Volumes by Slices and Cylindrical Shells

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Building a model with disks.

1. Open a new file and save it as three-disks.c4d
2. Left click on the **Cube** in the Object Creation part of the top menu, and select the **Cylinder**: this will be your disk.
3. Go to the Cylinder icon in the Object Manager. Delete the two brown circles to the right of the Cylinder.
   (These are called Phong tags and have to do with how the surface is rendered. Notice how the cylinder changes appearance. When 3D printing, we need to know what the mesh actually looks like.)
4. Go the the Attribute Manager for the cylinder.
   - Adjust the radius and height of the cylinder. Make $r = 5$ cm, $h = 1$ cm. Zoom in so you can see the cylinder clearly.
   - The cylinder's coordinates are given by the central point of the cylinder (center of the circle and half the height). Thus in order for the cylinder to sit flat on the xz-plane, we need to shift the cylinder up 0.5 cm in the y-direction.
   - Adjust the number of rotation segments to somewhere between 60 and 100. Notice how this smooths out the appearance of the cylinder.
5. Save your file again!
6. Add another cylinder. This time make $r = 4$ cm, $h = 1$ cm. Shift the cylinder up 1.5cm (can you see why?). Don't forget to delete the Phong tags and increase the number of rotation segments.
7. Save your file again!
8. Add another cylinder. This time make $r = 4.5$ cm, $h = 1$ cm. Shift it up 2.5 cm (can you see why?). Don't forget to delete the Phong tags and increase the number of rotation segments.
9. Save your file again!
10. We will now join the disks together using two different methods. The start point for each method will be the three-disks.c4d file you have just saved.

Connect the disks: Method 1

Remark: This method is a quick and dirty way of joining the disks into one object. Some 3D printers will **NOT** be able to correctly read the models produced from this file. This method produces an object which is mathematically correct, but is not necessarily the most elegant 3D print design.

1. Save a copy of the three-disks.c4d file under a different name, say three-disks-m1.c4d.
2. Go to the Object Manager and select all of the Cylinders. (Do this by holding the Shift (or Command) key and clicking on each name.)
3. Make the cylinders editable (into polygons) by clicking on the **Make Editable** button (with the two spheres and an arrow) found at the top of the left hand menu.
4. With all the objects still selected, go to the **Mesh** menu at the top of the viewport (near the rotate tool), then go to **Conversion** and select **Connect Objects + Delete**. (Alternatively, you can right click and select **Connect Objects + Delete**).
5. This creates just one object in the Object Manager. Notice that you can move the object as a whole.
6. Why is this object not a great design for 3D printing? Fly inside the object by zooming in. Notice that you can see the walls between the slices. It's these walls that some 3D printers don't like.

Connect the disks: Method 2 - Boole

Remark: This method is a more time consuming way of joining the disks into one object. However the finished model has a beautiful 3D print design. The finished model won't be 100% mathematically correct. However the errors are so small, that once printed, this model is indistinguishable from a mathematically correct model.

1. Open up your original three-disks.c4d file.
2. Save a copy of the file under a different name, say three-disks-m2.c4d.
3. **The plan.**
   (a) Make the middle cylinder slightly thicker so it overlaps (by a tiny amount) with the other two cylinders.
   (b) Use the **Boole Tool** to join the cylinders together.
4. Click on the middle cylinder (with radius 4 cm). In the Attribute Manager for the cylinder, make the height 1.01cm.

- This tiny increase in the height causes the middle cylinder to **overlap the other two cylinders by a small amount**.
- The height has been changed only by 0.01 cm, or 0.1 mm. This is a tiny amount and within the thickness of the filament used to 3D print a model.

5. Go to the Object Manager and select all of the Cylinders. (Do this by holding the Shift (or Command) key and clicking on each name.)

6. Make the cylinders editable (into polygons) by clicking on the **Make Editable** button (with the two spheres and arrow) found at the top of the left hand menu.

7. Go to the Object Creation part of the top menu. Left click and hold on the green shape that looks a bit like a flower. (This is the Array button.) Then select the **Boole tool** (two overlapping circles).

8. Go to the Object Manager. Move two of the cylinders (say Cylinder.1 and Cylinder.2) until they are under the Boole. (As you move the Cylinders in the Object Manager you will see a down arrow appear when they are under the Boole.) Don't panic when one cylinder vanishes.

9. Click on the Boole in the Object Manager. Look at the Attribute Manager. Under Boolean Type, change from "A Subtract B" to "A union B". Notice that the cylinder reappears.

10. In the Object Manager, select "Boole", "Cylinder.1" and "Cylinder.2" (by holding down the Shift key). Then go to the **Mesh** menu at the top left of the view-port (near the rotate tool), then go to **Conversion** and select **Current State to Object**. An L^0 Boole will now appear in the Object Manager.

11. Delete the original Boole.

12. Drop down the menu for L^0 **Boole** by clicking on the +. Hold down the Shift key and select "L^0 Boole", "Cylinder.1", and "Cylinder.2". Go to the **Mesh** menu, then go to **Conversion** and select **Connect Objects + Delete**. (Alternatively, you can right click and select **Connect Objects + Delete**). You will be left with "Boole.1" in the Object Manager.

13. Don't forget to save your work!

14. Pause a moment and Zoom in so you can see inside the two cylinders you have just joined together. Notice that there is no interior wall! Zoom out again.

15. Join the remaining cylinder to the Boole.1 object by repeating steps (7) – (13).

WARNING 1: If your objects do not overlap by a tiny amount, then this Boole method will **not** remove the walls between the objects. You may as well join the cylinders together using Method 1.

WARNING 2: Once you have created a model using this method, you have deleted the original objects used to construct the model. At this point, you can **not** return to these objects later on.

It is for this reason that it is smart to keep a separate file with a copy of all the original disks until you are satisfied with the model you have created.

Cinema 4D tips for more complex models.

Volumes by cylindrical shell method

1. Left click on the Tube Object in the Object Creation part of the top menu, and select the **Tube**. This will be your cylindrical shell.

2. Go the the Attribute Manager for the Tube.

   - Adjust the inner and outer radii, and the height of the tube.
   - Adjust the number of rotation segments to somewhere between 60 and 100.
   - Move the tube into its correct position (via the Coordinate Manager).

3. Repeat with other tubes. **Save a file with all of the separate tubes as a reference.**

4. Join the tubes together. If using the Method 2 with the Boole Tool, then remember to adjust the radii so the cubes are overlapping by a tiny amount.

TIP 1: If the innermost cylindrical shell has zero inner radius, then it is a cylinder. Use the Cylinder object, rather than the Tube object here.

TIP 2: The tube's coordinate are given by the central point of the tube (center of the circle(s) and half the height).

Volumes made of square slices

1. Left click on the Cube Object in the Object Creation part of the top menu, and select the **Cube**.

2. With the cube selected, click on the **Make Editable** button.

3. Go to the Coordinate Manager.

- Adjust the size of the cube to be an appropriately sized square slice.
- Move the square slice into place.

4. Repeat with other square slices. **Save a file with all of the separate square slices as a reference.**

5. Join the cubes together. If using the Boole Tool, then remember to adjust the height so the cubes are overlapping by a tiny amount.

Volumes made of triangular slices

1. We first construct a triangle of the right size.

   - Left click on the Tube Object in the Object Creation part of the top menu, and select the **Polygon**.
   - Go to the Attribute Manager and click on the Triangle button. (You can adjust the height and width of your triangle here, or you can do it as described below.)
   - With the Polygon selected, click on the **Make Editable** button.
   - Click on the **Point Mode** button on the menu on the left hand side. This is the cube with two vertices highlighted.) Click on the **Live Selection** button on the top menu (the arrow in the red circle.)
   - Click on one of vertices of the triangle. Use the Coordinate manager to move the vertex to the correct position. Repeat with the other vertices.

2. We now thicken the triangle into a triangular slice.

   - Click on the **Polygon Mode** button on the menu on the left hand side. (This is the cube with a highlighted face.) Make sure the **Live Selection** button is highlighted.
   - Click on the triangle, it will turn a yellow color.
   - Go to the **Mesh** menu, then go to **Create Tools** and select **Extrude**. Go to the Attribute Manager. Change the "Offset" to be the thickness of your slice. Click on the "Create Caps" button. Hit "Apply".
   - Go to the **Model Mode** (right below the Make Editable button). Click on **Live Selection** button. Go to the Coordinate Manager and, if necessary, move the slice into position.
   - Check that the slice is properly oriented. First go to **Polygon Mode**. Then Control+A to select all of the faces on the triangular slice. (Alternatively go to **Select** menu, then **Select All**.) All the faces on the triangular slice should be an orange color. [If it is not, it will be a blue color. This means the slice is inside out. To fix this, go to **Mesh**, then **Normals**, then **Reverse Normals**.]

3. Repeat this process with other triangular slices. **Save a file with all of the separate triangular slices as a reference.**

4. Join the triangular slices together. If using the Boole Tool, then remember to adjust the height so the triangular prisms are overlapping by a tiny amount.