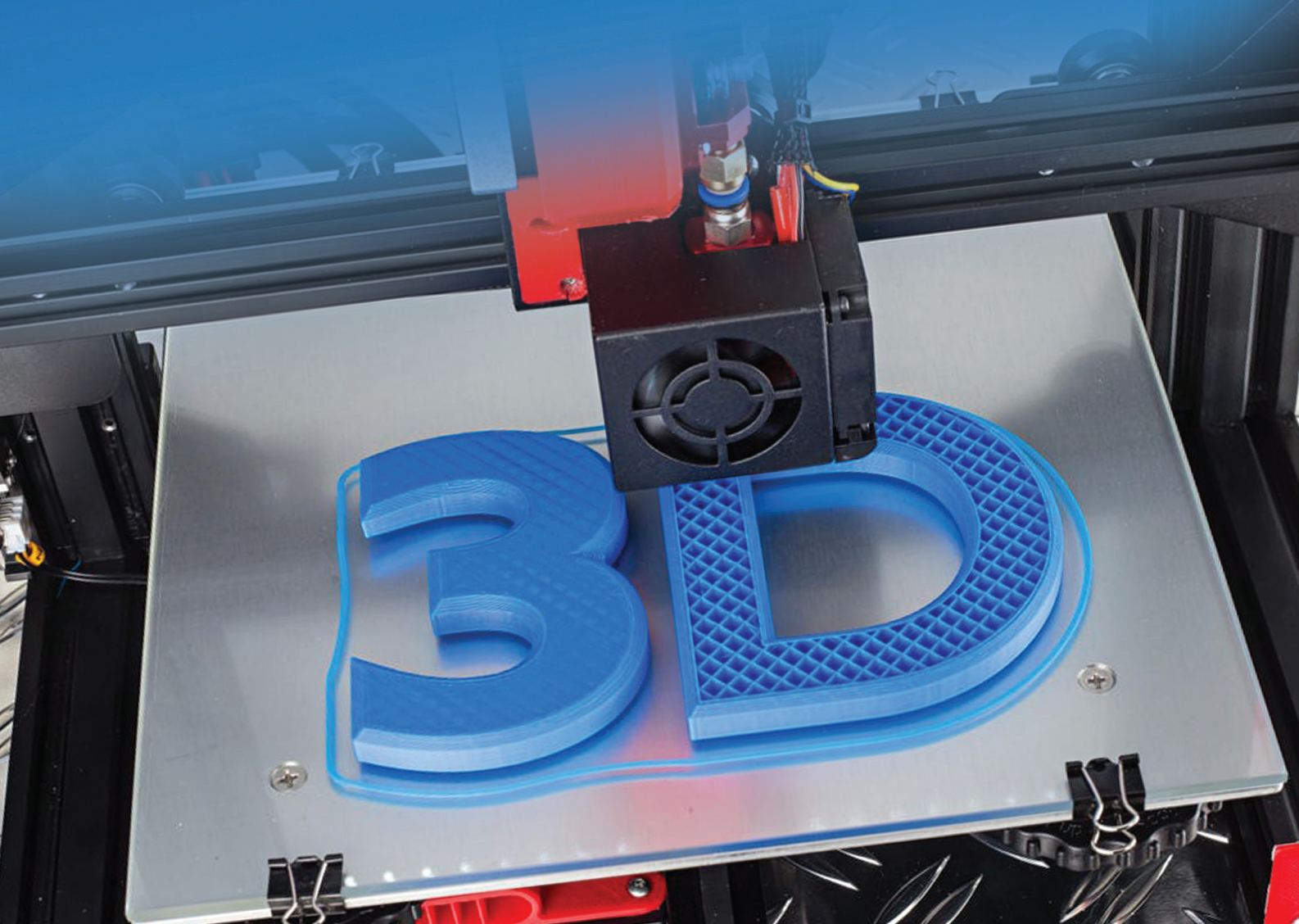
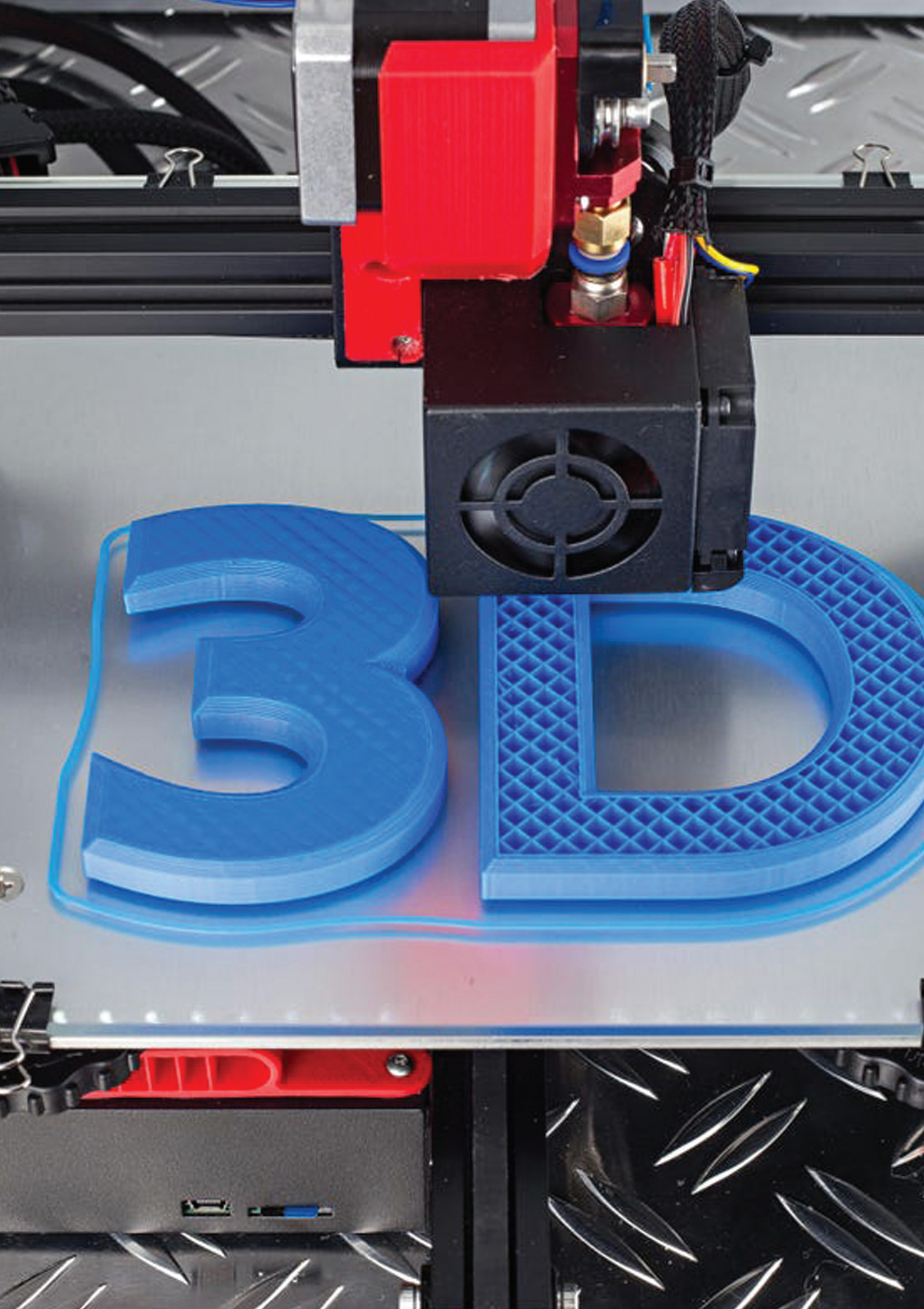
ROBOTROAD
by Olatus Systems Private Limited

VOLUME 3

3-D PRINTING




3D

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Chapter 1: Introduction to 3D Printer

Print Bed

The print bed is the surface that your objects are printed on to. Typically, it will consist of a sheet of glass, a heating element, and some kind of surface on top to help the plastic stick.

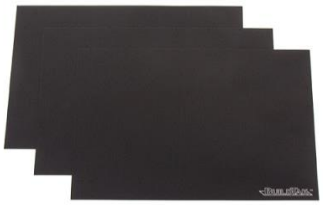
Heated/Non-Heated

Most print beds are heated in order to prevent the object from warping while it is being printed. Due to thermal contraction, the plastic will shrink slightly as it cools. This causes the object to warp upwards around the edges and peel off the bed. Heated beds keep the bottom of the object warm, in order to prevent this. See also; Enclosure, Bed Surfaces.

Some printers do not have heated beds. This limits them to printing a narrow range of materials including mainly PLA (the material that is least prone to warping) and sometimes PET.

Bed Surfaces

The bed surface helps the plastic stick to the bed during printing but also allows it to be removed easily when printing is done. There are many different kinds of bed surfaces. Most printers will come with some kind of all-purpose surfaces, like BuildTak or PEI film. However, for best results, you will want to use different surfaces depending on the material you are printing. Use this guide for print bed recommendations based on the material.

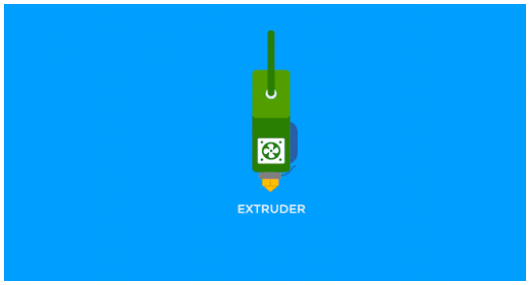


Filament

This is the plastic that's consumed by the printer. It comes on a spool. Printers use two different sizes of the filament, 1.75 mm and 3 mm. There are a variety of different materials. To learn more about them, check out the Matter Hackers filament guide.

Extruder

The extruder is the core of the printer. It is where the plastic gets drawn in, melted, and pushed out. It is essentially a fancy hot glue gun. It is small, but it is where most of the printer's technology is located. The extruder consists of two parts; the hot end and the cold end. The cold end has a motor that draws the filament in and pushes it through. The hot end is where the filament gets melted and squirted out.



Direct Drive Vs Bowden Extruder

- On **direct drive** printers, the hot end and cold end are connected together, one on top of the other. The filament goes straight down through the cold end and into the hot end.
- With a Bowden setup, the hot end and cold end are separated. The cold end will be stationary and bolted somewhere onto the printer's frame. The filament is pushed through a long tube (called a Bowden tube) to the hot end. This means that the printer has less weight to move around.

Hobbed Gear

This gear bites the filament and pushes it down through the hot end.

Idler Gear

The idler is a spring-loaded wheel that pushes the filament up against the hobbed gear. Most printers have a way to adjust the tension on the idler so that it neither squeezes the filament too hard or too little.

Hot End - All Metal Vs PEEK/PTFE

By not using any plastic insulators in their construction, all metal hot ends are able to reach much higher temperatures and print a wider range of materials. However, they require active cooling.

Hot End - Heat Sink / Hot End Fan

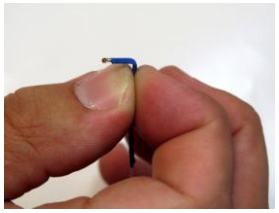
This ensures that heat does not travel up the plastic and melt it prematurely before it reaches the nozzle. This phenomenon is called heat creep and it causes jams, especially with PLA. This fan should be running whenever the hot end is warm.

Heater cartridge

The heater cartridge is pretty self-explanatory. It heats the plastic. It is simply a high-power resistor. Almost all modern printers use cartridge heaters, but many older printers used coils of nichrome wire (like the kind in a toaster). If you are replacing your heater cartridge, of even your entire hot end, make sure you know if your system is running 12v or 24v.

Thermistor/Thermocouple

These are all various types of sensors for determining the temperature of the hot end. They are essentially electronic thermometers. Thermistors are the most common type of sensor, but some printers will use thermocouples for extremely high-temperature printing.



Nozzle

The nozzle is simply a piece with a small hole for the melted filament to come out of. Nozzles are interchangeable, and come in various sizes; 0.4 mm is normal, while you might use a smaller nozzle for finer detail or a larger nozzle to print faster. Nozzles can also sometimes get clogged. This is one of the most common issues with 3D printers. See this article for advice on unclogging your nozzle.

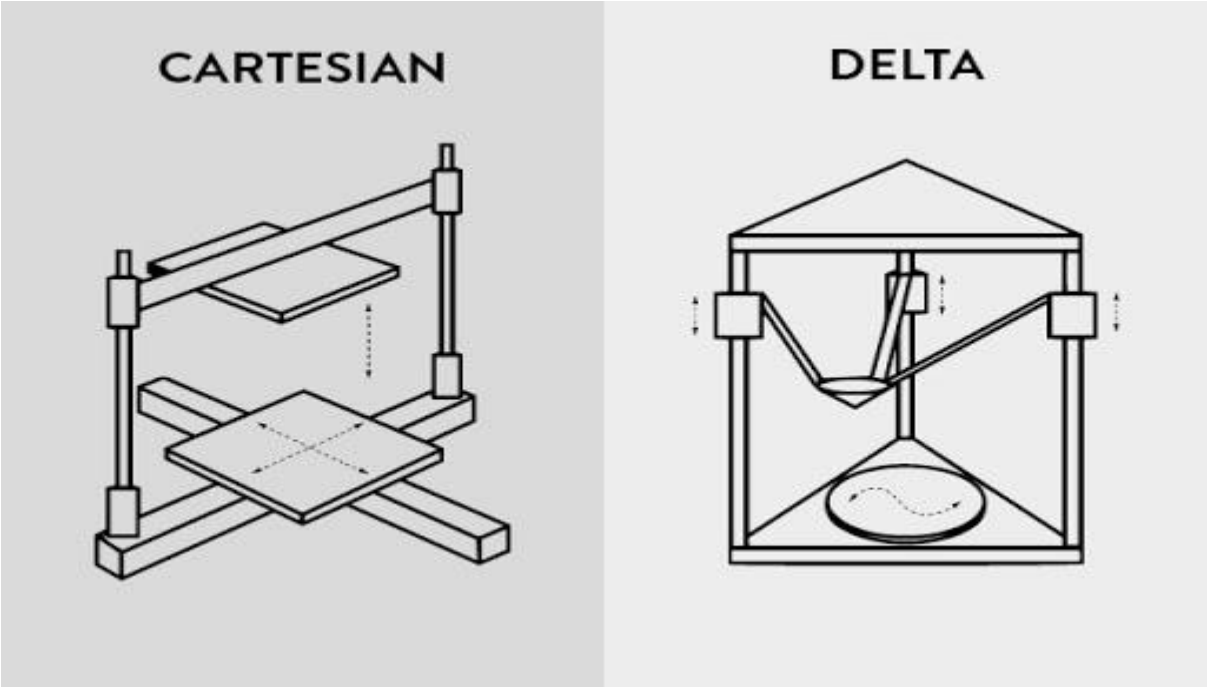
Layer Cooling Fan

This fan cools off the plastic immediately after it is deposited by the nozzle. It helps the object hold its shape. The slicer will turn this fan on and off under different circumstances, depending on what material you are printing. It is not to be confused with the heat sink fan, which cools the hot end itself and not the printed object.

Motion Control - X, Y, Z-axis:

Delta Vs Cartesian

- Cartesian printers move one or two motors along each of the X, Y, and Z axes and the name was derived from the Cartesian coordinates system. They typically have a rectangular build area and the printers themselves tend to have a cube-like shape. The Lulzbot Mini is a fine example of these types of printers.
- Delta printers have three arms that come together in the center to suspend the extruder above the build area. Deltas also use a Cartesian coordinates system to move around in, but instead of moving one motor per axis at a time, all three arms move at different rates or times to precisely move the nozzle with triangulation. The See Me CNC Rostock MAX V2 is a prime example of a delta printer.



Threaded Rods / Leadscrews

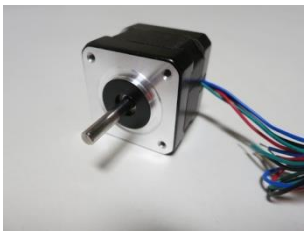
These are usually used on the printer's Z axis. They rotate, thus forcing nuts to move up and down. Inexpensive printers will use simple threaded steel rods, which are essentially extra-long bolts. Higher quality printers have smooth chrome plated lead screws designed to minimize backlash.

Belts

Belts move things. The X and Y motors have sprockets that drive the belts. Most printers also have some way of adjusting the tension on the belts.

Stepper Motors

Unlike regular DC motors, which rotate continuously when given power, stepper motors rotate in increments. This gives them precise control over their position. Most printers use NEMA 17 type motors with 200 increments (steps) per revolution.



Frame

The frame holds everything together. Early printers had frames made out of laser cut plywood. Printers now have frames made of sheet metal, aluminum beams, or plastic. Many parts of the frame are often 3D printed themselves. The more rigid the frame, the more precise the printer's movement will be.

Enclosures

Enclosures for 3D printing are used for safety. There are moving parts and heating elements that users will want to protect themselves from. If your printer does not offer an enclosure, it is easy to construct your own. Something as simple as a cardboard box could suffice.

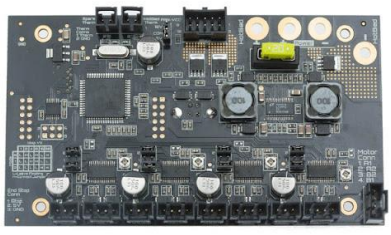
Electrical Components:

Power Supply

- This takes the 120V AC electricity from the wall and converts it to low voltage DC power for your printer to use
- **ATX Power Supplies**- These are the same power supplies used in desktop computers. They have been repurposed for use in many printers. They are very beefy and efficient and have separate lines that provide power at a variety of voltage (12V, 5V, 3.3V).
- **Voltage** - some machines run 12 volt systems, while others run 24 volt systems. This becomes critical if you are going to replace components - especially your heater cartridge or hot end. Make sure you order the appropriate parts.

Motherboard

The motherboard is the brain of the printer. It takes the commands given to it by your computer (in the form of G-Code) and orchestrates their execution. The motherboard contains a microcontroller (essentially a tiny, self-contained computer) and all the circuitry needed for running the motors, reading the sensors, and talking to your computer. Here is a comparison of the different motherboards we carry.



Stepper Drivers

These chips are responsible for running the stepper motors. They fire the coils of the motor in sequence, causing it to move in increments. Many motherboards have the stepper drivers built in, but some also have them in modules that can be unplugged. By balancing the power fed to each coil, the driver is also able to divide steps up into further increments. This is called micro stepping and allows more precise control over the motor than is normally possible. The stepper driver also controls how much electrical current is fed to the motor. More power makes the motor stronger, but also makes it run hotter. See this article for more information on adjusting your motor current.

User Interface

Some printers have an LCD screen so they can be controlled directly without hooking them up to a computer. These can be basic black and white displays like the VIKI 2 or advanced Wi-Fi-enabled touch screens like the Matter Control Touch.

SD Card Slot

Some printers also have an SD card slot from which they can load G-Code files. This allows them to run independently without a computer.

End Stops (one for each axis)

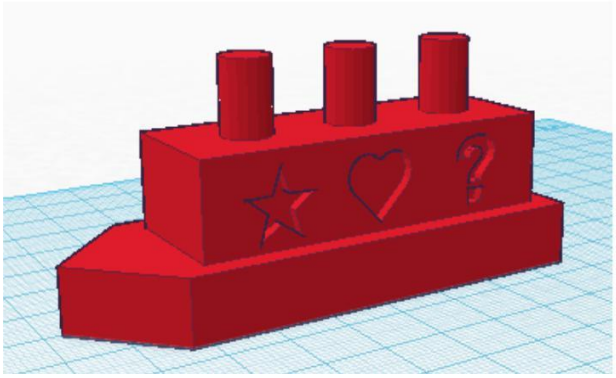
The end stops are how the printer knows where it is. They are little switches that get pushed whenever an axis moves to the end. This is how the printer finds it's starting point before printing. Most printers use mechanical switches, but some are known to use optical sensors.

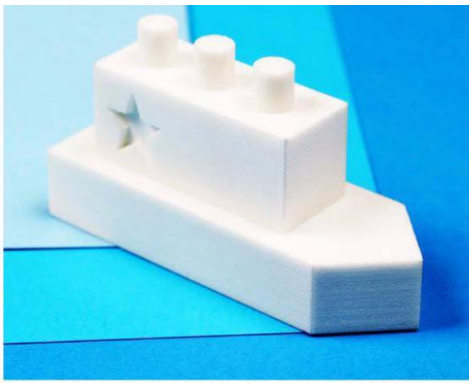
Bed Leveling

Many printers have some kind of a system for automatically making sure that the bed is level with the nozzle. Some do not, though, and must be calibrated by hand. Matter Control also has the ability to account for unevenness in software. For more information, see our wiki article on bed leveling.

Chapter 2-Getting Started in Tinkercad

Tinkercad is a fun, easy to use, web-based 3D design application. You don't need any design experience - Tinkercad can be used by anyone. In fact, kids are Tinkercad's target audience, so don't worry - this project isn't complicated! Sit back, follow the steps, and in no time, you'll be able to complete this cute little boat (shown in red below, next to a 3D printout in white, of a similar boat):

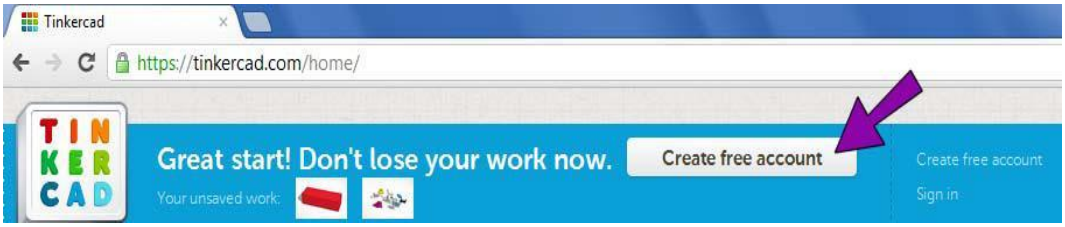




The cool thing about Tinkercad is that it's ideal for creating things that be *printed*. No, not printed on a boring and flat 2D sheet of paper! Tinkercad is made for producing *actual objects*: you can easily send your model to a 3D printer and end up with an actual object you can hold in your hand.

Have a Look Around

1. Tinkercad's website is (as you'd expect) www.tinkercad.com. All work is done and saved on the web; there's nothing to install onto your computer. You don't need a Tinkercad account to design things, but it's free to set one up, and with an account, you get to save your work. So, there's no reason not to create an account.

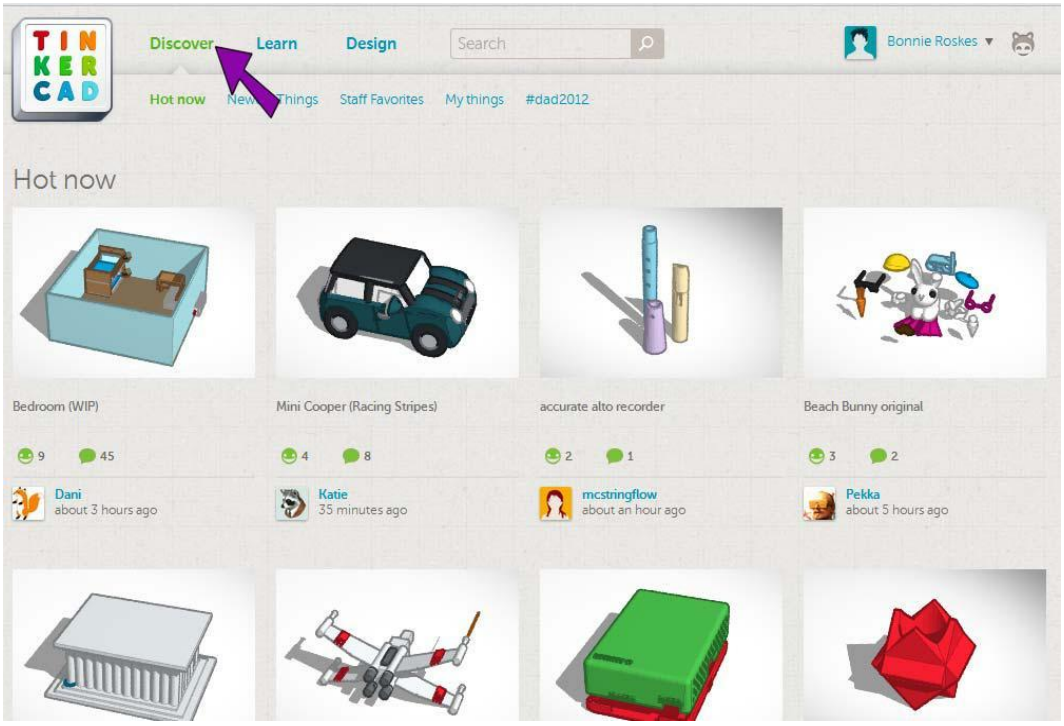


At the top of the Tinkercad site are three main links: **Discover**, **Learn**, and **Design**.

2. Click the **Discover** link, which takes you to a page of interesting models you can peruse. At the top of this page you can also search for something specific, check out the newest models, see what models the Tinkercad staff loves, and sometimes you can even see special seasonal models (such as stuff for Father's Day).

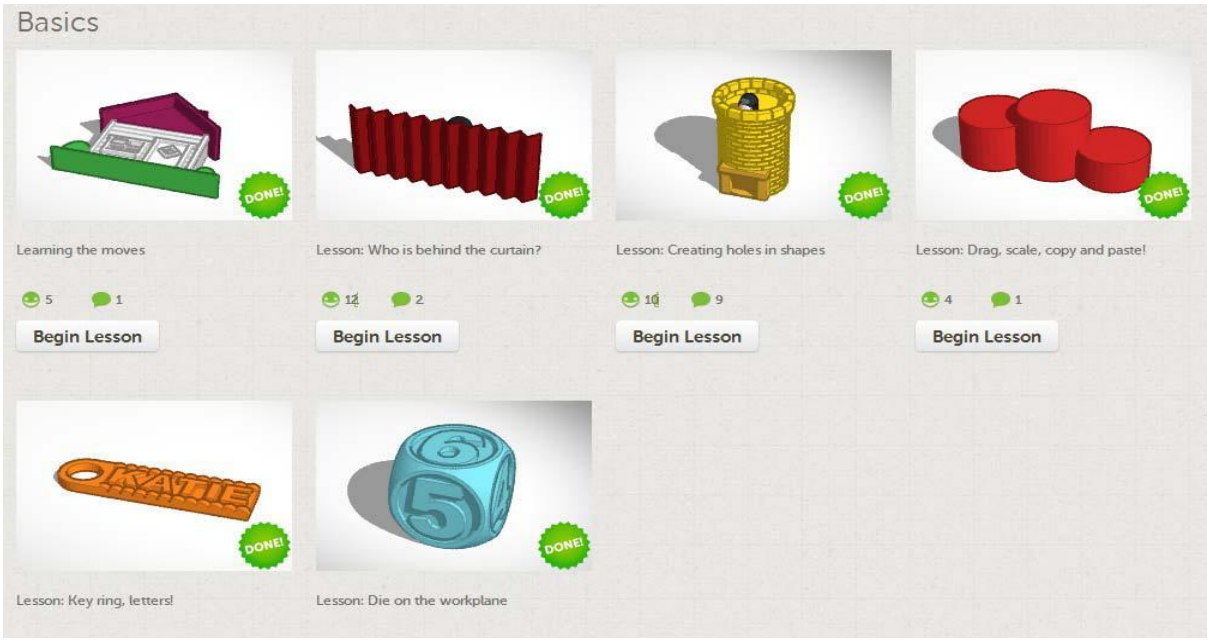
   If a model you see strikes your fancy and you want to see more, click on it to see a larger view. You can see a still view of the model, or view it in 3D so that you can turn it around and zoom in and out. The **Copy and Tinker** button lets you open it in Tinkercad so you can see how it was made; you can make any changes you like. And of course, you can send any Tinkercad model to a 3D printed, even if you didn't make it yourself!

   Your browser's Back button will take you back to Tinkercad's main pages when you're finished tinkering.



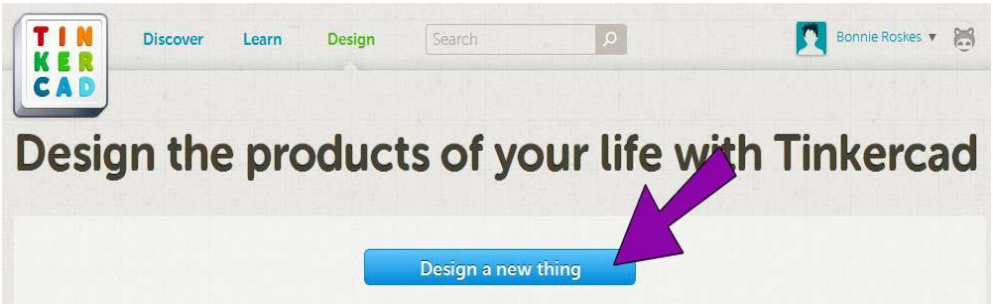
The **Learn** link at the top of the main page takes you to a series of lessons.

These are fun and short guided projects in which you follow directions in Tinkercad to create, move, and modify shapes. Try a few out.

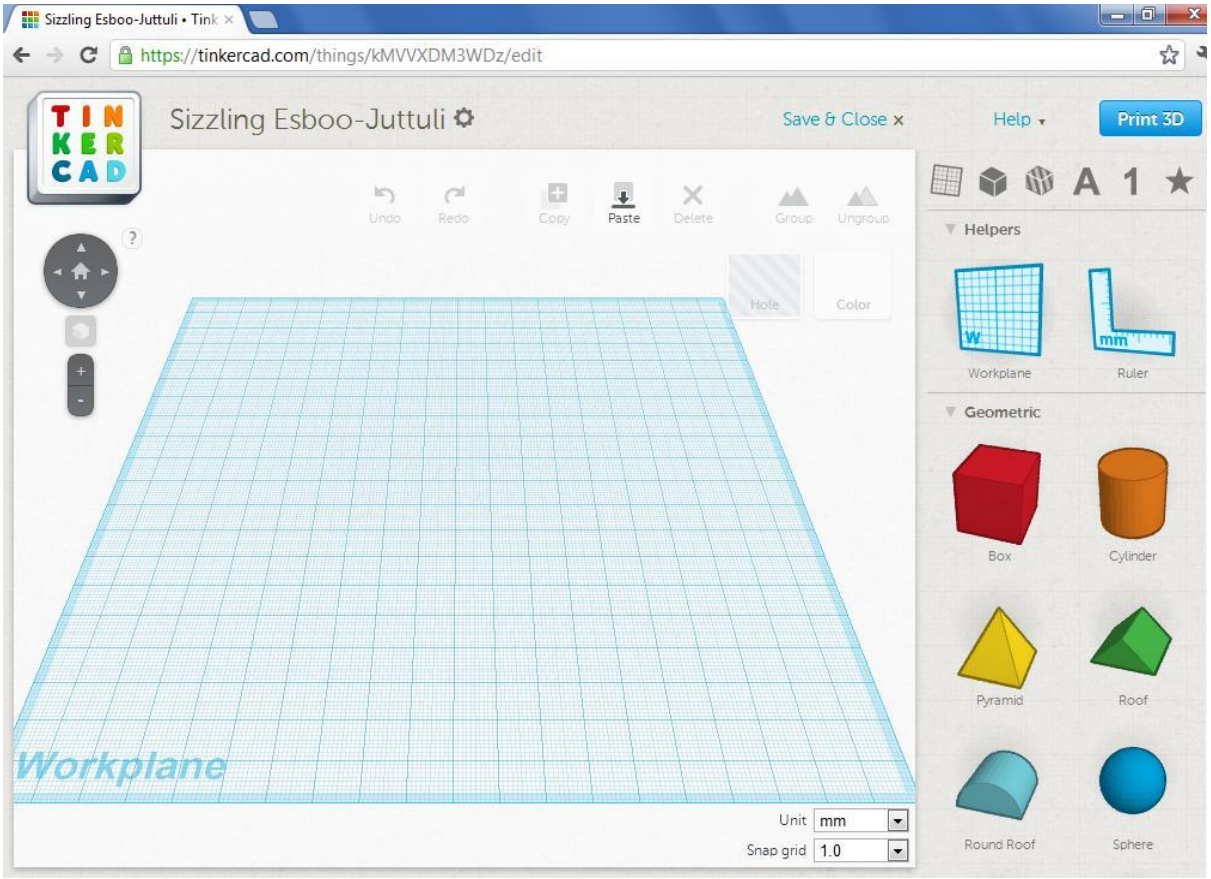


Start Your Thing - the First Shape

1. Ready to get started already? Click the **Design** link at the top, then click **Design a new thing**.

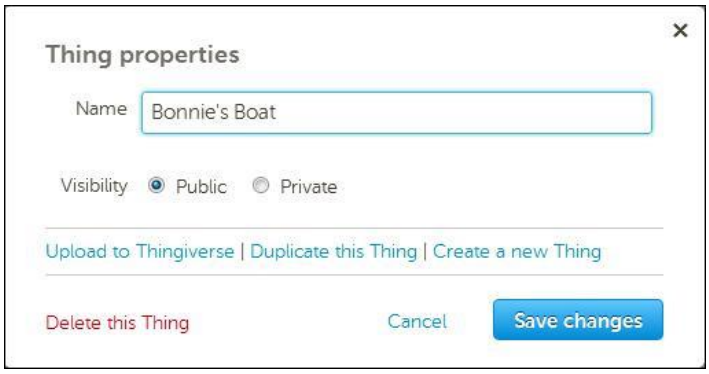


You're taken to a new webpage set up for your model, and your model is assigned a crazy name (what on earth is "Sizzling Esboo-Juttuli"?) An empty workplane (the large, blue grid) takes up most of the screen. The grid lines are all 1 mm apart, which makes it easy to see how large things are. **Snap grid** is set to 1 mm, which means you can move things by 1 mm increments (but you can change this via the **Unit** box at the lower right corner). The design tools are on the right side: the row of icons across the top open the various sets of tools: **Helpers**, **Geometric**, **Symbols**, etc. Scroll down the tool lists to see what's there for you to use.

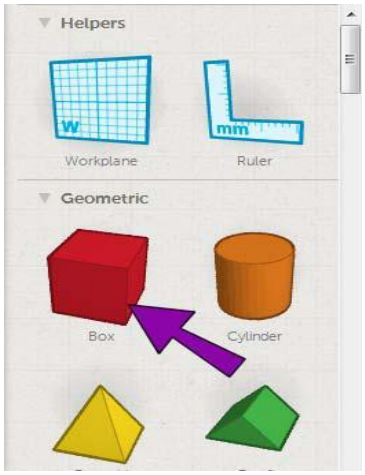


2. Unless you love the strange model name you get, click the gear icon next to the name, which opens the **Thing Properties**.

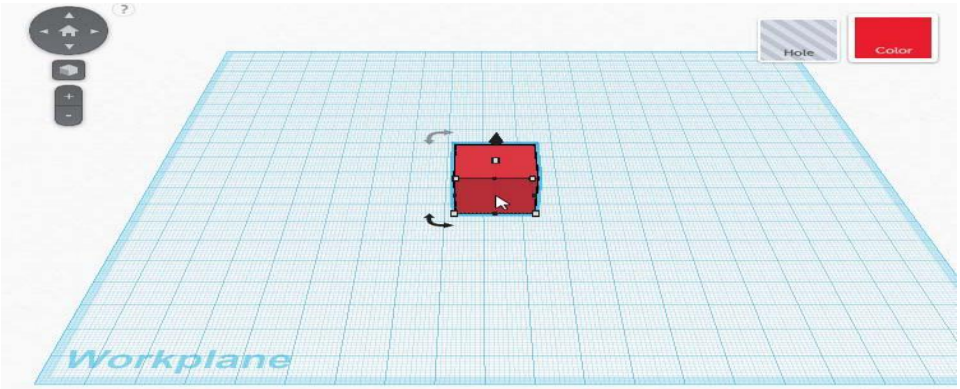
3. Set a new name, and choose whether it will be displayed for all to see (public) or just for you (private). Then click **Save changes**.



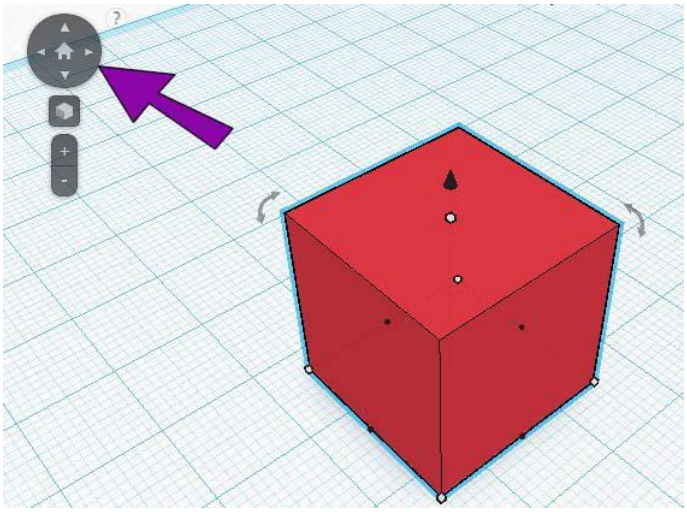
4. Let's start with the bottom of the boat. Click the **Box** tool, which is the first icon in the **Geometric** tool group.



5. Click anywhere on the blue workplane to add the box to the model.



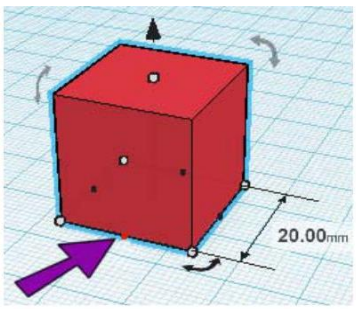
6. Before going on to make changes to this box, it's important to know how to "get around" in Tinkercad. The navigation tools in the top left corner are used to change your viewing angle: use the four arrows around the house icon to spin the model left or right, or to tilt the model up or down. You can also use the plus and minus icons to zoom in and out.



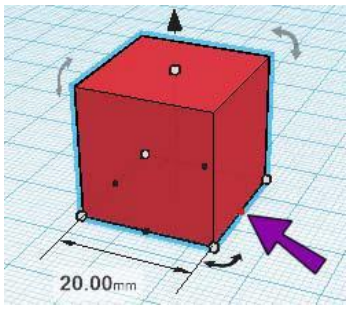
If you have a scroll wheel mouse, though, you don't need to use these navigation controls - you can rely on your mouse buttons, which is much more convenient. Press and hold the right mouse button and drag the mouse around - this is for spinning and tilting the model. Doing the same (holding the right mouse button) with the Shift key pressed lets you move the model. (Pressing and holding the scroll wheel does the same thing.) And finally, scrolling the mouse wheel up and down lets you zoom. Try out these moves with your mouse - once you get used to using these buttons, you'll never need to click those navigation buttons! (And if you forget which mouse buttons do what task, click the small question mark icon next to the navigation tools, for a reminder pop-up.)

The red box is outlined in light blue, which means it's selected, and it has all sorts of little squares and arrows all around it. To see what all these squares and arrows do, we'll hover our mouse over them ("hover" means to move the mouse somewhere, without clicking).

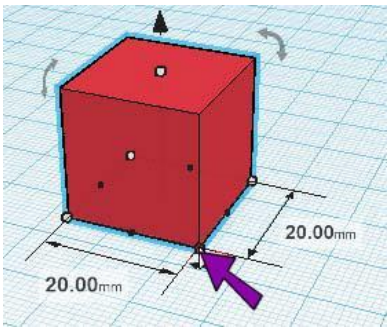
7. First, hover your mouse on one of the small black squares in the middle of an edge on the "ground" (also known as the workplane). The 20.00 dimension appears, showing you how long the box is in that direction - 20 mm.



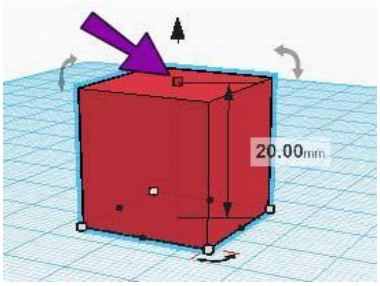
8. Hover over the same black square on another edge, and you'll see the same 20 mm measurement in the other direction.



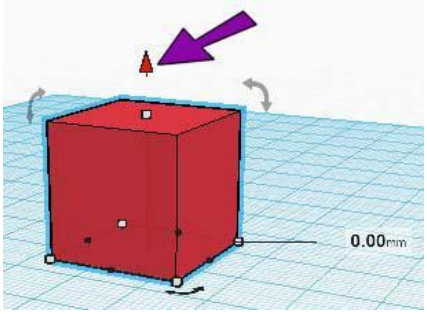
9. Hover over one of the white boxes on the corner, and you'll see both dimensions listed: 20 by 20



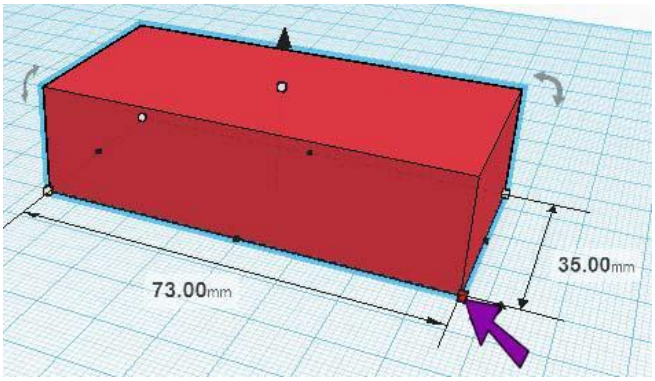
10. Hover on the white square at the top center of the box - it's 20 mm tall.



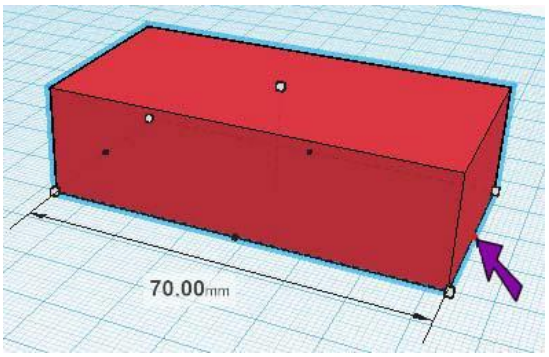
11. Hover over the round black arrow pointing up, above the top of the box. This measurement is zero, which means the box is sitting right on the workplane. (Say the box was "floating" 2 mm above the workplane - you'd see 2.00 instead of zero.)



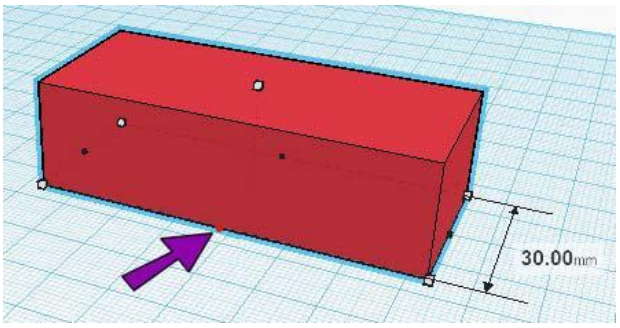
12. To make the box larger (but not taller), drag one of the white corner squares. Dragging a corner square lets you change both the length and width of the box. (It doesn't matter what size you make the box since we'll give the box exact sizes in the next steps.) Because the snap grid is set to 1 mm, you move in distances of 1 mm all the time (no fractions).



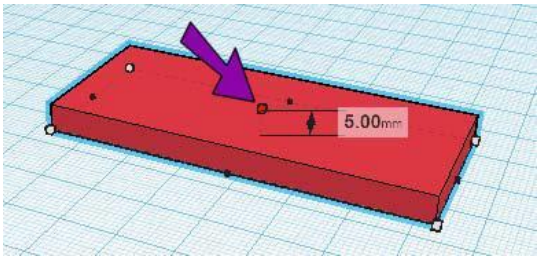
13. To set the box's length, click and drag the black square shown below, which resizes the box only in that specific direction. Stop when the box is 70 mm long.



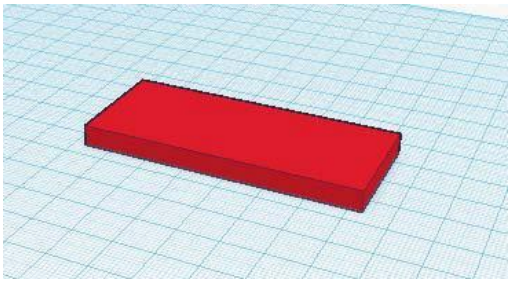
14. For the other measurement, use the arrow shown below, and stop when the width is 30 mm.



15. Next, use the white box on the top of the box to push the height down to 5 mm.



16. That's it for now with this box. To unselect it, click anywhere away from it.



Chapter 3- Wrench

Introduction

For this tutorial, we chose a wrench as an example because it is familiar, simple and useful in daily life. If you haven't seen a wrench before, it is used by mechanics for tightening nuts and bolts. Here's how a real-life wrench looks like:

A key principle in 3D modelling is "divide and conquer." It means that when modelling a complex real world object, we should divide it into smaller geometric shapes and then design these smaller units individually. In the final step, we should put these small units together. This makes modelling a complex object easy.

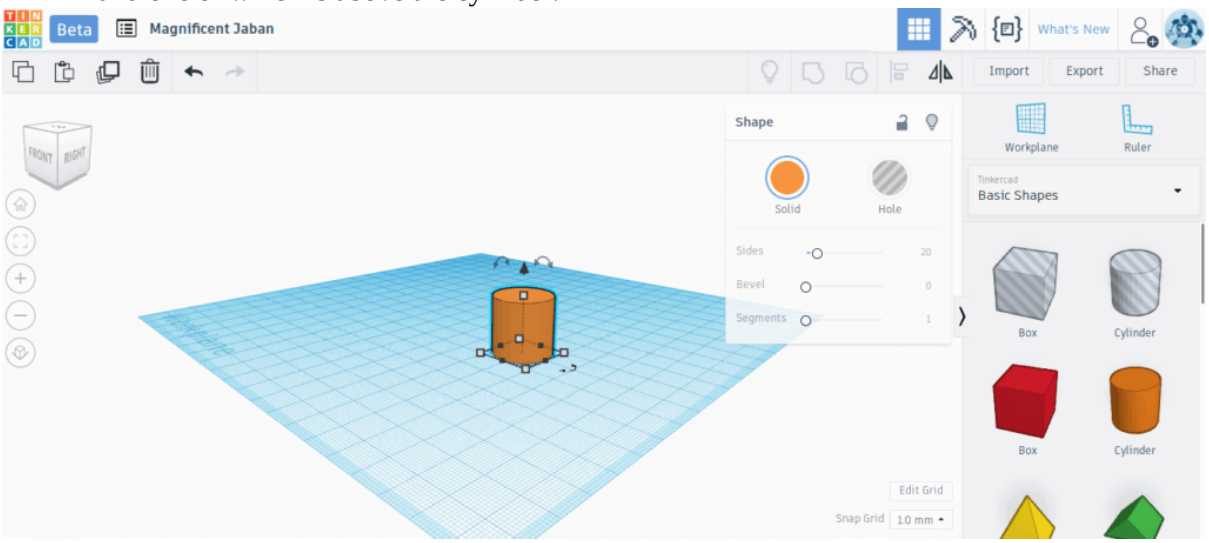
Applying this principle to the wrench, we divide it into three basic units:

- The ring
- The handle
- The jaw

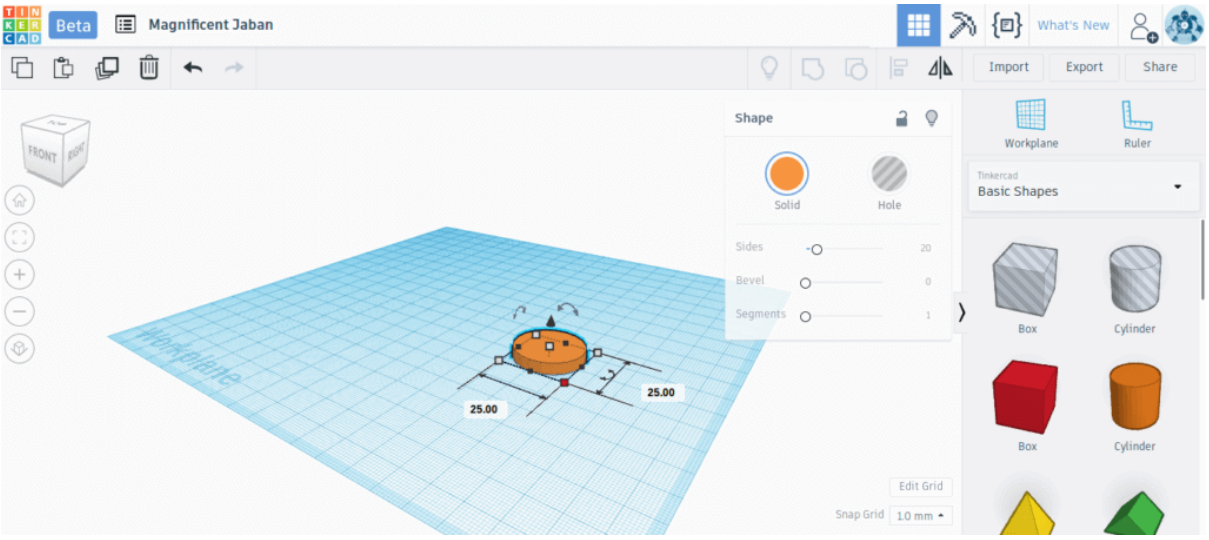
Design the Ring

Creating the Solid Circular Disk

1. To create this shape, we will first drag a cylinder from the Basic Shapes panel to the workplane. You will notice that the cylinder has five white square handles, four of which is on the plane and one of which is above the cylinder.



2. The four handles on the plane can be used for adjusting the cylinder's length and width. We want our ring to have a diameter of 25mm. Therefore, drag the square handles till the cylinder has a length and width of 25mm.
3. The one above the cylinder can be used for adjusting its height. We want our wrench to have a height of 4mm. Therefore, click the handle with the left mouse button and drag it down till the cylinder has a height of 4 mm.

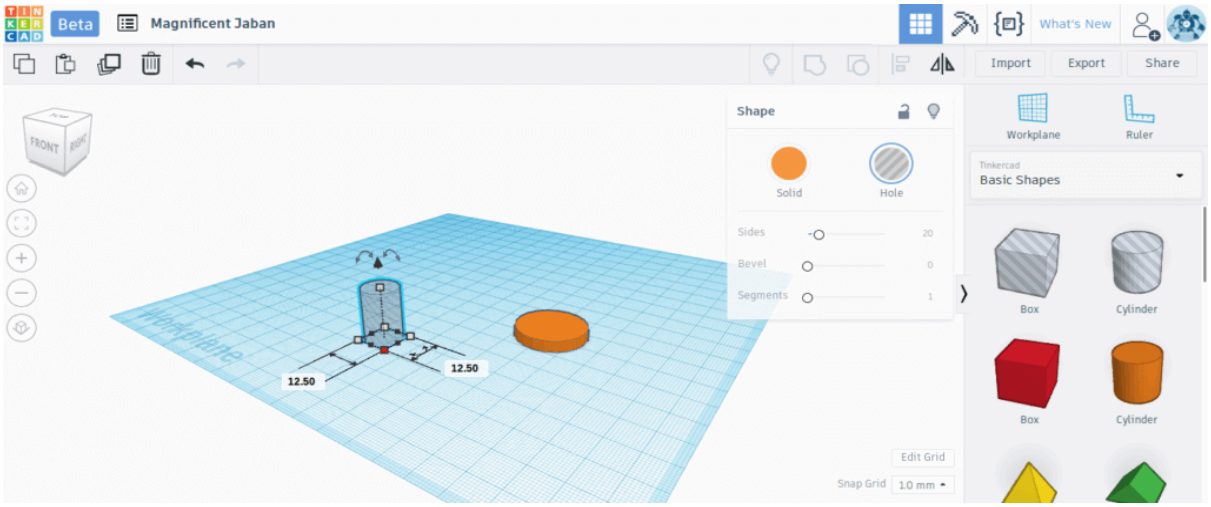


Creating the Circular Hole

We are making progress: we now have the solid disk. But how do we make the circular hole in the middle?

Tinkercad operates on the principle of Boolean design, which means it allows you to *subtract* objects to create hollow areas or *add* objects to join two shapes. In this case, we will need to use subtraction to create the circular hole in the middle of our ring.

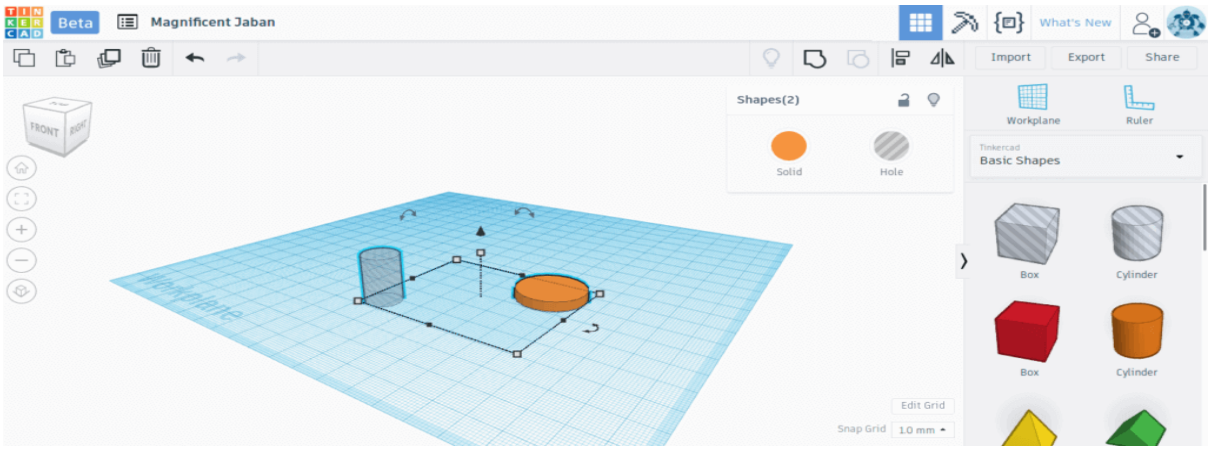
4. First, drag another cylinder to the workplane. Use the white handles on the plane to adjust the length and width of the cylinder to 12.5mm, which is the diameter of the hole that we want to create.
5. With this cylinder selected, choose "Hole" in the panel on the upper right corner (marked by the blue rectangle in the image). This prepares this shape to be subtracted out.



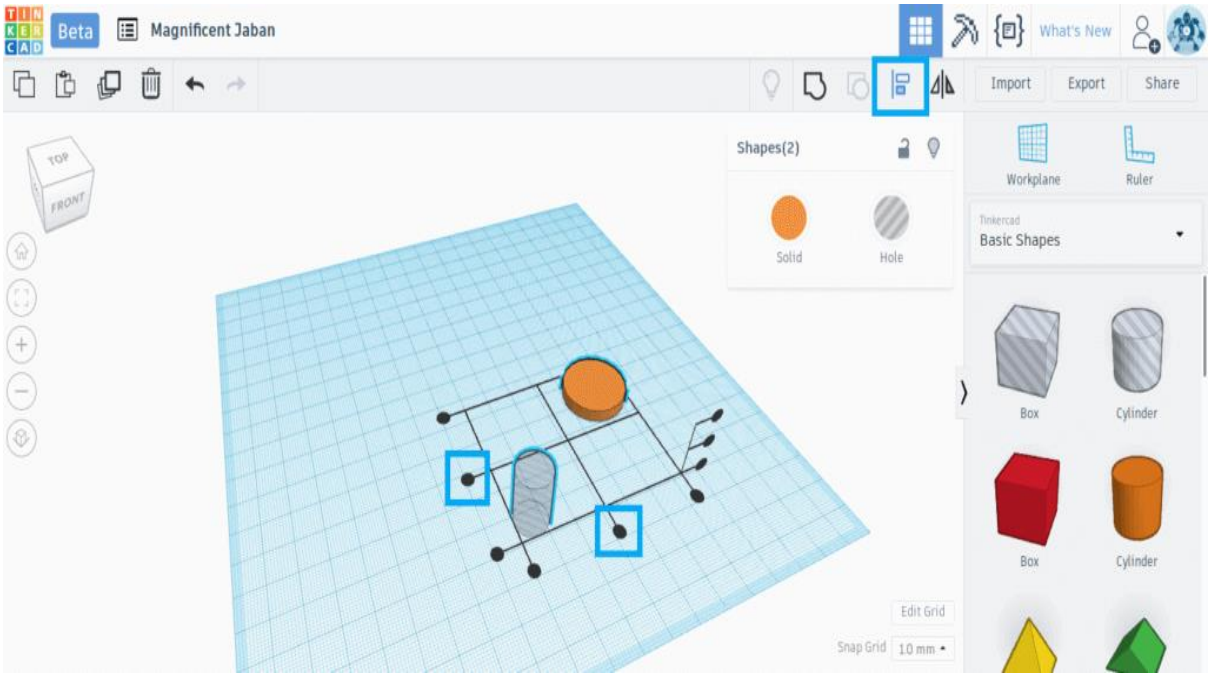
Aligning the Hole and the Disk

Next, we need to bring this cylinder shaped "hole" in the middle of the solid disk. We will use the alignment tool in the top menu to achieve this.

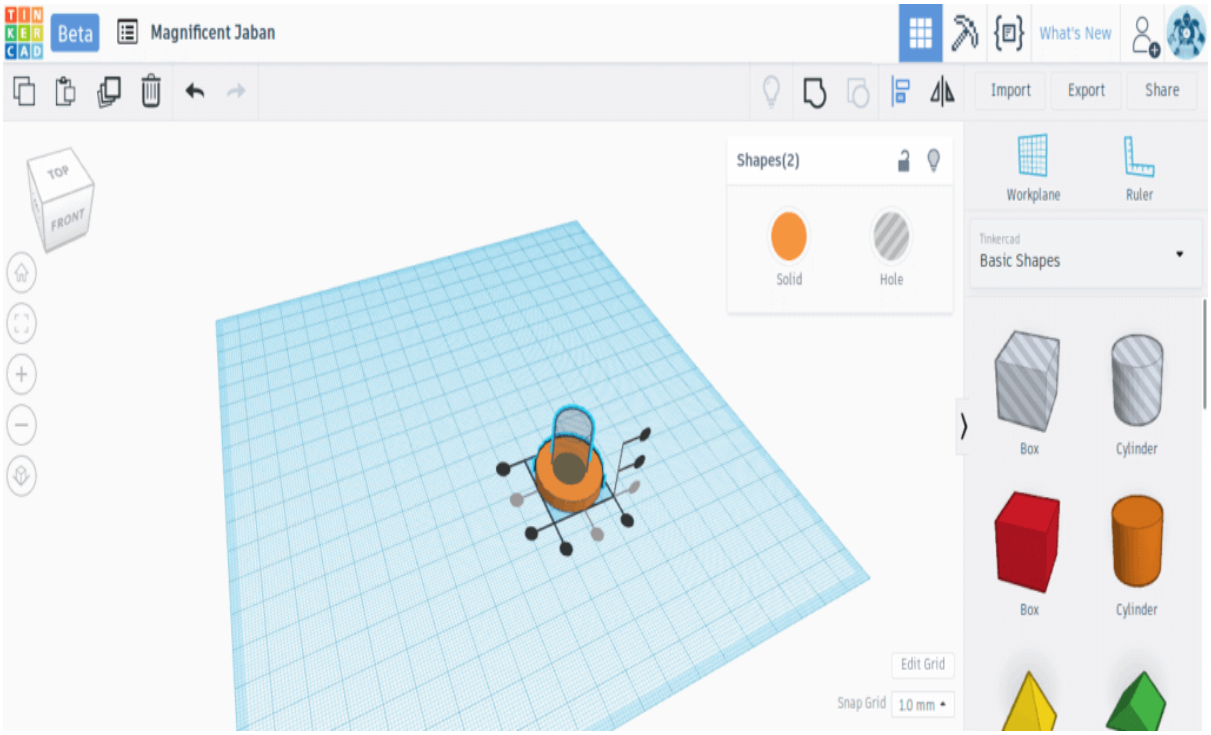
6. To use the alignment tool, select the cylinder-shaped hole by left clicking. Now press the shift button and select the solid disk. If you do this correctly, you will see that both objects are now simultaneously selected and highlighted.



7. Press the Align button on the top menu (marked with a blue rectangle). Black alignment handles will appear on the workplane. Click on the appropriate handles (also marked with blue rectangles) to bring the solid cylinder in the middle of the solid disk.



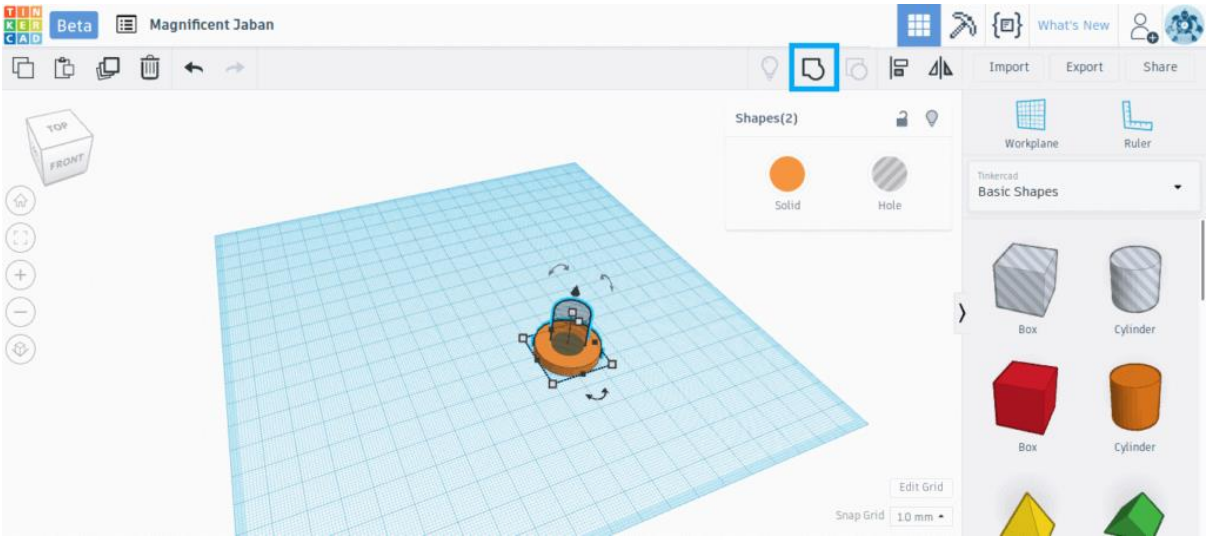
The black alignment handles help align two shapes in Tinkercad.



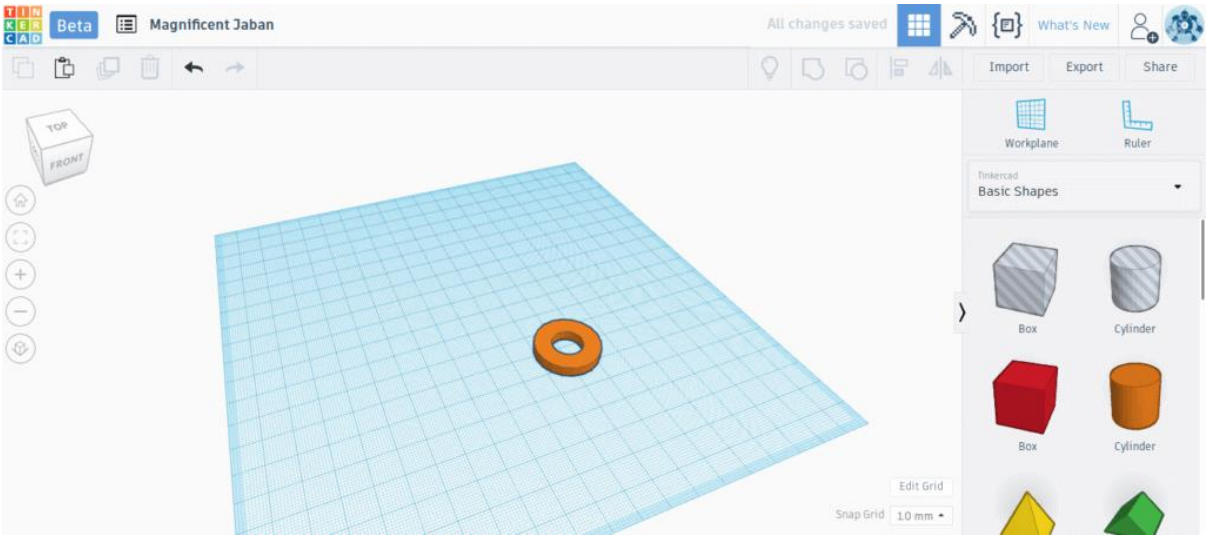
The disk and the cylinder-shaped hole are now perfectly aligned.

Grouping the Cylinder-Shaped Hole and the Disk to Create the Ring

8. When the two shapes are aligned, press the "Group" button in the top menu (marked in the blue rectangle). The Group button essentially joins two shapes together. However, if one of the shapes is a hole, then it creates a hollow area instead.



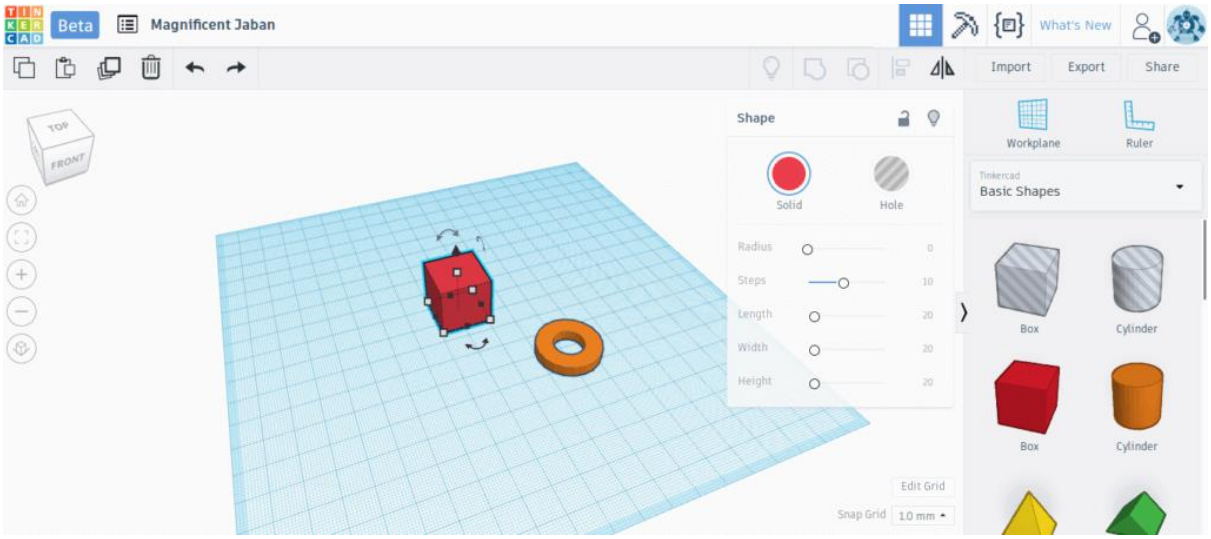
We have finished the first step in creating our wrench.



Design the Handle

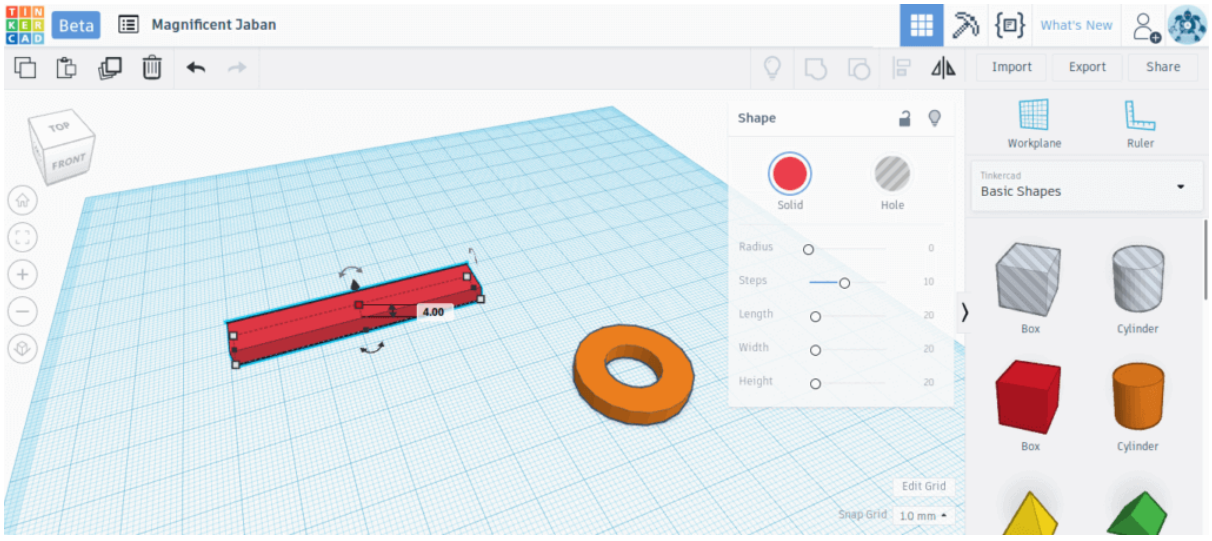
The handle is probably the easiest part of the wrench.

9. The handle is rectangular. So, we simply drag a box from the basic shapes panel into the workplane.



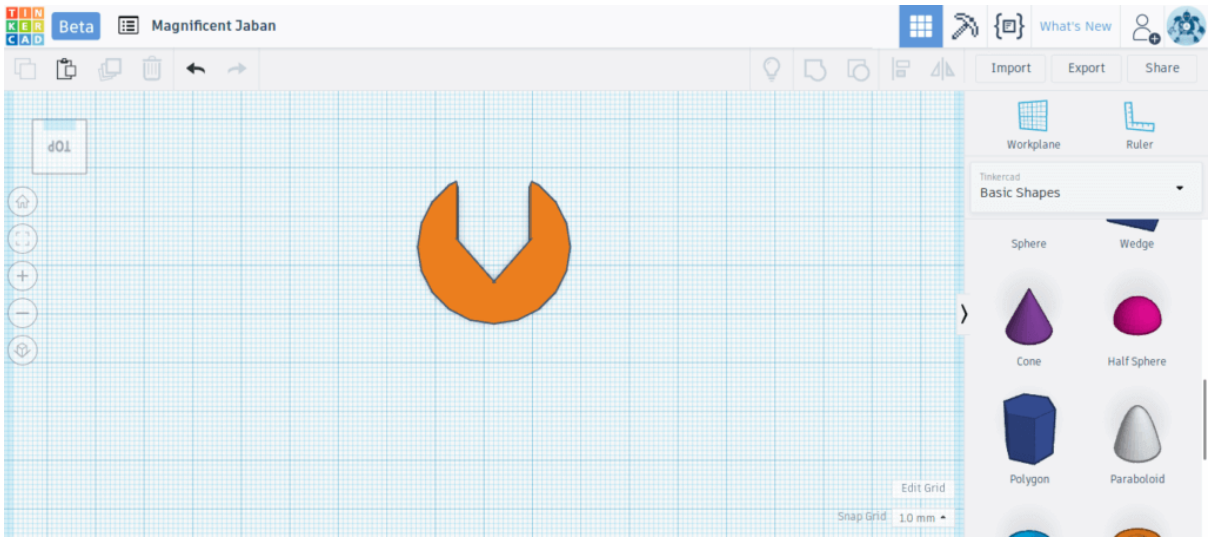
10. Using the white handles on the plane, we set the length of the box to 100mm, the width of the box to 10mm.

11. By dragging the white handle on the top of the box, we set the height to 4mm so that it matches the height of the solid ring.

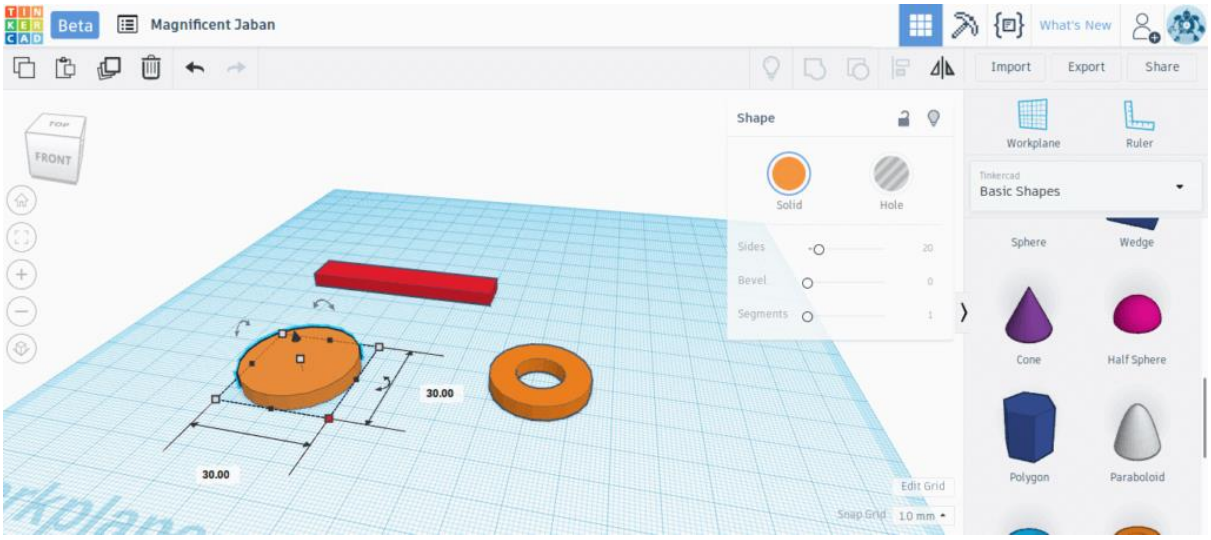


Design the Jaw

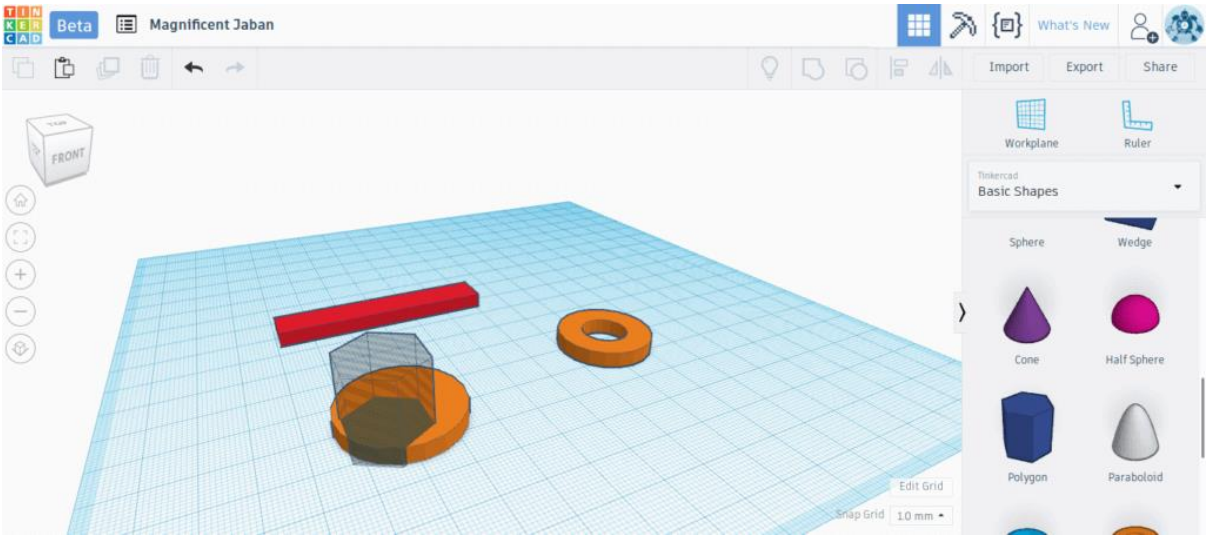
The design of the jaw is also a circular disk, but with a polygonal hole carved out at an angle.



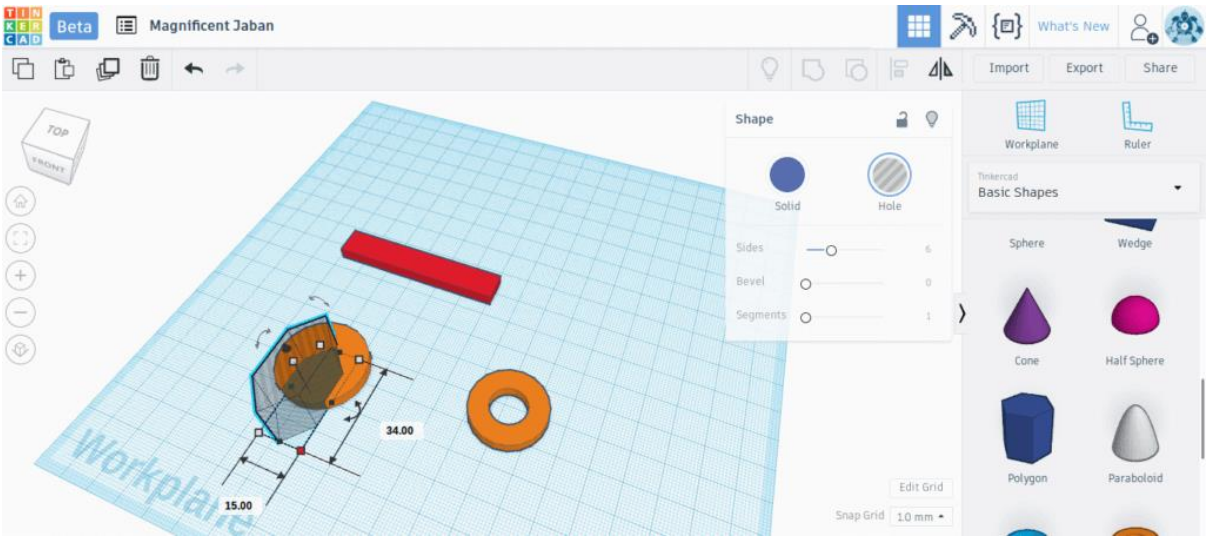
12. As with the ring, we first need to create a circular disk of diameter 30mm and height 4mm. We have done this before, so you should be able to do this step without much problem.



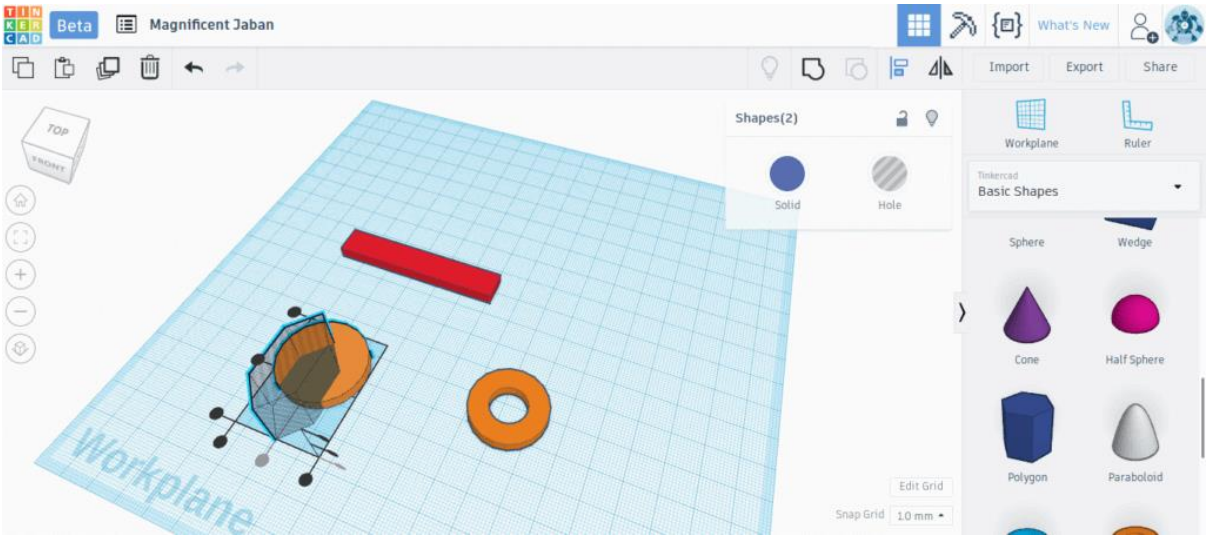
13. To create the jaw like shape, we will use the basic shape called “Polygon”. Drag the Polygon to the workplane, select it, and turn it into a hole. Now position the Polygon and adjust its dimensions.



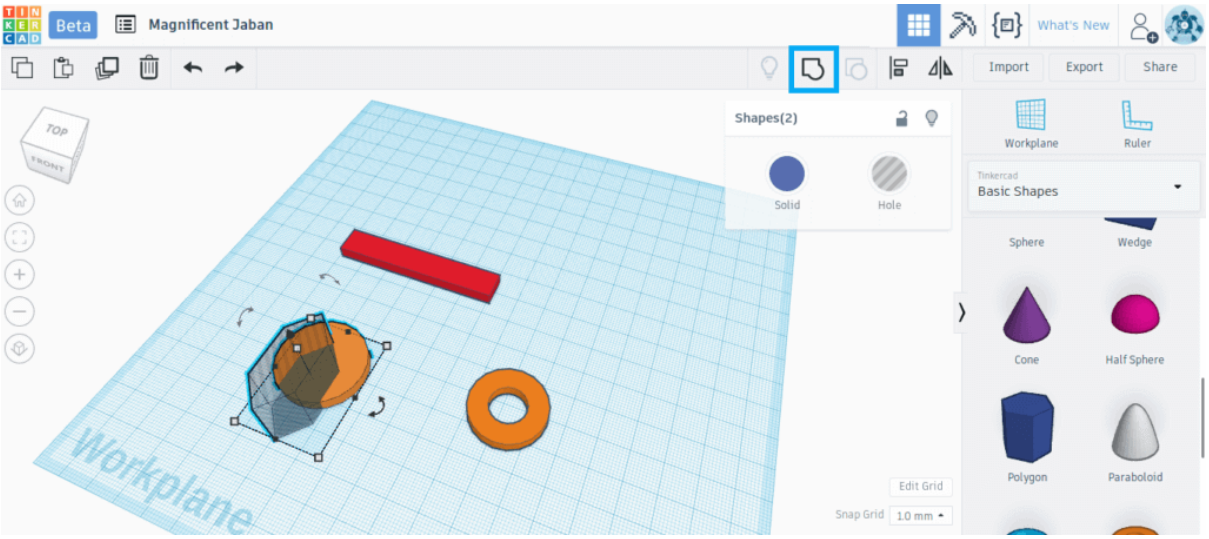
14. If you are planning to use the wrench from this Tinkercad tutorial for household repairs, you can choose the dimension of the corresponding nut and bolt. We will use a 15mm jaw and adjust the width of the polygon to 15mm accordingly.



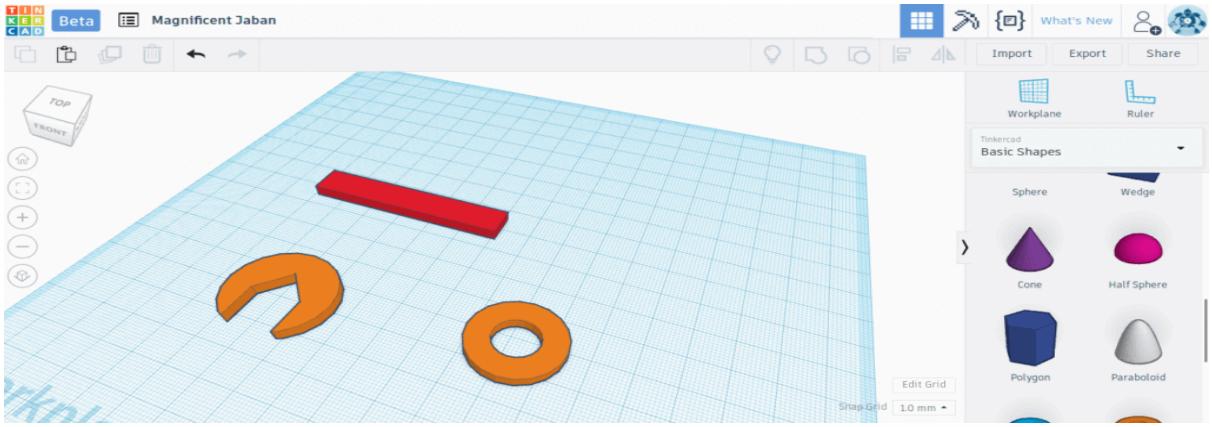
15. Make sure the polygon is aligned with the center of the disk by using the alignment tool.



16. Now we will do some subtraction. Select both the polygonal hole and the disk by holding shift and selecting both. When they are selected simultaneously, press the Group button on the top menu (marked in the blue rectangle).



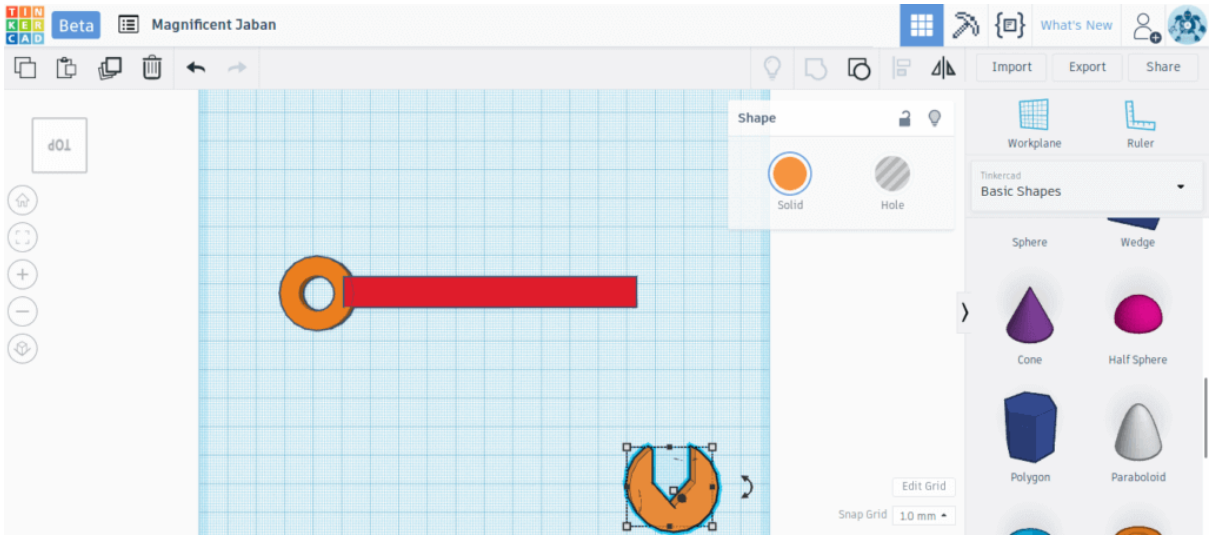
Putting it All Together



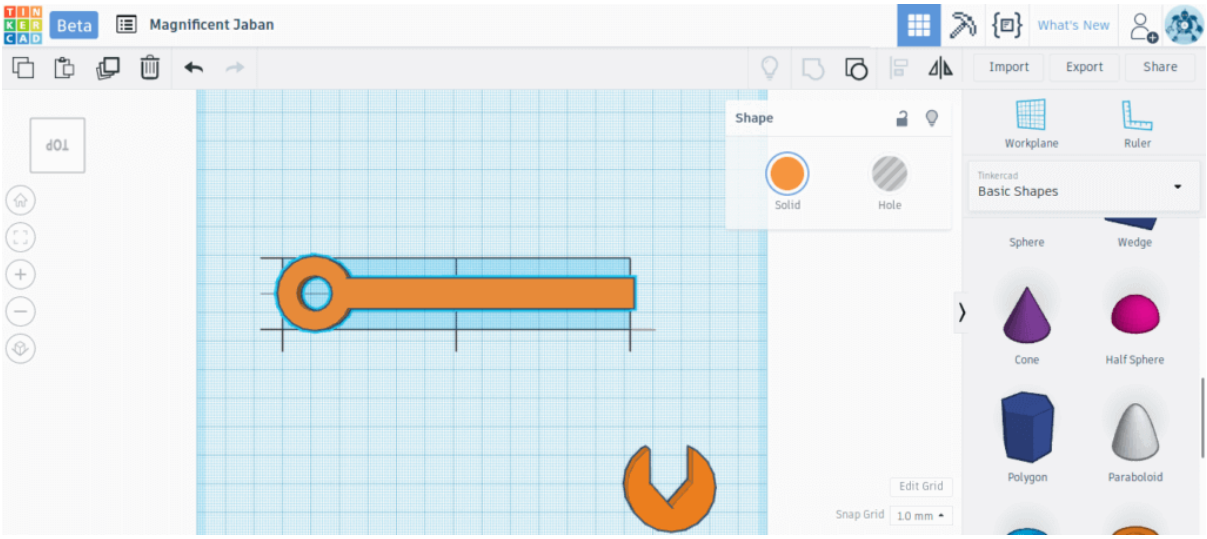
We have so far designed the individual parts of the wrench. Now it is time to put it all together.

Merging the Handle and the Ring

First, position the handle so that it goes a little bit into the body of the ring.



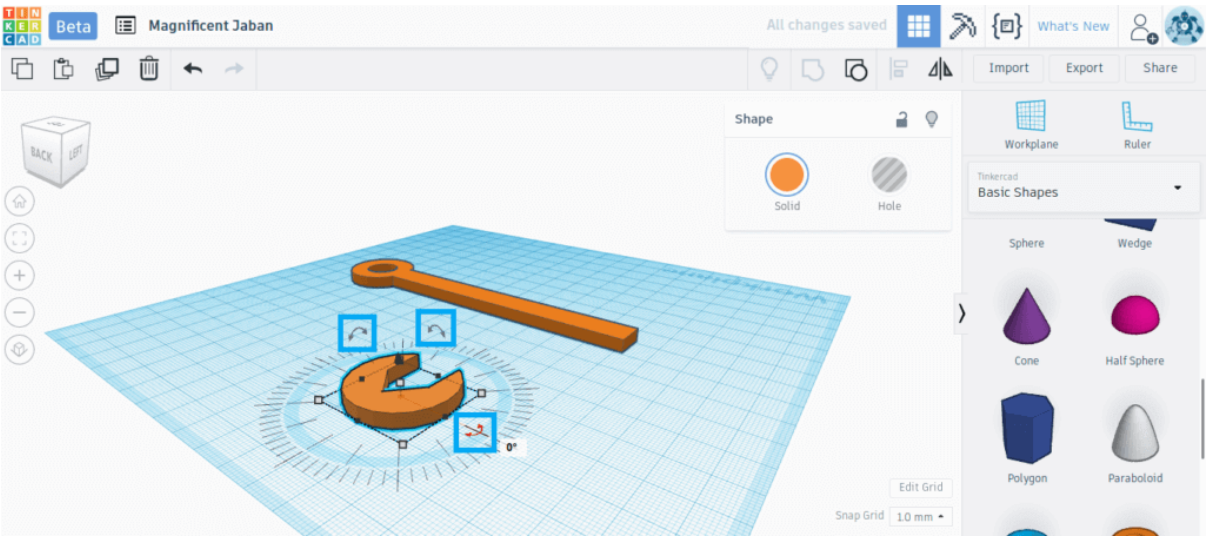
17. Select the handle and the ring together and align it so that the handle aligns with the center of the ring. Now press the Group button. This should merge the handle and the ring into one continuous unit. Notice that the merged unit now has a single color instead of two colors.



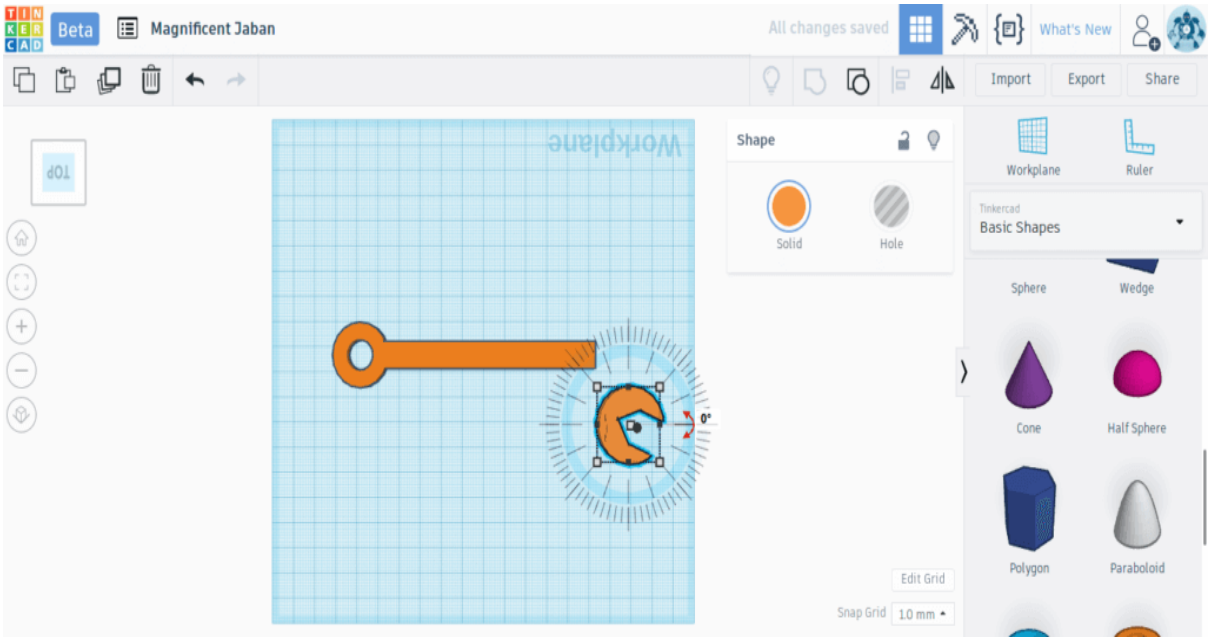
Rotating the Jaw

The jaw is facing the wrong direction. We need to fix that by rotating it.

18. To rotate the jaw, first select it. You will see that in addition to the white square handles that we have used before, there are three curved handles with double arrows (marked in blue rectangles).



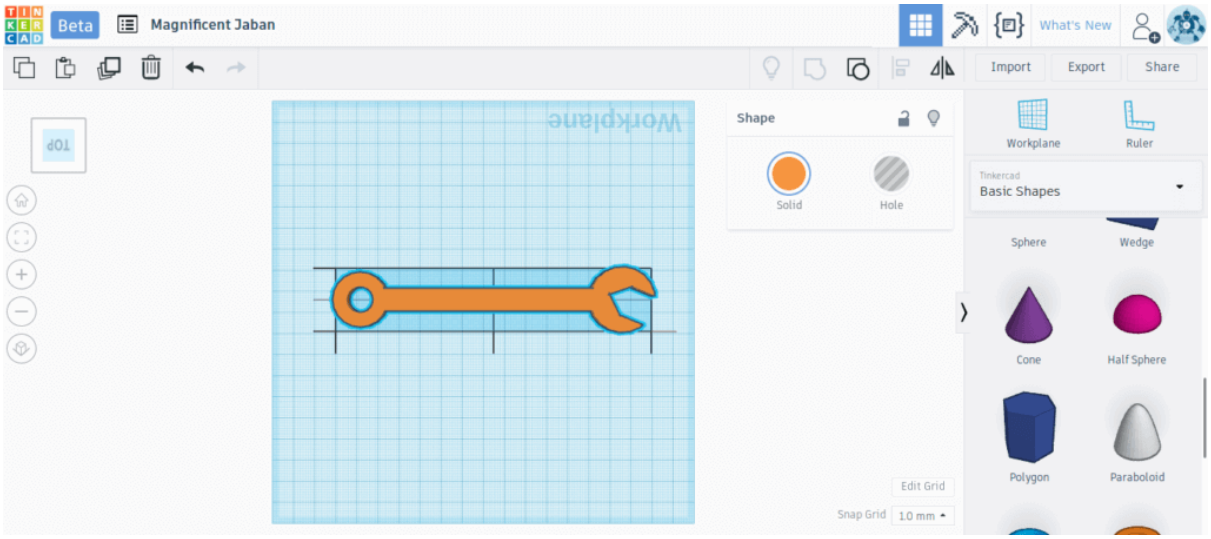
19. These are the rotation handles. Use the X-Y plane rotation handle to rotate the jaw so that it faces the direction shown in the figure below.



Merging Everything Together

Now let's add the jaw to the previously merged unit. The procedure is more or less the same as what we used for adding the handle and the ring.

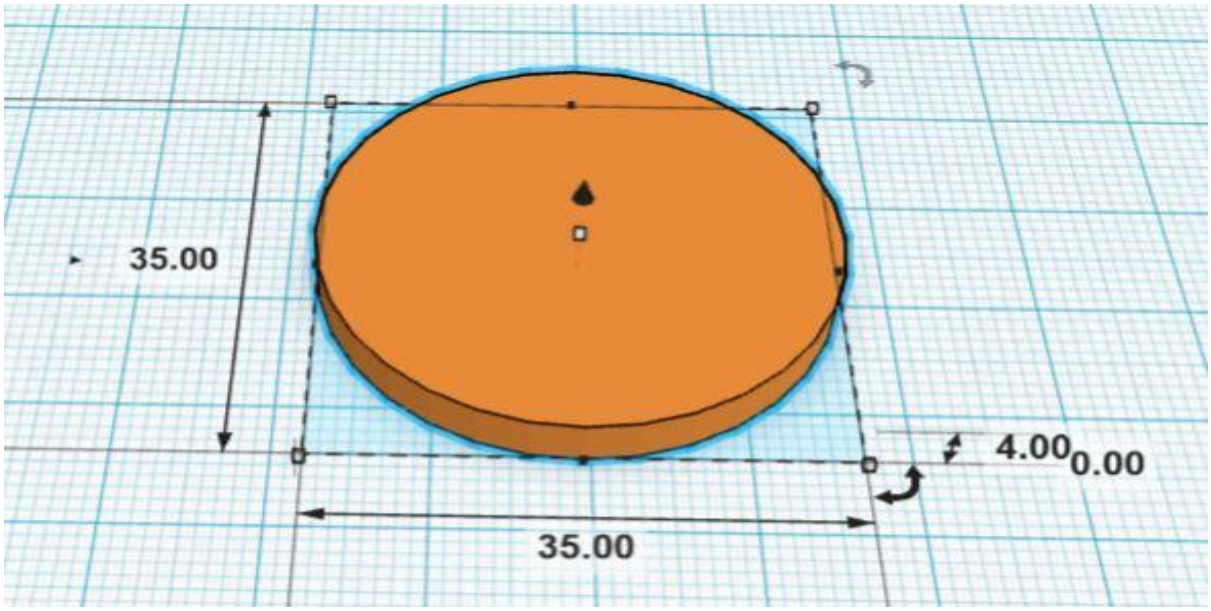
20. First, drag the jaw and position it so that the handle goes a little bit inside the body of the jaw. Select the jaw and the merged unit simultaneously and align them so that the handle aligns with the centre of the jaw. Press the Group button to merge them.



Chapter 4- Gear

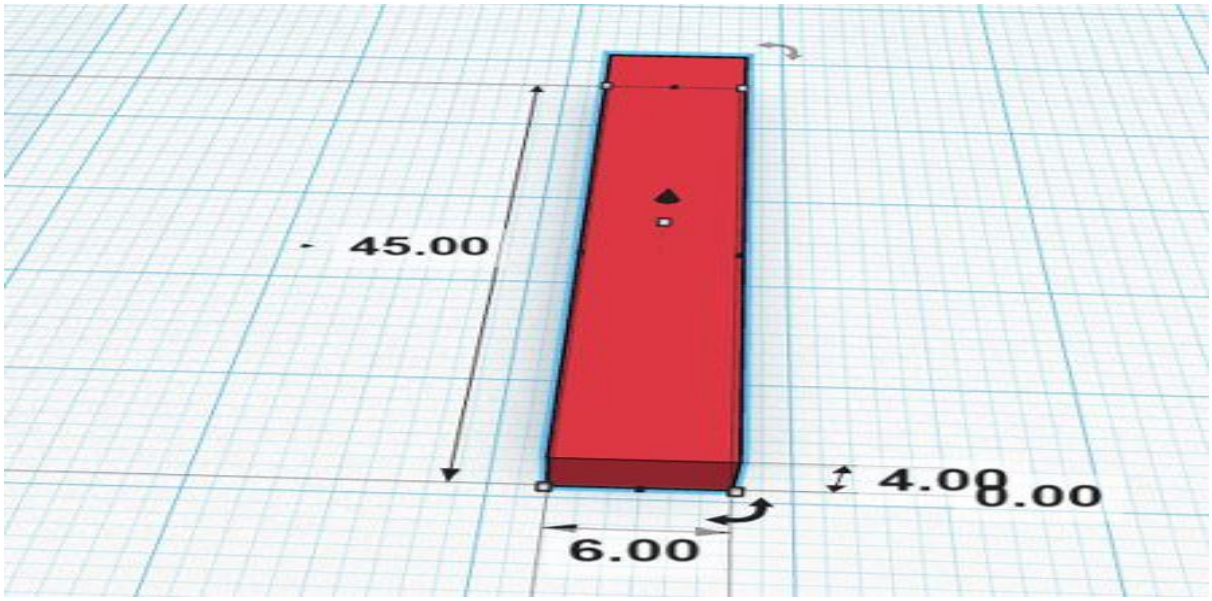
Adding a Cylinder

1. Click and drag a cylinder onto the work plane.
2. Change the cylinder dimensions to 35mm x 35mm x 4mm.



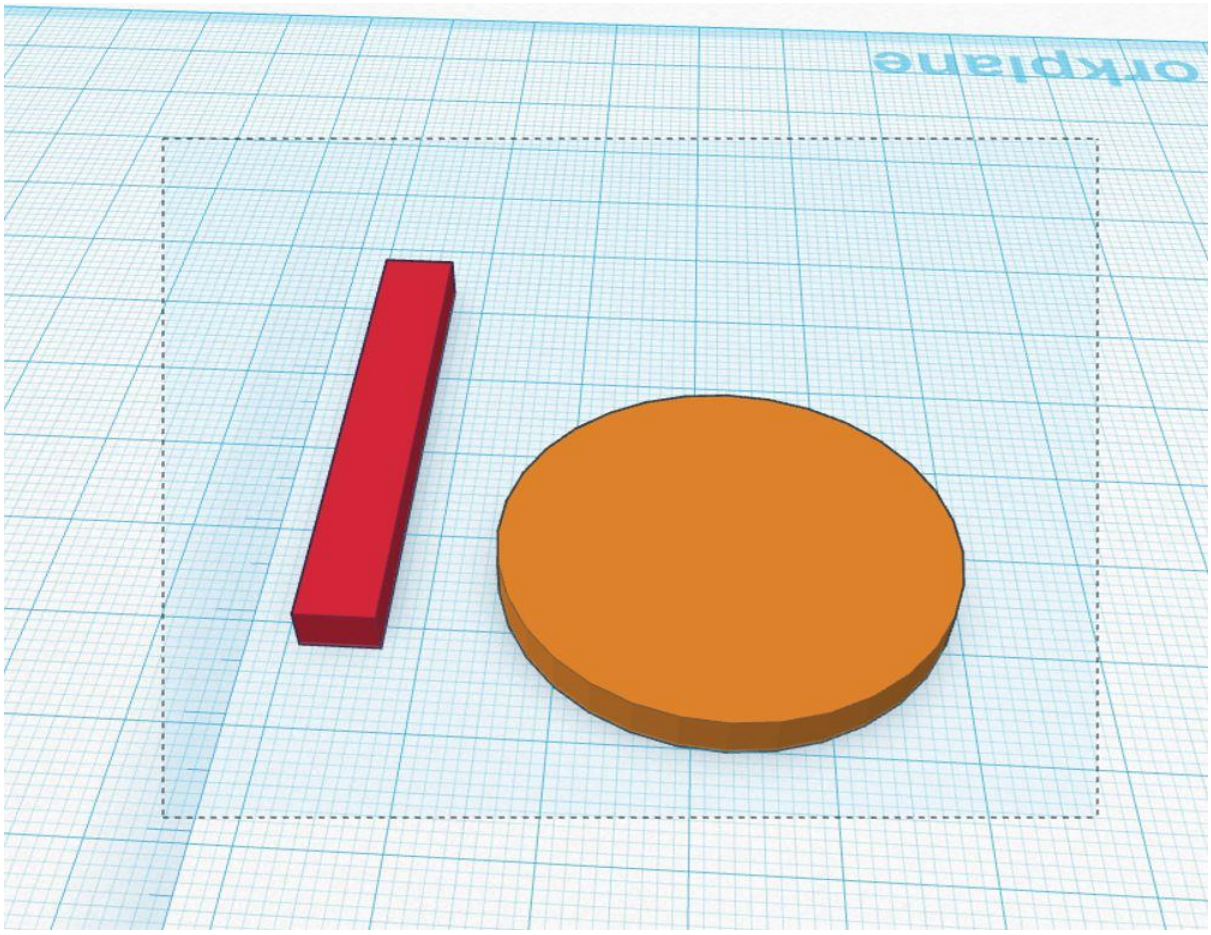
Adding a Box

3. Click and drag "box" onto the work plane.
4. Change the box dimensions to 45mm x 6mm x 4mm.

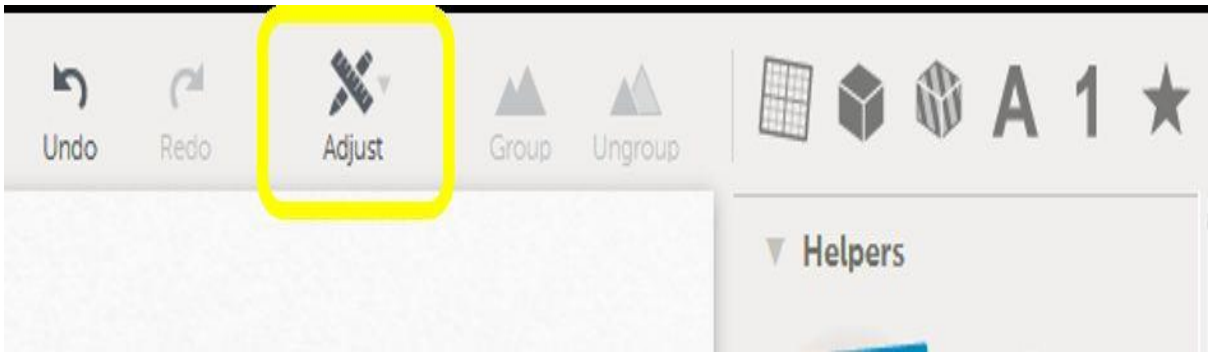


Centering the Box in the Circle

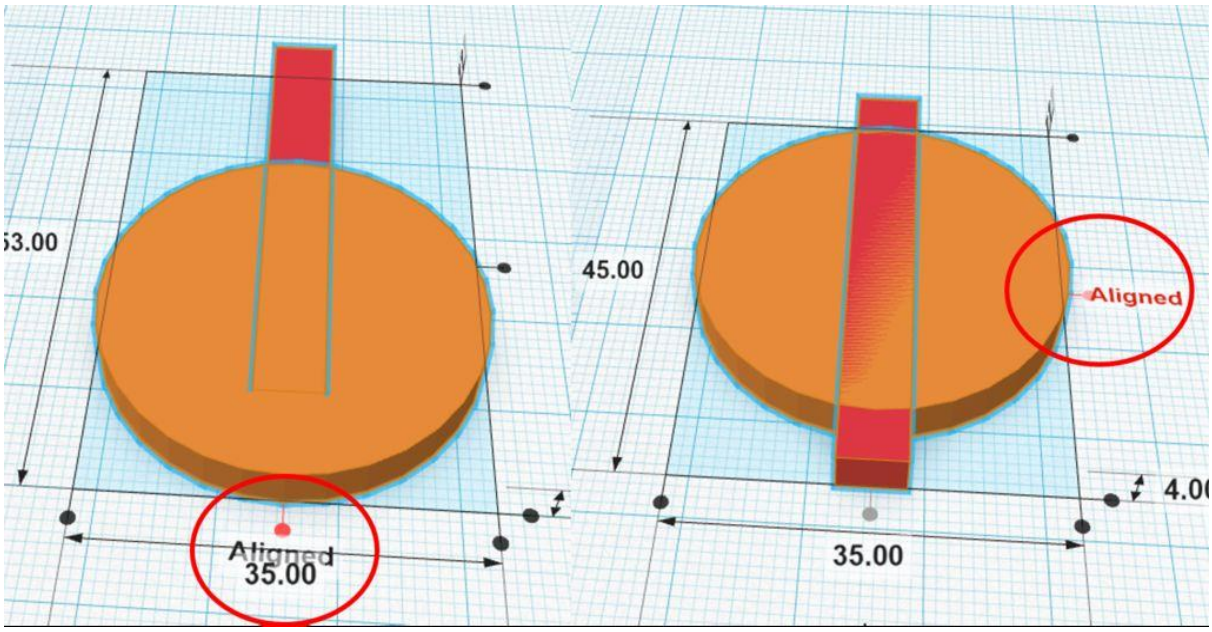
5. Left click and drag to select both the cylinder and the box.



6. Select "Adjust" on top right drop down menu



7. Select "Align" from drop down menu. Click on the two middle dots to center.
8.



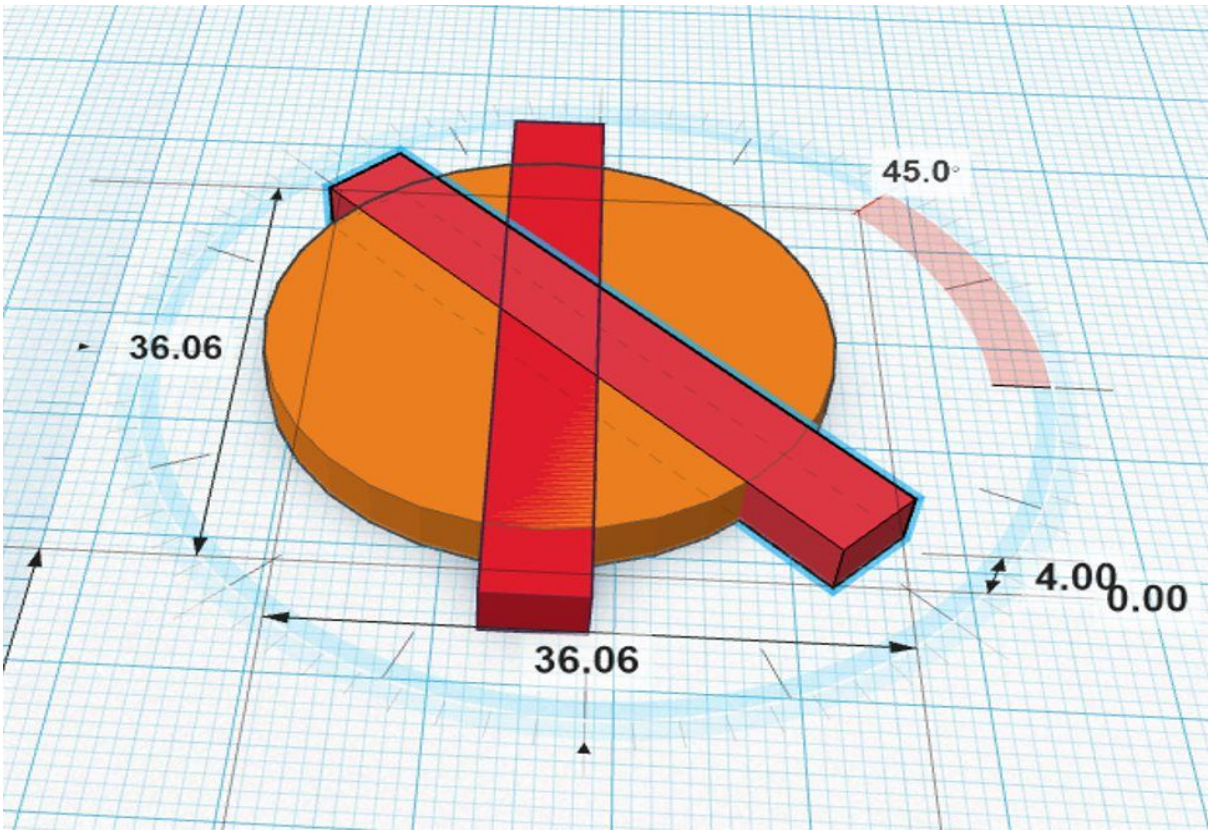
9. Once aligned, click the "x" on the bottom of the screen to close the align function.

Adding More Boxes

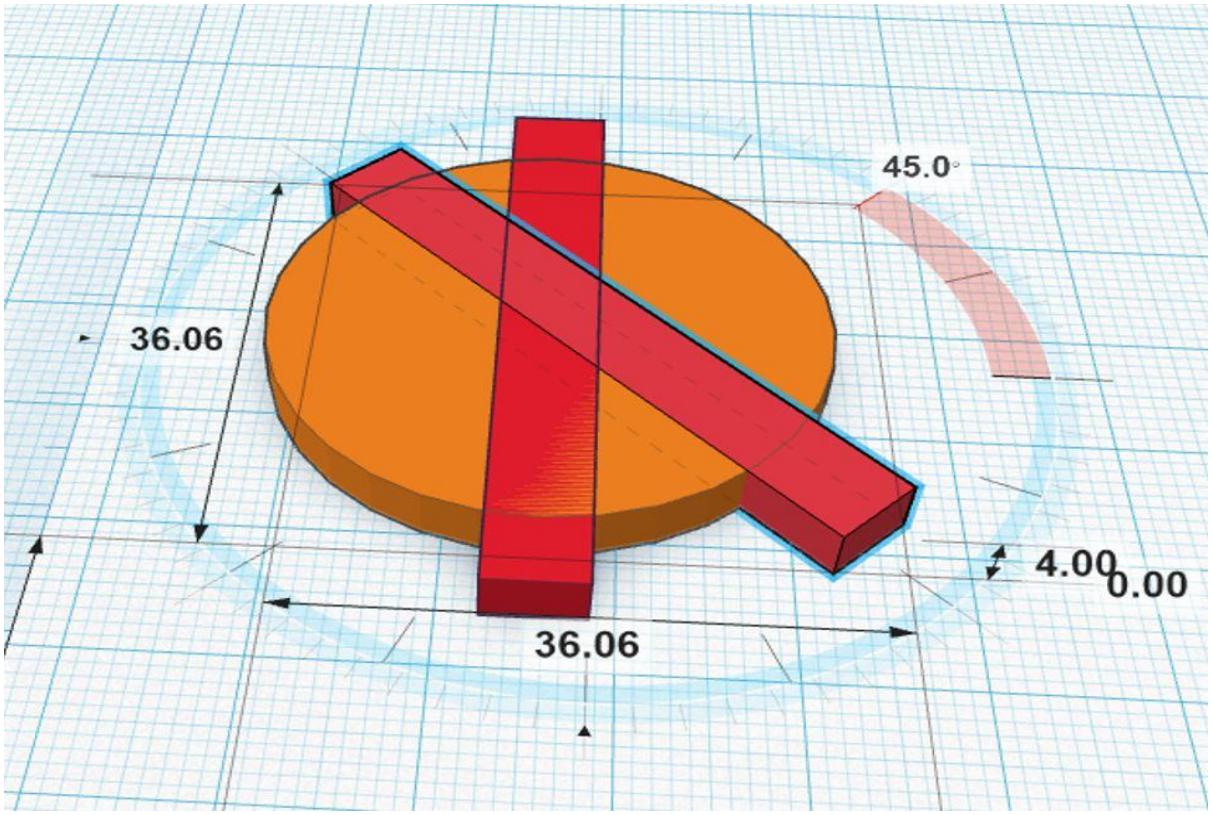
10. Copy this shape by typing "ctrl" + "C", or clicking "edit" + "copy".
11. Paste this shape by typing "ctrl" + "V", or clicking "edit" + "paste".

12.Using the curved arrow, rotate this box within the circle 45 degrees.

13.Use the align tool again to center the new box.



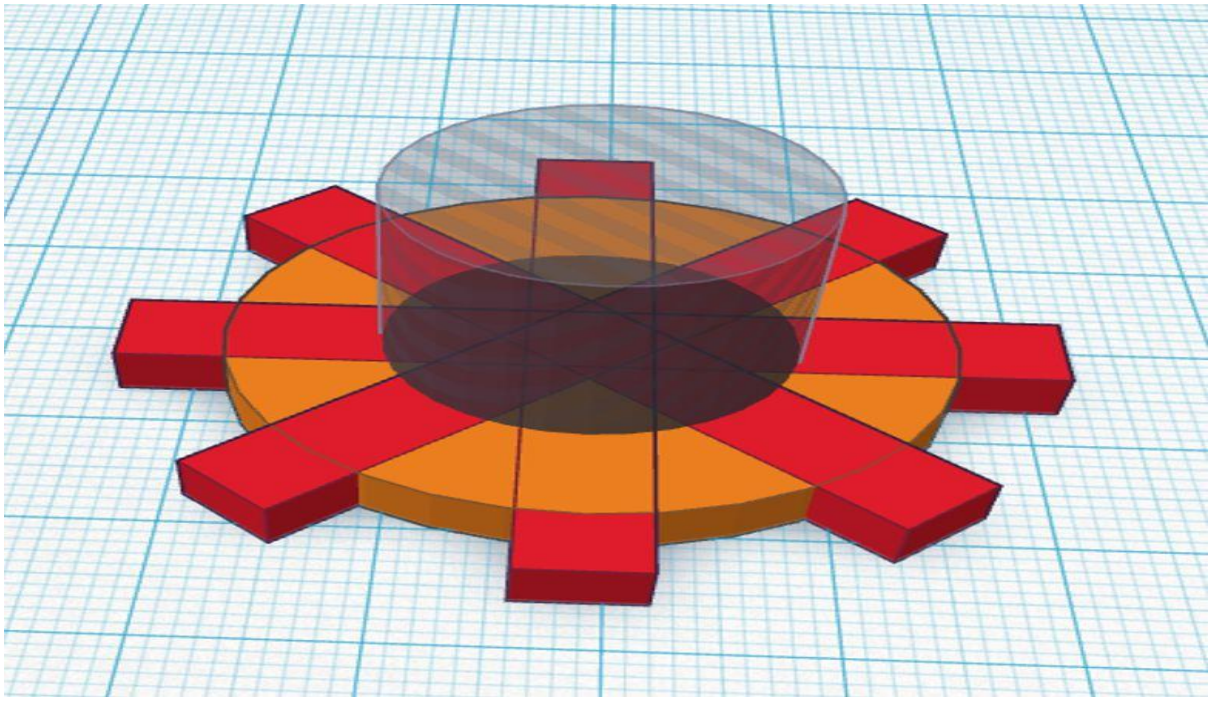
14. Copy, paste, rotate, and align two more boxes.



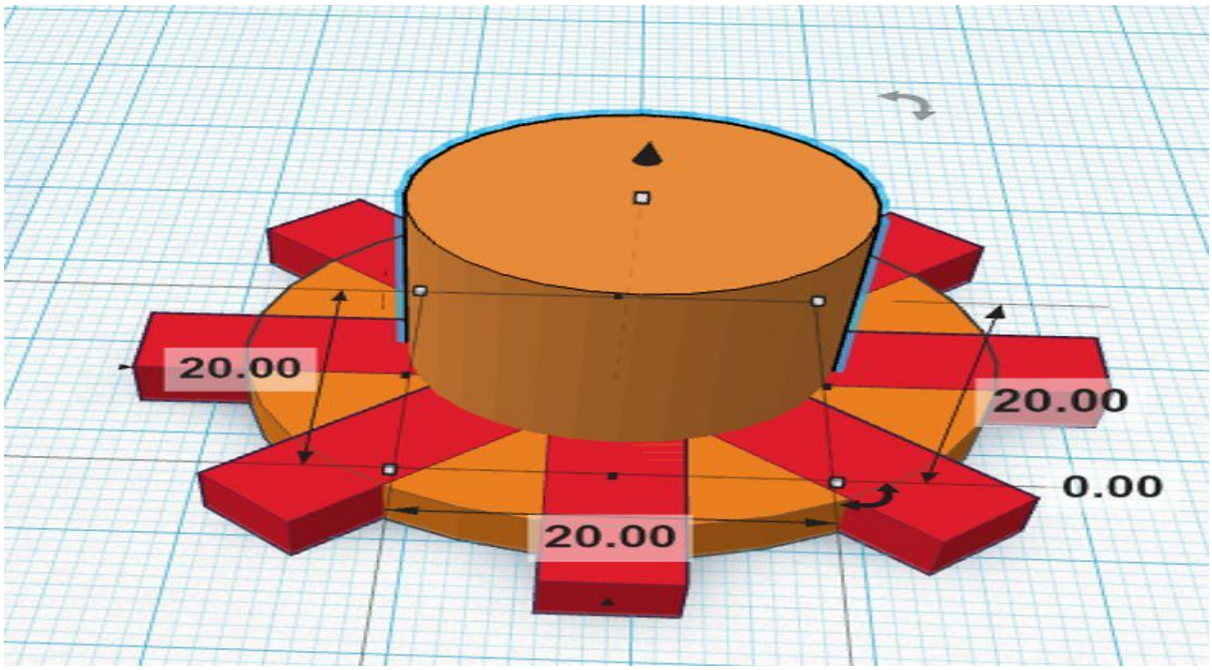
Adding the Hole

15. Drag and drop another cylinder onto the work plane. Do not resize.

16. Drag and select every shape and use the align tool to center.

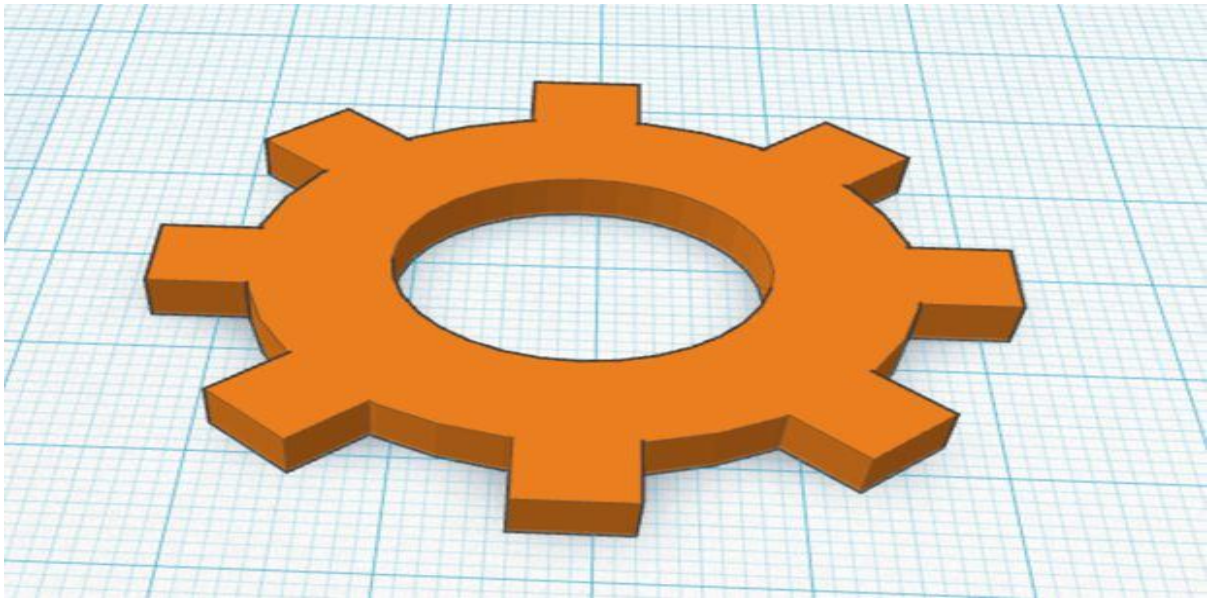


17. Select new cylinder, then click "hole" in top right of the screen.



18.Click and drag to select all shapes.

19. Select new cylinder, then click "hole" in top right of the screen.



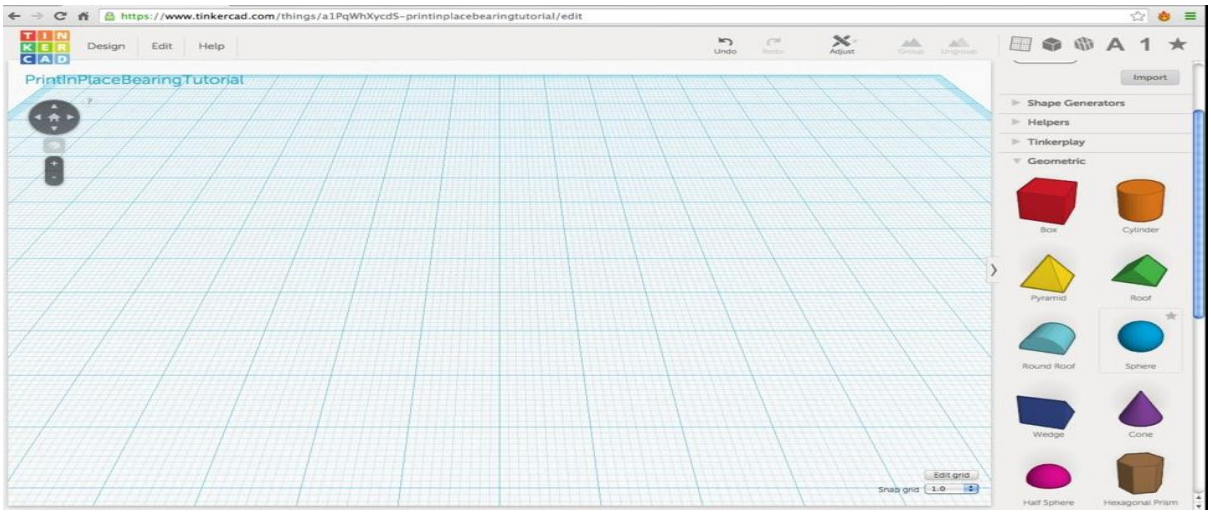
Chapter 5- Ball Bearing

Set the Snap Grid

Set the Snap Grid to 1.0 (located below “Edit Grid”).

Create the First Ball Bearing

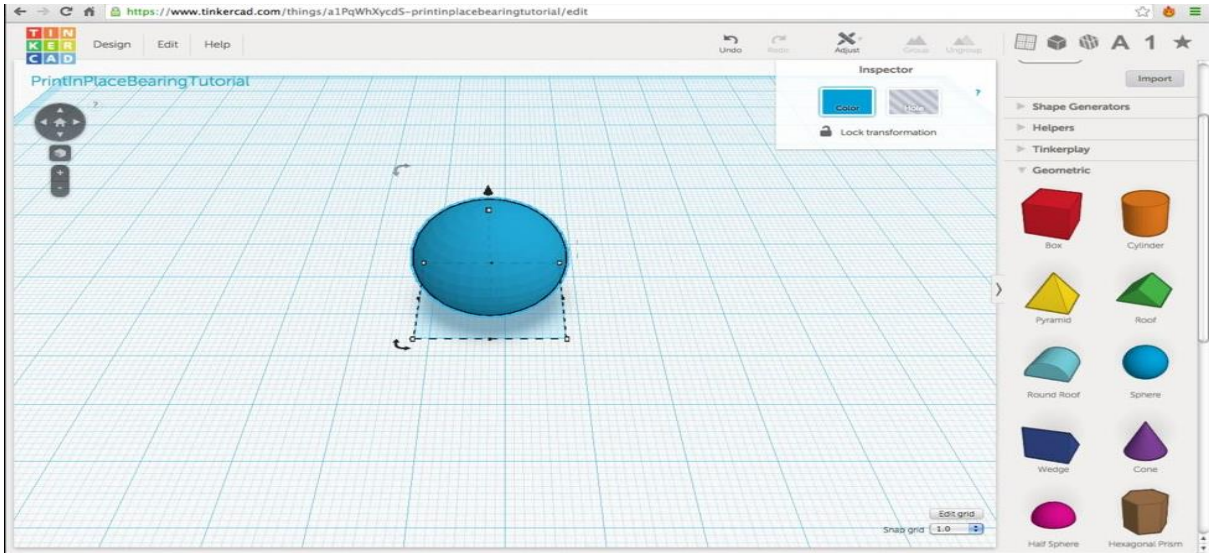
1. Use the Mouse to go to right side of Tinkercad interface, click on “>Geometric” then left click on “Sphere” and drag it to the Workplane.



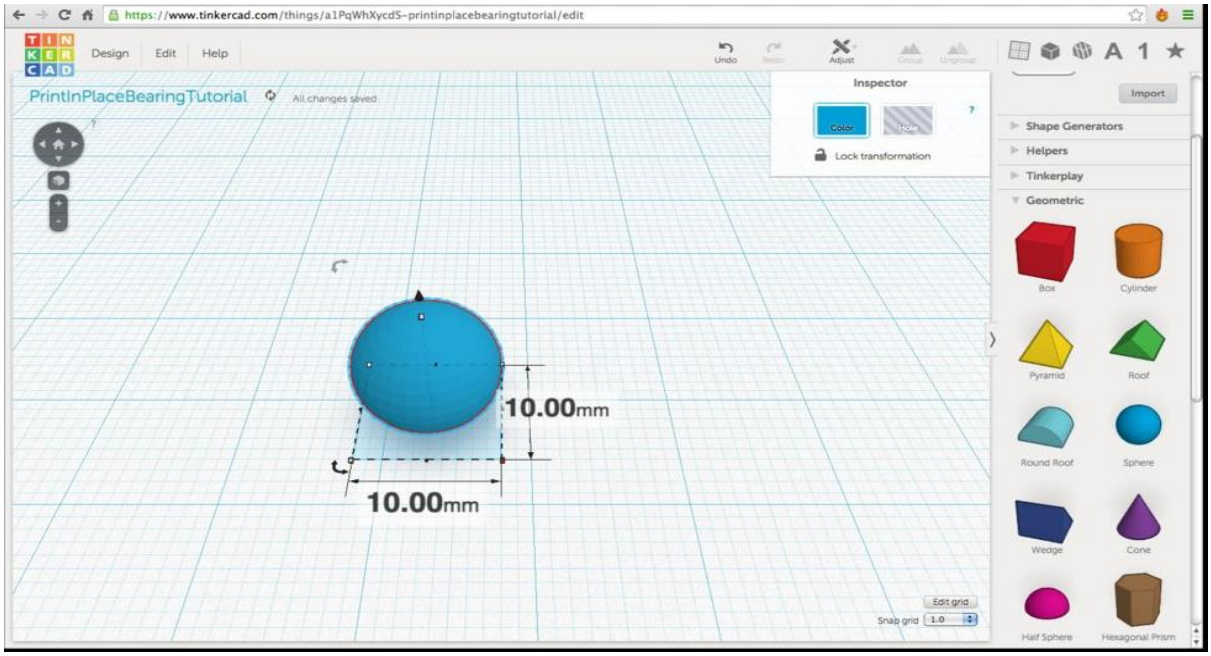
2. Once the sphere is on the Workplane, make sure it is selected. If it is selected, then you will see a square around it called a bounding box.

The bounding box is comprised of the white-box corner control handles, black-box side control handles and the black elevation control cone, as well as the rotation controls.

If it is not selected, then simply left click on the sphere and it will be selected.

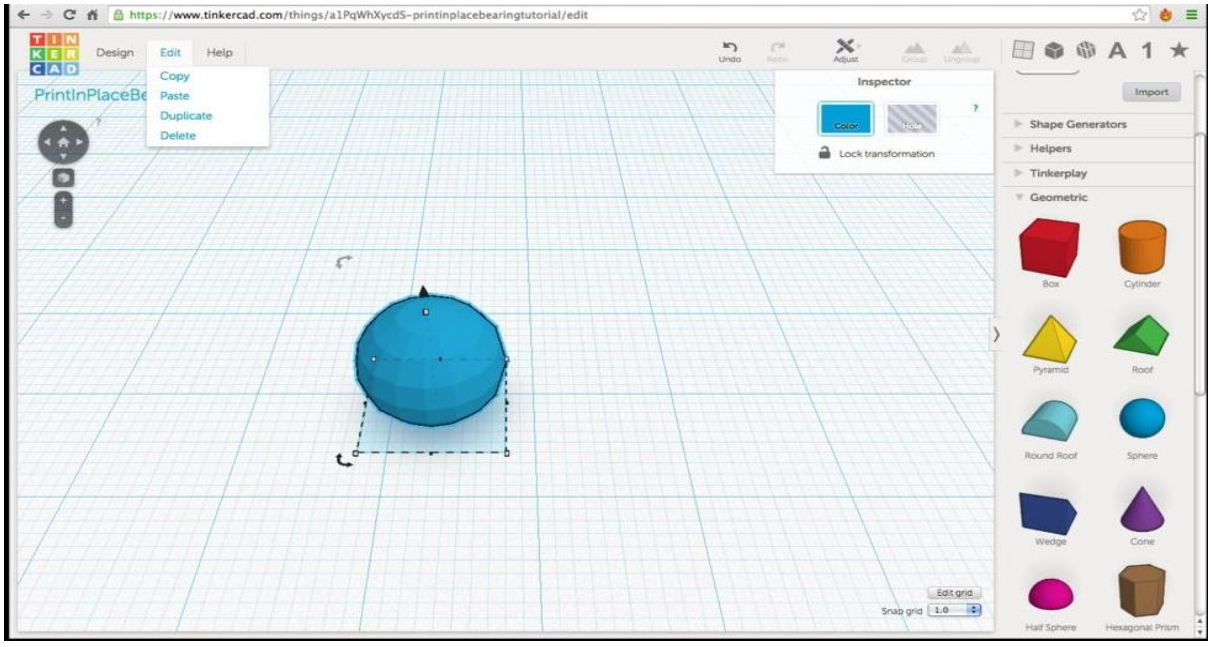


3. Using the Shift key and Left Mouse button, click and drag one of the white-box control handles. This will scale the sphere equally in all directions.
   Scale the sphere down to 10.00mm.



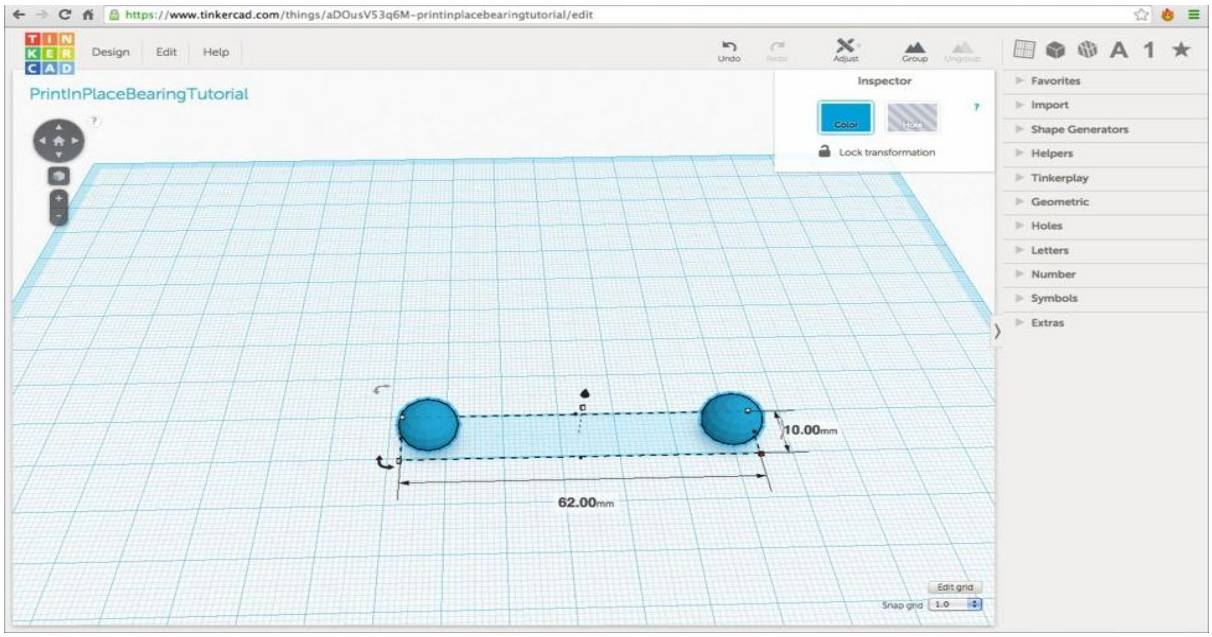
Create the Circle of Ball Bearings

4. While the sphere is selected, click on “Edit” in the upper left area of the Tinkercad interface. Click on “Duplicate”. This will create a duplicate of the sphere in the exact position as the first.



5. Move the duplicate (which should still be selected) 52mm to the right on the X axis. Since our grid is set to 1.0, we could use the right arrow on the keyboard and press it 52 times. This will move the duplicate sphere exactly 52mm to the right.

Math Involved: Our bearing assembly is going to have sixteen 10mm balls arranged in a circular pattern and we know that we need at least .2mm between each ball. The circumference of this circle can be calculated by using this equation: Circumference = 16 x 10mm + 16 x .2mm (or more simply Circumference = 16 x 10.2) The circumference equals 163.2mm and if we divide that by PI, we arrive at a diameter of 51.94mm. In this case, rounding up to a 52mm diameter is appropriate as it increases that gap between each ball from .2mm to .21mm.



6. Verify that the spheres are 52mm apart. This can be done by selecting both spheres. If one sphere is already selected, then using the Shift key and Left Mouse button, click on the unselected sphere.

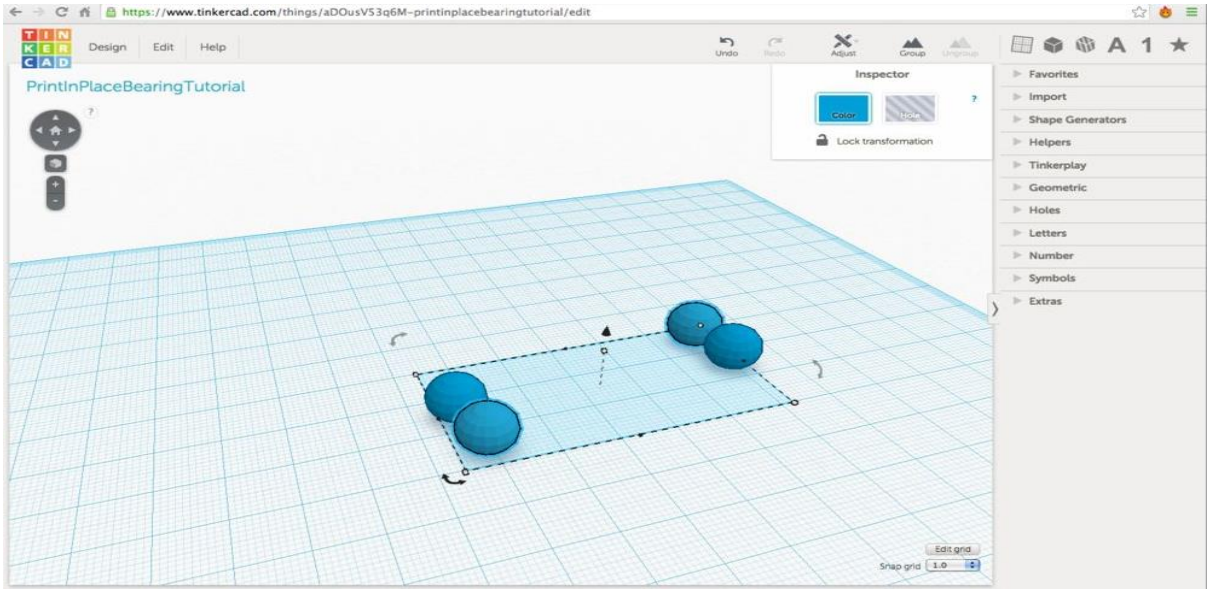
The bounding box will now be seen to extend around both spheres. Simply hover the cursor over one the corner white-box control handles and the dimensions will now be displayed. Hopefully, you will see 10.00mm x 62.00mm.

7. If not, then we'll need to adjust. Make a mental note of the dimension you saw and figure out how much more or less you need to move the sphere. If you saw, for example 10.00mm x 59.00mm, then you know you would need to move one the spheres 3mm to achieve the dimension of 62.00mm. Deselect one of the spheres by using the Shift key and Left Mouse button to click on the sphere you wish to deselect.

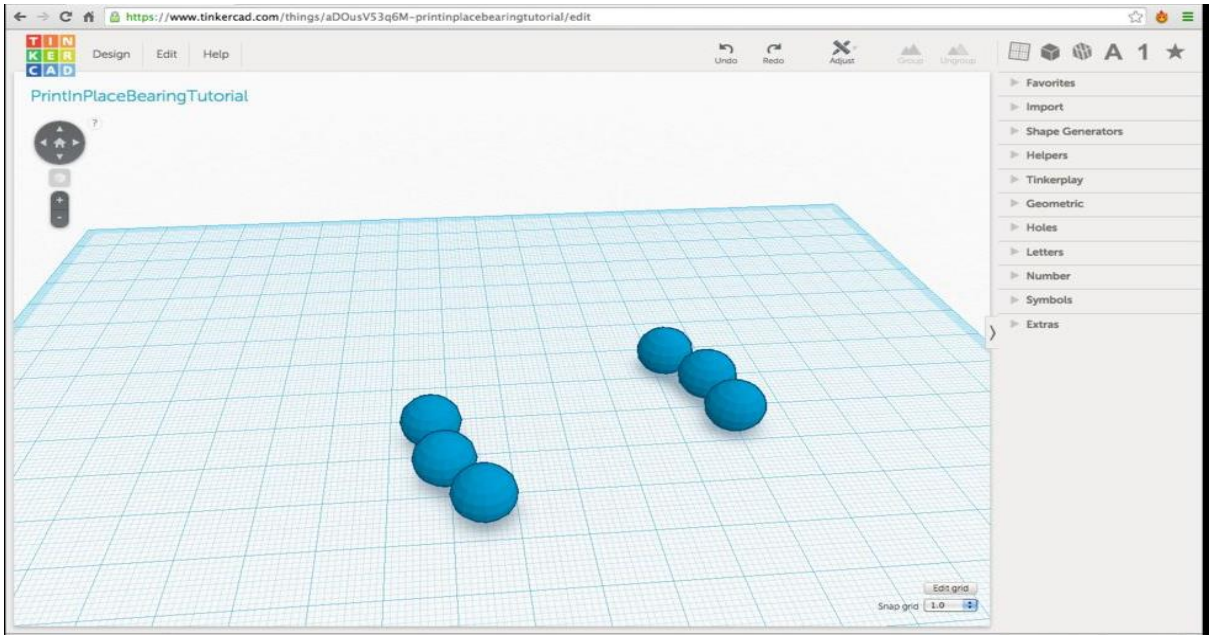
This should leave the one of the spheres selected. Now use the arrow on the keyboard left or right the desired number of times until you get a dimension of 10.00mm x 62.00mm.

8. Select both spheres. While spheres are selected, click on "Edit" and "Duplicate". This will make a duplicate of both spheres.
9. Now locate the black rotation handle. It looks like a curved set of arrows and allows you to rotate the selected object(s) in the same plane as the workplane.

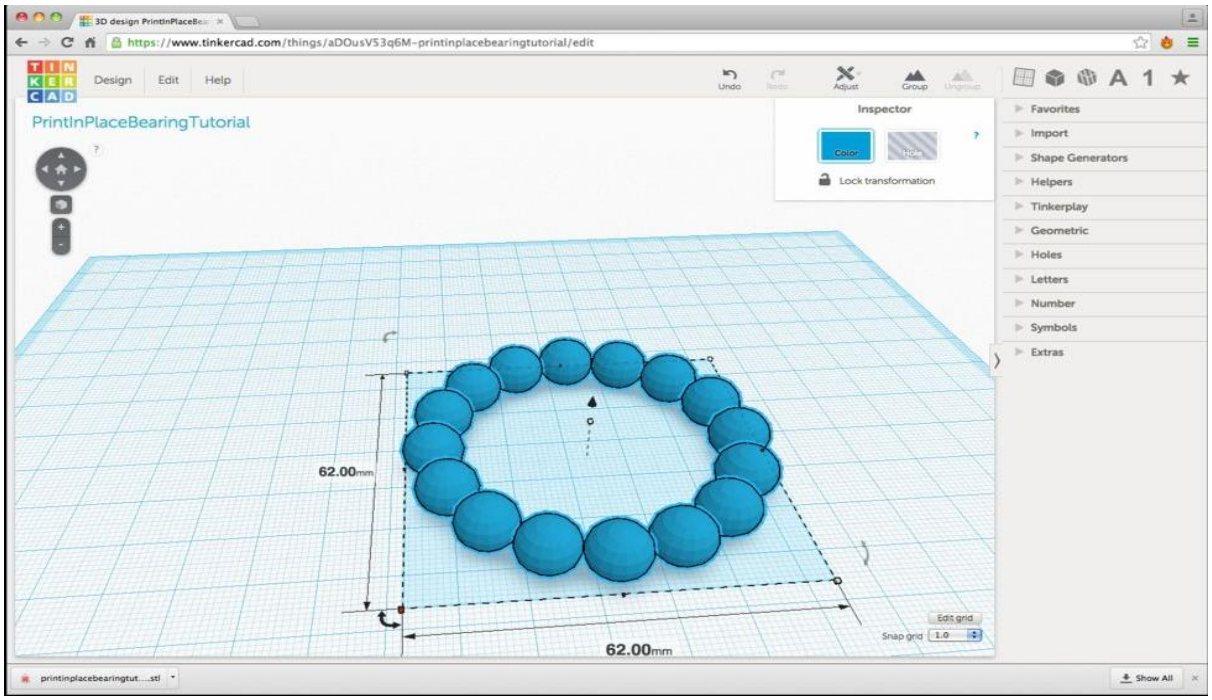
10. When your mouse is on the rotation handle, it will turn red. Using the Left Mouse, drag the rotation handle until the duplicated balls have turned 22.5 degrees.



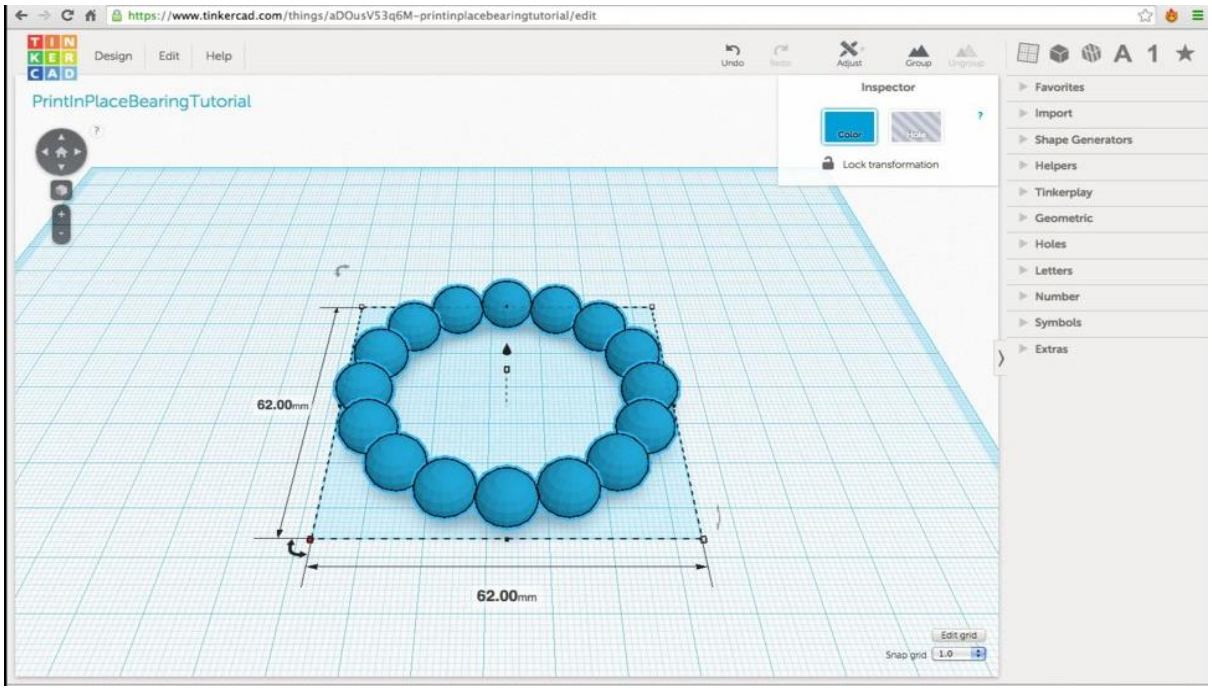
11. Click on “Edit” and “Duplicate” again. This will create another set of spheres, however, it should include that rotation.



12. Continue to click on “Edit” and “Duplicate” until there is a complete circle of balls.

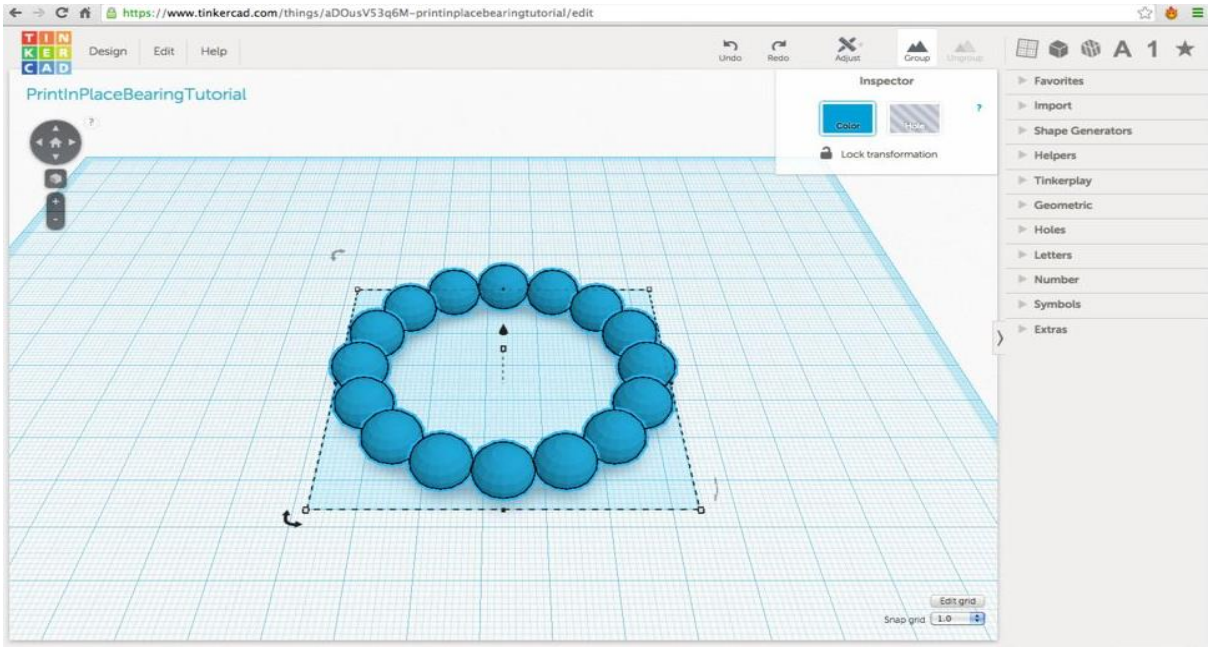


13. Verify that the group has the correct dimensions of 62.00mm x 62.00mm x 10.00mm.
14. On a PC, pressing Control and A will select all objects. (On a Mac, Command and A does the same.



With all objects selected, hover the cursor over the white-box corner controls to see the X and Y dimensions. Then, hover the cursor over the white-box depth control to see the Z dimension.

15. With all objects selected, click on “Group” on the upper part of the Tinkercad interface. You will have 16 balls.



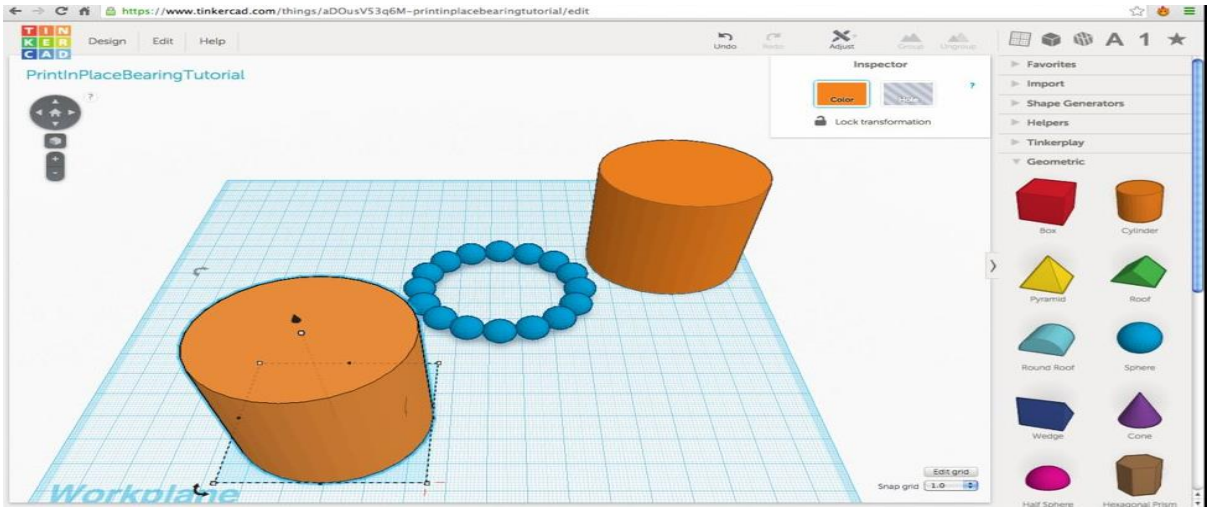
Make a Reference Cylinder

16. Use Mouse to go to right side of Tinkercad interface, click on “>Geometric” then left click on “Cylinder” and drag it to the Workplane.
17. With the cylinder selected, use the Shift key and Left Mouse button to click and drag one of the white-box control handles and scale the cylinder to 52mm in all directions.

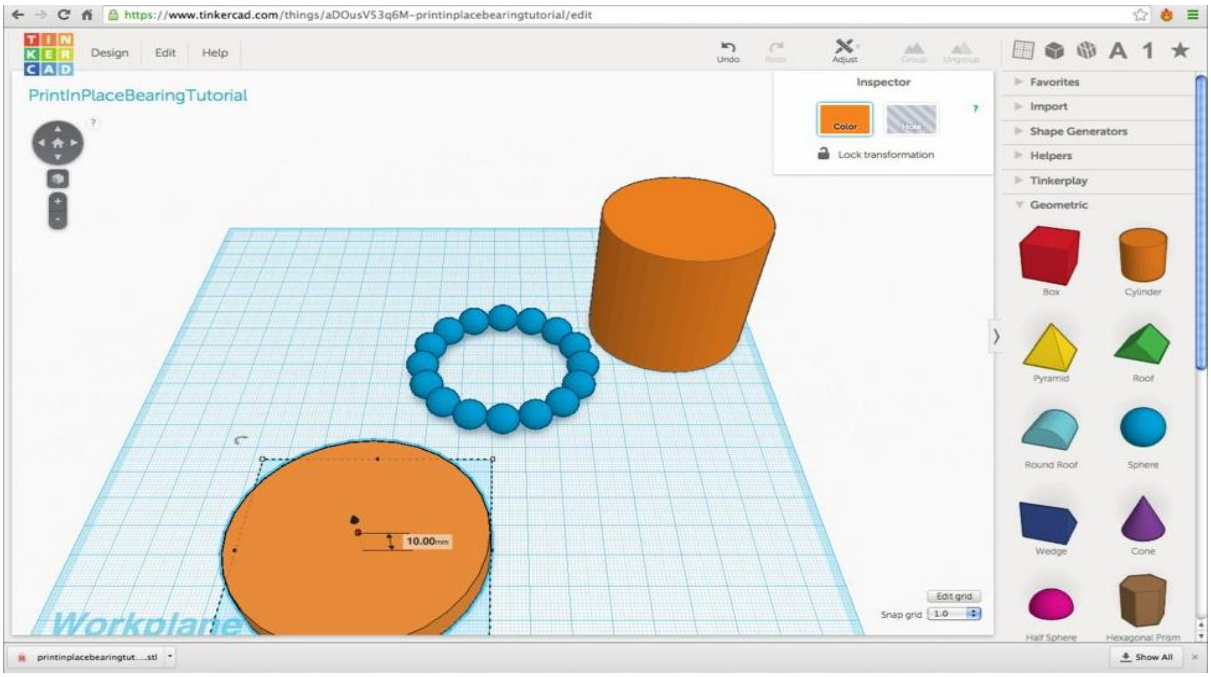
Make Outer Diameter of Bearing Assembly

In this step, we'll be making the overall size of the bearing assembly, focusing on the OD (outer diameter)

18. Select the reference cylinder that was just made and click on "Edit" and "Duplicate".
19. While the duplicate is selected, use the Left Mouse button to grab and move the new cylinder and drag it to the front of the Workplane.



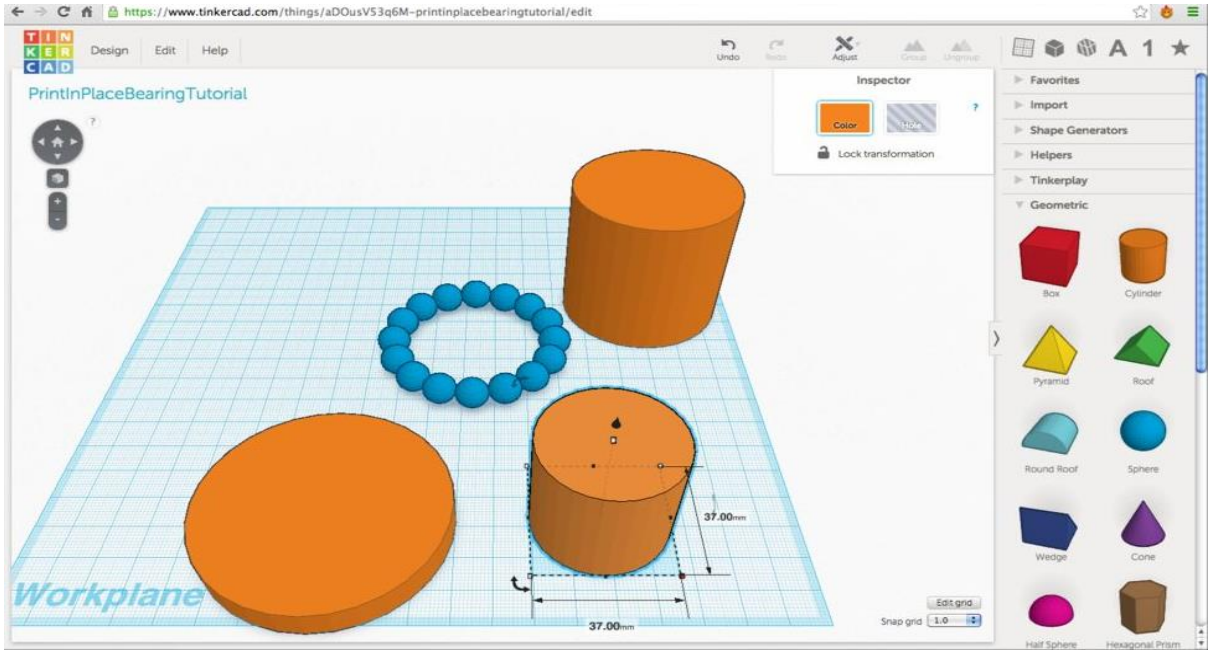
20. Use the Shift key and Left Mouse button to click and drag one of the white-box control handles and scale the cylinder to 67mm (Note: 67mm is 15mm greater than 52mm) in all directions. Then, with just the Left Mouse button, click and drag the top white-box depth control handle and scale the depth to 10mm.

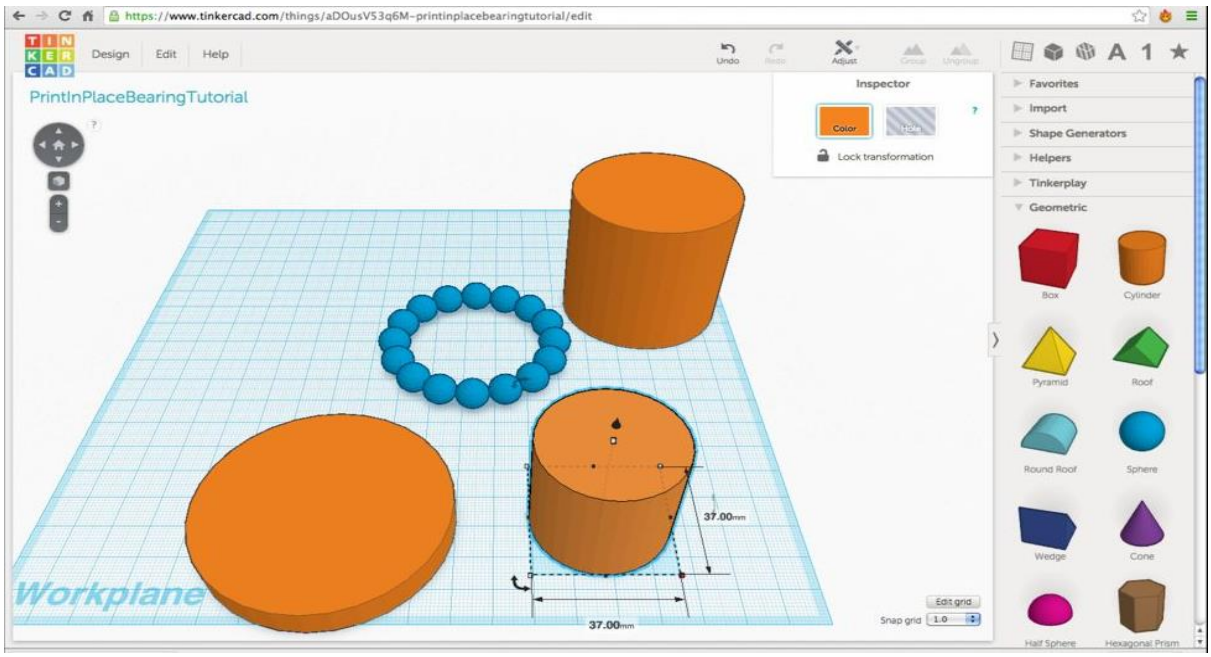


Make Inner Diameter of Bearing Assembly

In this step, we'll be making the inside hole of the bearing assembly, focusing on the ID (inner diameter)

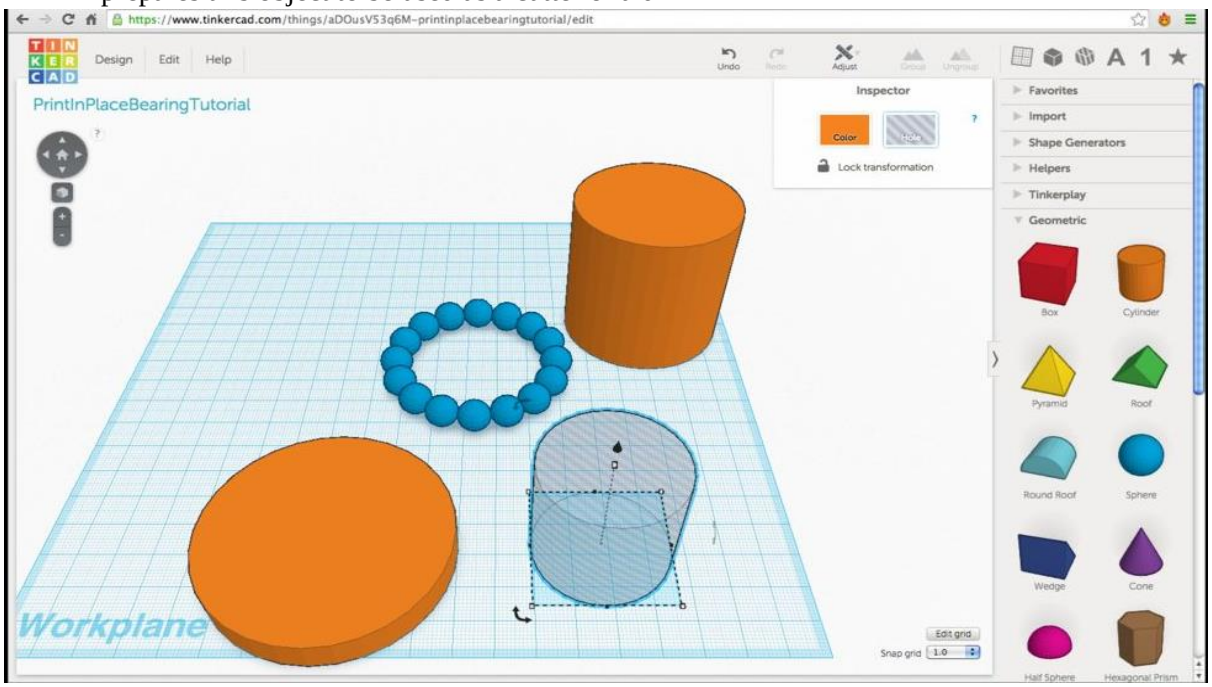
21. Select the reference cylinder that was made earlier and click on "Edit" and "Duplicate"
22. While the duplicate is selected, use the Left Mouse button to grab and move the new cylinder and drag it anywhere near the front of the Workplane.
23. Use the Shift key and Left Mouse button to click and drag one of the white-box control handles and scale the cylinder to 37mm (Note: 37mm is 15mm less than 52mm) in all directions.





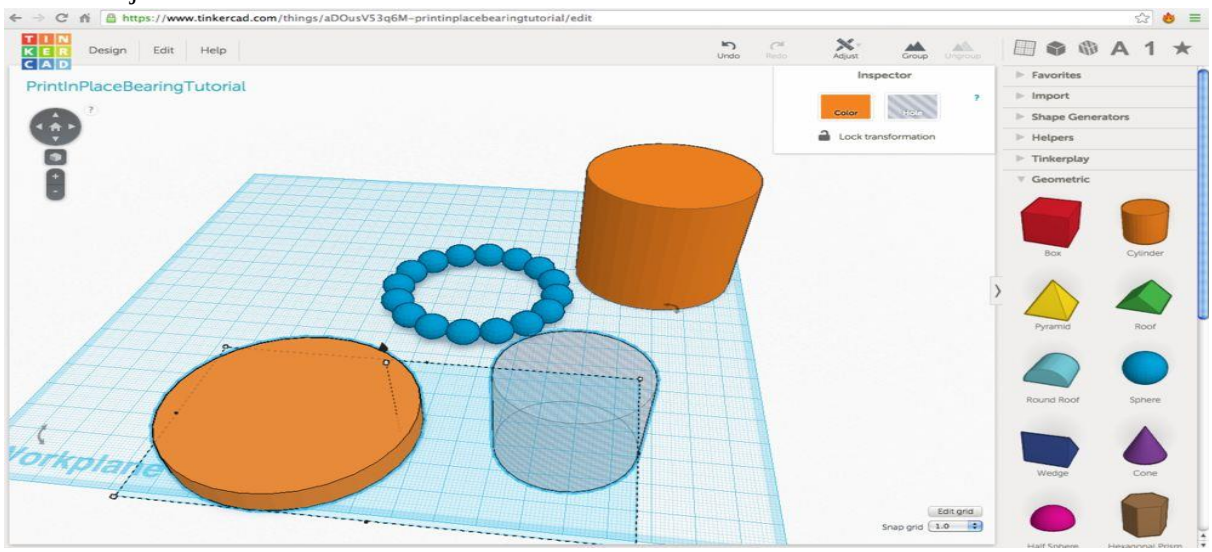
While this cylinder is selected, find the “Inspector” in the upper right part of the work area.

24. Click on “Hole” and notice how the cylinder changes from a color to a transparency. This prepares this object to be used as a cutter or a drill.

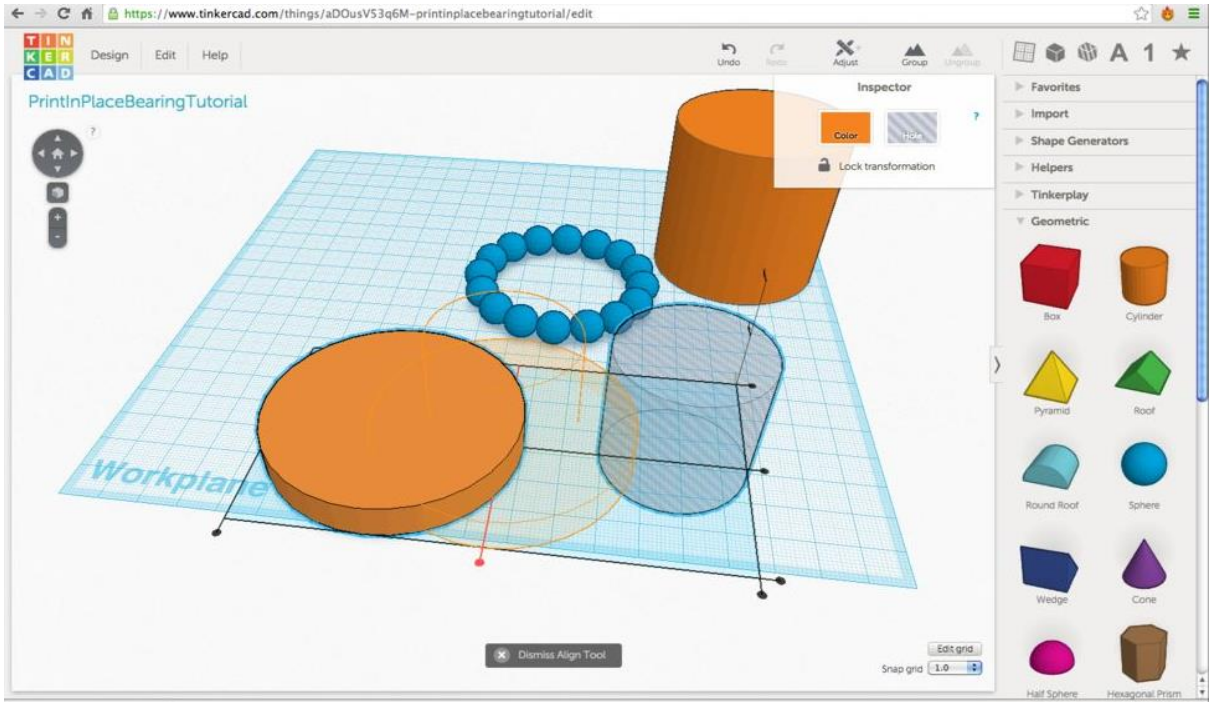


Create Overall Shape of Bearing Assembly

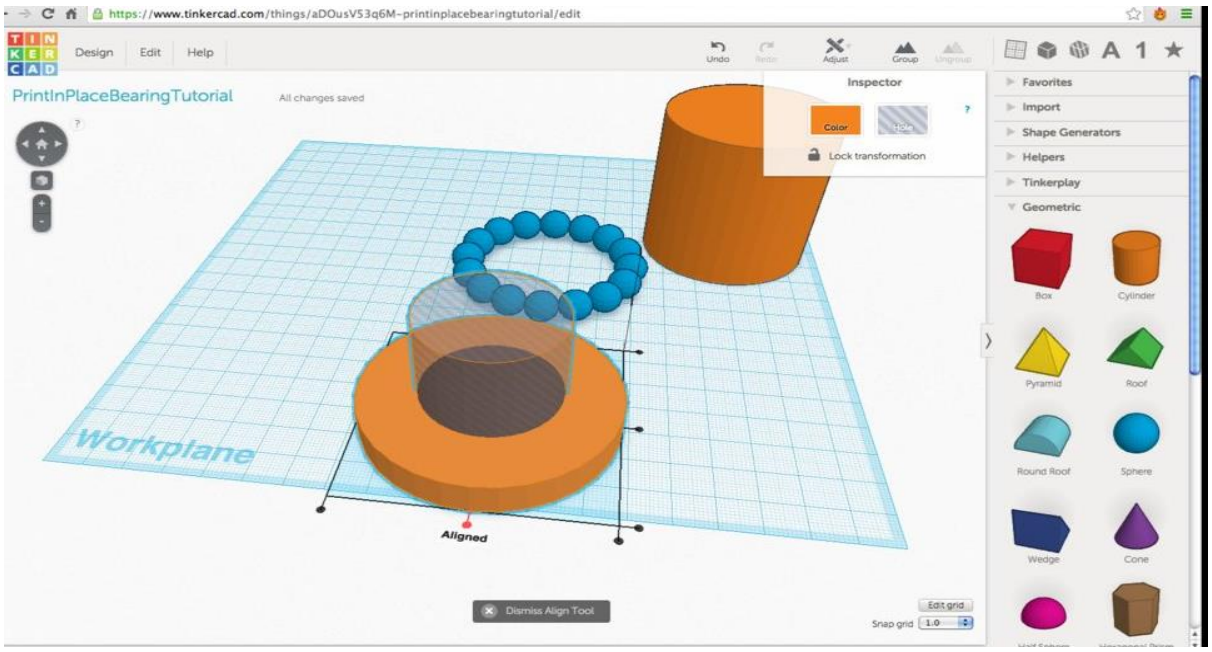
25. Select the two new cylinders by holding the Shift key and using the Left Mouse button to click on both objects. When they are, both selected, the bounding box will extend around both objects.



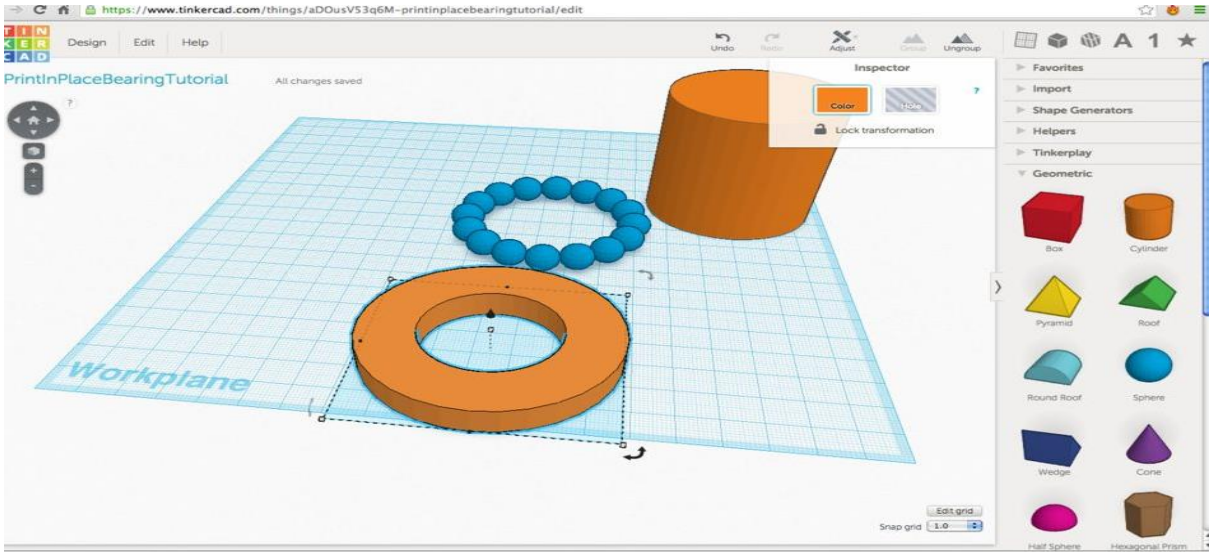
26.Now click on “Adjust” on the upper part of the Tinkercad interface. Then click on “Align”. Now you will see additional controls on the workplane.



27. Clicking on the front-center of these, in this view, aligns the two objects relative to each other on the X axis. When the objects have been aligned on an axis, the word “Aligned” can be seen when the cursor is hovered over the control for that axis. Repeat for the Y axis.

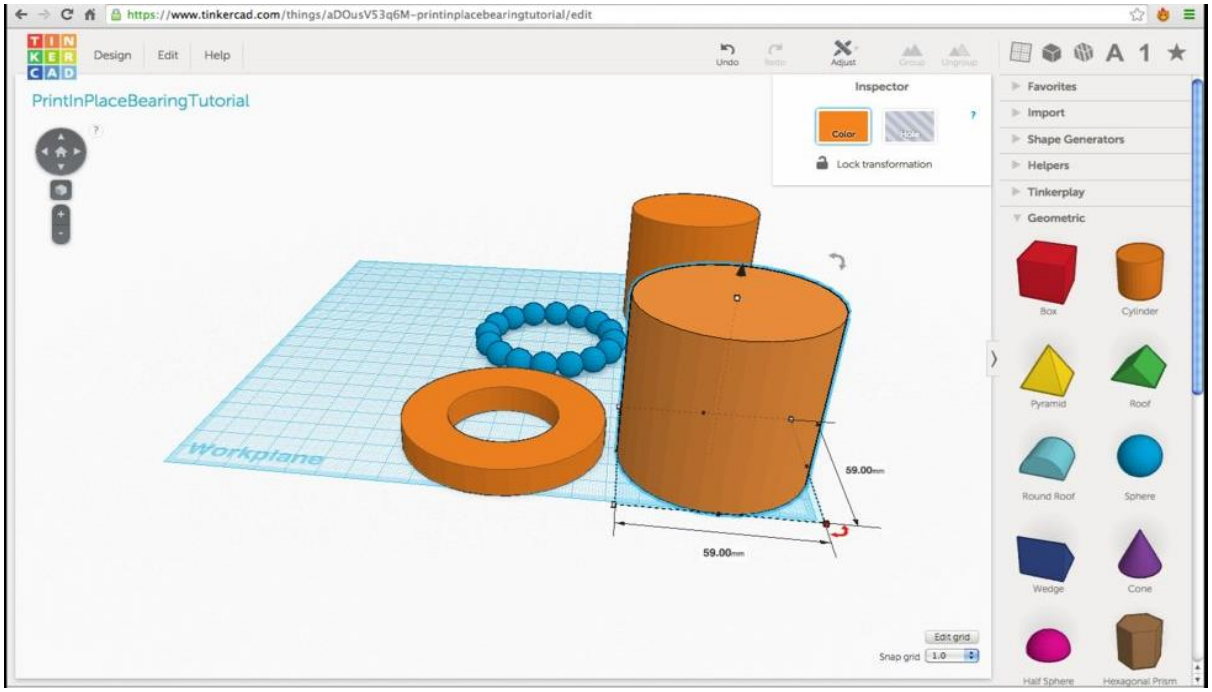


28. With both cylinders still selected, now click on “Group” on the upper part of the Tinkercad interface. Tinkercad will automatically “subtract” the inner cylinder from the outer cylinder.

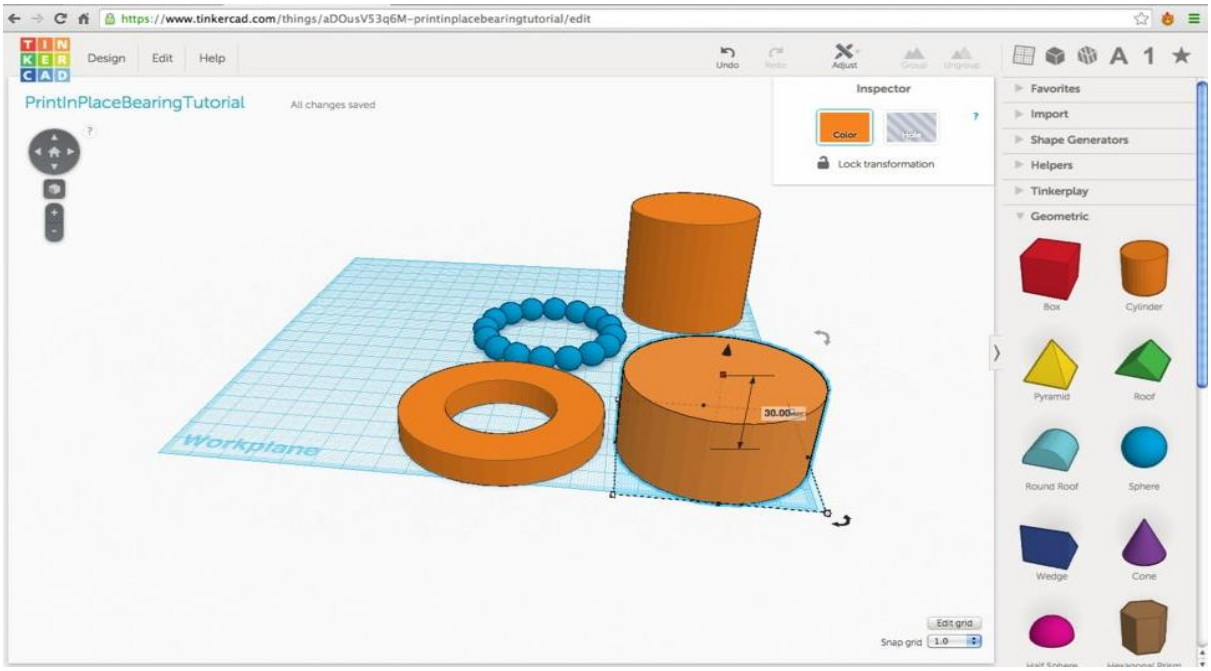


Separate Inner Race from Outer Race

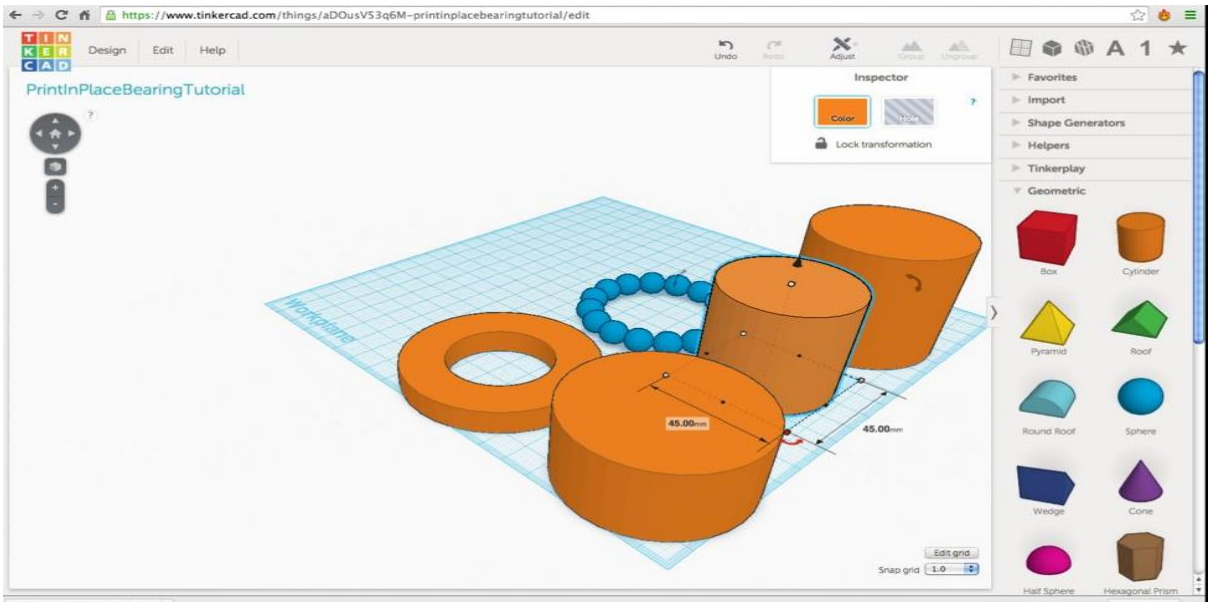
29. Select the reference cylinder from the back of the workplane, then click on “Edit” and “Duplicate” and drag the duplicate closer to the front of the workplane.
30. Use the Shift key and Left Mouse button to click and drag one of the white-box control handles and scale the cylinder to 59mm (Note: 59mm is 7mm greater than 52mm) in all directions.



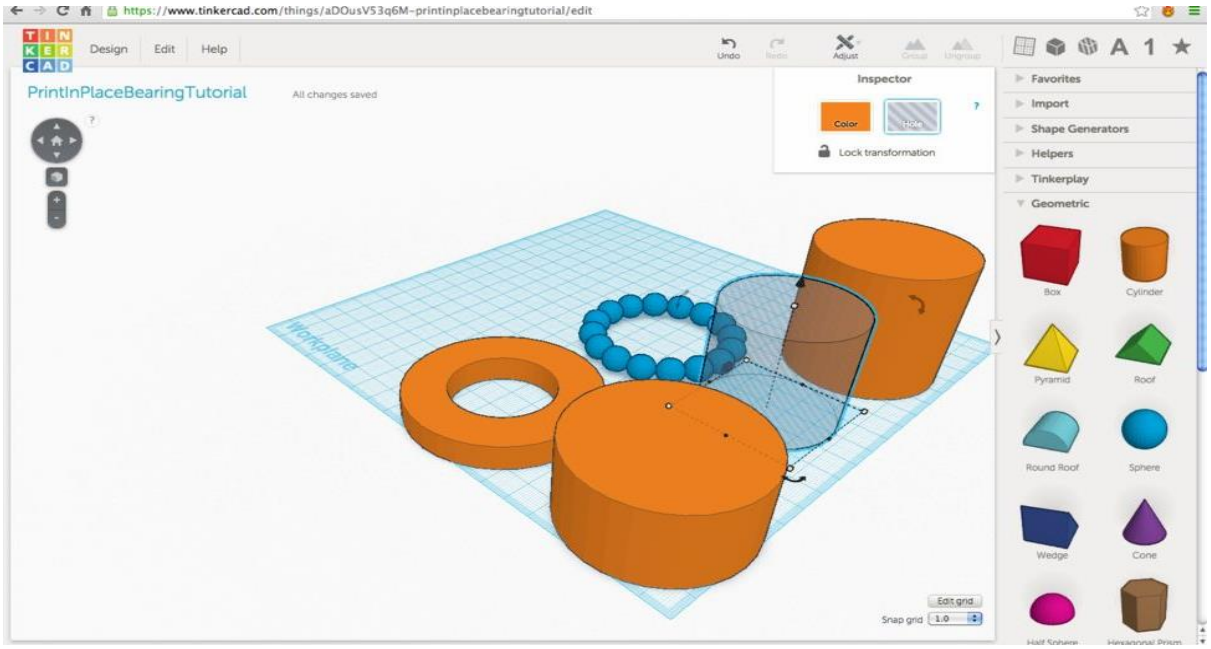
31. Then, with just the Left Mouse button, click and drag the top white-box depth control handle and scale the depth to 30mm.



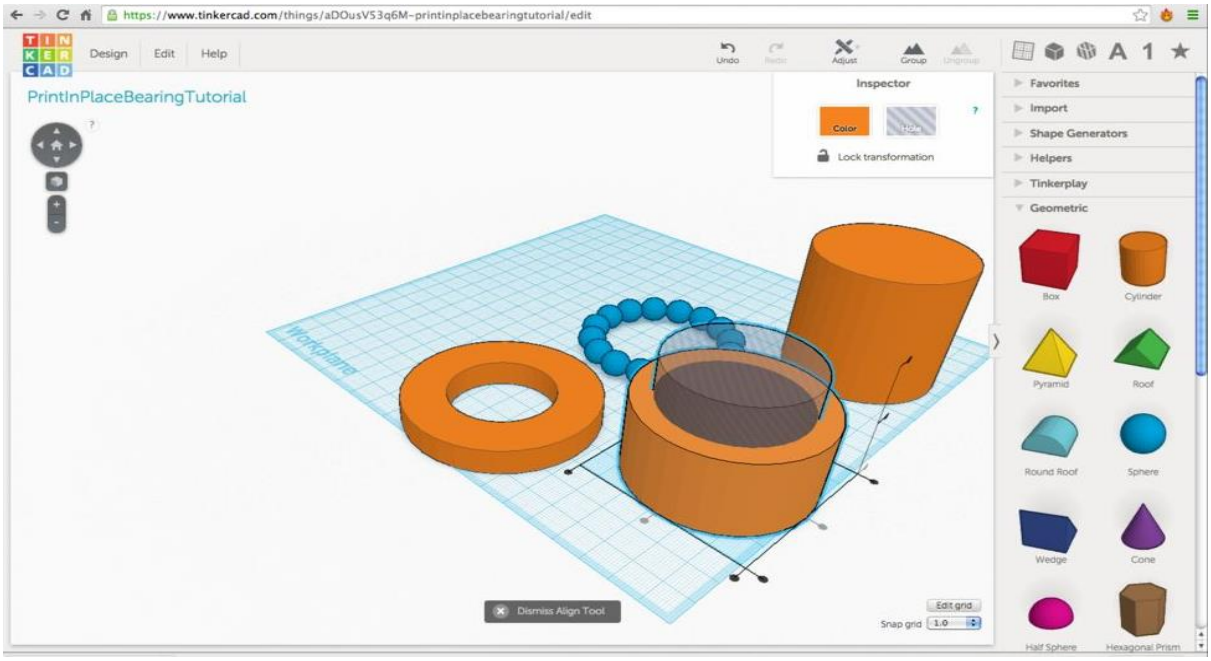
32. Once again, select the reference cylinder from the back of the workplane and click on “Edit” and “Duplicate” and drag it anywhere near the front of the Workplane. Use the Shift key and Left Mouse button to click and drag one of the white-box control handles and scale the cylinder to 45mm (Note: 45mm is 7mm less than 52mm) in all directions.



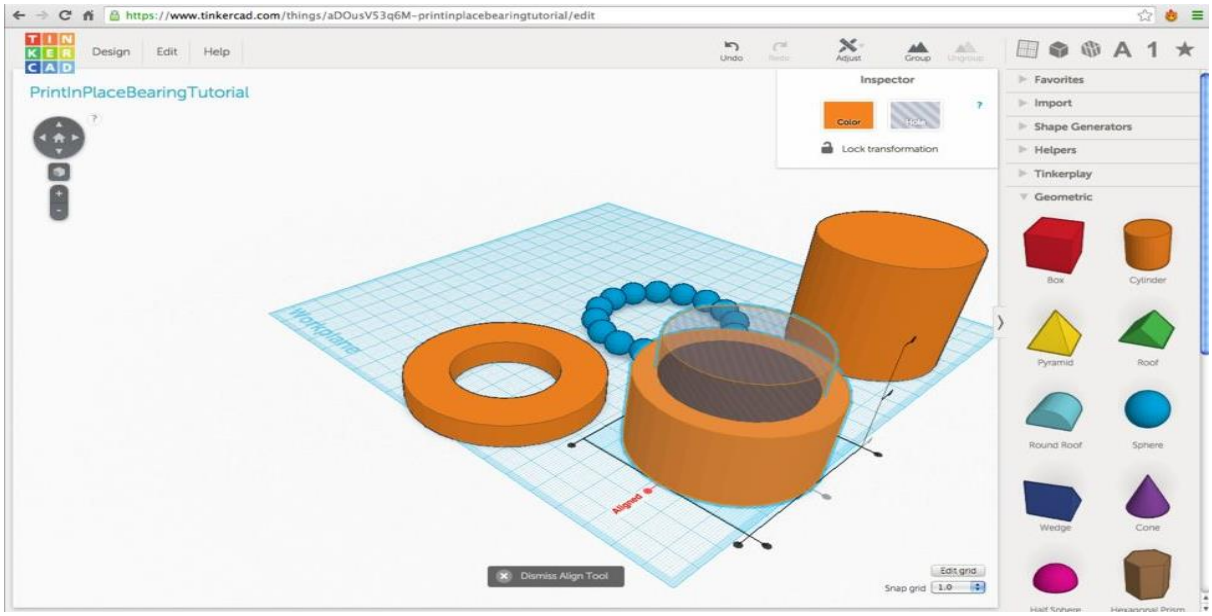
33. While this cylinder is selected, find the “Inspector” in the upper right part of the work area. Click on “Hole”.



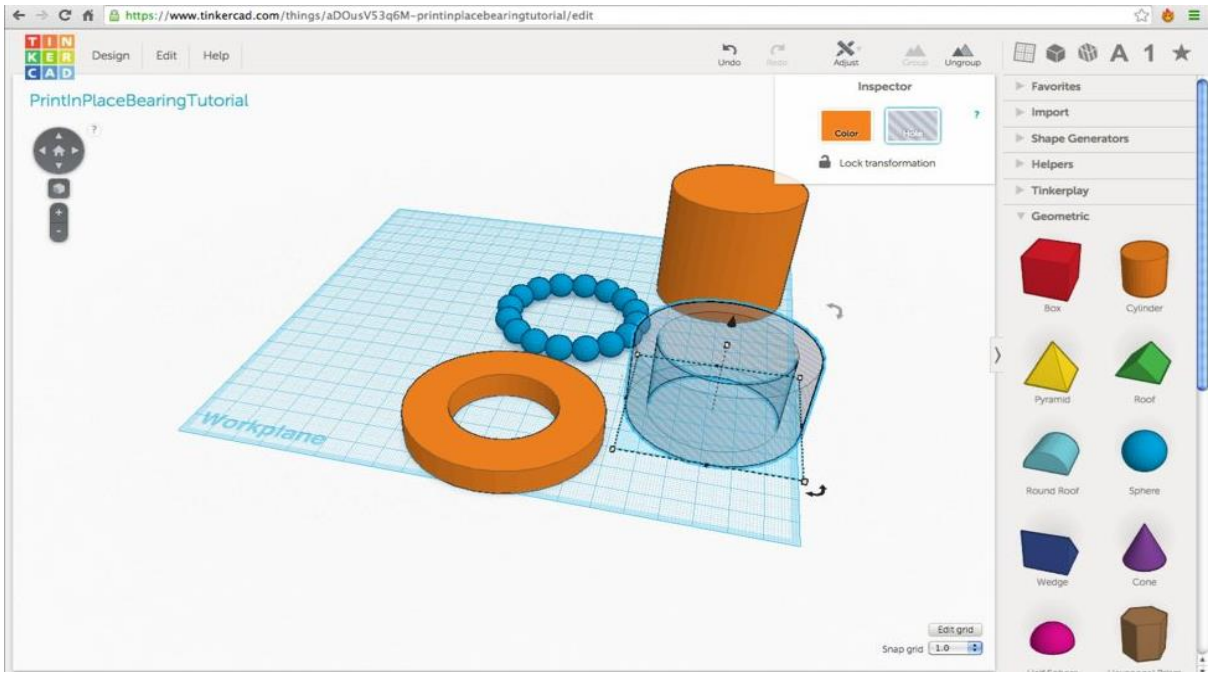
34. Select these two new cylinders by holding the Shift key and using the Left Mouse button to click on both objects. When they are, both selected, the bounding box will extend around both objects.



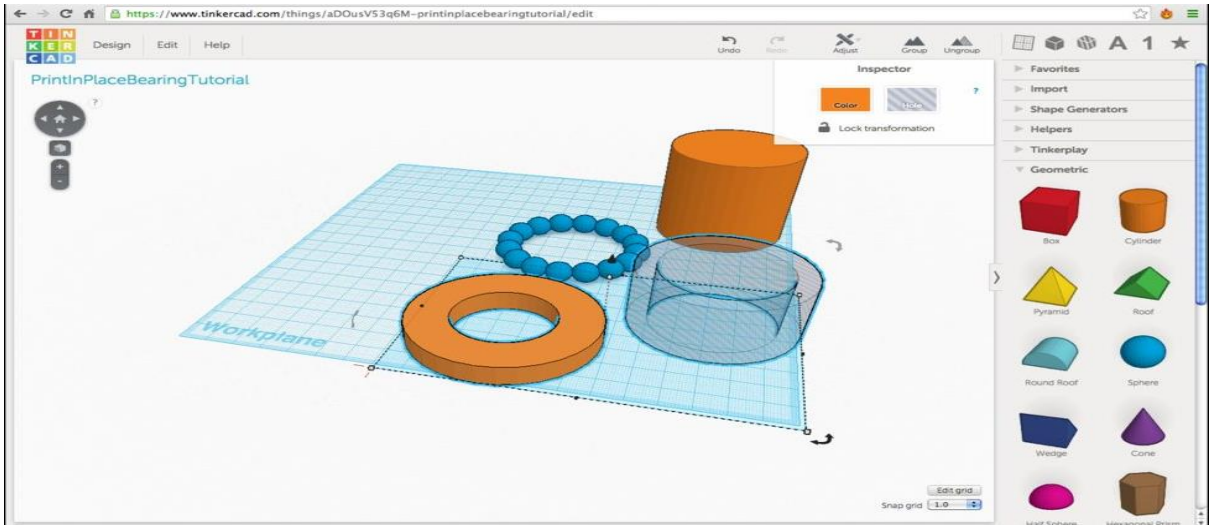
35. Now click on “Adjust” on the upper part of the Tinkercad interface. Then click on “Align”. Now you will see additional controls on the workplane. Align on both X and Y axes.
36. While both cylinders are still selected, click on Group” on the upper part of the Tinkercad interface.



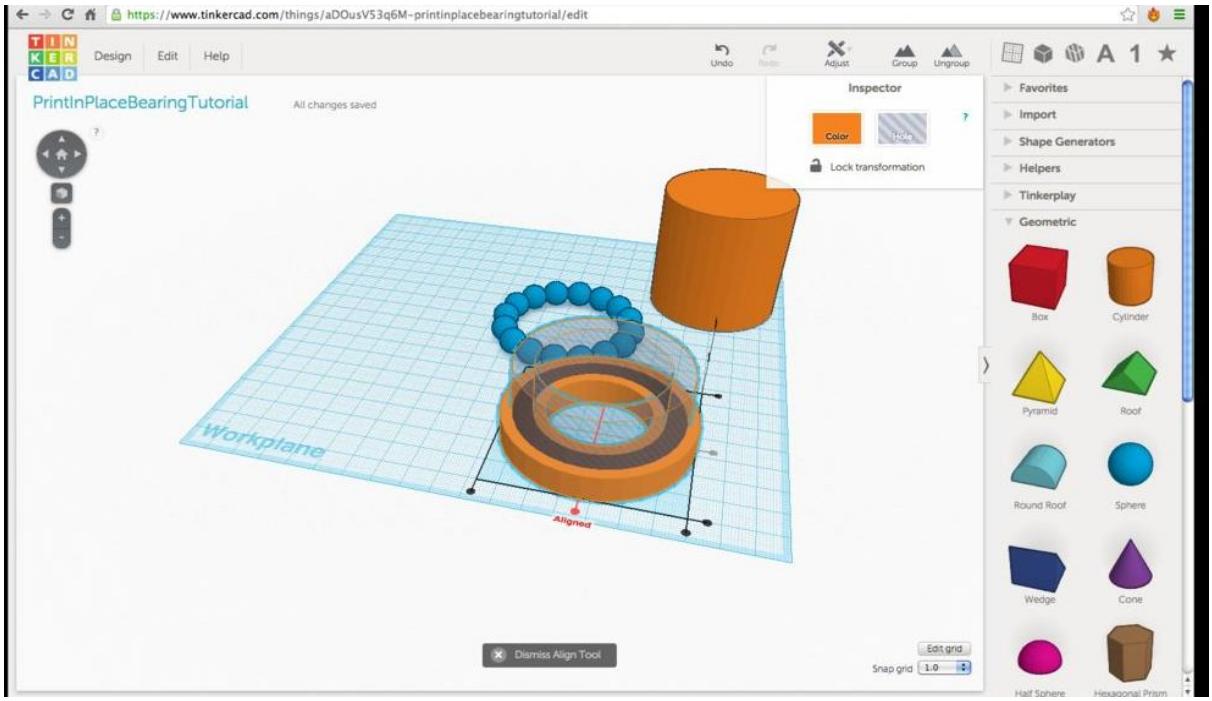
37. There should now be two “donuts” (toroid) near the front of the workplane. Select the taller toroid and then go the “Inspector” in the upper right part of the work area and click on “Hole”.



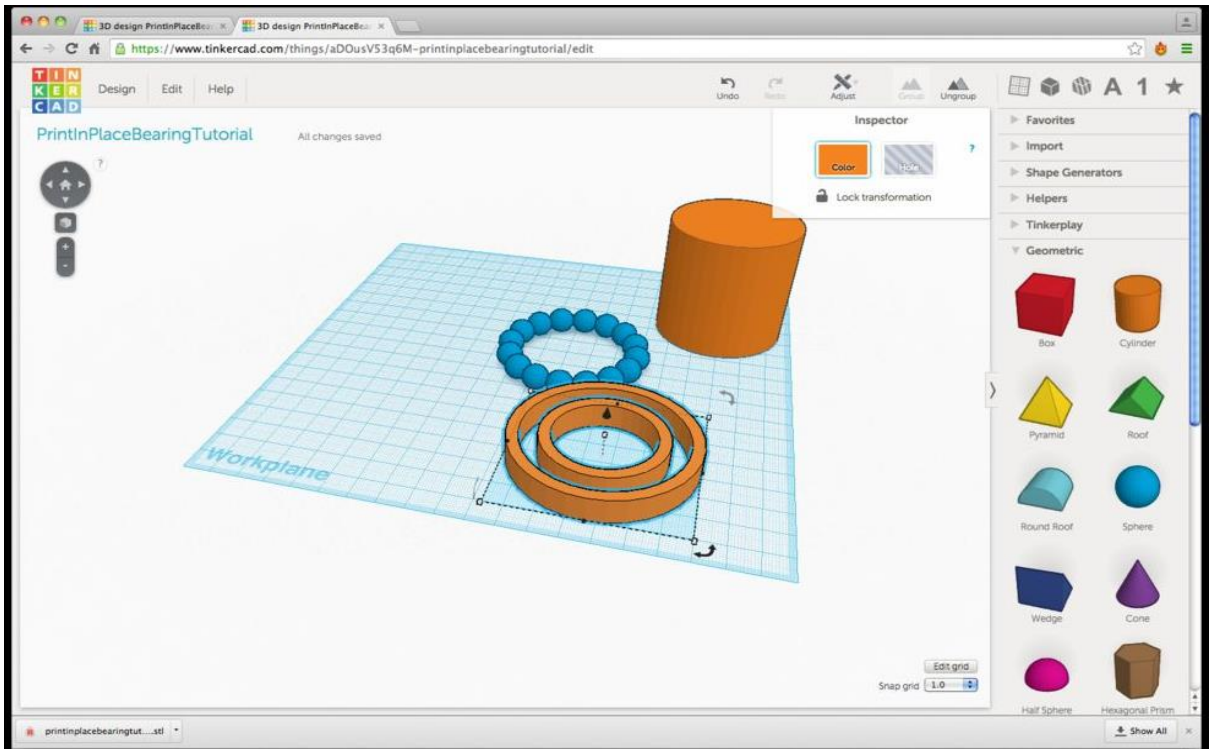
38. Now also select the shorter toroid so that both toroids are selected.



39. Now click on "Adjust" on the upper part of the Tinkercad interface. Then click on "Align". With the additional controls on the workplane, align on both X and Y axes.

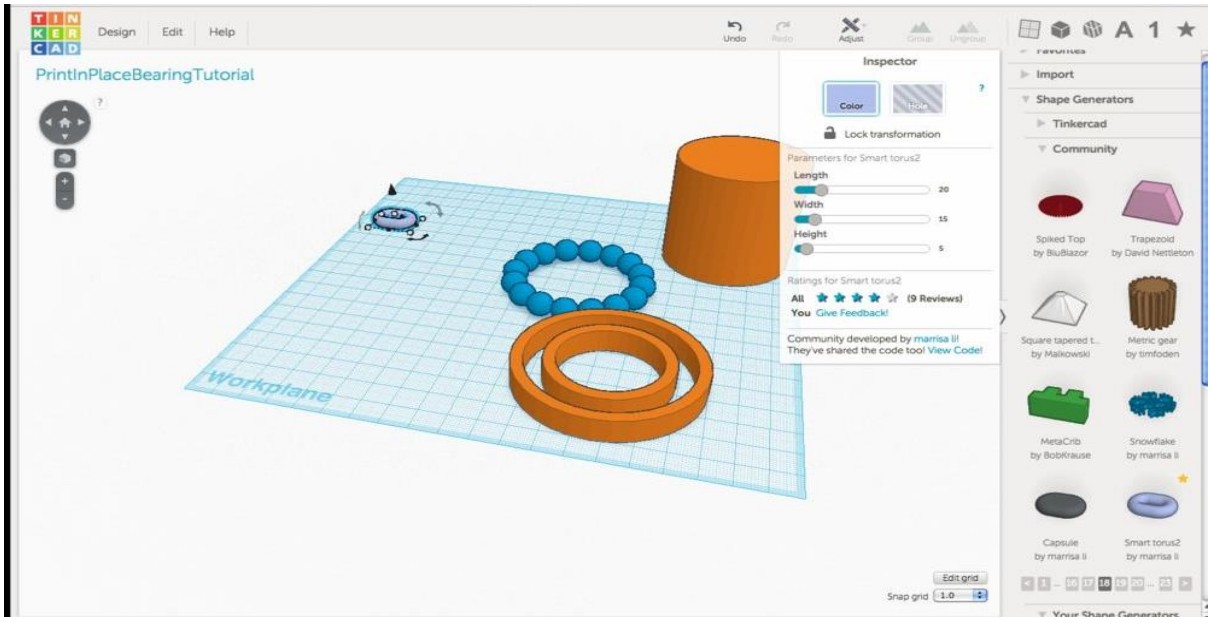


40. While both cylinders are still selected, click on Group" on the upper part of the Tinkercad interface.

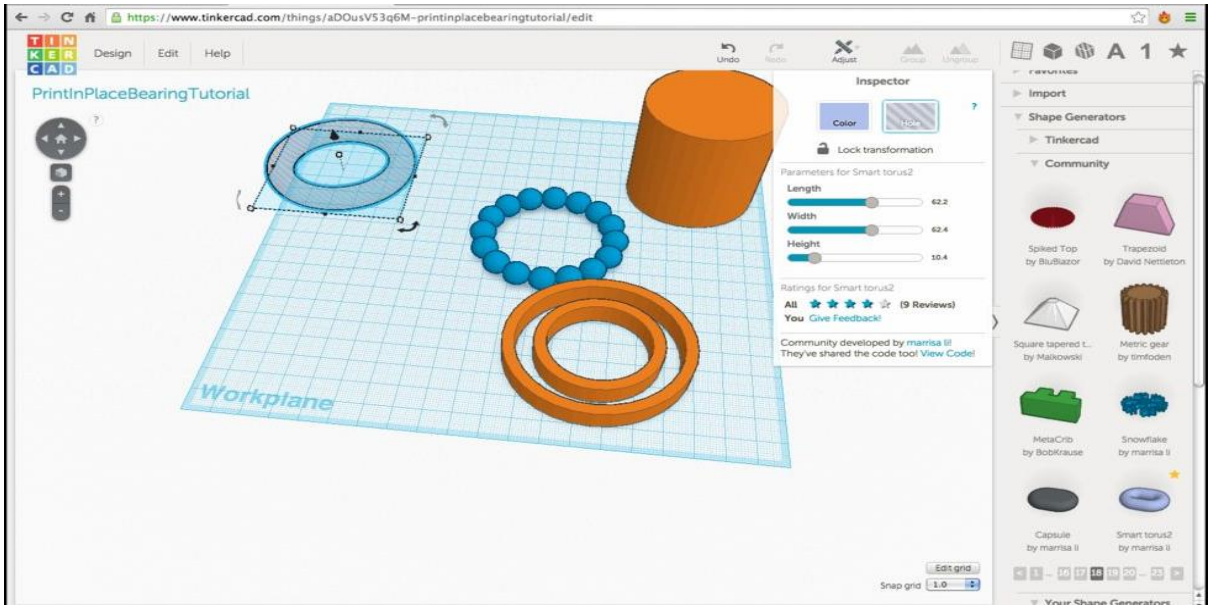


Form the Groove That the Bearings Will Ride In

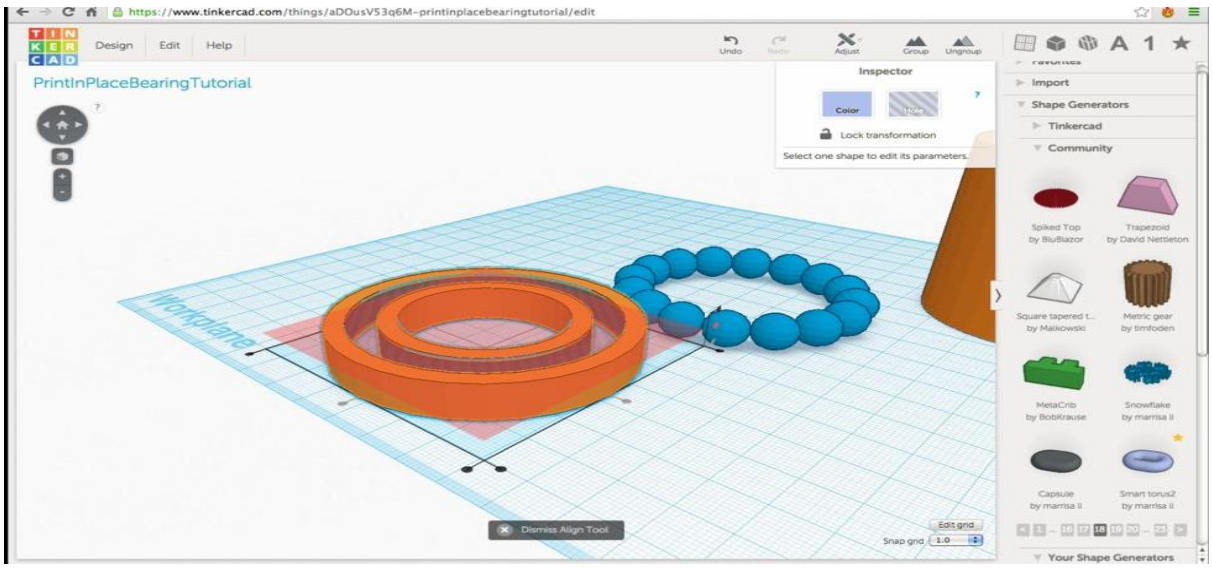
41. Use the Mouse to go to right side of Tinkercad interface, click on ">Shape Generators" then click on the subheading ">Community". Currently on Page 18, there is a shape generator called "Smart Torus2". Navigate to Page 18, then drag "Smart Torus2" to the left of the Workplane.



42. Notice that the Inspector now has editable parameters that we can manipulate. For the Length, click on the number to the right of the slider and type 62.4 then repeat, entering 62.4 for Width. For Height, enter 10.4. While this is selected be sure to click on “Hole”. Now drag it to near the front of the Workplane.

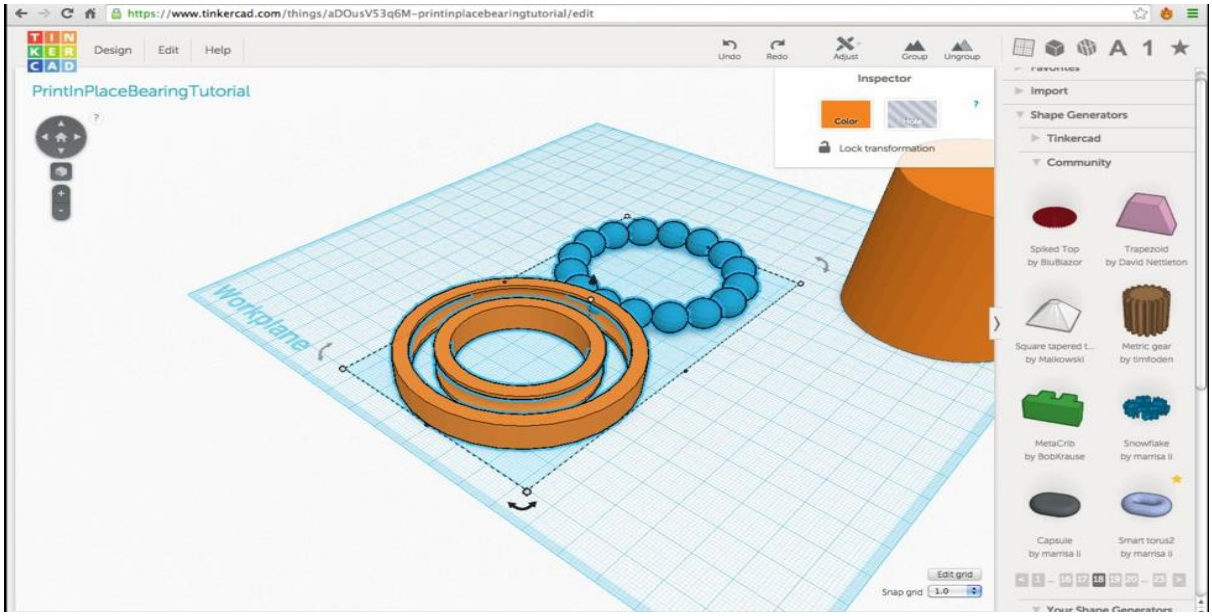


43. While the new torus that you just made is still selected, also select the other set of rings. With all rings selected, click on “Adjust” on the upper part of the Tinkercad interface. Then click on “Align”. With the additional controls on the workplane, align on both X and Y axes. You also NEED to align the Z axis (depth) to center as well. While these are all selected, click on Group” on the upper part of the Tinkercad interface.

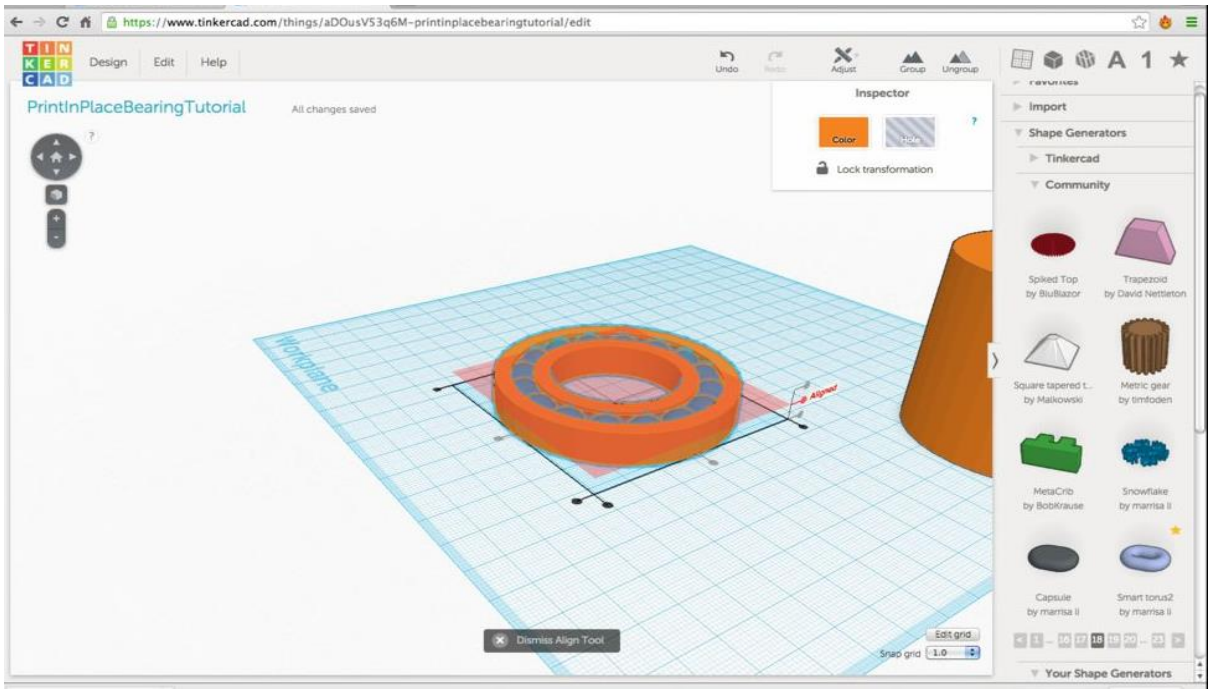


Place Bearings Inside Races

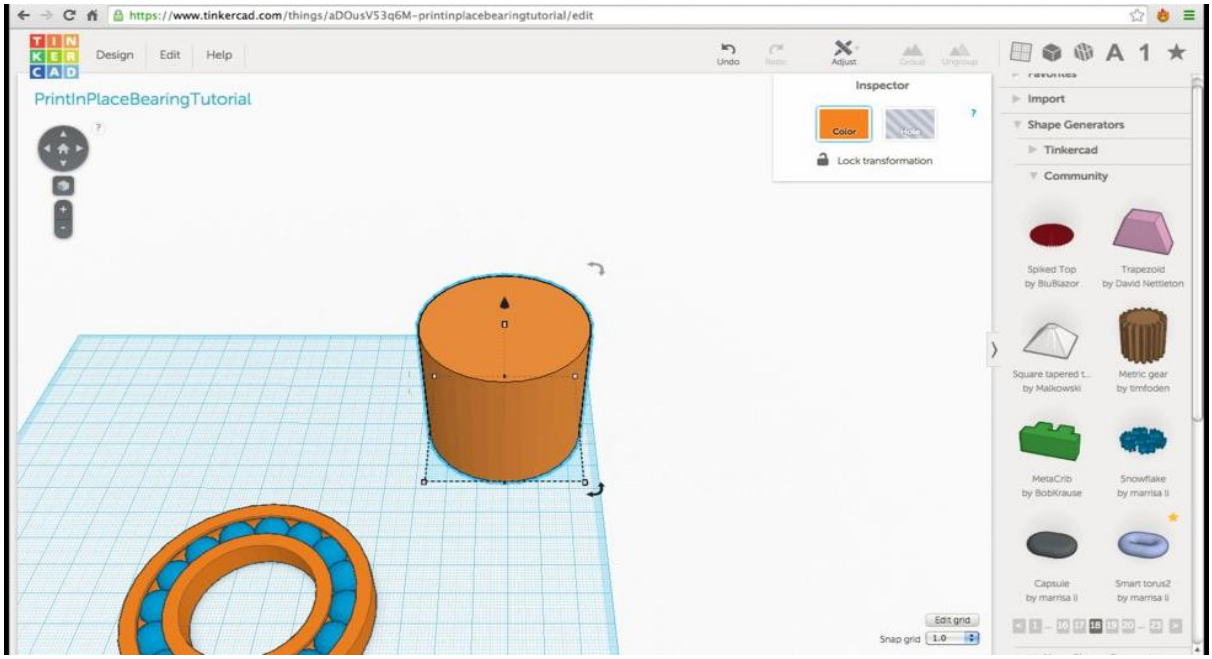
44. Select the remaining set of rings and the balls by holding the Shift key and using the Left Mouse button to click on both objects. With both objects selected, click on “Adjust” on the upper part of the Tinkercad interface.



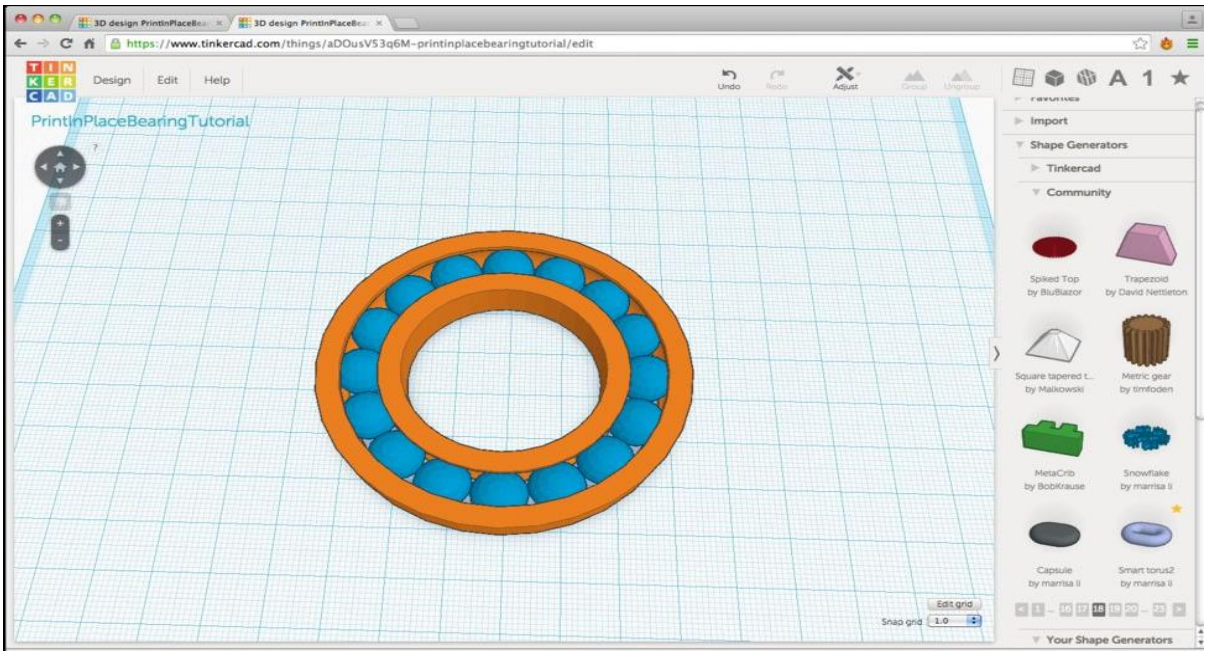
45. Then click on “Align”. With the additional controls on the workplane, align to center on X, Y and Z axes.



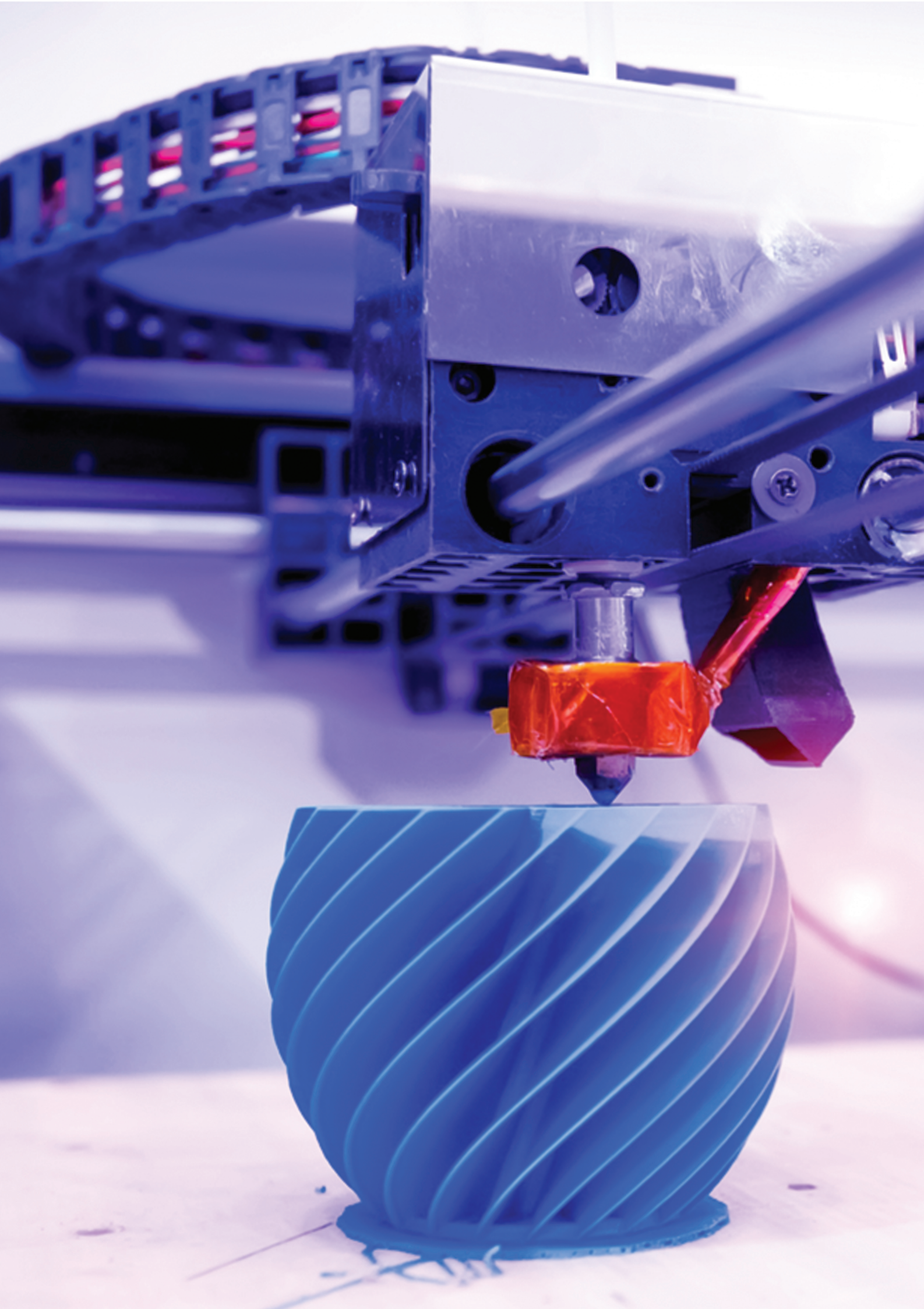
46. Select the reference cylinder from the back of the Workplane. Make sure it is the only thing selected now. When it is selected, press ‘Delete’ on the keyboard and the only thing remaining on your Workplane is your bearing assembly.



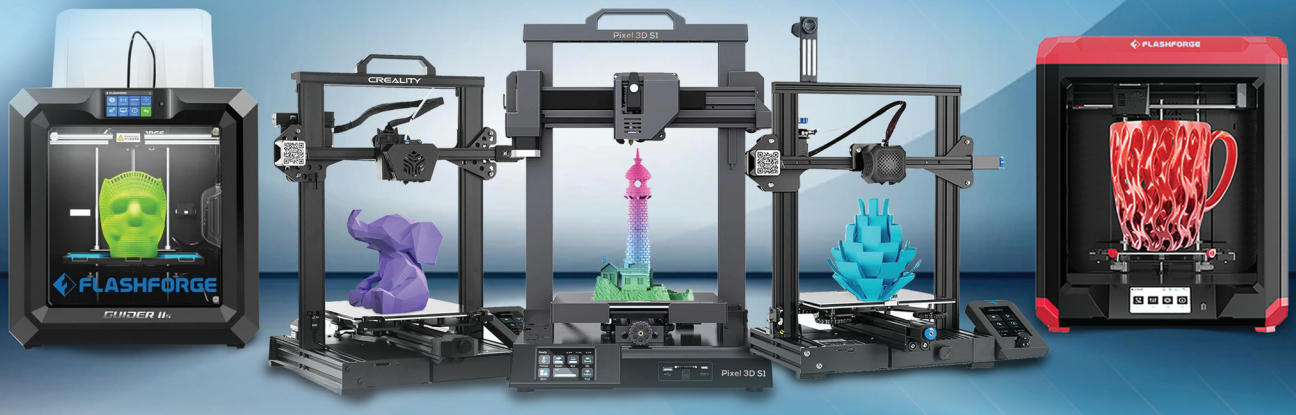
The image below represents the final image of the product.




UNIVERSAL ROBOTS




TOWER PRO


FLASHFORGE
CREALITY
Pixel 3D S1
Pixel 3D S1
FLASHFORGE