Builder** window, right-click **Electric Potential (ec)** and choose **Contour**.

Color Expression 1

1. In the **Model Builder** window, right-click **Contour 1** and choose **Color Expression**.
2. In the **Settings** window for **Color Expression**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)> Electric Currents>Currents and charge>ec.normJ - Current density norm - A/m²**.
3. Locate the **Coloring and Style** section. From the **Color table** list, choose **ThermalEquidistant**.

Electric Potential (ec)

Then, add an arrow plot of the electric field.

Arrow Surface 1

1. In the **Model Builder** window, right-click **Electric Potential (ec)** and choose **Arrow Surface**.
2. In the **Settings** window for **Arrow Surface**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)> Electric Currents>Electric>ec.Ex,ec.Ey - Electric field**.

Color Expression 1

1. Right-click **Arrow Surface 1** and choose **Color Expression**.
2. In the **Settings** window for **Color Expression**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)> Electric Currents>Currents and charge>ec.normJ - Current density norm - A/m²**.
3. Locate the **Coloring and Style** section. From the **Color table** list, choose **ThermalEquidistant**.
4. Clear the **Color legend** check box.
5. In the **Electric Potential (ec)** toolbar, click **Plot**.
6. Click the **Zoom Extents** button in the **Graphics** toolbar.

   Compare the resulting plot with Figure 2.

Electric Potential (ec)

1. In the **Model Builder** window, click **Electric Potential (ec)**.
2. In the **Settings** window for **2D Plot Group**, locate the **Data** section.
3. From the **Parameter value (sigma_2 (S/m))** list, choose **10**.

4 In the **Electric Potential (ec)** toolbar, click **Plot**.

This should look like Figure 3.

Finish by reproducing Figure 4.

5 From the **Parameter value (sigma_2 (S/m))** list, choose **0.1**.

6 In the **Electric Potential (ec)** toolbar, click **Plot**.