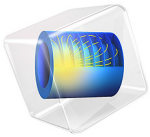


Light Bulb Geometry

Introduction

In COMSOL Multiphysics you can easily create complex two-dimensional shapes by drawing directly in the graphics window. After drawing an initial sketch, the geometry nodes corresponding to the individual components of the drawn curves can be edited to adjust the shape or to introduce parameters in the size expressions. You may also freely combine the shapes you have drawn by joining them with Boolean operations.

In this tutorial, you will create the cross section of a light bulb inside a 2D axisymmetric model component. You will first sketch the outline of the geometry and then modify the elements of the composite curves to obtain the desired shape. In addition, you will use named selections to create the selections for setting up the physics.

The step-by-step instructions demonstrate how to draw the geometry in Sketch mode, while following a workflow typical of creating geometry in COMSOL Multiphysics. Read on to find out more about the following topics:

- How to draw 2D shapes with the drawing tools, and how to edit the resulting geometry nodes
- How to partition an edge to create additional boundaries for the physics setup
- How to unite the created geometry objects to form the final geometry for the simulation
- How to set up selections that make the definition of physics settings more efficient

The multiphysics analysis of the light bulb is described in the *Free Convection in a Light Bulb* model located in the Heat Transfer Module Application Library.

Model Definition

The geometry you are going to create in this tutorial is the cross section of a light bulb, see Figure 1, used in the model *Free Convection in a Light Bulb* in the Heat Transfer Module Application Library. The outer silhouette and inner structure are created using

two composite curves. In the geometry sequence you will also set up the selections for assigning the material and physics definitions.

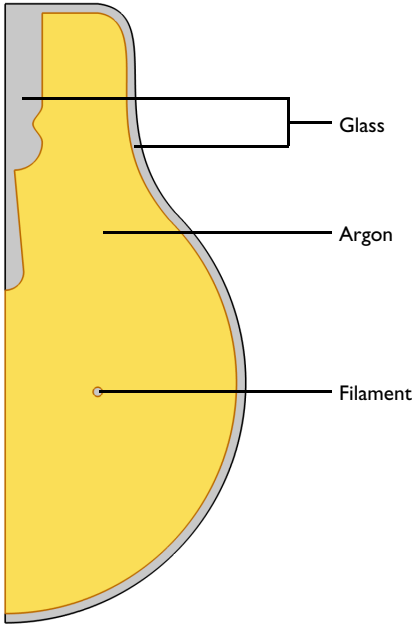


Figure 1: Cross section of a light bulb.

This example describes only the process of creating the geometry sequence. For the physics setup, follow the instructions in *Free Convection in a Light Bulb* in the Heat Transfer Module Application Library.

Application Library path: `COMSOL_Multiphysics/Geometry_Tutorials/light_bulb_geometry`

Modeling Instructions

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

NEW

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

ADD COMPONENT

In the **Home** toolbar, click **Add Component** and choose **2D Axisymmetric**.

GEOMETRY 1

1 In the **Settings** window for **Geometry**, locate the **Units** section.

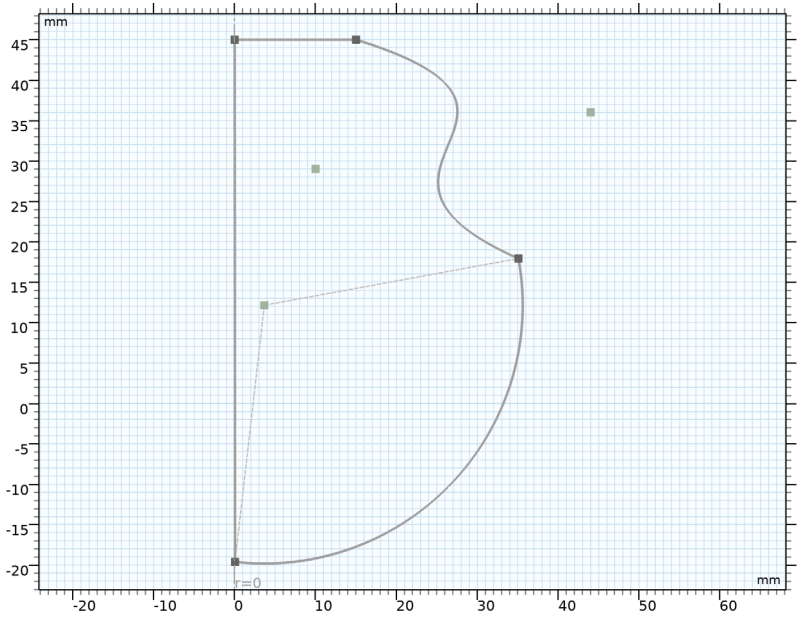
2 From the **Length unit** list, choose **mm**.

Begin by drawing a rough outline of the bulb. Don't worry about getting it exactly right as you will adjust it later.

The dimensions of the light bulb are larger than the default zoom level in the Graphics window. Adjusting the shape is easier if the original sketch is drawn closer to the final size, so you can start by zooming out a few steps.

Composite Curve 1 (cc1)

Draw a shape similar to the figure below, starting from the top left corner and continuing clockwise.



1 In the **Geometry** toolbar, click **Polygon**, then in the **Graphics** window place the first vertex by clicking on the centerline close to the top of the canvas.

2 Move the pointer to the right, and at the end of the first horizontal segment click once to place a vertex.

3 To switch drawing a Cubic Bézier polygon, right-click and from the context menu choose **Cubic**.

4 Place the two control points of the Bézier curve, followed by the vertex at the end by clicking once on the canvas for each point.

5 To switch drawing a circular arc, right-click in the **Graphics** window, and from the context menu choose **Circular Arc**, then choose **Start, Center, Angle**.

6 Place the center of the arc on the centerline, then move the pointer to draw the arc, and click to place the end vertex so that the arc finishes at the centerline.

7 Right-click, then from the context menu choose **Polygon**.

8 To close the shape, position the pointer on top of the first vertex, then click to place the last vertex. The shape will be closed automatically.

When done, the **Composite Curve 1** node is added to the geometry sequence. This node contains the polygon, cubic Bézier, and circular arc features that you have drawn. Note that the two adjacent straight segments are automatically combined into one feature.

Composite Curve 1 (cc1)

Next adjust the features inside **Composite Curve 1** to obtain the outer shape of the light bulb.

Polygon 1 (pol1)

1 In the **Model Builder** window, expand the **Component 1 (comp1)>Geometry 1> Composite Curve 1 (cc1)** node, then click **Polygon 1 (pol1)**.

2 In the **Settings** window for **Polygon**, locate the **Coordinates** section.

3 In the table, enter the following settings:

r (mm)	z (mm)
0	-25
0	42
10	42

When editing the coordinates of the features in a **Composite Curve**, the adjacent features are automatically updated to keep the start and end points of adjacent edges are coincident.

Cubic Bézier 1 (cb1)

1 In the **Model Builder** window, click **Cubic Bézier 1 (cb1)**.

2 In the **Settings** window for **Cubic Bézier**, locate the **Control Points** section.

3 In row **2**, set ***r*** to 18.

4 In row **2**, set **z** to `41`.

5 In row **4**, set **r** to `13*sqrt(2)`.

6 In row **4**, set **z** to `13*sqrt(2)+1`.

Circular Arc 1 (ca1)

1 In the **Model Builder** window, click **Circular Arc 1 (ca1)**.

2 In the **Settings** window for **Circular Arc**, locate the **Center** section.

3 In the **r** text field, type `0`.

4 In the **z** text field, type `1`.

5 Locate the **Radius** section. In the **Radius** text field, type `26`.

6 Locate the **Angles** section. In the **Start angle** text field, type `45`.

7 In the **End angle** text field, type `-90`.

8 Click **Build All Objects**.

Composite Curve 1 (cc1)

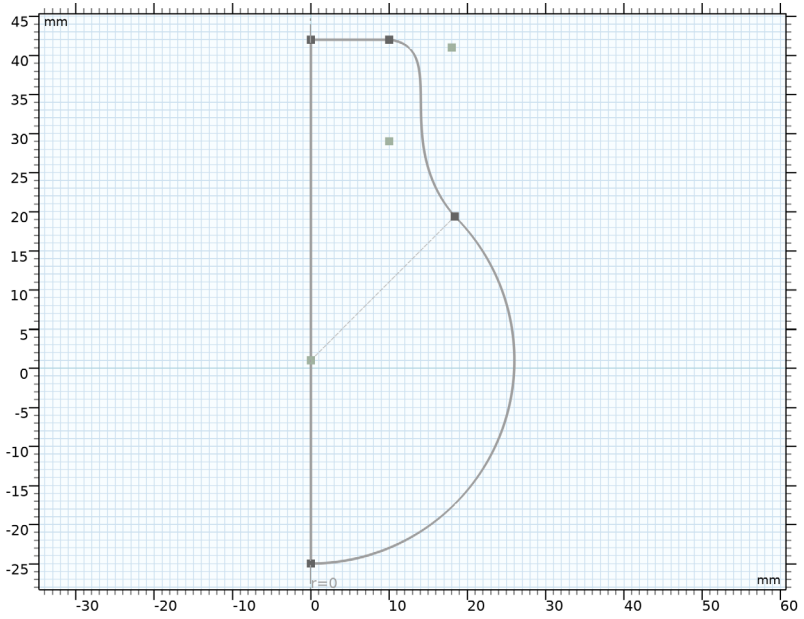
1 In the **Model Builder** window, click **Composite Curve 1 (cc1)**.

2 In the **Settings** window for **Composite Curve**, locate the **Selections of Resulting Entities** section.

3 Select the **Resulting objects selection** check box.

4 From the **Show in physics** list, choose **Off**. With this setting the selection is available only as input for features in the geometry sequence. This way you can keep only the relevant

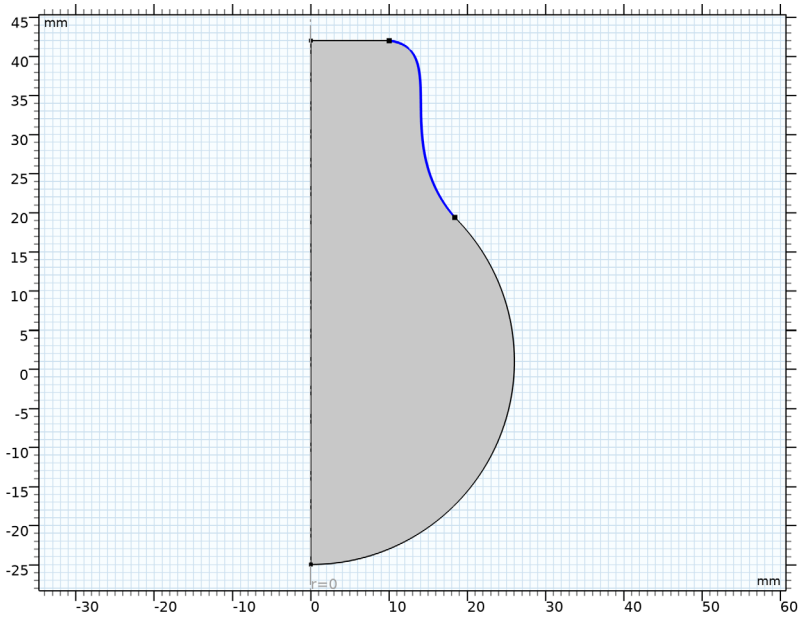
selections in the list of selections when you are defining, for example, physics and mesh features.



Partition Edges 1 (pare1)

1 In the **Geometry** toolbar, click **Booleans and Partitions** and choose **Partition Edges**.

2 On the object **cc1**, select Boundary 3 only.

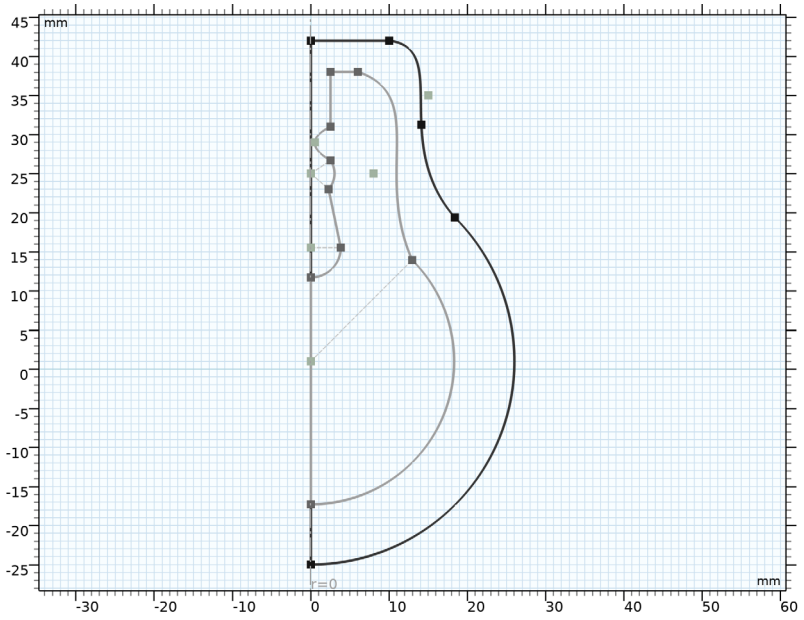


The partitioning operations can be useful in many cases. Here, we are partitioning the selected edge to create segments that reflect that a portion of the upper boundaries of the bulb are covered by a cap.

3 In the **Settings** window for **Partition Edges**, click **Build Selected**.

Composite Curve 2 (cc2)

Continue with creating the interior boundaries. Draw a rough outline by starting again from the top left corner, then continuing clockwise.



Use the drawing tools in the following order:

1. Start with a **Polygon** to draw an edge perpendicular to the rotation axis. Its first vertex is located inwards from the start vertex of the outer shape.
2. Continue with a **Cubic** Bézier polygon. Try to follow the outer shape.
3. Add a **Circular Arc** that ends on the centerline.
4. Draw a **Polygon** up along the centerline to about halfway up the geometry.
5. Continue with a **Circular Arc** that curves away from the centerline.
6. Use the **Polygon** tool to draw an edge that tilts towards the centerline.
7. Draw another **Circular Arc** that curves away from then back towards the centerline. The start and end vertices can be aligned vertically.
8. Switch to an **Interpolation Curve** to create a curved segment that first curves towards the centerline then away. Use the **Interpolation Points** option to define the curve, and add one interpolation point. Try to align the start and end vertices vertically.
9. Close the shape with a vertical edge, using the **Polygon** tool.

Composite Curve 2 (cc2)

Continue with editing the features inside **Composite Curve 2**.

Polygon 1 (pol1)

1. In the **Model Builder** window, expand the **Component 1 (comp1)>Geometry 1> Composite Curve 2 (cc2)** node, then click **Polygon 1 (pol1)**.
2. In the **Settings** window for **Polygon**, locate the **Coordinates** section.
3. In the table, enter the following settings:

r (mm)	z (mm)
4	31
4	41
10	41

Cubic Bézier 1 (cb1)

1. In the **Model Builder** window, click **Cubic Bézier 1 (cb1)**.
2. In the **Settings** window for **Cubic Bézier**, locate the **Control Points** section.
3. In row **2**, set **r** to `18`.
4. In row **2**, set **z** to `40`.
5. In row **3**, set **r** to `9`.
6. In row **3**, set **z** to `29`.
7. In row **4**, set **r** to `12.5*sqrt(2)`.
8. In row **4**, set **z** to `12.5*sqrt(2)+1`.
9. Locate the **Weights** section. In the **2** text field, type `3/4`.

Polygon 2 (pol2)

1. In the **Model Builder** window, click **Polygon 2 (pol2)**.
2. In the **Settings** window for **Polygon**, locate the **Coordinates** section.
3. In the table, enter the following settings:

r (mm)	z (mm)
0	11

Circular Arc 2 (ca2)

1. In the **Model Builder** window, click **Circular Arc 2 (ca2)**.
2. In the **Settings** window for **Circular Arc**, locate the **Center** section.
3. In the **z** text field, type `13`.

4 Locate the **Radius** section. In the **Radius** text field, type 2.

Polygon 3 (pol3)

1 In the **Model Builder** window, click **Polygon 3 (pol3)**.

2 In the **Settings** window for **Polygon**, locate the **Coordinates** section.

3 In the table, enter the following settings:

r (mm)	z (mm)
1	24

Circular Arc 3 (ca3)

1 In the **Model Builder** window, click **Circular Arc 3 (ca3)**.

2 In the **Settings** window for **Circular Arc**, locate the **Center** section.

3 In the **r** text field, type 1.

4 In the **z** text field, type 27.

5 Locate the **Radius** section. In the **Radius** text field, type 3.

6 Locate the **Angles** section. In the **Start angle** text field, type -90.

7 In the **End angle** text field, type 0.

Interpolation Curve 1 (ic1)

1 In the **Model Builder** window, click **Interpolation Curve 1 (ic1)**.

2 In the **Settings** window for **Interpolation Curve**, locate the **Interpolation Points** section.

3 In the table, enter the following settings:

r (mm)	z (mm)
3	29
4	31

4 Locate the **End Conditions** section. From the **Condition at starting point** list, choose **Tangent direction**.

5 In the **r** text field, type 0.

6 In the **z** text field, type 1.

7 From the **Condition at endpoint** list, choose **Tangent direction**.

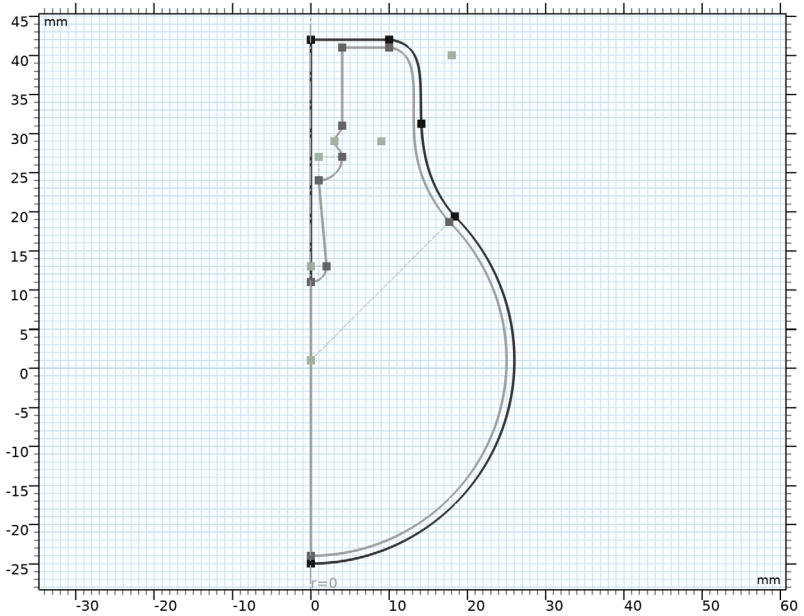
8 In the **r** text field, type 0.

9 In the **z** text field, type 1.

Composite Curve 2 (cc2)

1 In the **Model Builder** window, click **Composite Curve 2 (cc2)**.

2 In the **Settings** window for **Composite Curve**, click **Build Selected**.



3 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** check box.

4 From the **Show in physics** list, choose **Off**.

Tungsten

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

2 In the **Settings** window for **Circle**, type `Tungsten` in the **Label** text field.

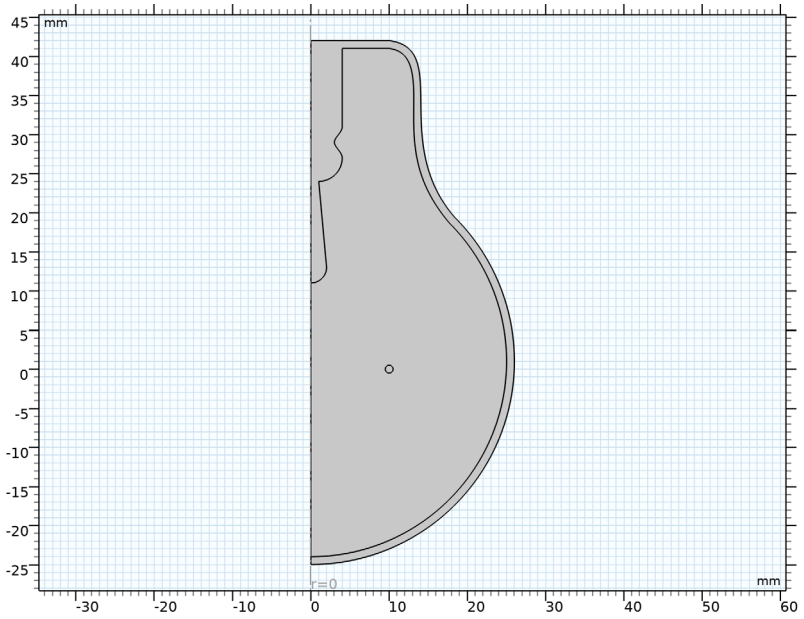
3 Locate the **Size and Shape** section. In the **Radius** text field, type `0.5`.

4 Locate the **Position** section. In the **r** text field, type `10`.

5 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** check box.

6 From the **Show in physics** list, choose **All levels**.

7 Click **Build Selected**.



The geometry is finished, but before continuing let's leave Sketch mode, and inspect the geometry using the **Selection List** window.

8 In the **Geometry** toolbar, click **Sketch**.

9 In the **Home** toolbar, click **Windows** and choose **Selection List**.

SELECTION LIST

1 Go to the **Selection List** window.

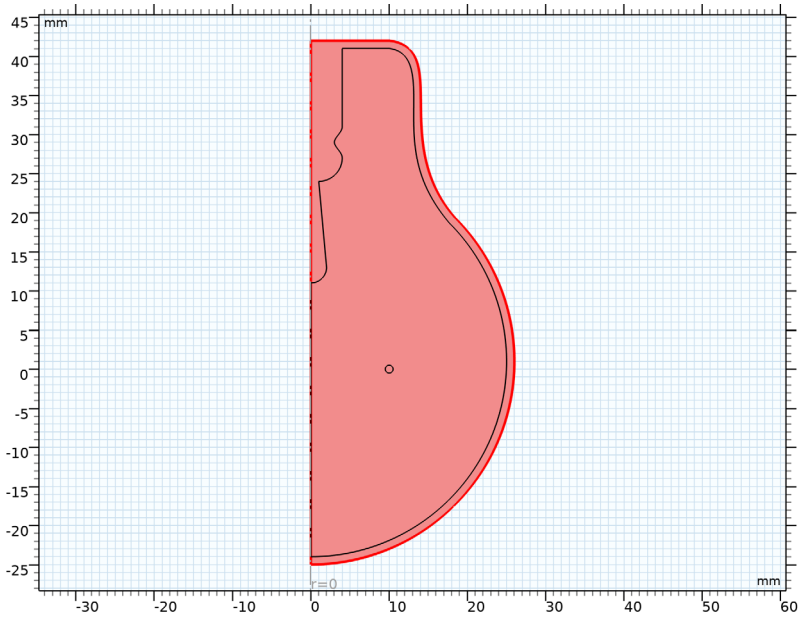
Here you can view a list of geometric objects and entities, and named selections, that exist in the geometry at the current build state for the selected entity level. The list on the top contains objects and entities, and the one at the bottom displays the named selections.

Let's take a look at the three objects that comprise the geometry.

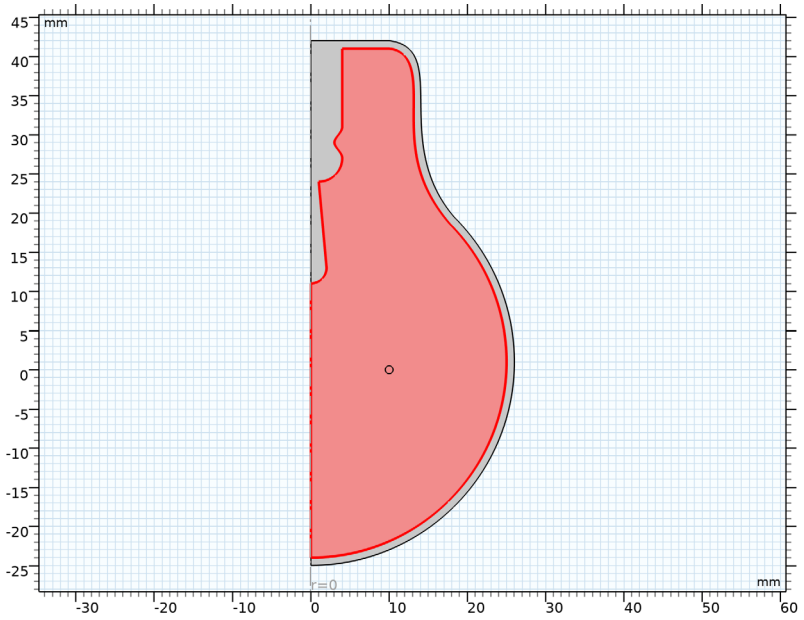
2 In the **Graphics** window toolbar, click next to **Select Objects**, then choose **Select Objects**.

3 Go to the **Selection List** window.

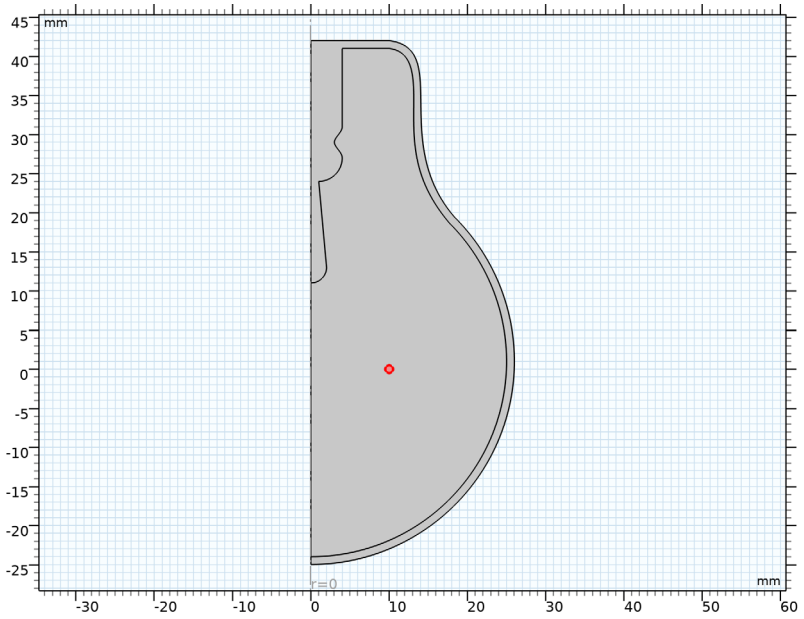
4 In the tree, select **Composite Curve 1**.



5 In the tree, select **Composite Curve 2**.



6 In the tree, select **Tungsten**.



The domains for the glass, and the Argon gas, and the Tungsten filament result after geometric Boolean operations of these three objects. Namely, the domain for the glass is the difference of the Composite Curve 1 and Composite Curve 2 objects, and the domain for the Argon gas is the difference of the Composite Curve 2 and Tungsten objects.

Fortunately, COMSOL Multiphysics automatically computes these domains in the Form Union operation, which is at the end of the geometry sequence, and creates the union of all geometry objects that exist in the sequence while preserving interior boundaries to separate domains.

GEOMETRY 1

Form Union (fin)

1 In the **Model Builder** window, under **Component 1 (comp1)>Geometry 1** click **Form Union (fin)**.

2 In the **Settings** window for **Form Union/Assembly**, click **Build Selected**.

After **Form Union**, only one object is displayed in the upper list of the **Selection List** window. This finalized geometry is divided into domains along the boundaries of the initial objects.

3 In the **Graphics** window toolbar, click ▾ next to **Select Objects**, then choose **Select Domains**.

SELECTION LIST

1 Go to the **Selection List** window.

2 Check the domains corresponding to the glass, Argon gas, and Tungsten filament by clicking the entries in the Domains list.

In the following sections we will set up named selections that you can use when defining the physics settings

GEOMETRY 1

Glass

1 In the **Geometry** toolbar, click **Selections** and choose **Difference Selection**.

2 In the **Settings** window for **Difference Selection**, type `Glass` in the **Label** text field.

3 Locate the **Input Entities** section. Click **Add** right below the **Selections to add** list.

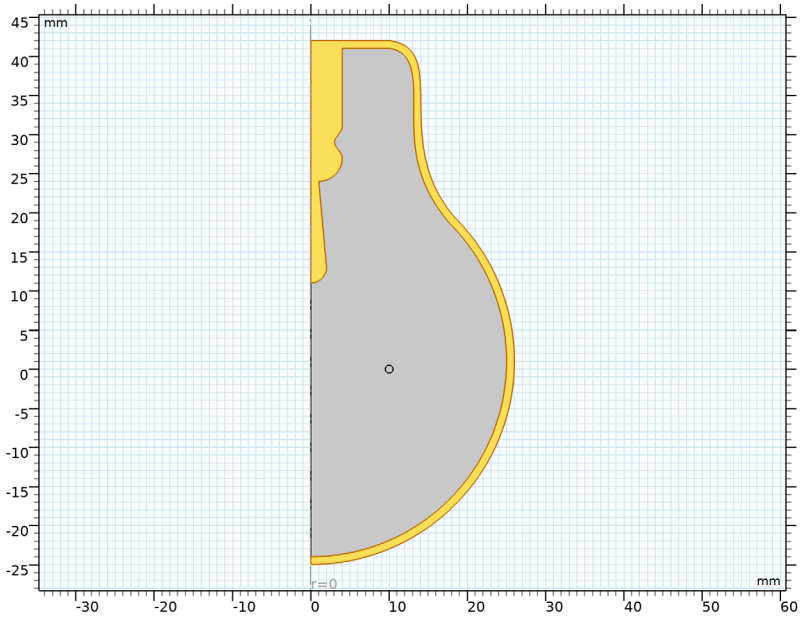
4 In the **Add** dialog box, select **Composite Curve 1** in the **Selections to add** list.

5 Click **OK**.

6 Locate the **Input Entities** section. Click **Add** right below the **Selections to subtract** list.

7 In the **Add** dialog box, select **Composite Curve 2** in the **Selections to subtract** list.

8 Click **OK**.



Now that you have a selection for the glass domain, use an **Adjacent Selection** feature to obtain its boundaries.

Glass Boundaries

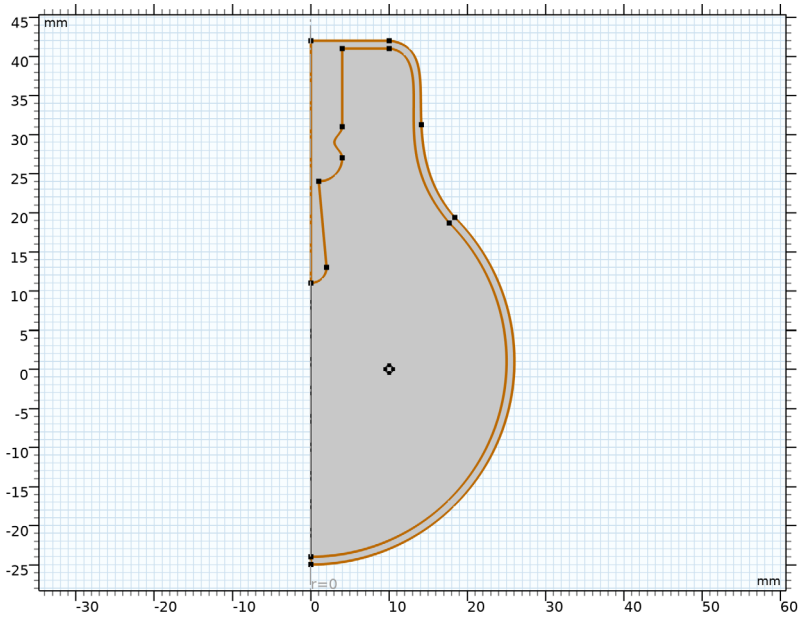
1 In the **Geometry** toolbar, click **Selections** and choose **Adjacent Selection**.

2 In the **Settings** window for **Adjacent Selection**, type `Glass Boundaries` in the **Label** text field.

3 Locate the **Input Entities** section. Click **Add**.

4 In the **Add** dialog box, select **Glass** in the **Input selections** list.

5 Click **OK**.



Argon

1 In the **Geometry** toolbar, click **Selections** and choose **Difference Selection**.

2 In the **Settings** window for **Difference Selection**, type `Argon` in the **Label** text field.

3 Locate the **Input Entities** section. Click **Add** right below the **Selections to add** list.

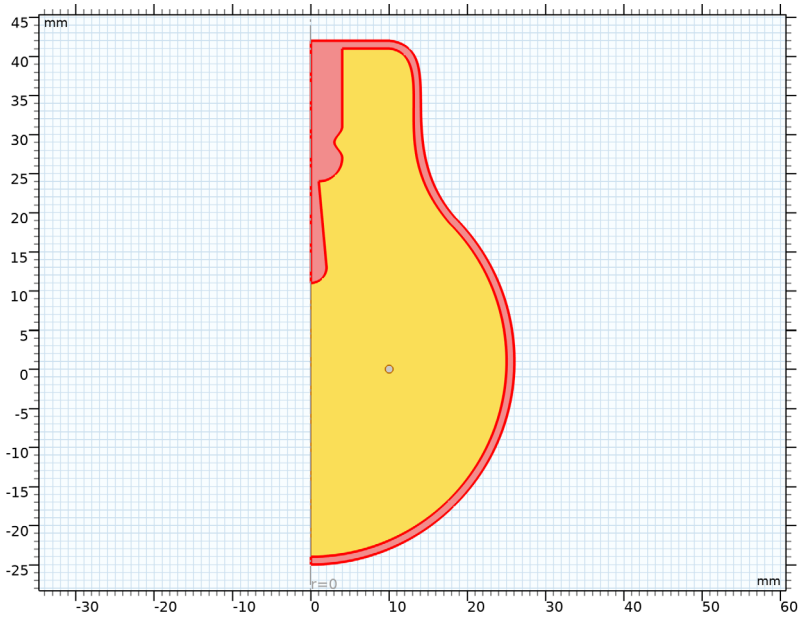
4 In the **Add** dialog box, select **Composite Curve 2** in the **Selections to add** list.

5 Click **OK**.

6 Locate the **Input Entities** section. Click **Add** right below the **Selections to subtract** list.

7 In the **Add** dialog box, select **Tungsten** in the **Selections to subtract** list.

8 Click **OK**.



Interior Radiation

1 In the **Geometry** toolbar, click **Selections** and choose **Difference Selection**.

Combine the previously defined **Resulting objects selections** to get the boundaries for the interior radiation.

2 In the **Settings** window for **Difference Selection**, type `Interior Radiation` in the **Label** text field.

3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.

4 Locate the **Input Entities** section. Click **Add** right below the **Selections to add** list.

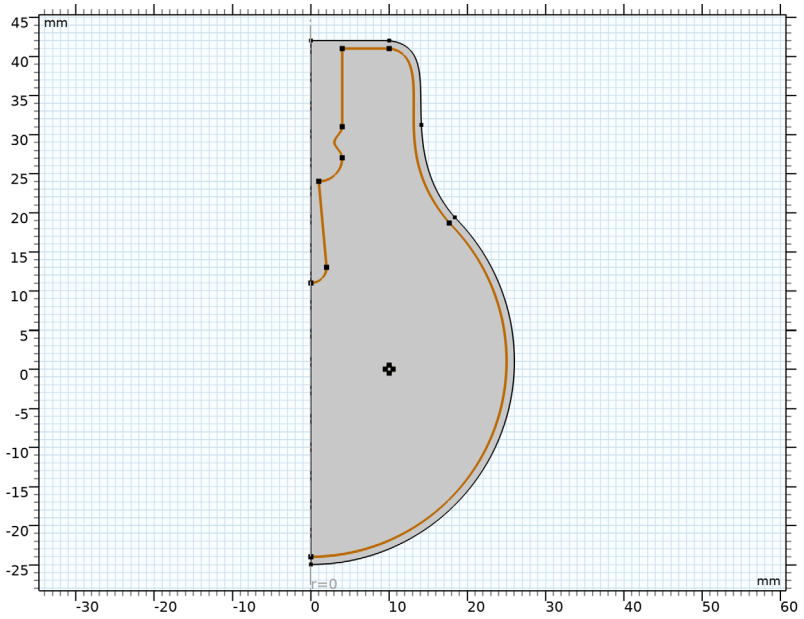
5 In the **Add** dialog box, in the **Selections to add** list, choose **Tungsten** and **Glass Boundaries**.

6 Click **OK**.

7 Locate the **Input Entities** section. Click **Add** right below the **Selections to subtract** list.

8 In the **Add** dialog box, select **Composite Curve 1** in the **Selections to subtract** list.

9 Click **OK**.



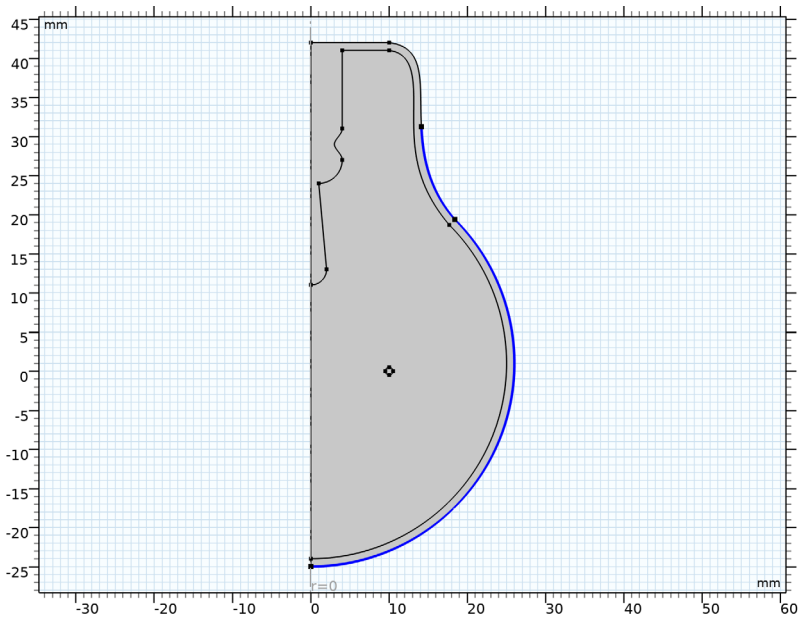
Exterior Radiation

1 In the **Geometry** toolbar, click **Selections** and choose **Explicit Selection**.

2 In the **Settings** window for **Explicit Selection**, type `Exterior Radiation` in the **Label** text field.

3 Locate the **Entities to Select** section. From the **Geometric entity level** list, choose **Boundary**.

4 On the object **fin**, select Boundaries 14 and 15 only.



Radiation

1 In the **Geometry** toolbar, click **Selections** and choose **Union Selection**.

2 In the **Settings** window for **Union Selection**, type `Radiation` in the **Label** text field.

3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.

4 Locate the **Input Entities** section. Click **Add**.

5 In the **Add** dialog box, in the **Selections to add** list, choose **Interior Radiation** and **Exterior Radiation**.

6 Click **OK**.

7 In the **Settings** window for **Union Selection**, click **Build Selected**.