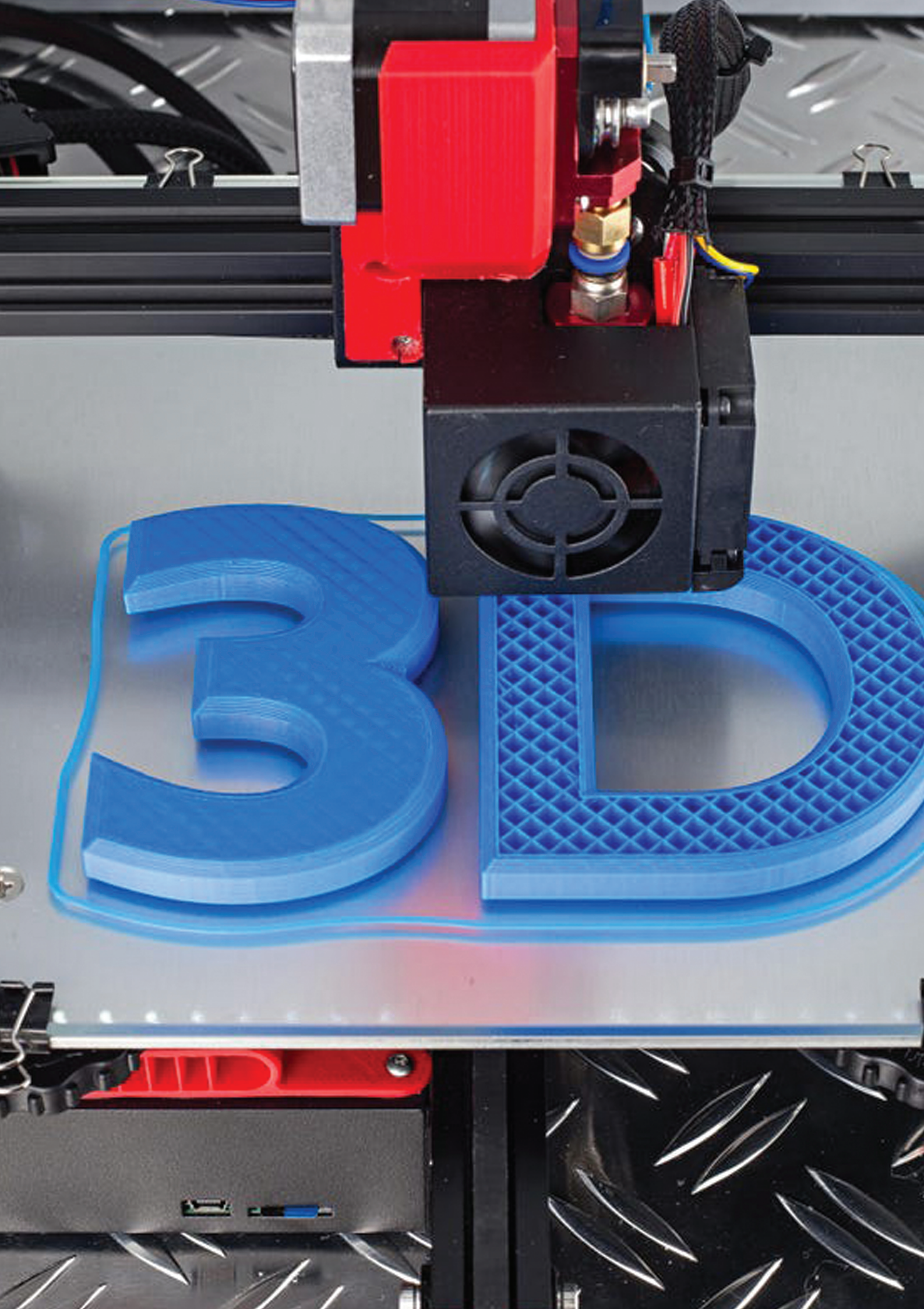
ROBOTROD
by Olatus Systems Private Limited

VOLUME 2

3-D PRINTING


3D

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Chapter 1: Introduction to 3D Printer

Print Bed

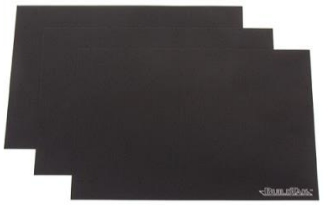
The print bed is the surface that your objects are printed on to. Typically, it will consist of a sheet of glass, a heating element, and some kind of surface on top to help the plastic stick.

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



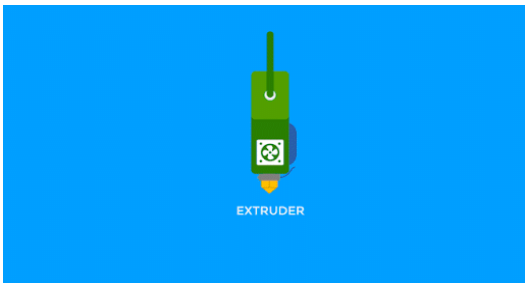
The bed surface helps the plastic stick to the bed during printing but also allows it to be removed easily when printing is done. There are many different kinds of bed surfaces. Most printers will come with some kind of all-purpose surfaces, like BuildTak or PEI film. However, for best results, you will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

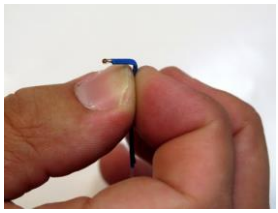
This ensures that heat does not travel up the plastic and melt it prematurely before it reaches the nozzle. This phenomenon is called heat creep and it causes jams, especially with PLA. This fan should be running whenever the hot end is warm.

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.

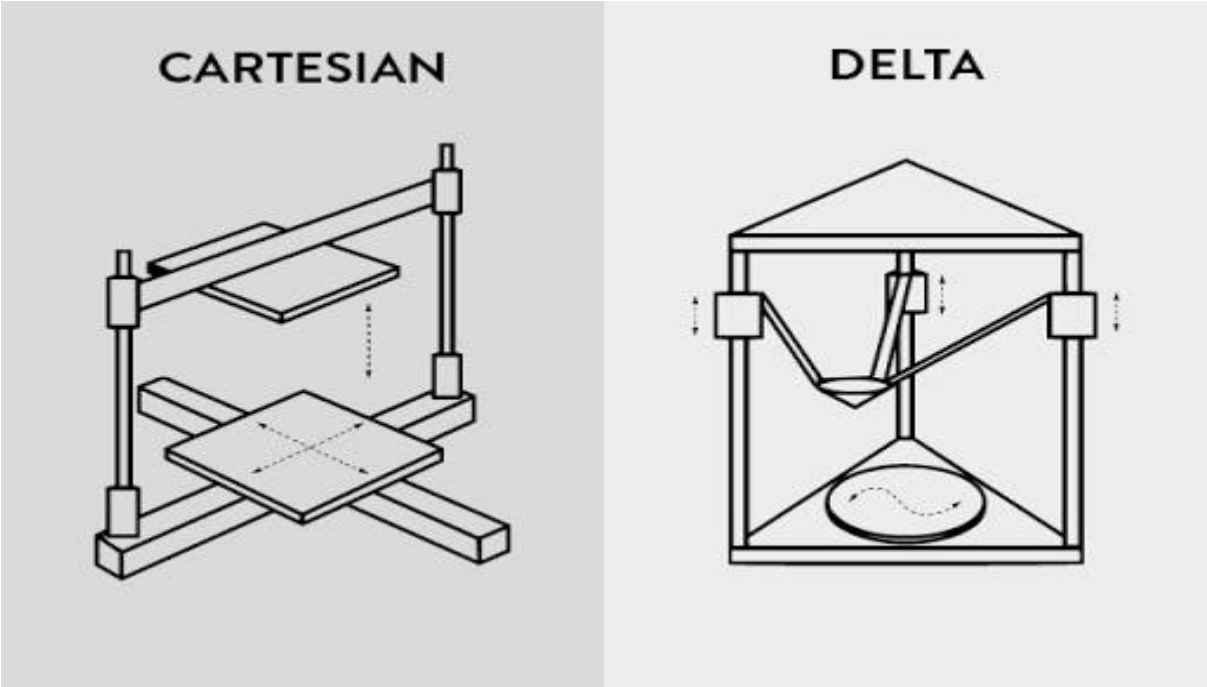
Layer Cooling Fan

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

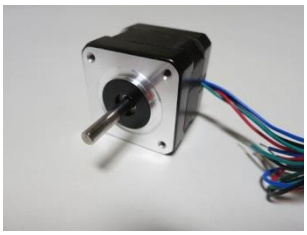
These are usually used on the printer's Z axis. They rotate, thus forcing nuts to move up and down. Inexpensive printers will use simple threaded steel rods, which are essentially extra-long bolts. Higher quality printers have smooth chrome plated lead screws designed to minimize backlash.

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.

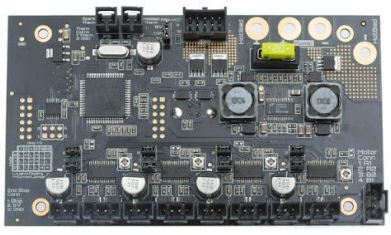
Electrical Components:

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)

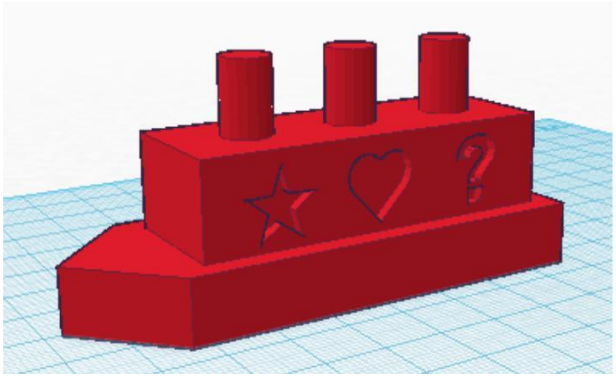
The end stops are how the printer knows where it is. They are little switches that get pushed whenever an axis moves to the end. This is how the printer finds it's starting point before printing. Most printers use mechanical switches, but some are known to use optical sensors.

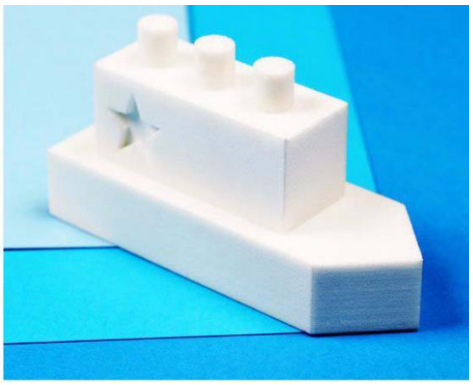
Bed Leveling

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):

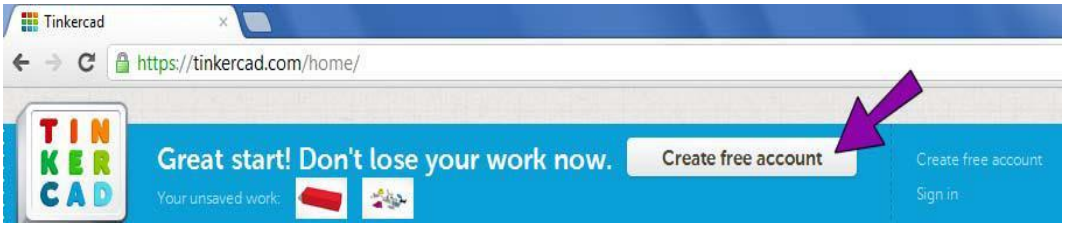




The cool thing about Tinkercad is that it's ideal for creating things that be *printed*. No, not printed on a boring and flat 2D sheet of paper! Tinkercad is made for producing *actual objects*: you can easily send your model to a 3D printer and end up with an actual object you can hold in your hand.

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.

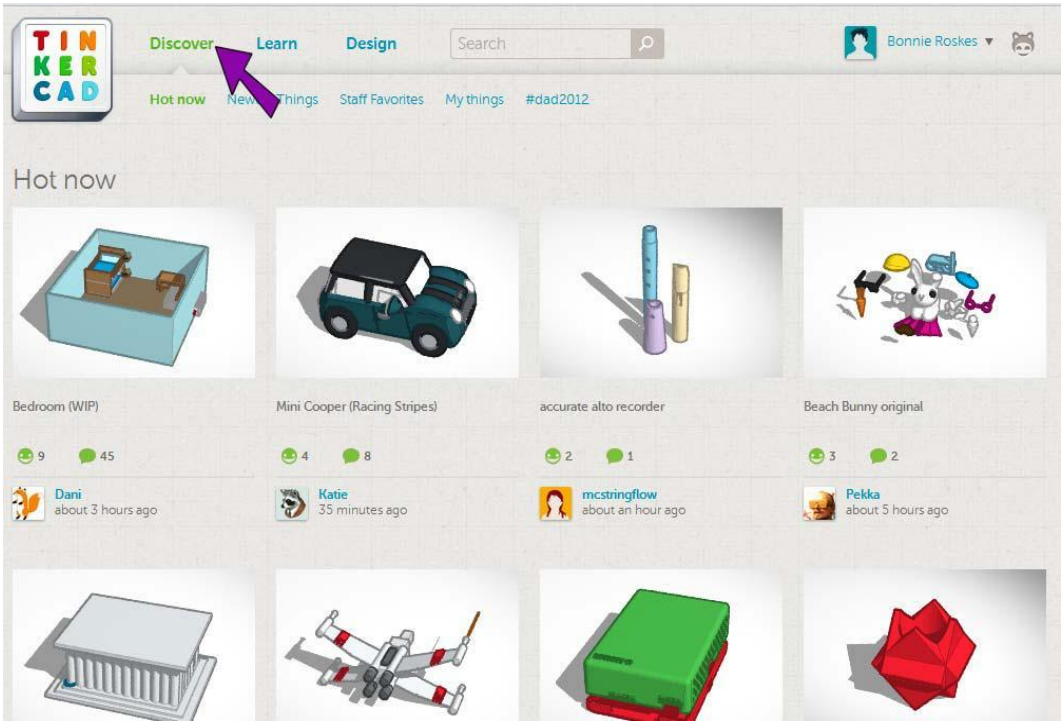


At the top of the Tinkercad site are three main links: **Discover**, **Learn**, and **Design**.

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).

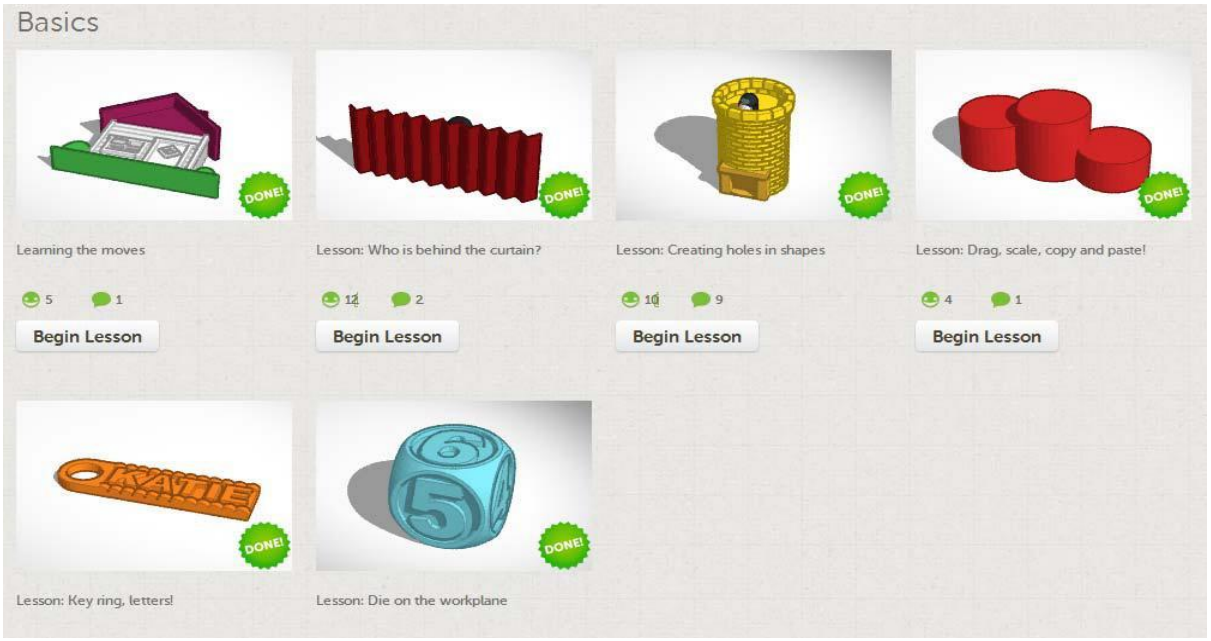
   If a model you see strikes your fancy and you want to see more, click on it to see a larger view. You can see a still view of the model, or view it in 3D so that you can turn it around and zoom in and out. The **Copy and Tinker** button lets you open it in Tinkercad so you can see how it was made; you 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.



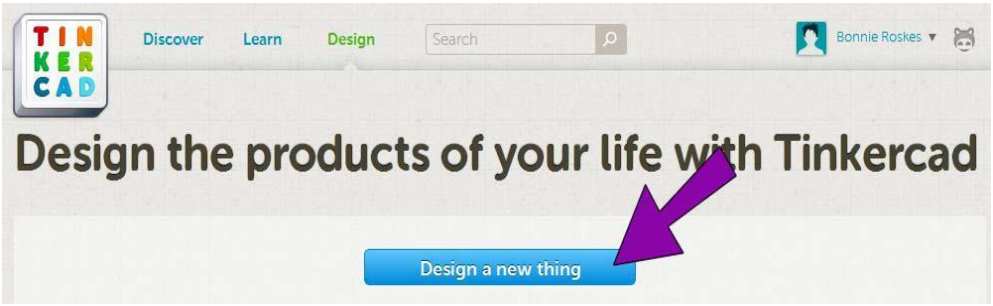
The **Learn** link at the top of the main page takes you to a series of lessons.

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

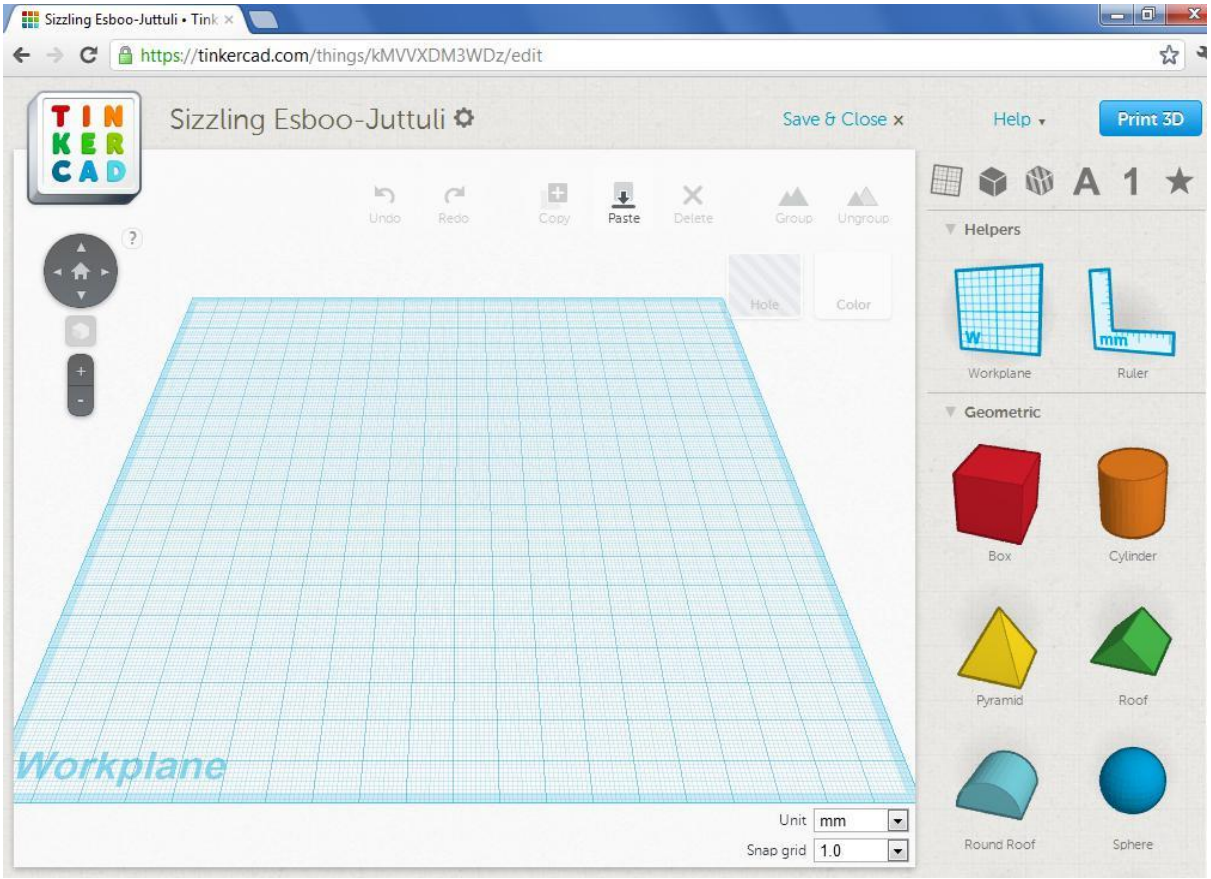


Start Your Thing - the First Shape

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

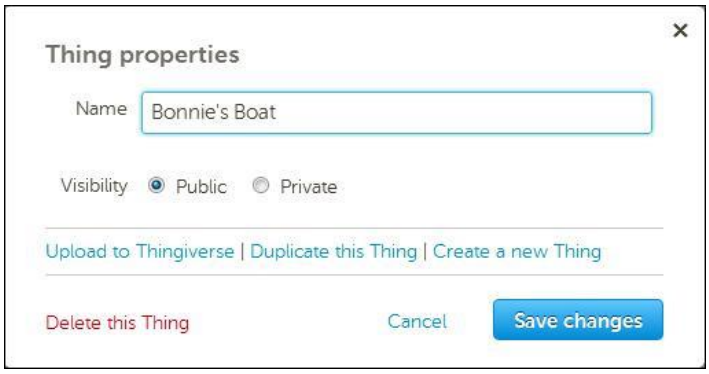


You're taken to a new webpage set up for your model, and your model is assigned a crazy name (what on earth is "Sizzling Esboo-Juttuli"?) An empty workplane (the large, blue grid) takes up most of the screen. The grid lines are all 1 mm apart, which makes it easy to see how large things are. **Snap grid** 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.

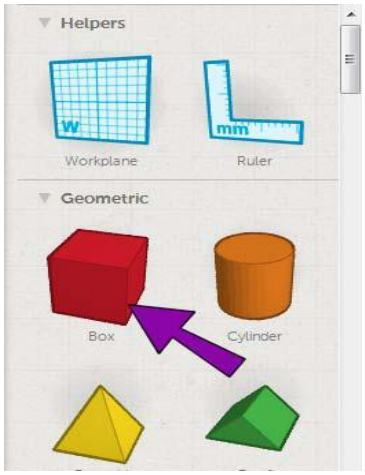


2. Unless you love the strange model name you get, click the gear icon next to the name, which opens the **Thing Properties**.

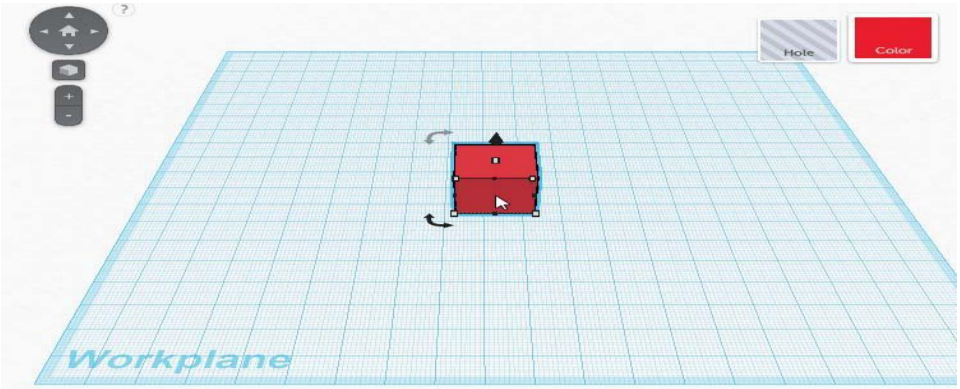
3. Set a new name, and choose whether it will be displayed for all to see (public) or just for you (private). Then click **Save changes**.



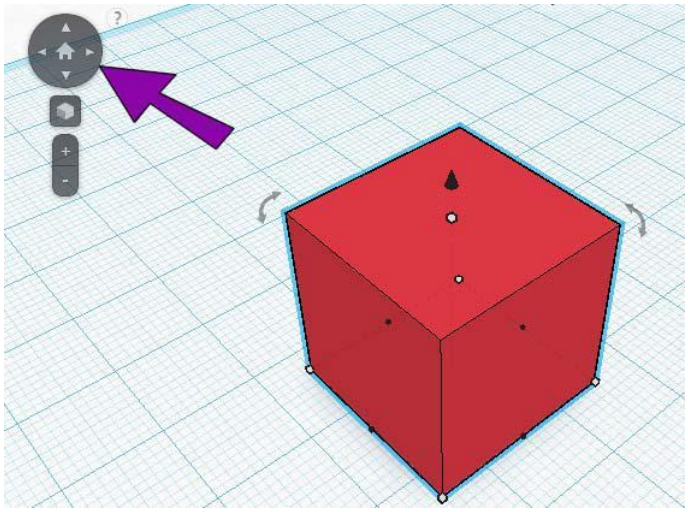
4. Let's start with the bottom of the boat. Click the **Box** tool, which is the first icon in the **Geometric** tool group.



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



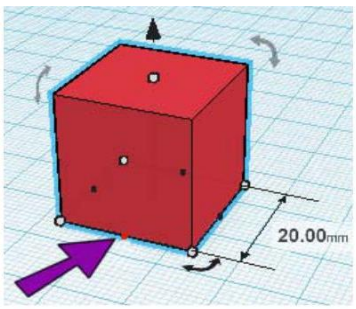
6. Before going on to make changes to this box, it's important to know how to "get around" in Tinkercad. The navigation tools in the top left corner are used to change your viewing angle: use the four arrows around the house icon to spin the model left or right, or to tilt the model up or down. You can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



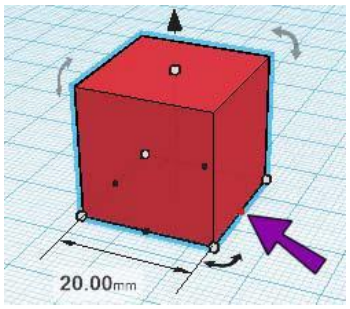
If you have a scroll wheel mouse, though, you don't need to use these navigation controls - you can rely on your mouse buttons, which is much more convenient. Press and hold the right mouse button and drag the mouse around - this is for spinning and tilting the model. Doing the same (holding the right 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).

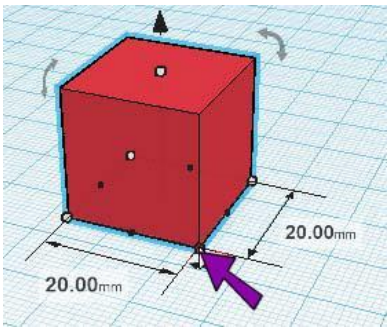
7. First, hover your mouse on one of the small black squares in the middle of an edge on the "ground" (also known as the workplane). The 20.00 dimension appears, showing you how long the box is in that direction - 20 mm.



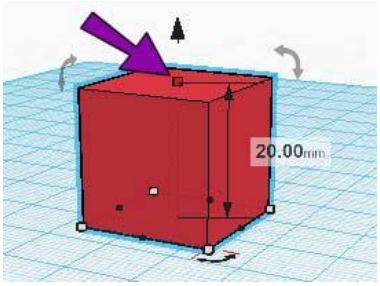
8. Hover over the same black square on another edge, and you'll see the same 20 mm measurement in the other direction.



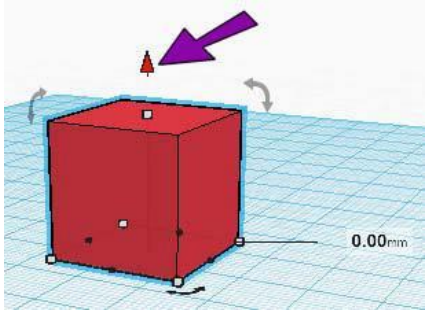
9. Hover over one of the white boxes on the corner, and you'll see both dimensions listed: 20 by 20



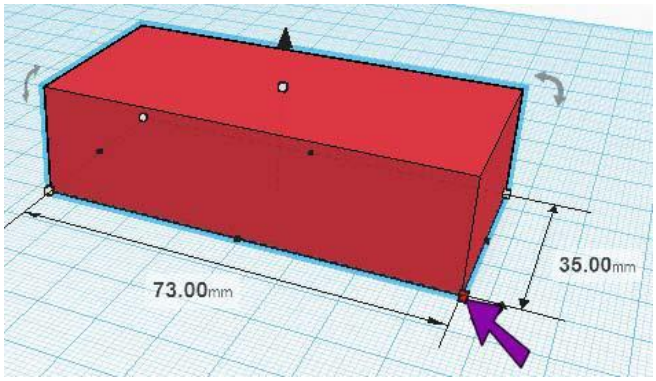
10. Hover on the white square at the top center of the box - it's 20 mm tall.



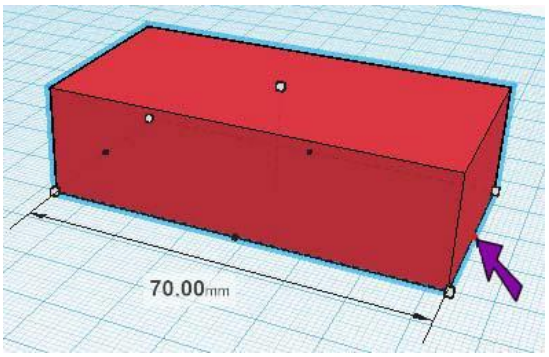
11. Hover over the round black arrow pointing up, above the top of the box. This measurement is zero, which means the box is sitting right on the workplane. (Say the box was "floating" 2 mm above the workplane - you'd see 2.00 instead of zero.)



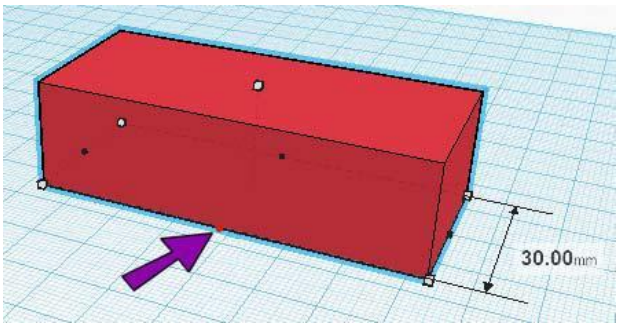
12. To make the box larger (but not taller), drag one of the white corner squares. Dragging a corner square lets you change both the length and width of the box. (It doesn't matter what size you make the box since we'll give the box exact sizes in the next steps.) Because the snap grid is set to 1 mm,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



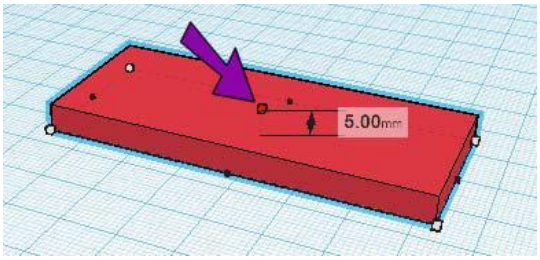
13. To set the box's length, click and drag the black square shown below, which resizes the box only in that specific direction. Stop when the box is 70 mm long.



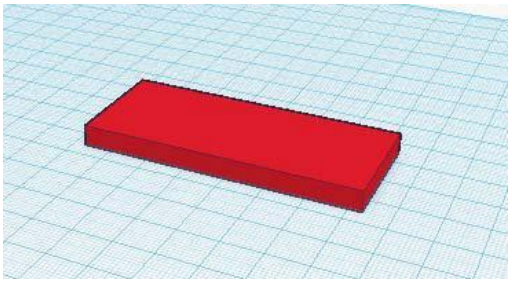
14. For the other measurement, use the arrow shown below, and stop when the width is 30 mm.



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



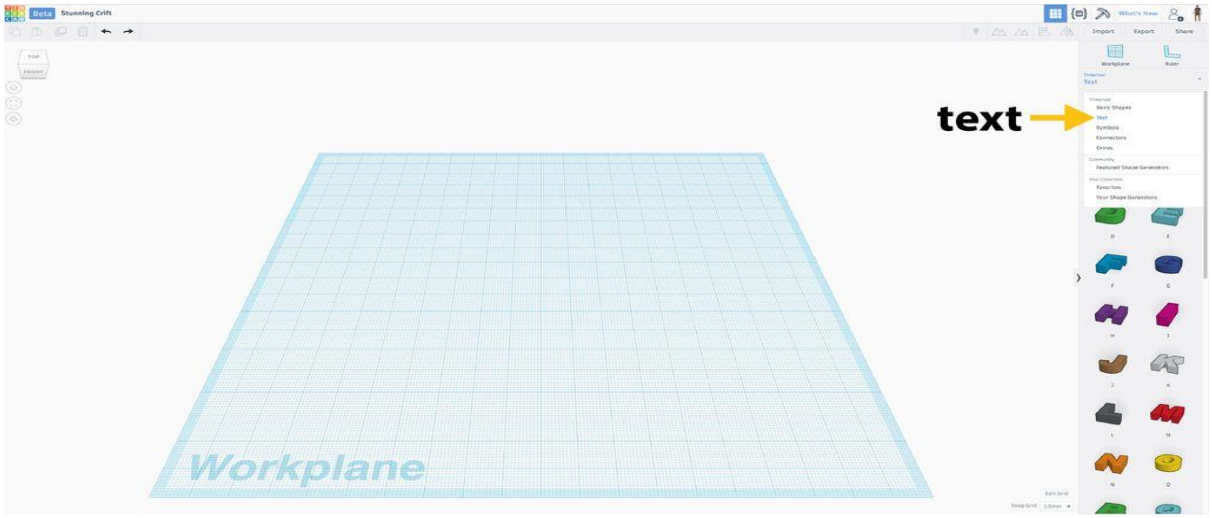
16. That's it for now with this box. To unselect it, click anywhere away from it.



Chapter 3-Name That Keychain

In this project, We'll learn how we can make a keychain by connecting letters together to make a solid object for 3D printing.

Select Your Letters

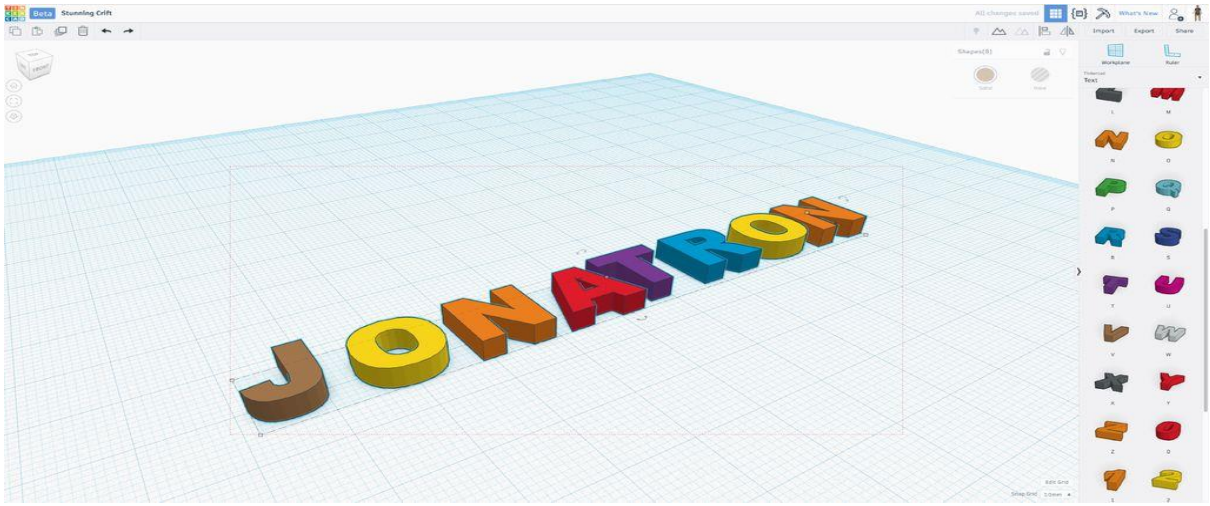


1. If you don't see the panel on the right side of the window, click the arrow in the middle to expand it.

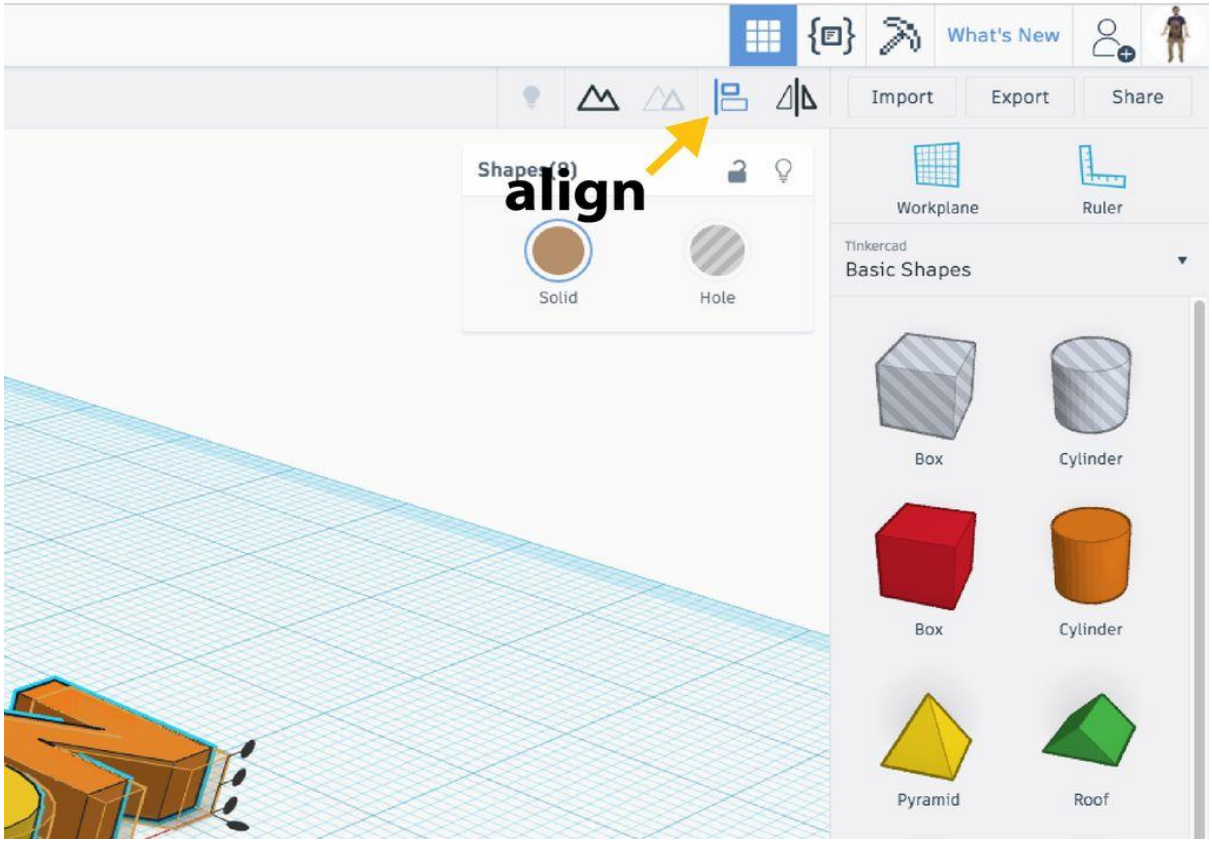
2. Expand the Text panel on the right side of the screen, then click and drag the letters onto the workplane.

3. Drag each letter of your name onto the workplane. Remember: I used the letters of my alias, but you should use the letters from your name or any other word you would like to turn into a keychain.

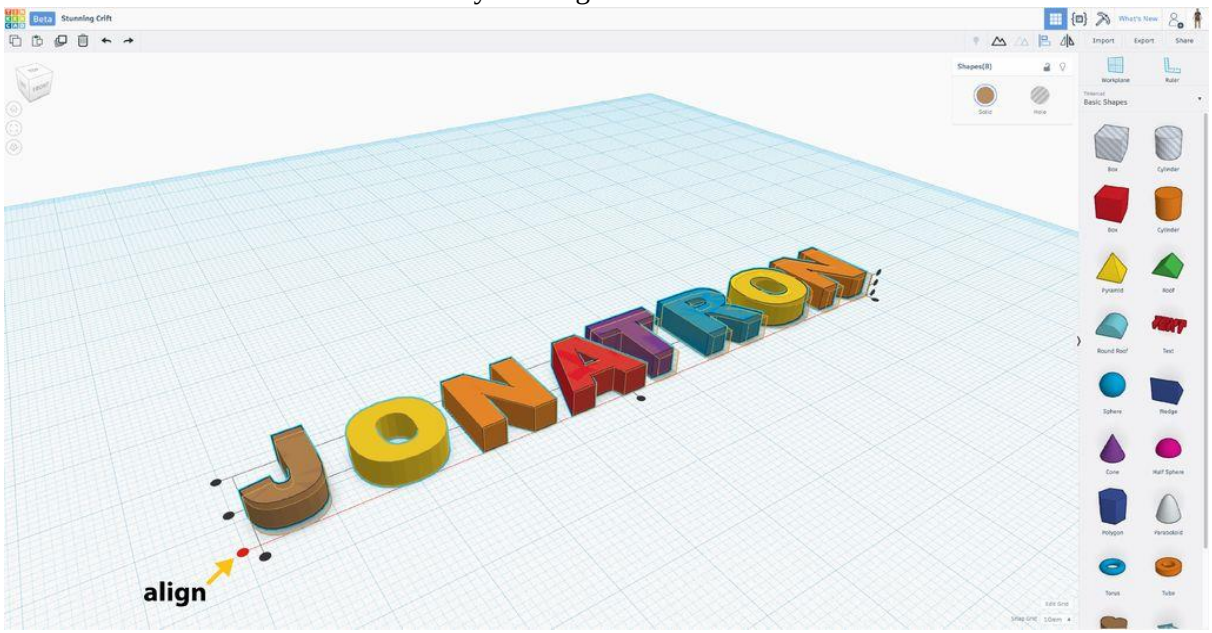
Align the Letters



4. Select all the letters on the workplane.



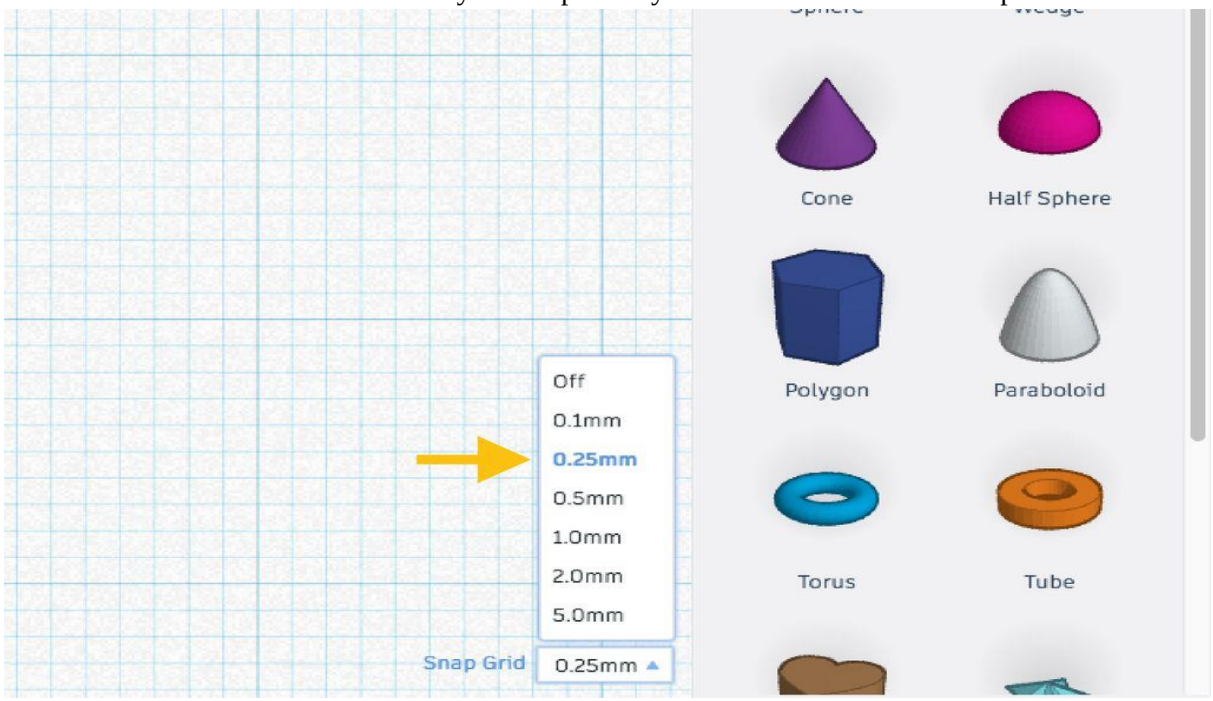
5. Select Align from the Adjust menu on the toolbar. Align the letters so the bottom of each letter is in line with the others by clicking on the black dot.



Make the Letters Overlap

6. Rotate your view so you are looking down on your name by clicking Top on the View Cube. Select the second letter in your name and use the arrow keys on the keyboard to nudge in closer to the first. Note: Each letter should overlap the letter before it by about 1mm, but this doesn't need to be exact.

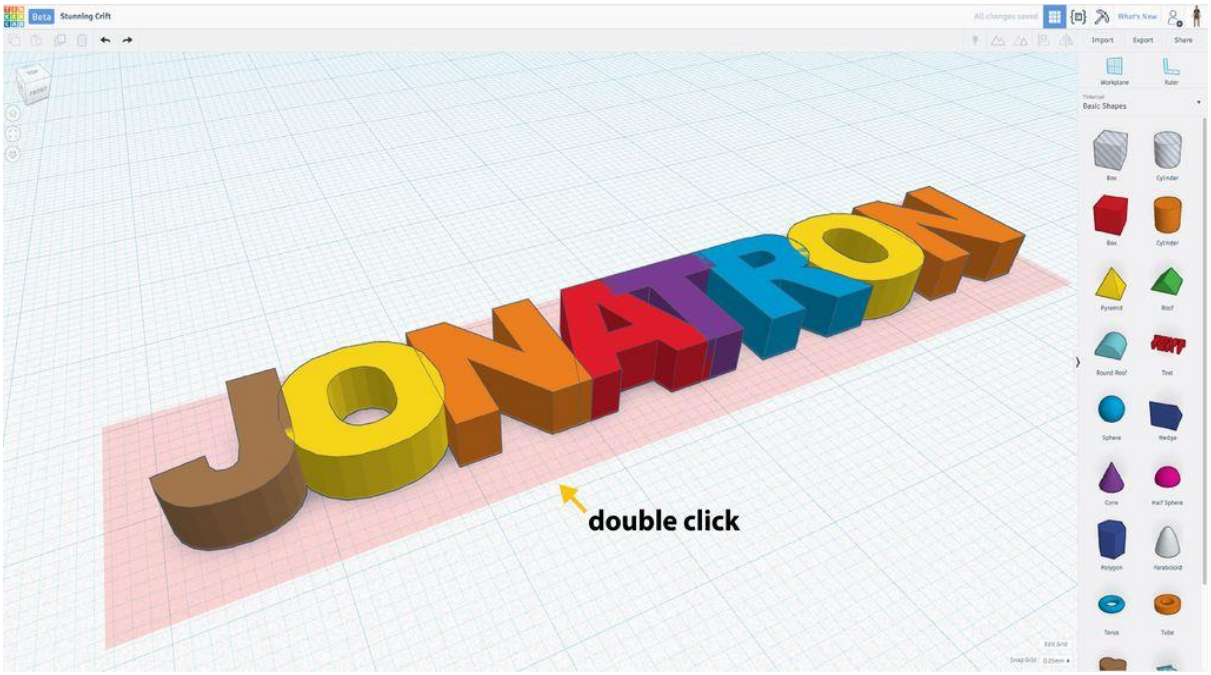
7. Repeat the previous step for each of the remaining letters in your name. When each of the letters is overlapping the letter before it in your name, you are almost finished.Not all the letters are the same width and you will probably find that some letters overlap more than



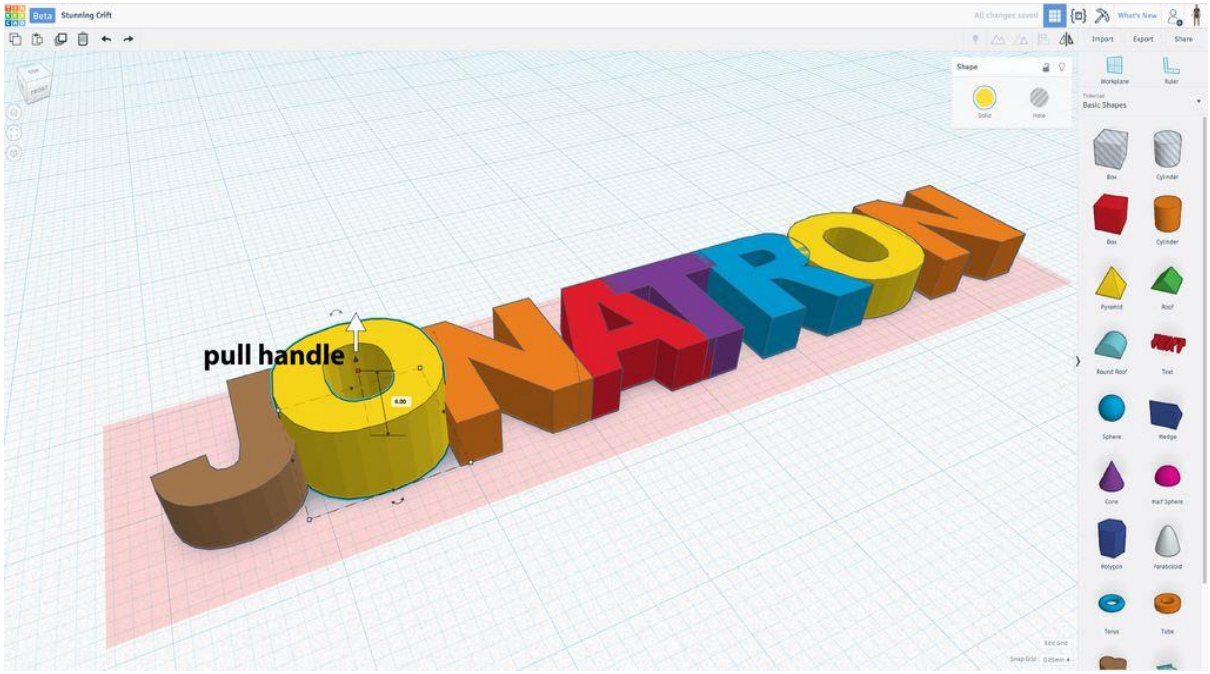
others. If you want to fine tune how much your letters overlap you can set the grid snap to 0.25 and use the arrows on your keyboard to adjust the amount each letter overlaps its nearest neighbor.

Adjust the Letter Height

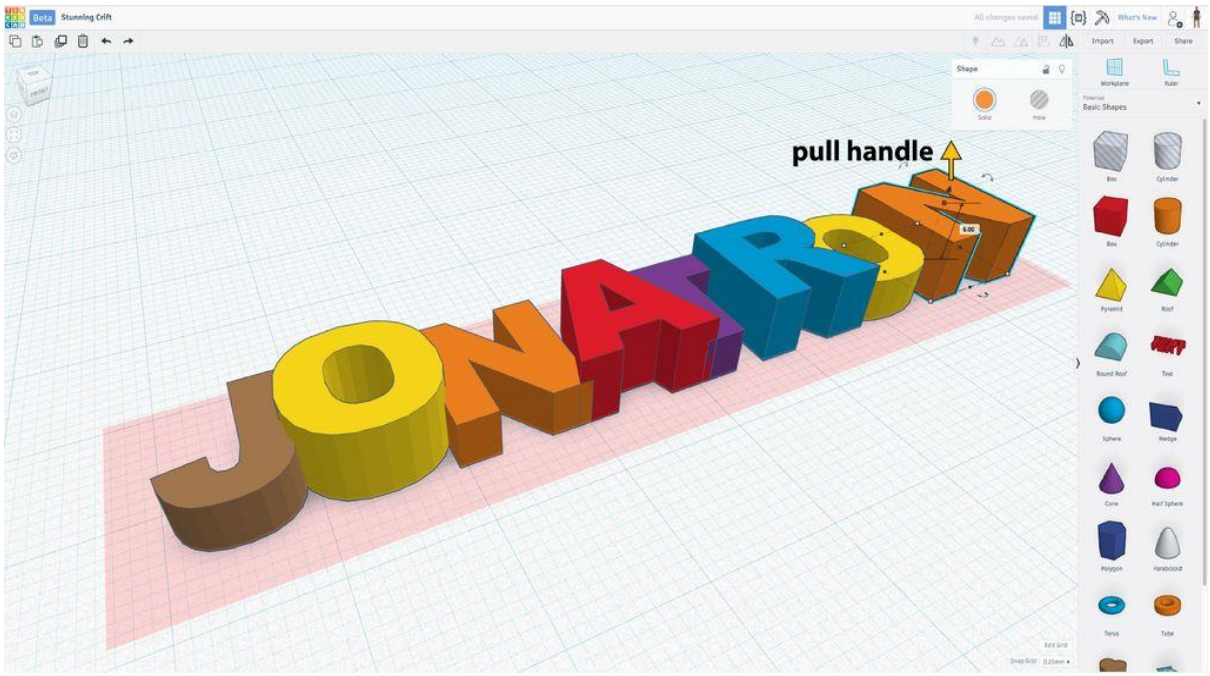
8. Select all your letters and group them into a single object. To do this, click and drag a box over all the letters, then click the Group button in the upper right corner of the editor as shown in the picture above. Is your name a little hard to read like mine was? Let's fix this.



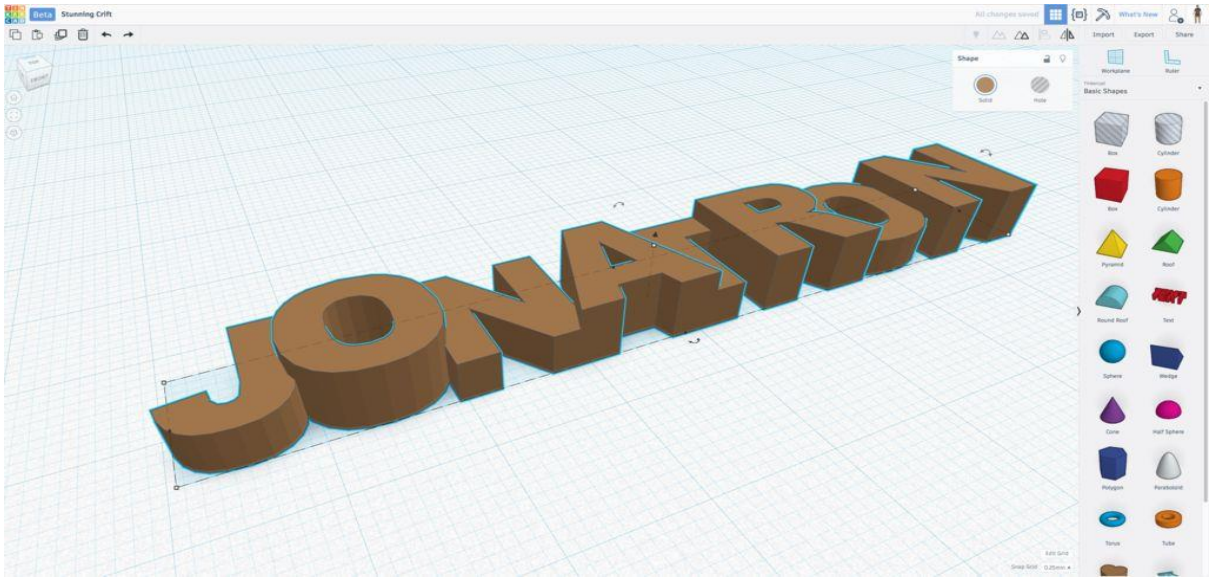
9. Double click on your name to edit the group. Note: You will know you are editing the group if you see a red rectangle under your letters. The letters should also return to their original colors while editing the group.



10. Select the second letter in your name and use the white dot (handle) on the top to make the letter shorter than letter next to it.



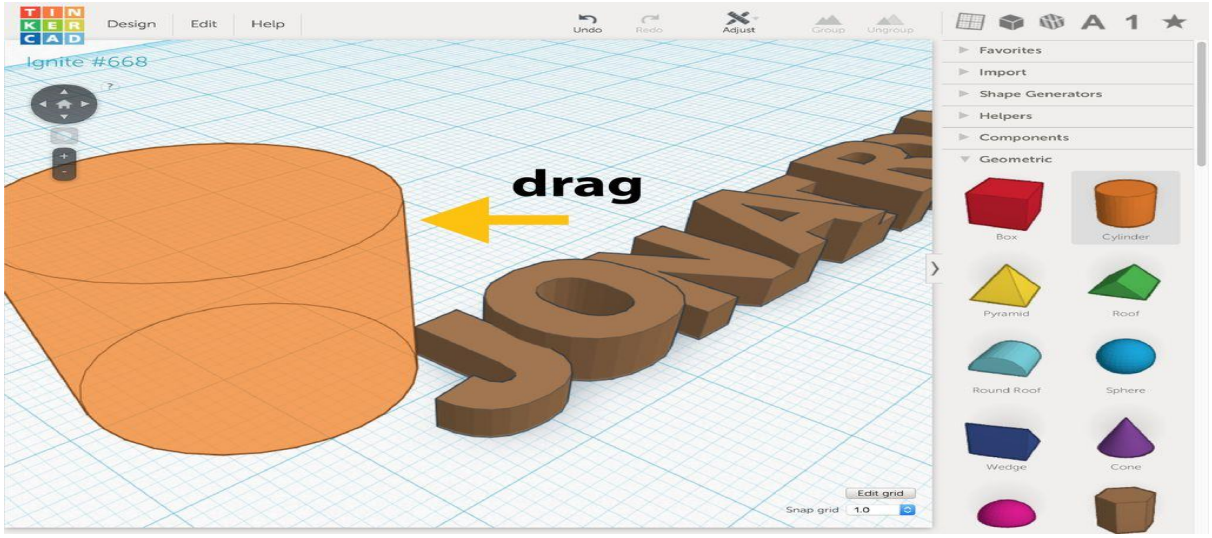
11. Repeat the previous step with every other letter in your name. By doing this we will be able to see each of the letters in the group better when we finish editing the group.



12. Click anywhere on the workplane outside of the red group edit rectangle to finish editing the group. You should see your name change back to the group color and it should be much easier to see each letter.

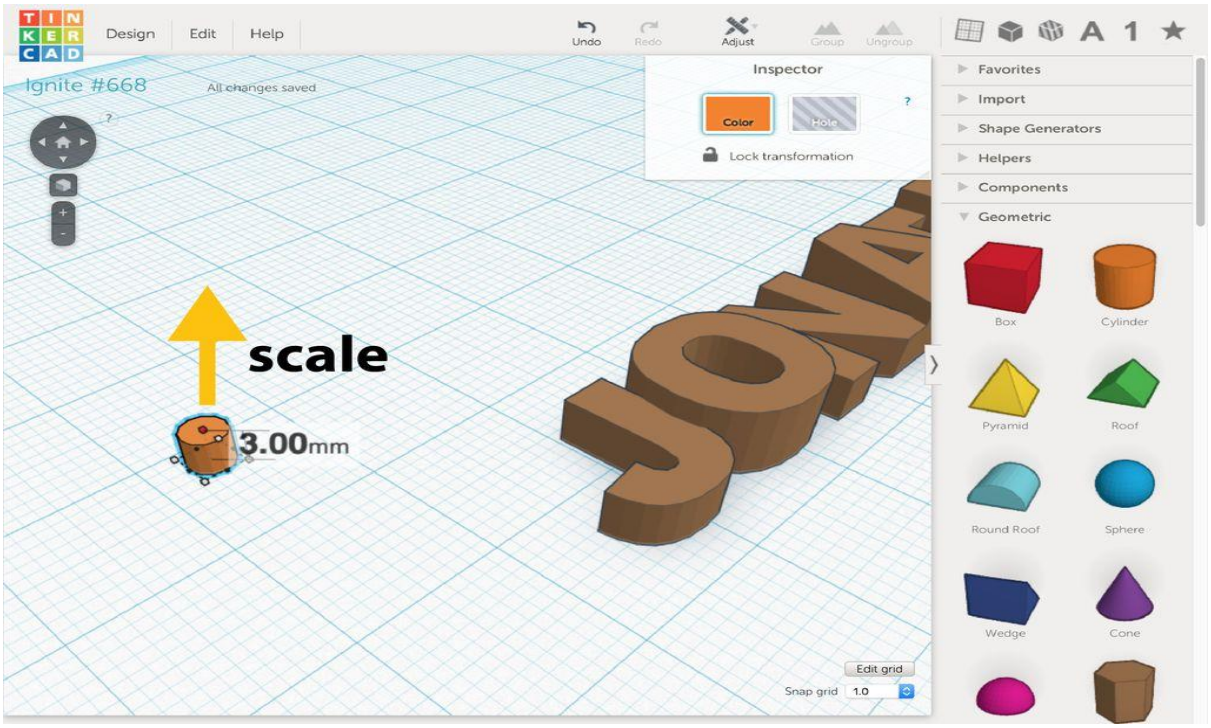
Add a Keyring Loop

13. Drag and drop to place a cylinder on the workplane.

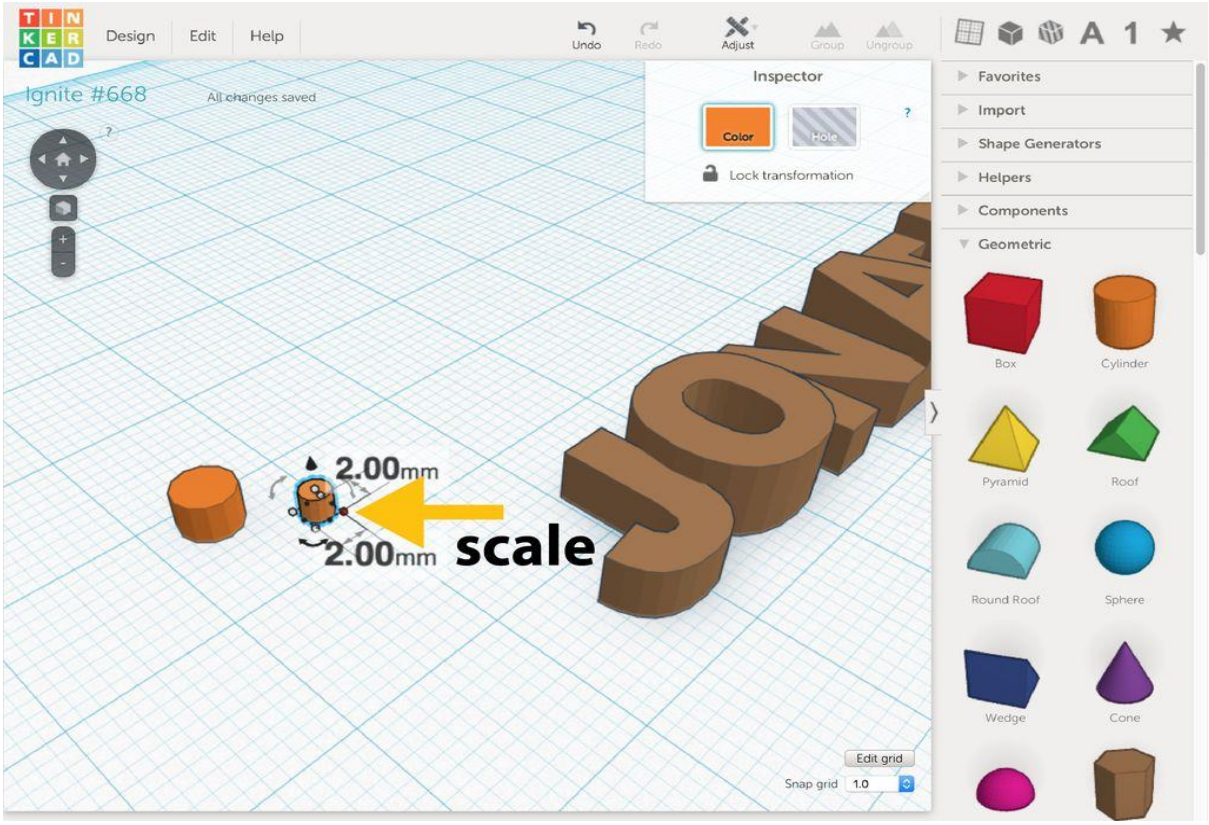


14. Shift + Drag the handle on the workplace and make the cylinder 4mm X 4mm in the X/Y dimensions.

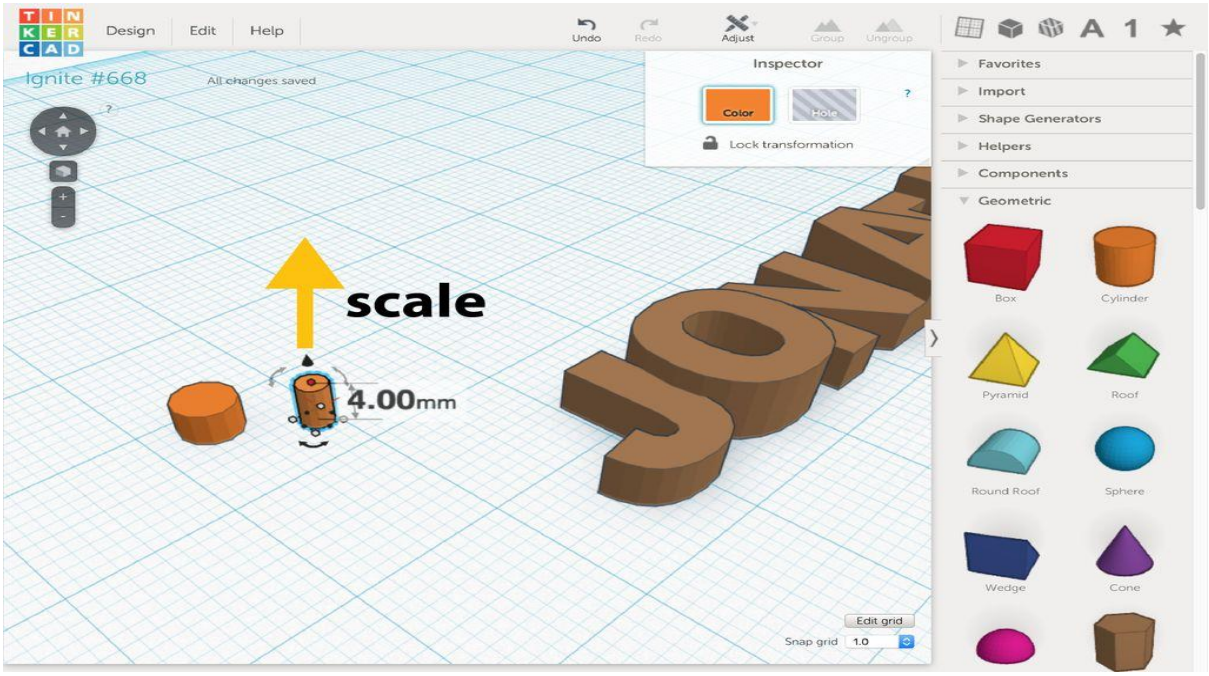
15. Drag the Z dimension (vertical) handle to make the cylinder 3mm tall.



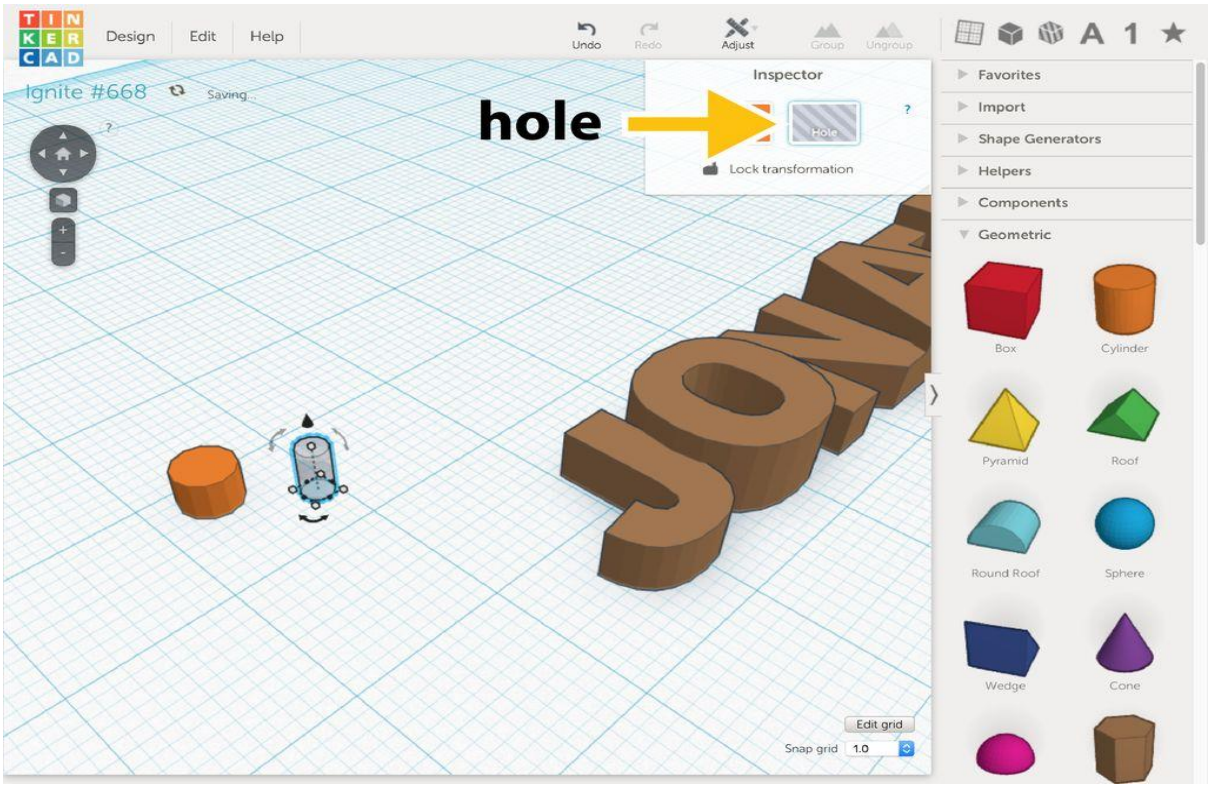
16. Drag and drop to place the second cylinder on the workplane and size it to 2mm square.



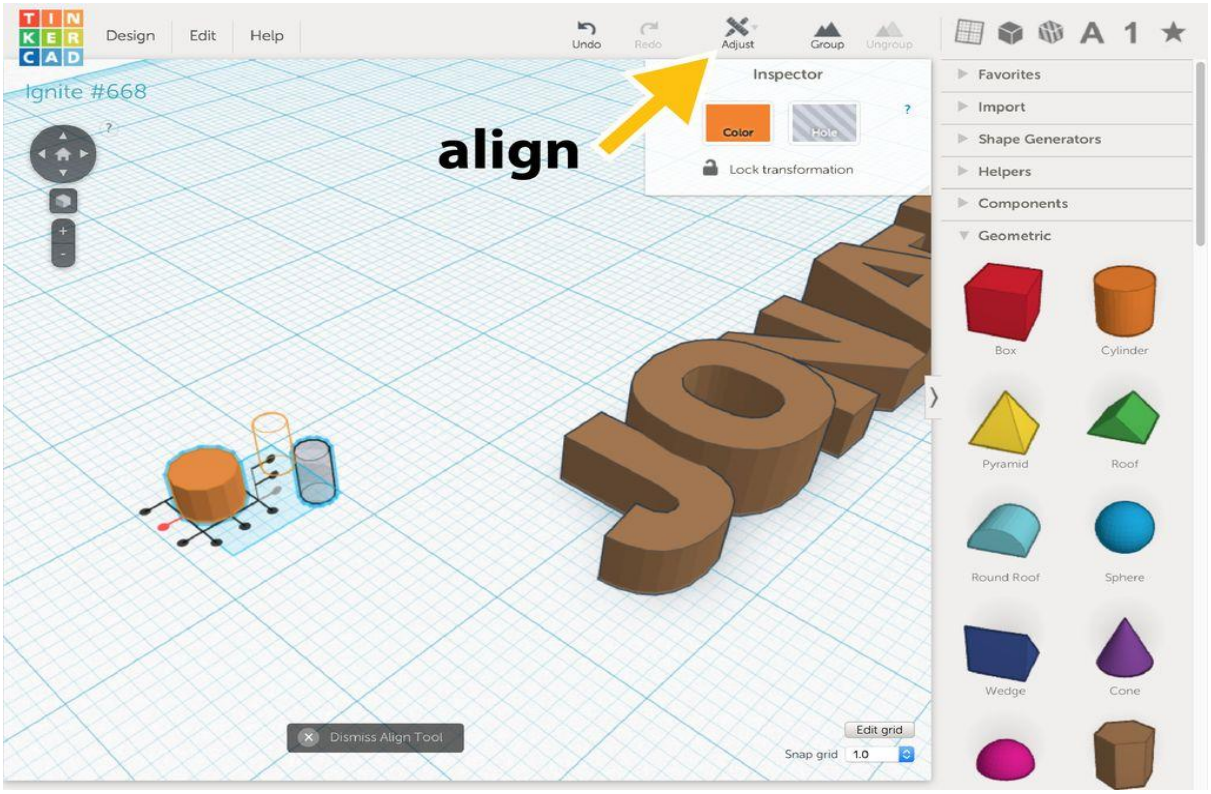
17. Drag the vertical scale handle to 4mm tall.



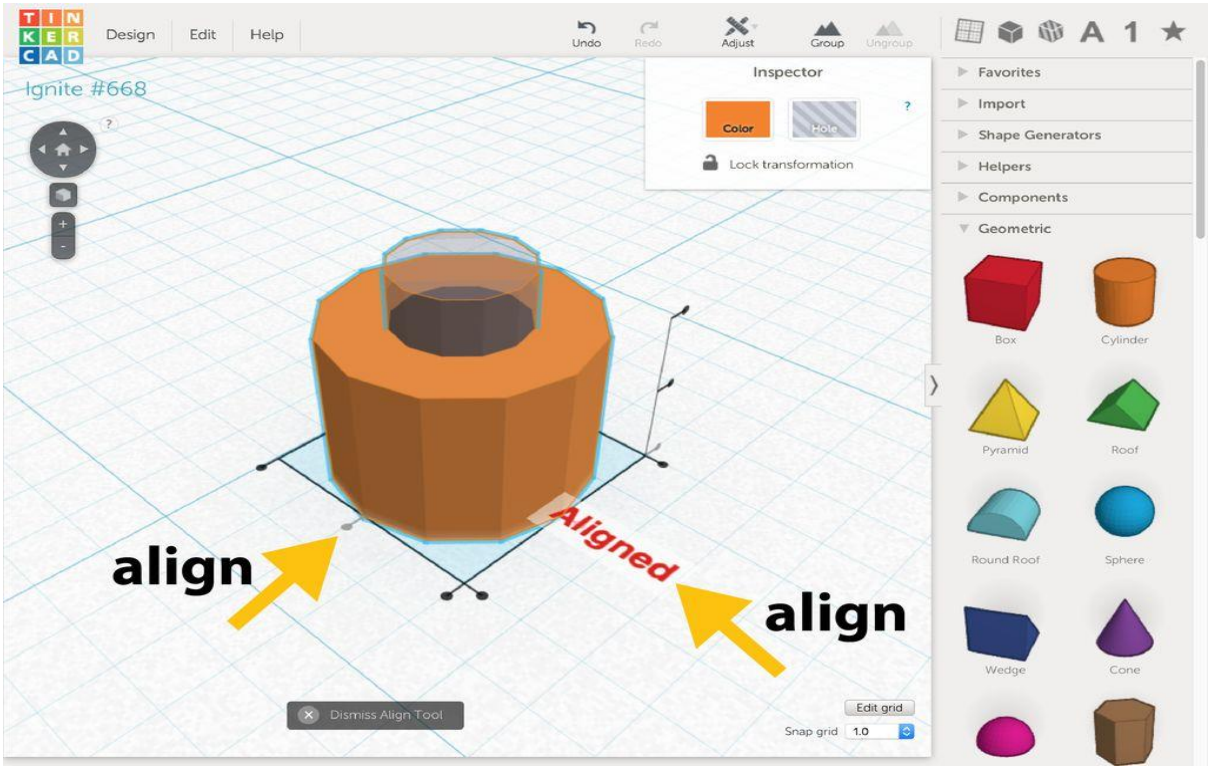
18. Select the second cylinder and make it a Hole in the inspector window.



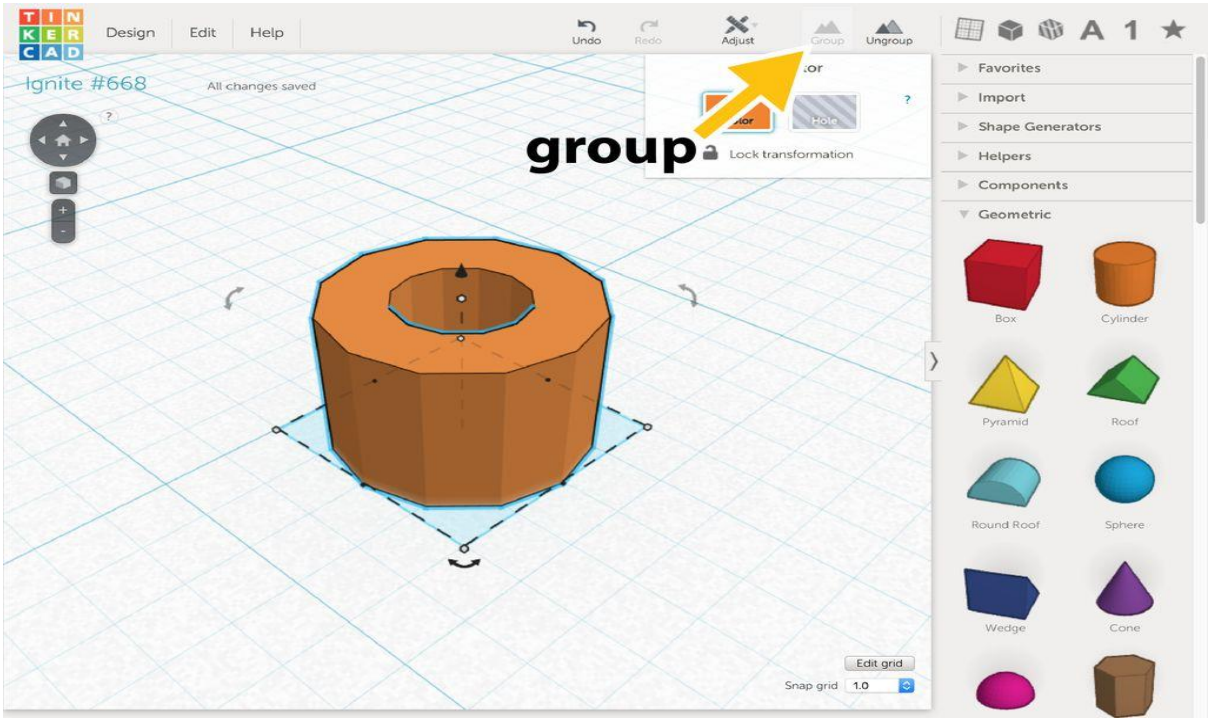
19. Select both cylinders and click on Align in the Adjust menu.



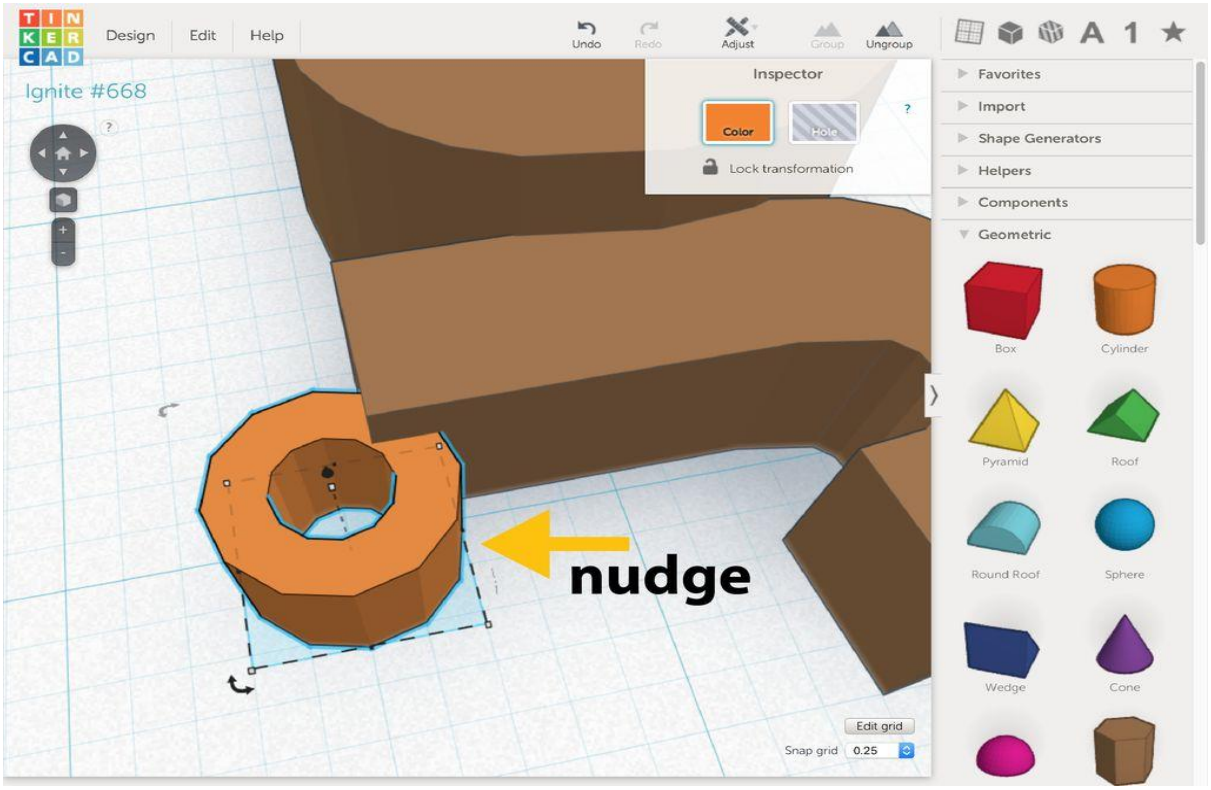
20. Click the dots to align the cylinders so they have the same center.



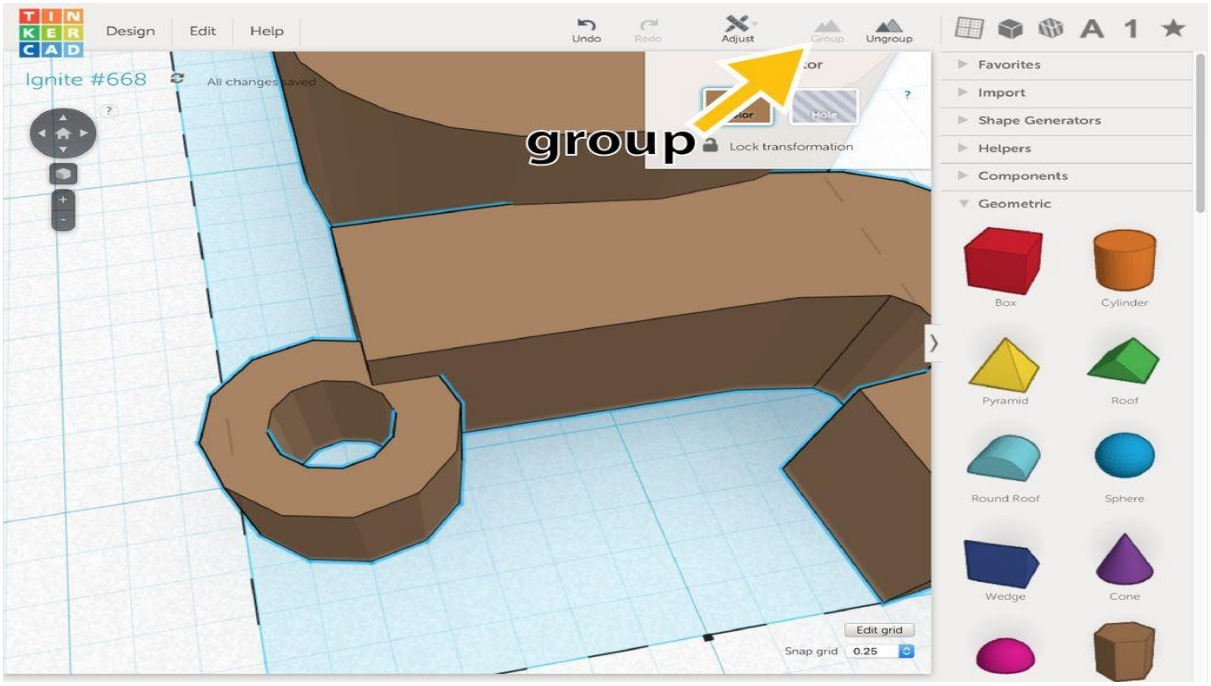
21. With both cylinders selected, group the cylinders into a single object by clicking the Group button on the top bar.



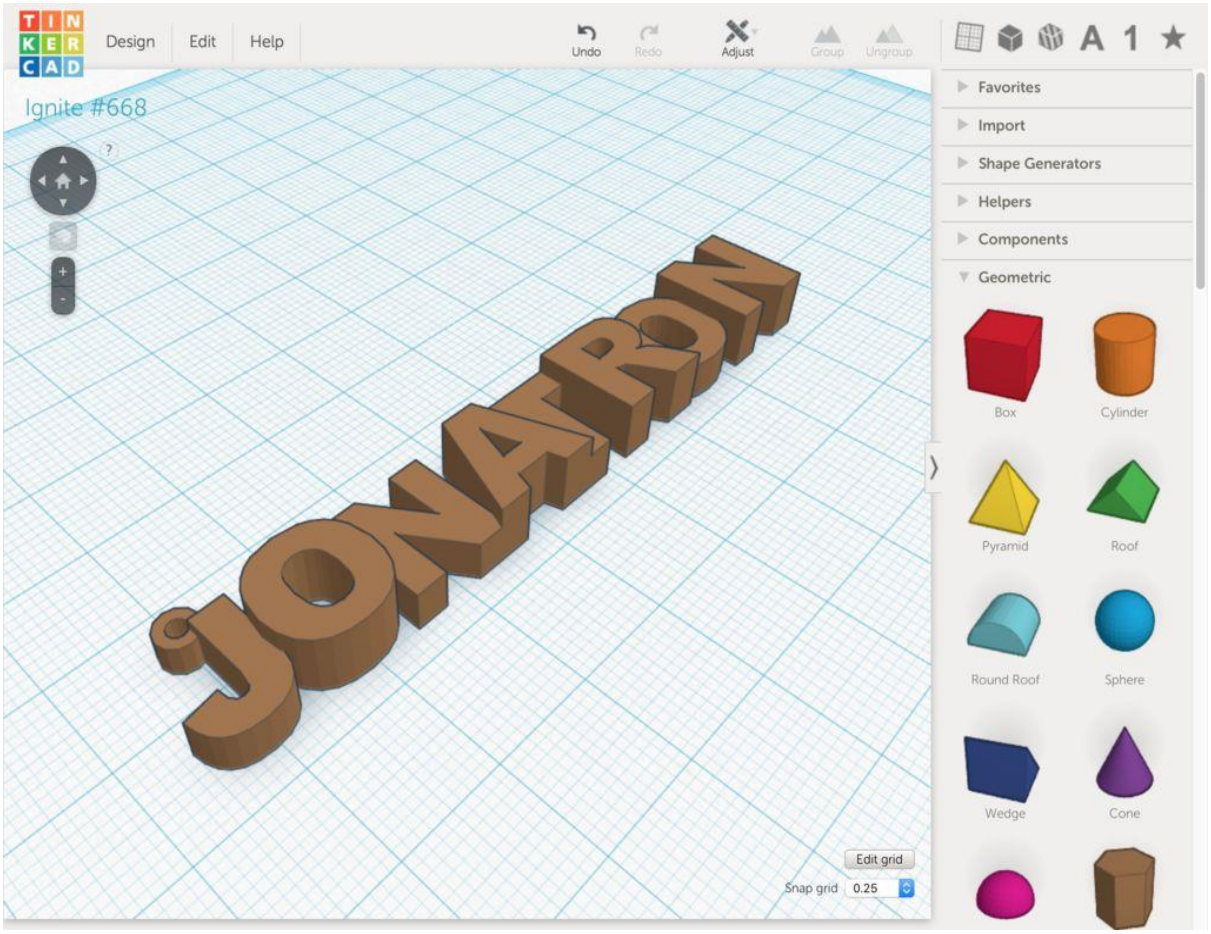
22. the key ring and use the arrow keys on your keyboard to nudge the ring into the first letter of your name.



23. To complete the key chain, Group your name and the ring together into a single object.



The keychain is ready to get print.

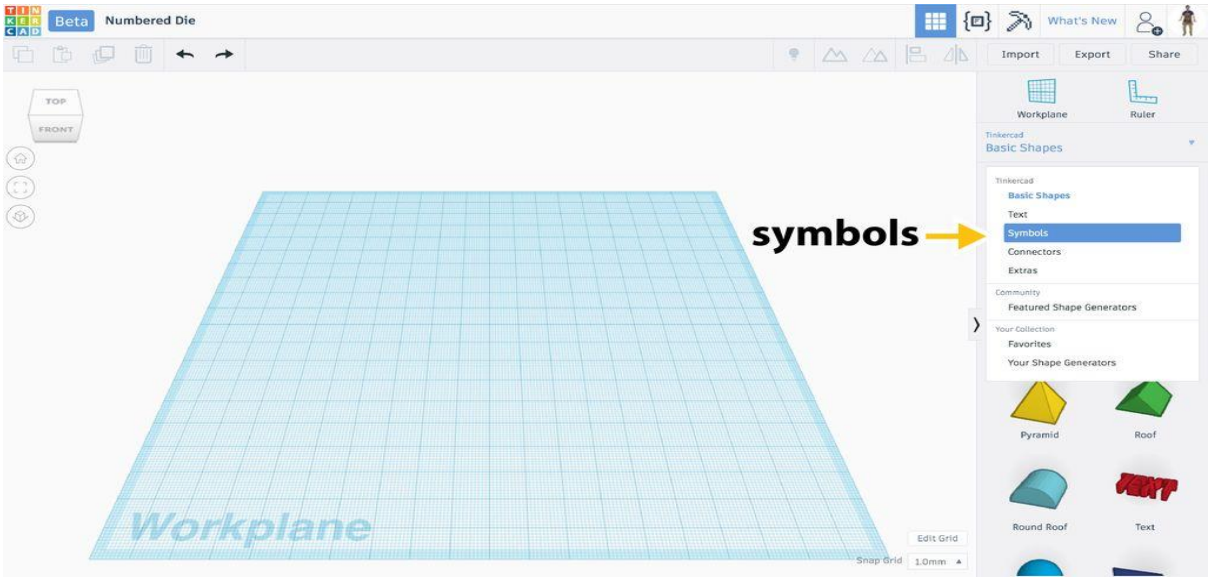


CHAPTER 4-NUMBERED DIE

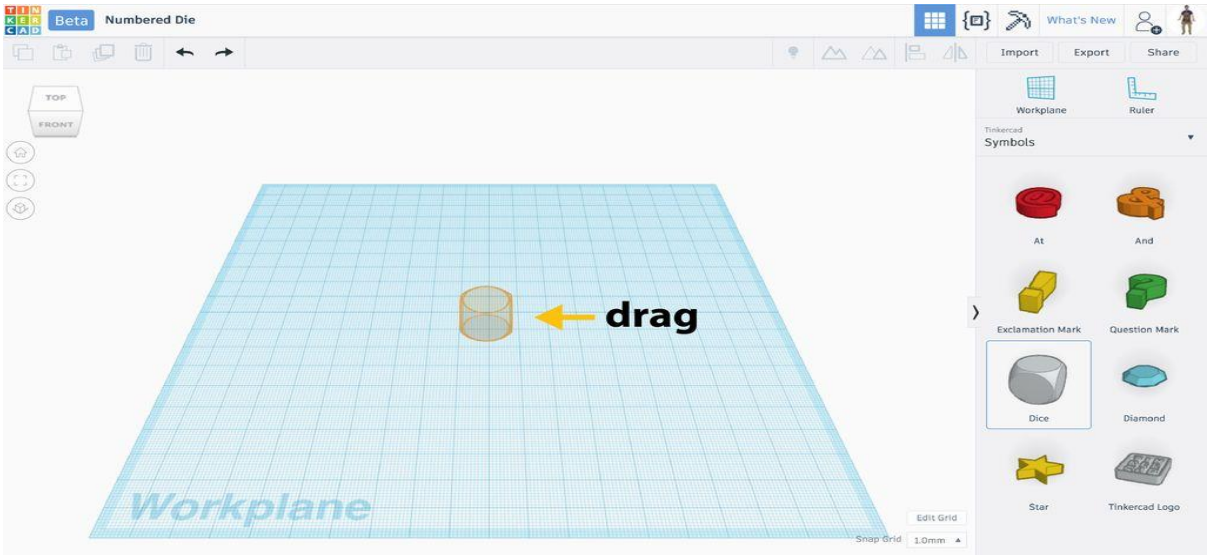
Rounded Cube

A die may look like a cube, but if you want it to roll well, you'll need to make sure the corners are rounded.

It's possible to round the corners on a cube in TinkerCAD, but there's a pre-made dice-shape in the shapes menu.

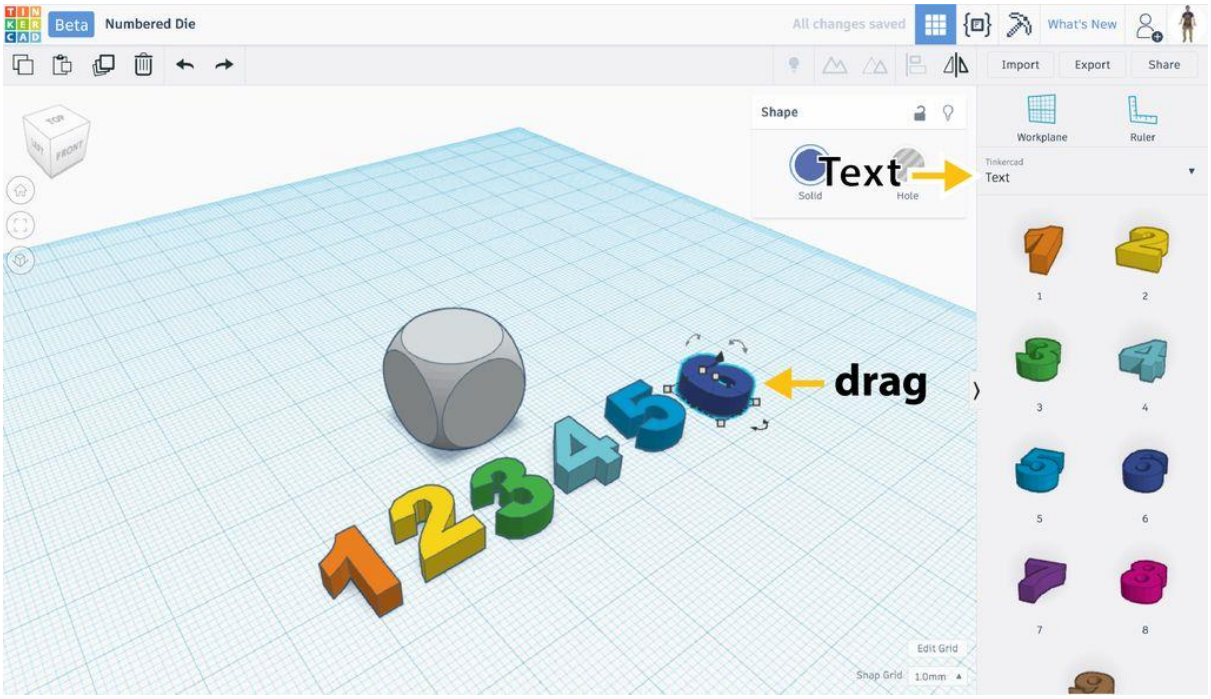


1. Click on the Basic Shapes tab in the menu on the right to show the Symbols drop-down menu.
2. Now, drag the dice shape to the workplane.



Creating the Numbers

3. Click on the Text menu and drag the numbers one through six onto the workplane.

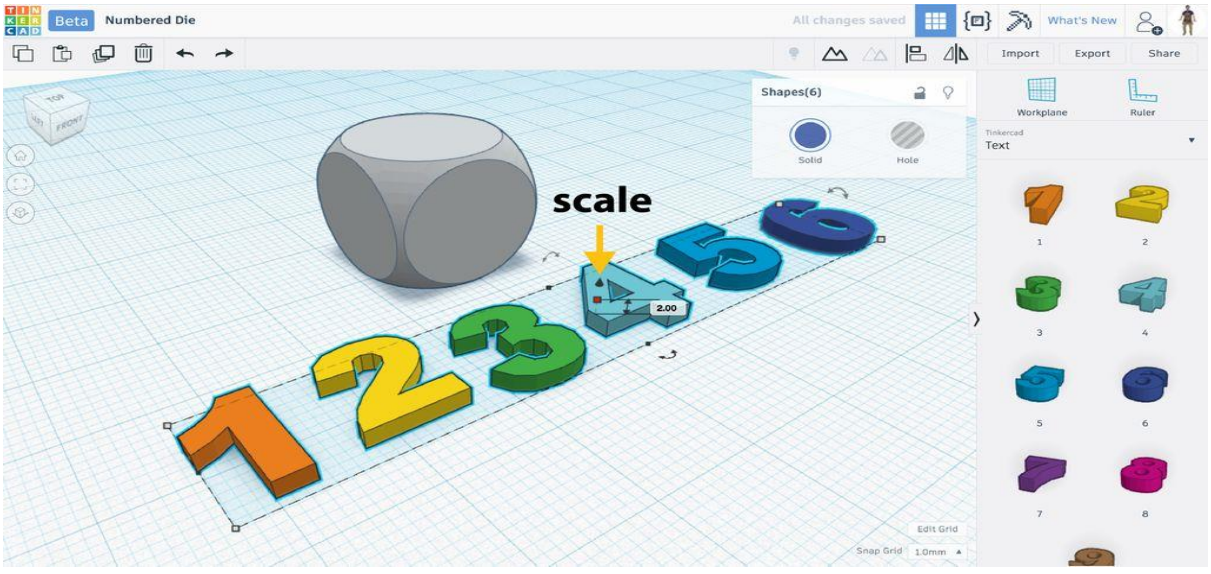


Turning the Numbers into Holes

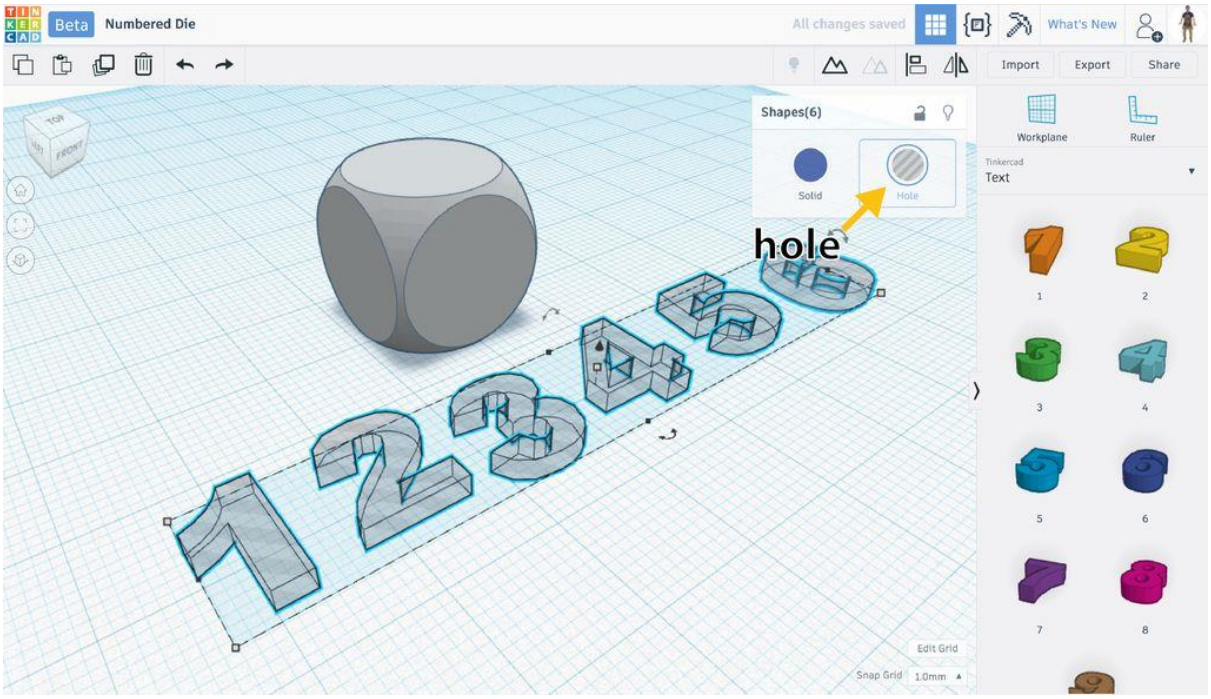
Though the numbers will fit within the faces of the die, they are much too tall. We need to resize them so they fit properly.

After we resize the numbers, we will need to cut the numbers out of the die so they can be seen on the sides of the die. When you drag the numbers onto the workplane, they're automatically 4mm tall. If you cut these out of the die they'll be too deep.

4. Select all the numbers, then drag the Z axis scaling handle down until all of the shapes are 2mm tall.



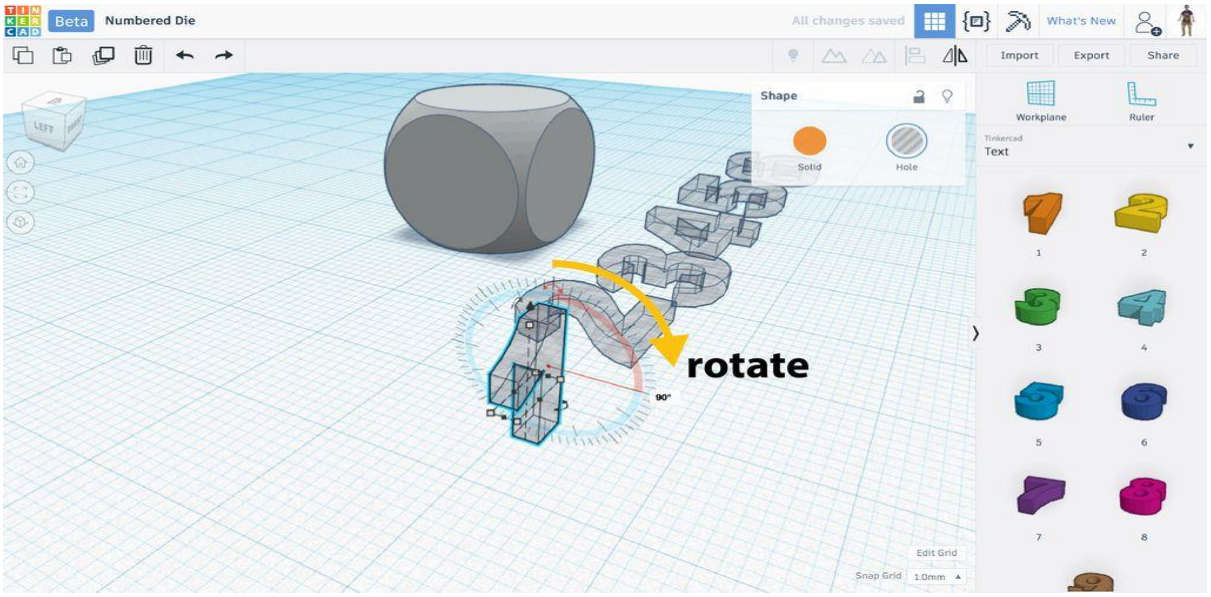
5. In the Inspector window, click the Hole button.



Creating Side One of Your Die

Now we just need to combine the numbers with the sides. Before we can do that, we need to reorient the number so it is readable from the face we'll be aligning it to.

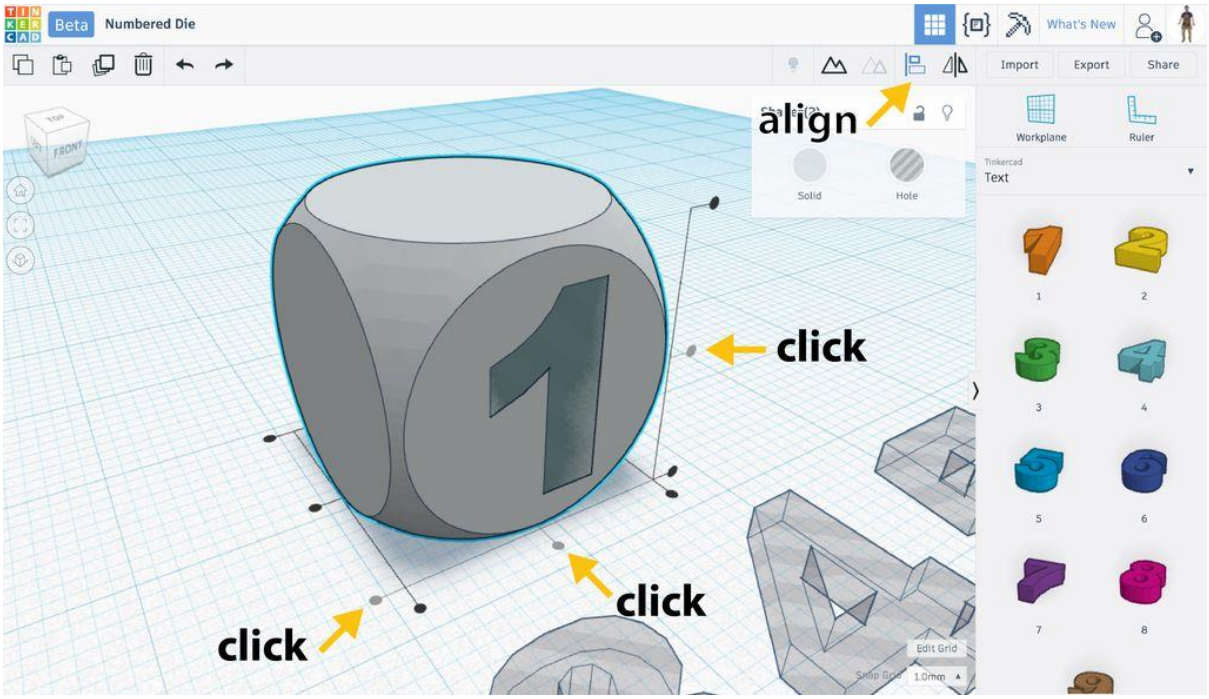
6. Select the first number, then click and drag the rotating icon to rotate it around the X axis so that the number is facing up.



Aligning the Number

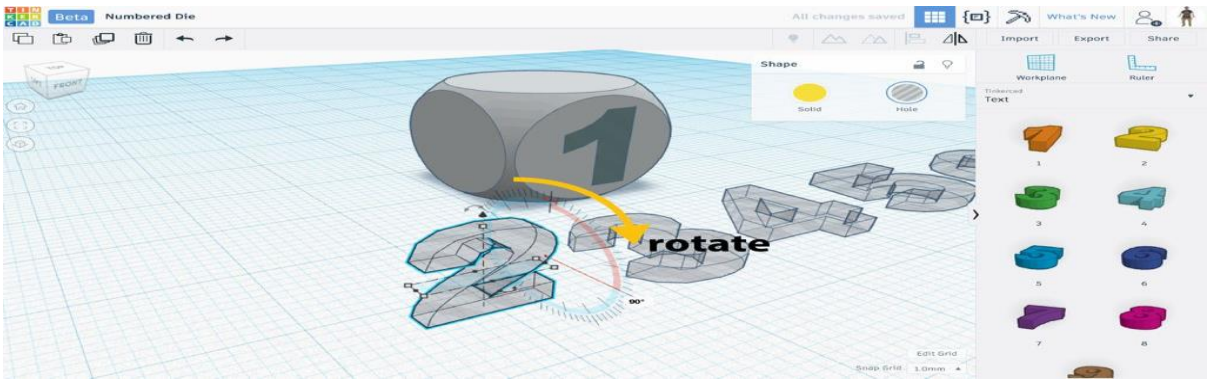
Now we're going to use Tinkercad's Align tool to align the number shape to its face. Select both the number one and the die and click Align from the adjust menu. Click the die again to keep it from moving when you align the two parts.

7. Next, click on the die shape- this will keep the die in place while you align the number.
8. Click the center handles along both the X and Z axes and the lower limit along the Y axis.

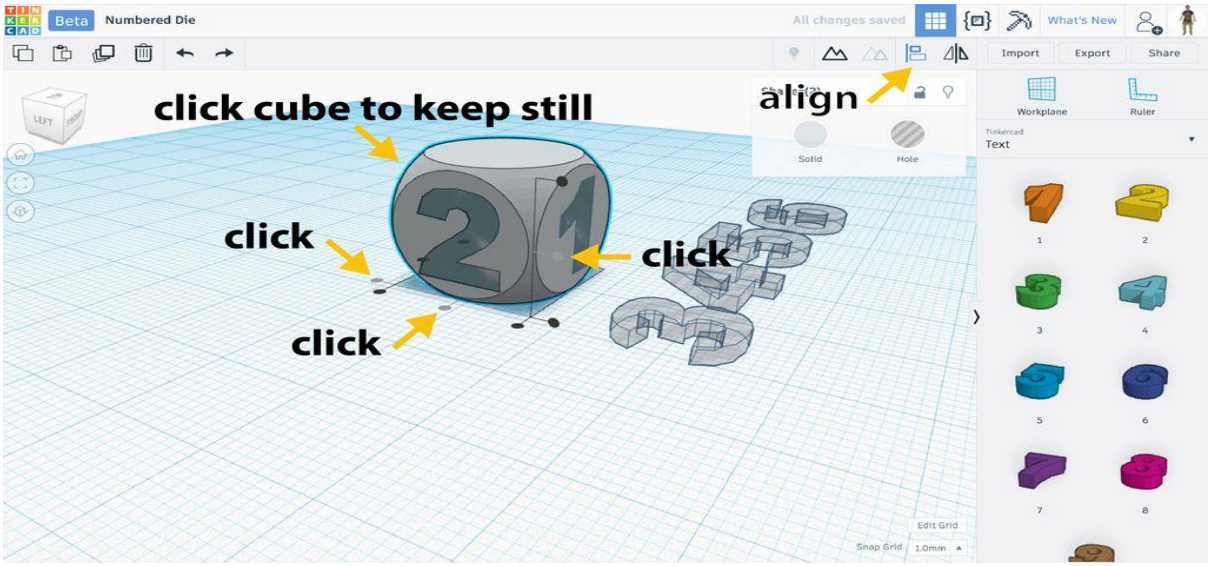


Completing Side 2

9. As you might have guessed, adding the rest of the sides follows exactly the same process as the previous step.
10. Rotate the number two shape 90° around its X and Z axes.



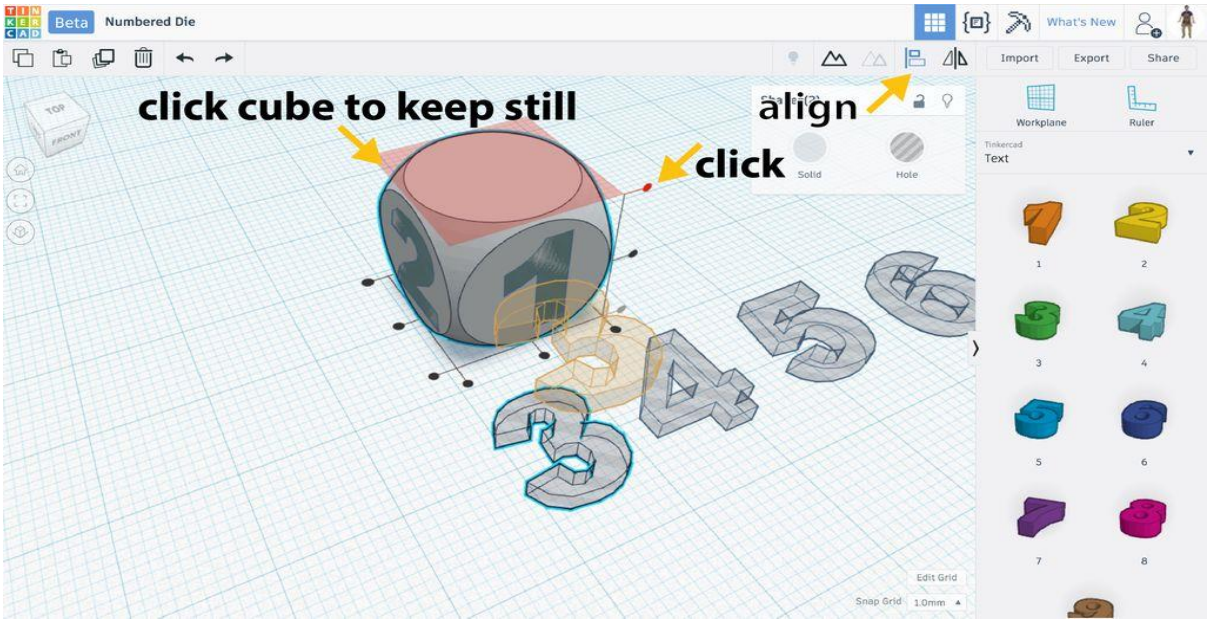
11. Select both the number two and the die and click Align from the adjust menu. Click the die again to keep it from moving when you align the two parts. Click the center handles along both the Y and Z axes and the lower limit along the X axis.



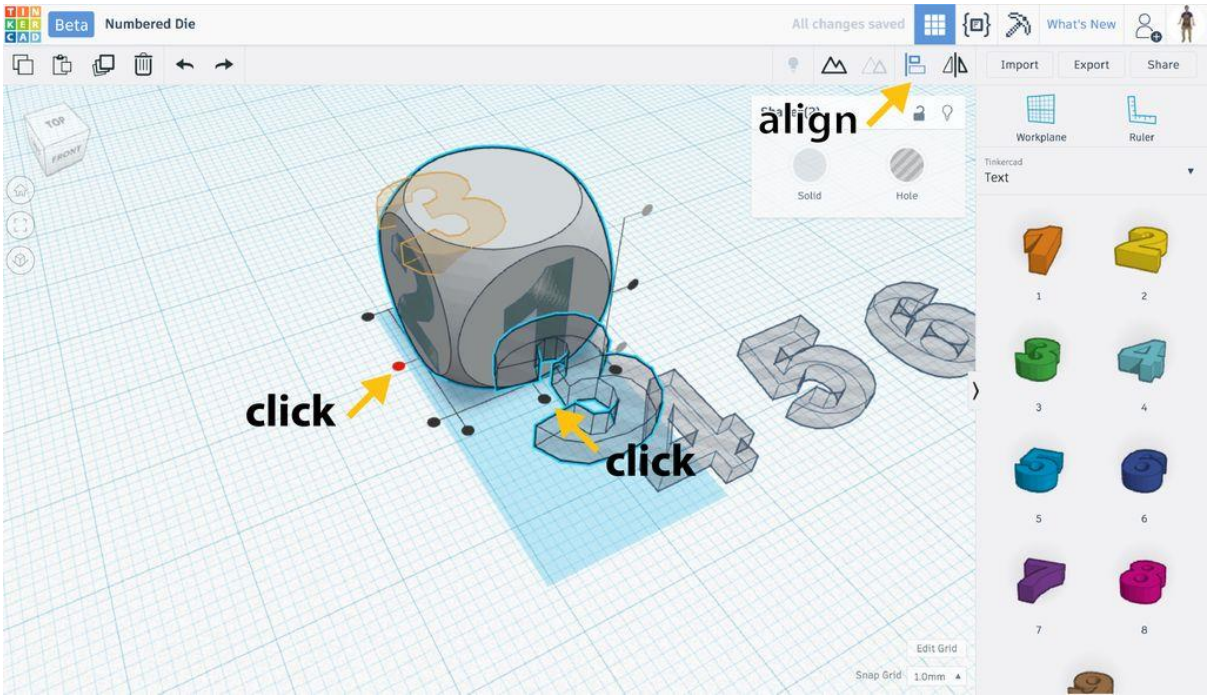
Completing Side 3

Just to make sure you know what you're doing, we are going to practice a bit more. We are going to show you how to do one more side and then you are on your own to create the remaining three.

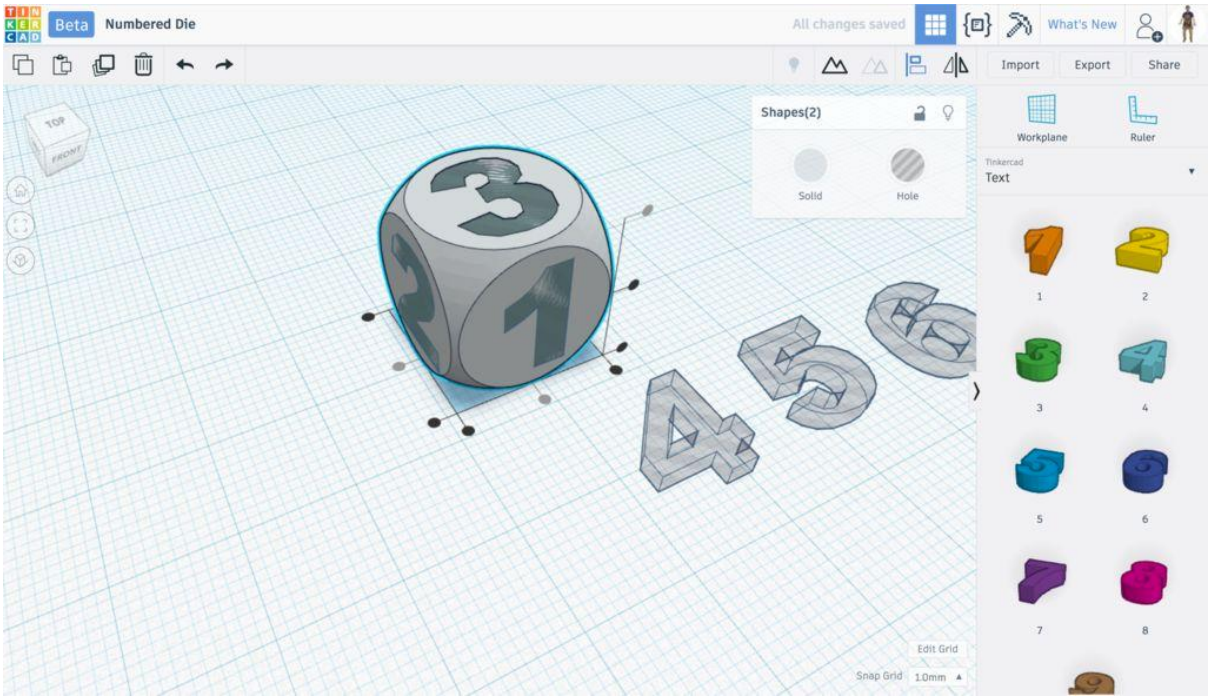
12. Select both the number three and the die and click Align from the adjust menu. Click the die again to keep it from moving when you align the two parts.



13. Click the center handles along both the X and Y axes and the upper limit along the Z axis.



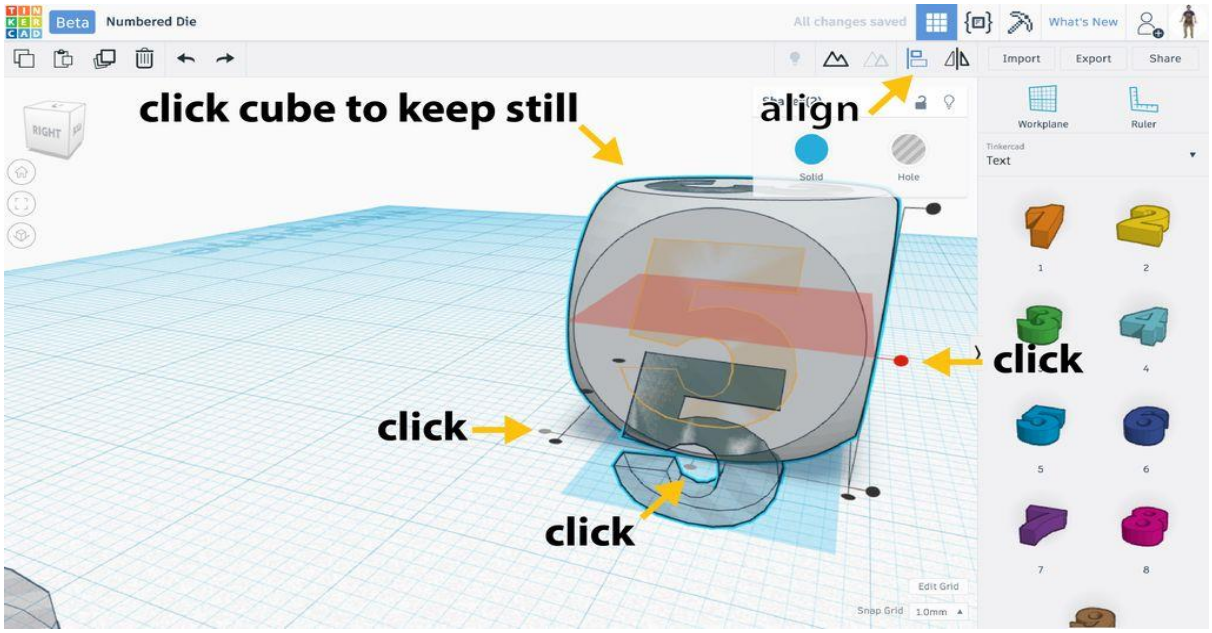
14. Group the number three shape and the die.



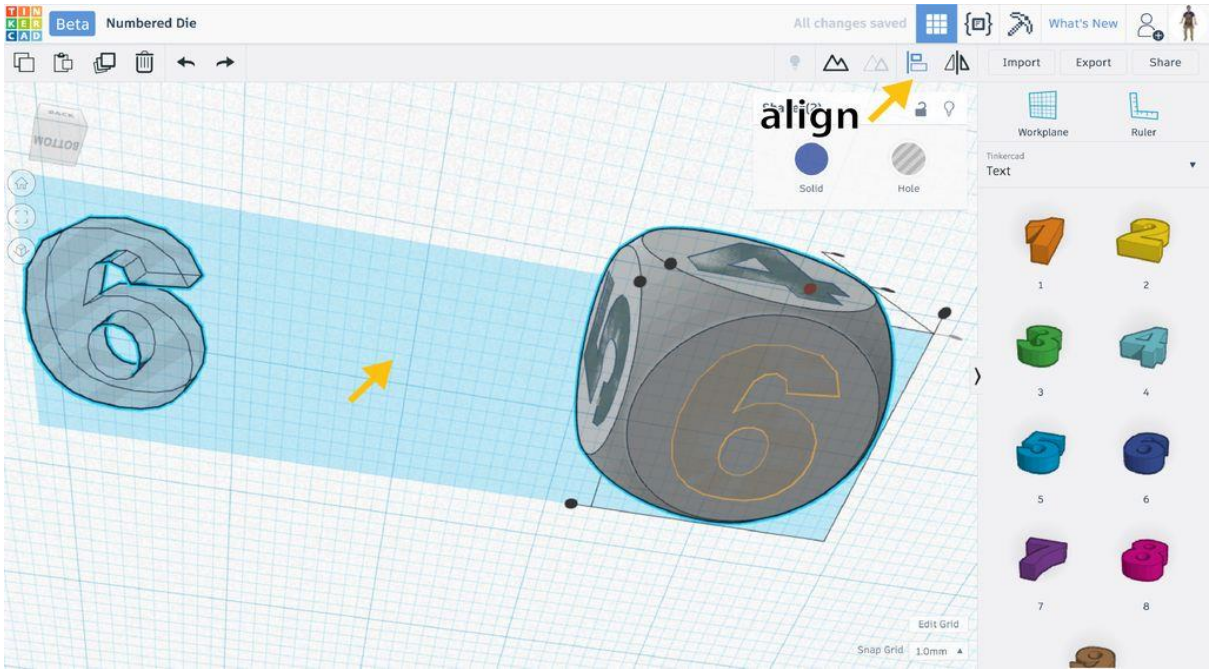
Finishing the Die

Now that you're an expert, it's up to you to complete the remaining three sides of your die. To do this, you'll just need to rotate each number so that it will be facing the right way, then use the align tool to get the number centered on the correct face of the die.

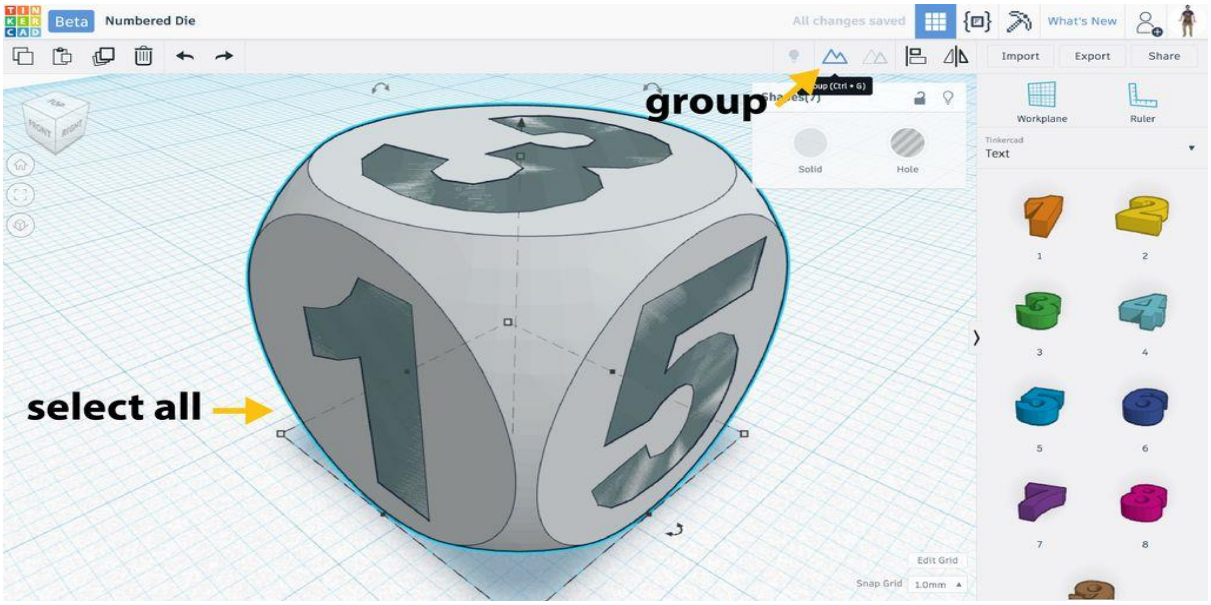
15. Rotate the number so that it is parallel to the face, then use the align tool just like before to get the 5 and 6 into the proper place.



16. You'll have to align the 6 from the underside.

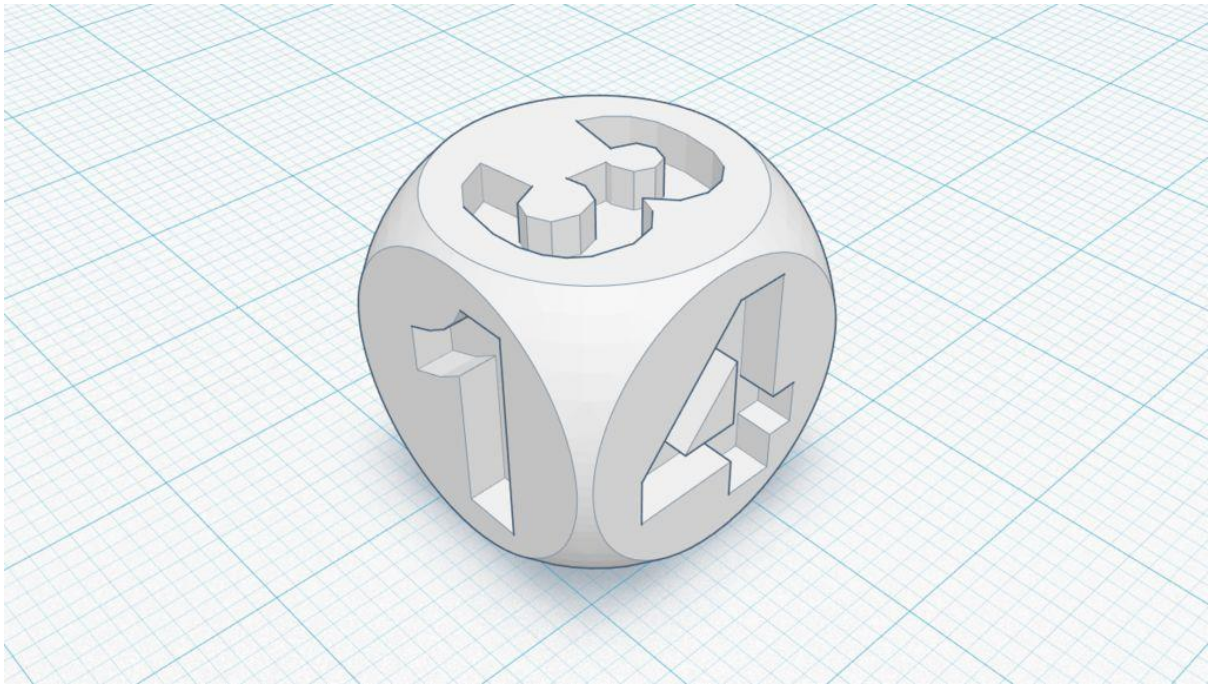


Finally, select all the parts and click Group to cut the numbers out of the die shape. This is a bit different from the instructions in the Learn tab on TinkerCAD because we're only grouping once at the end instead of making a new group every time we move a number, but you'll get the same result either way.



Recap

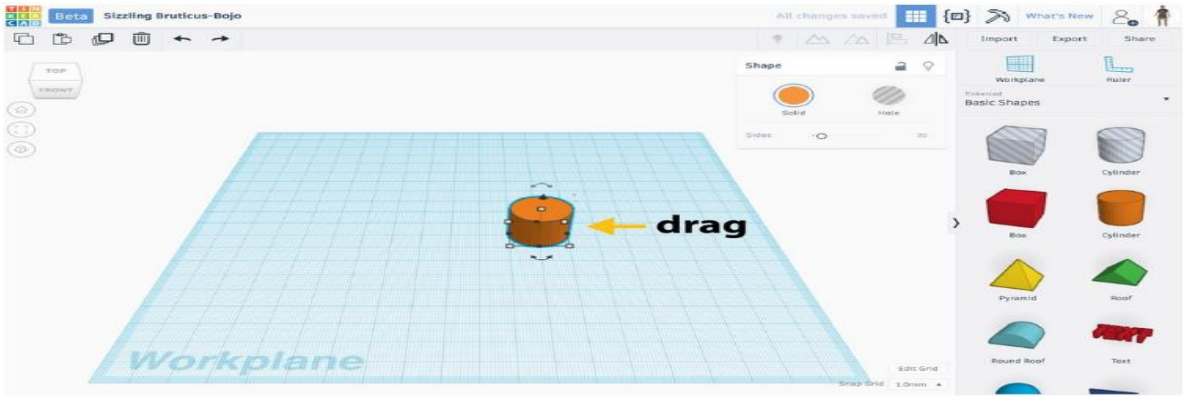
To recap, we learned how to Scale, Rotate, Align, and Group objects to make cutouts in multiple planes. These skills will be super useful for just about anything.



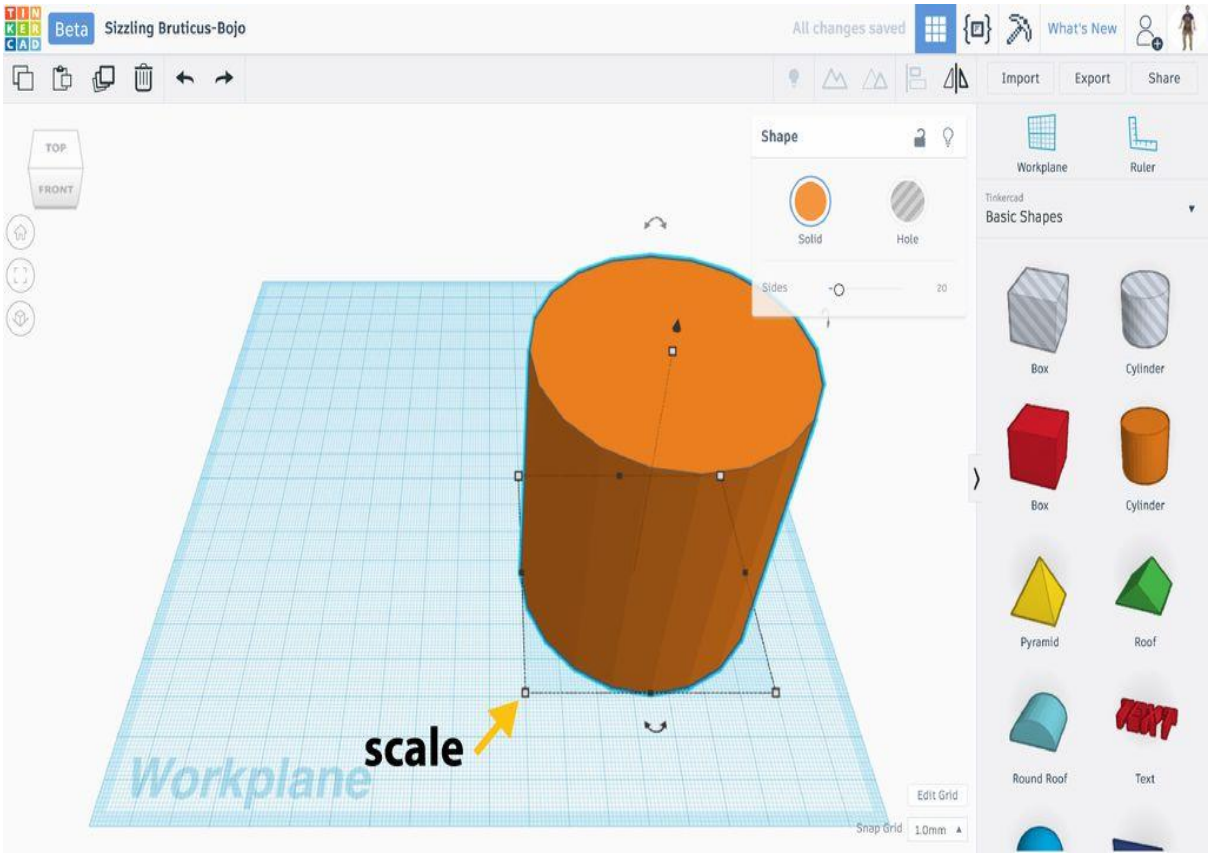
Chapter 5-Smart Phone Amplifier

First, you're going to make the *horn* part of the amplifier. This will be a hollow acoustical cylinder that will make the sound waves bounce off of it on the inside, directing the sound and making it louder.

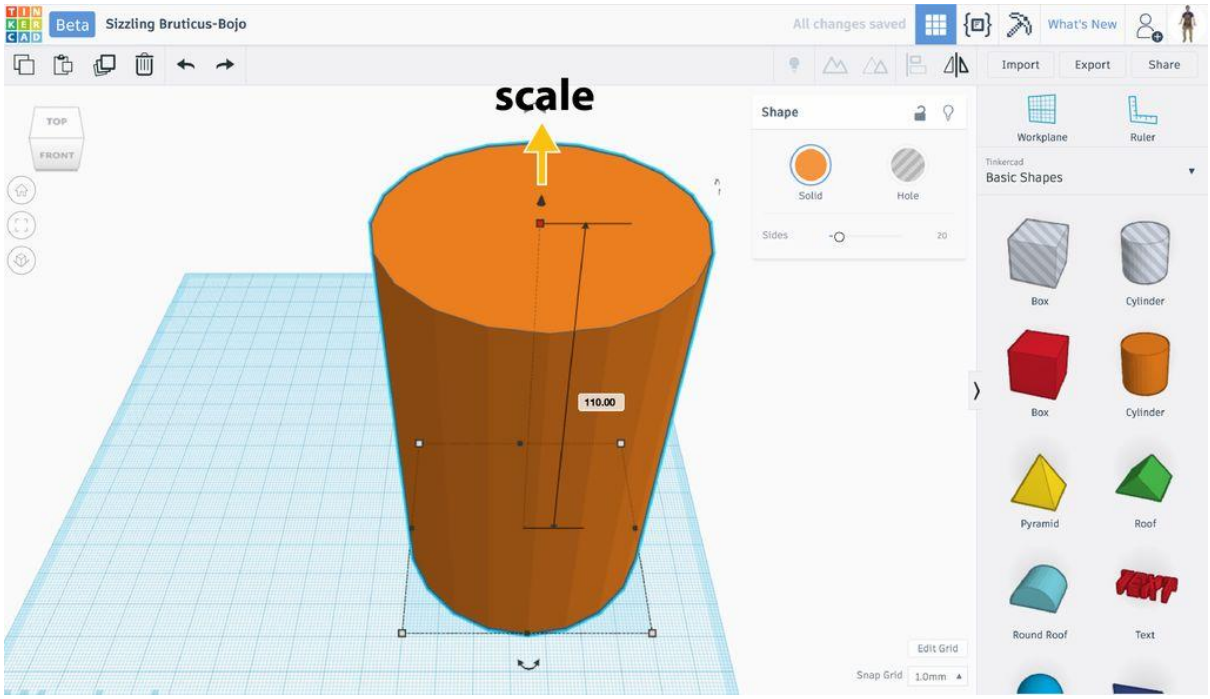
1. Drag and drop a cylinder onto the workplane.



2. Drag the handle on the workplane to make it 70mm X 70mm. TIP: You can constrain the scale by holding Shift while you drag the handle.

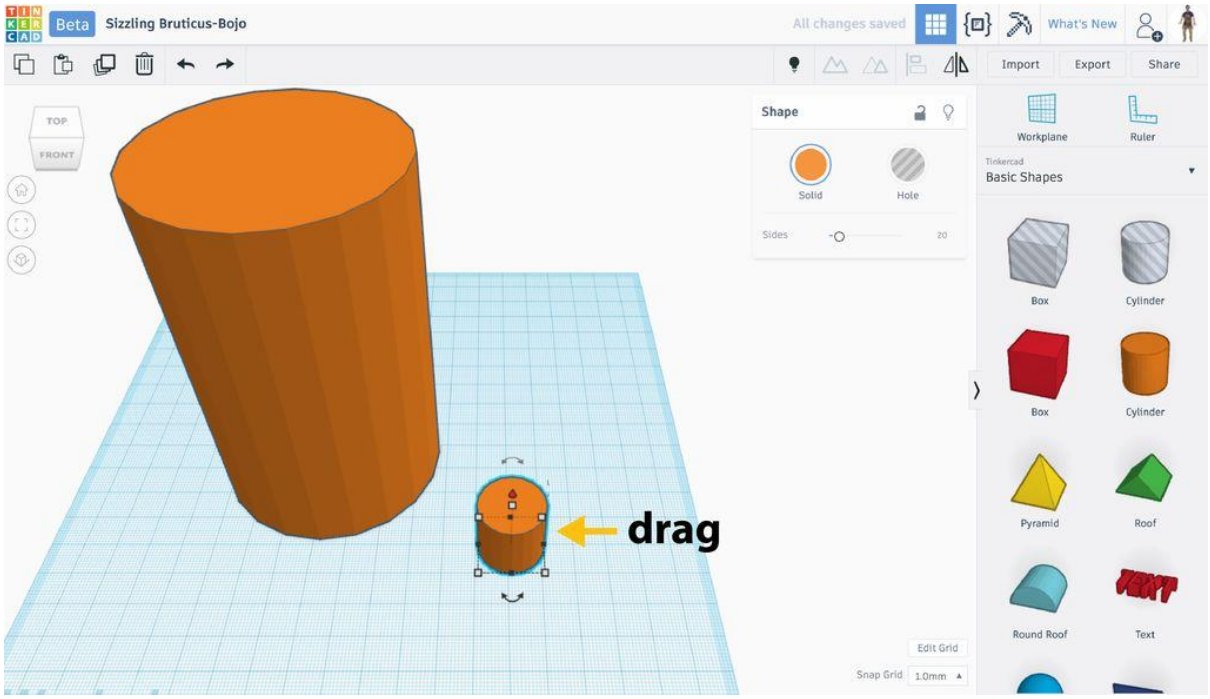


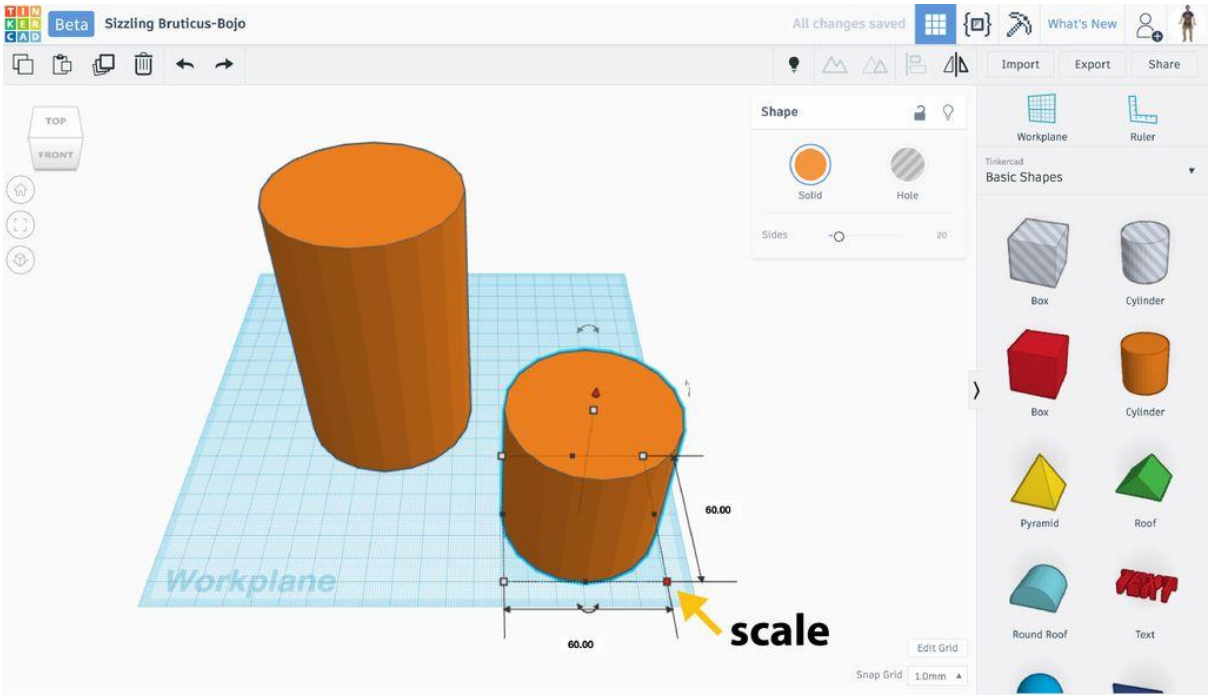
3. Drag the top handle to make the cylinder 110mm tall.

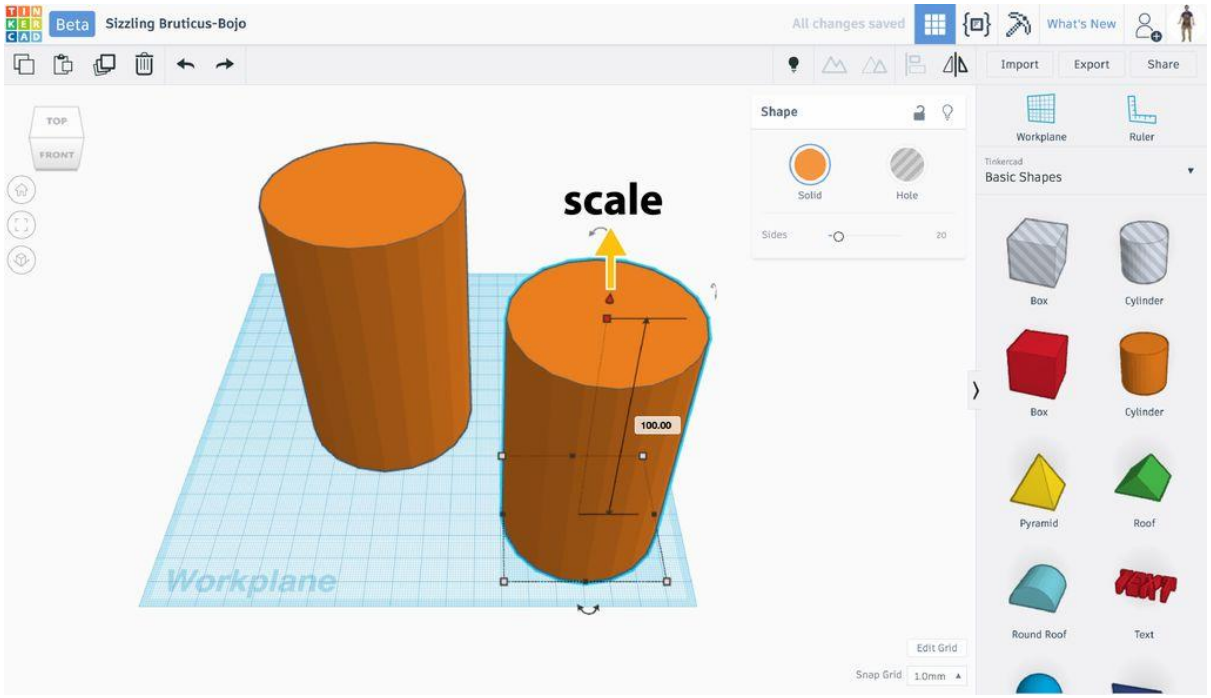


Turn the Cylinder into a Tube

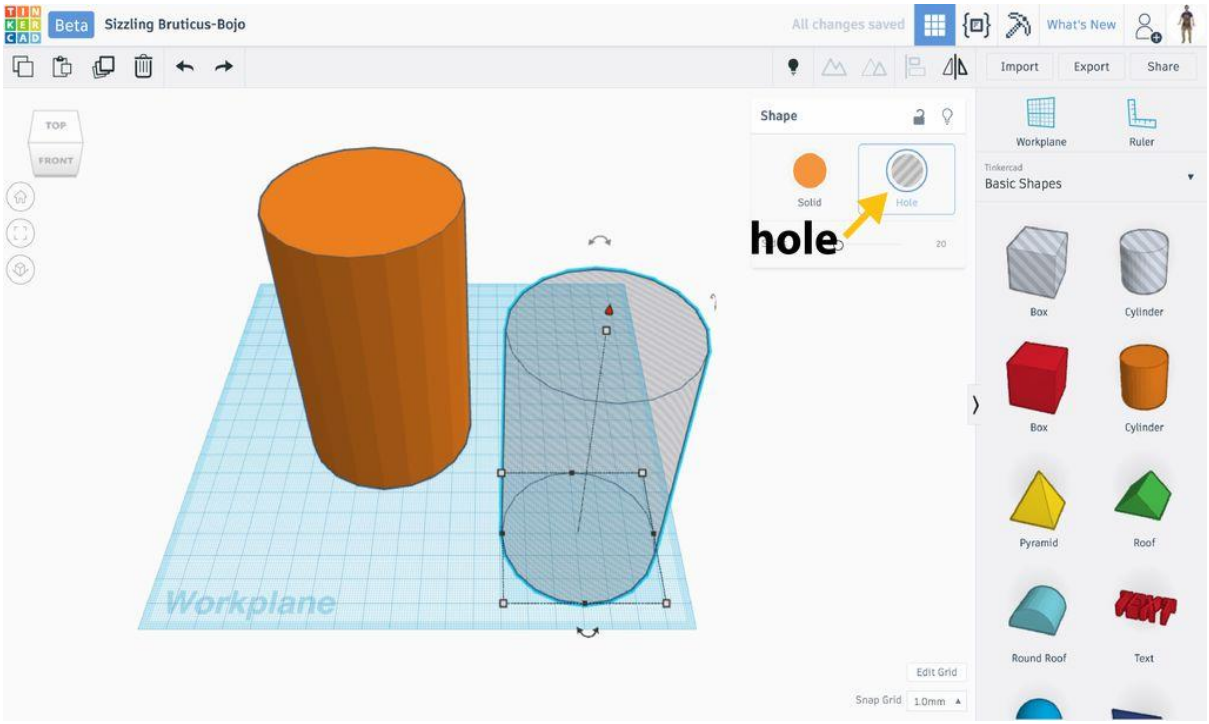
4. Just like you did in the last step, place a cylinder on the workplane. This time, make it 60mm wide and 100mm tall.




Beta
Sizzling Bruticus-Bojo
All changes saved
What's New
Import
Export
Share
Shape
Solid
Hole
Sides
Workplane
Ruler
Tinkercad
Basic Shapes
Box
Cylinder
Box
Cylinder
Pyramid
Roof
Round Roof
Text
60.00
60.00
scale
Workplane
Edit Grid
Snap Grid
1.0mm

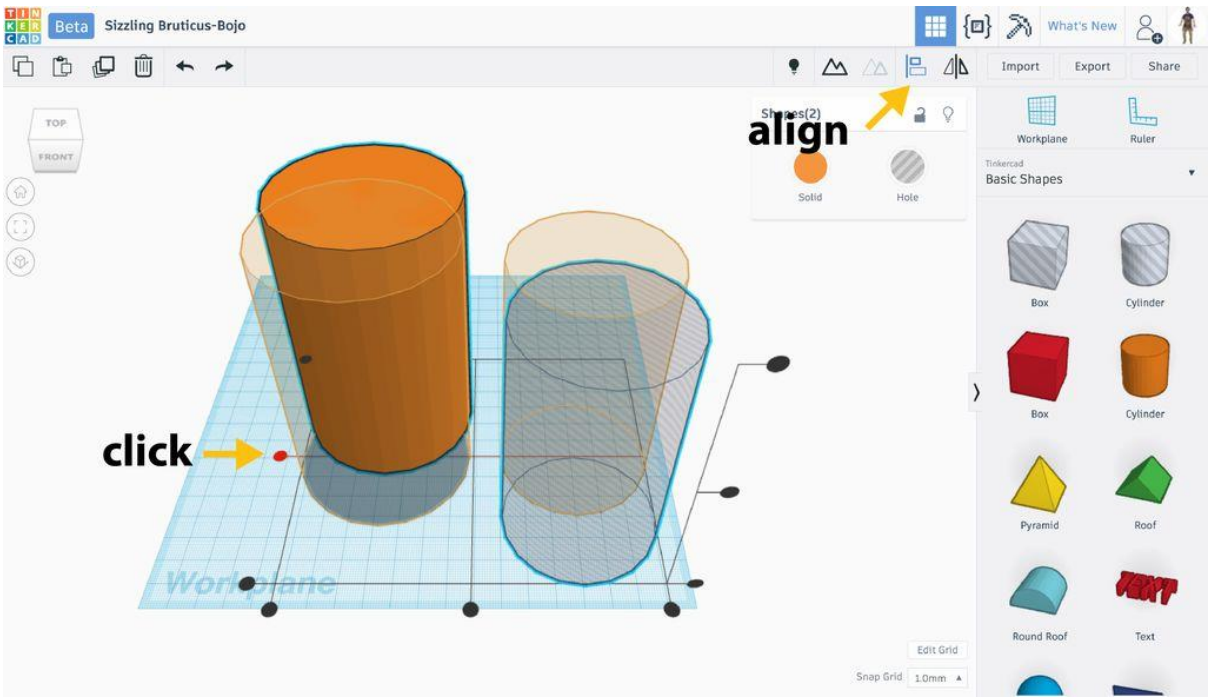

Beta
Sizzling Bruticus-Bojo
All changes saved
What's New
Import
Export
Share
Shape
Solid
Hole
Sides
Workplane
Ruler
Tinkercad
Basic Shapes
Box
Cylinder
Box
Cylinder
Pyramid
Roof
Round Roof
Text
scale
100.00
Workplane
Edit Grid
Snap Grid
1.0mm

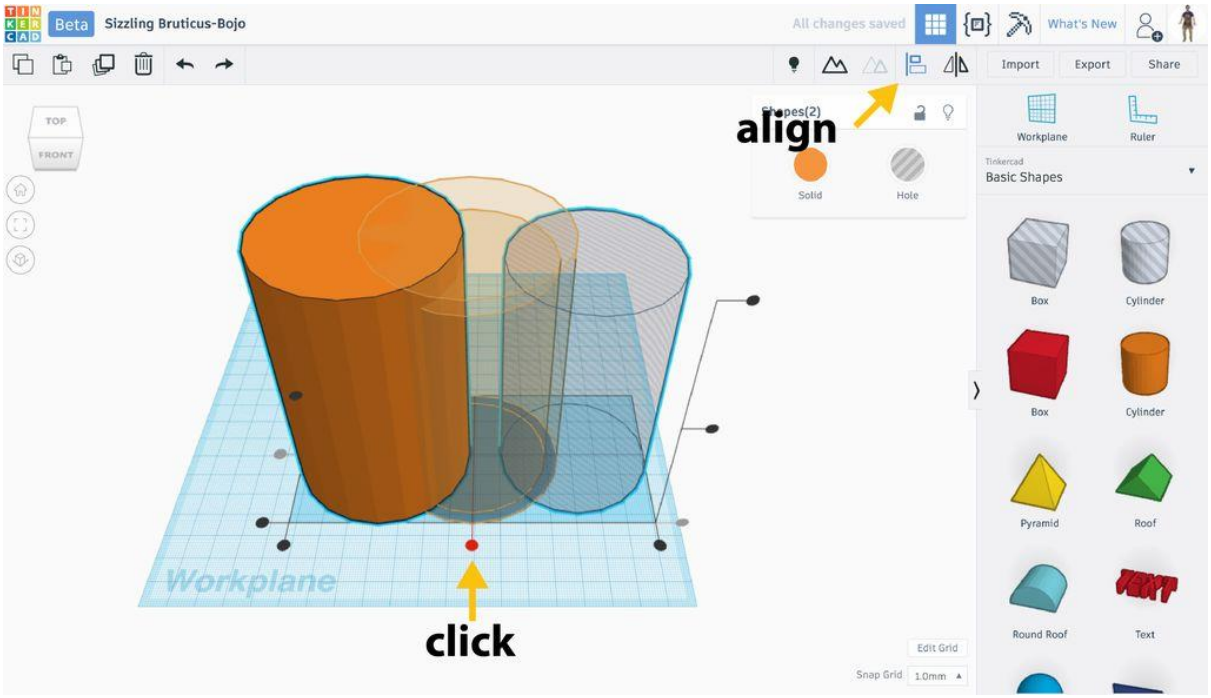
5. With the new cylinder selected, click the Hole button in the Inspector.



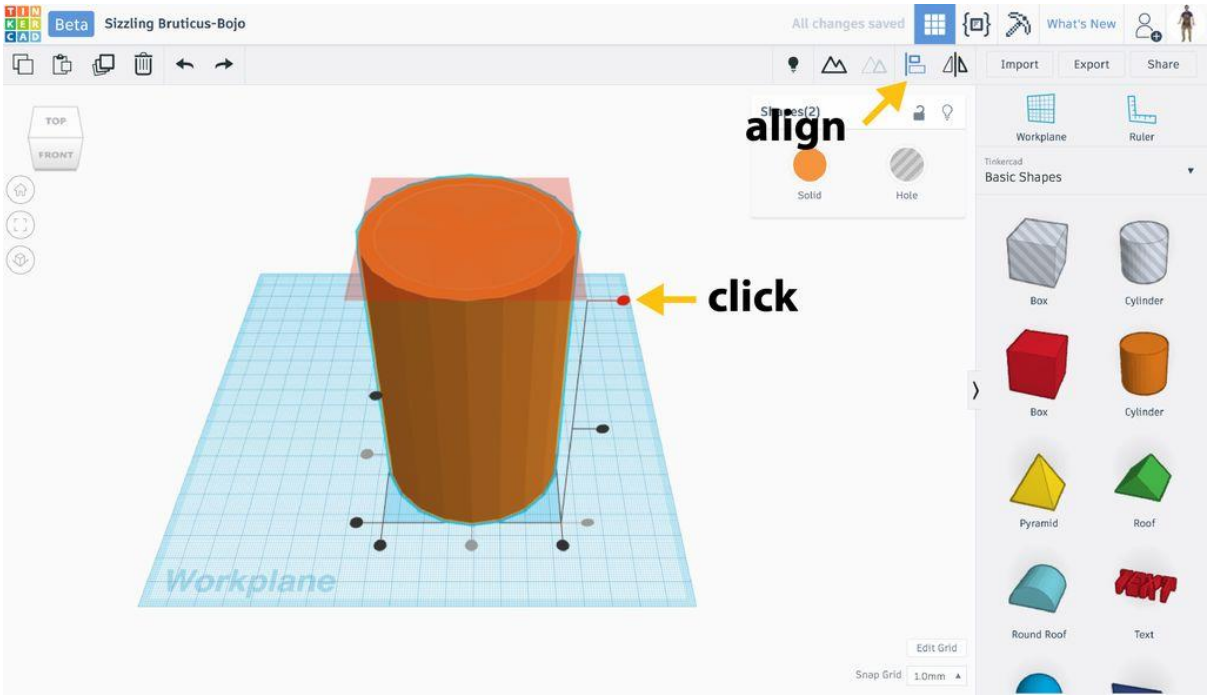
To make a tube, the hole and the solid cylinder will need to be aligned. With both cylinders selected, click the Align button in the Adjust menu. Click on the first cylinder to make it the dominant object, then click one of the centers aligns handles on the workplane.

6. Click the other center align handle.

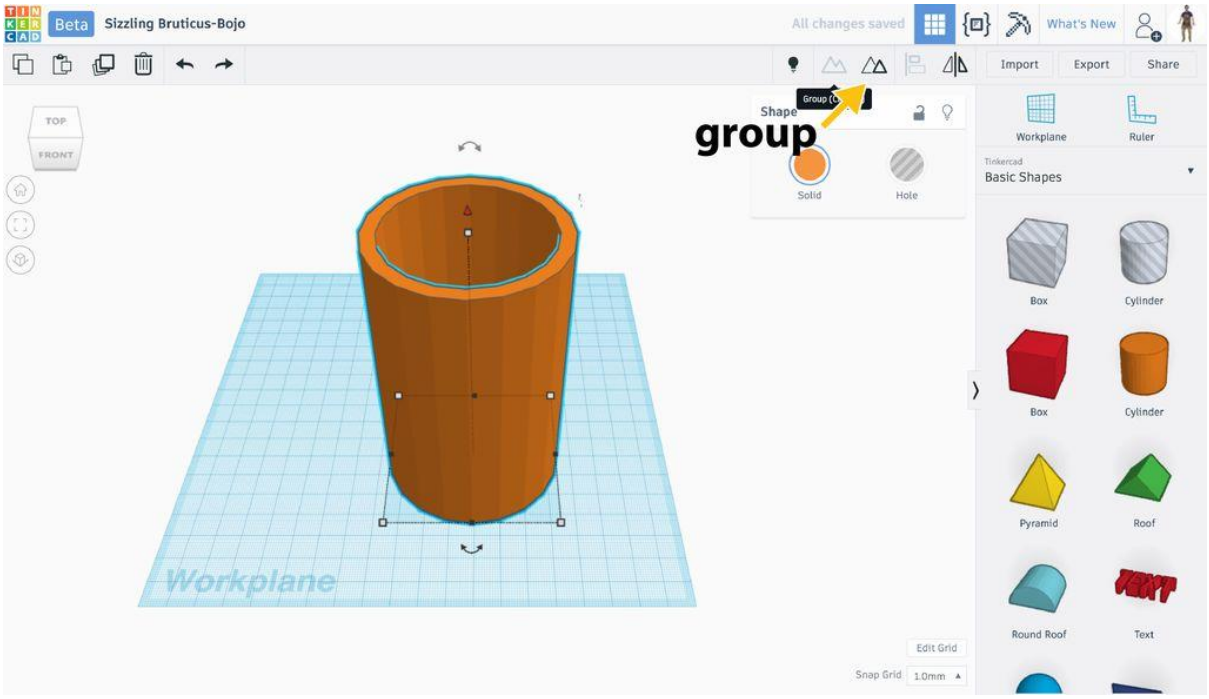




7. Click the top handle to align the cylinders to the top plane so that the tube will be open on the top.

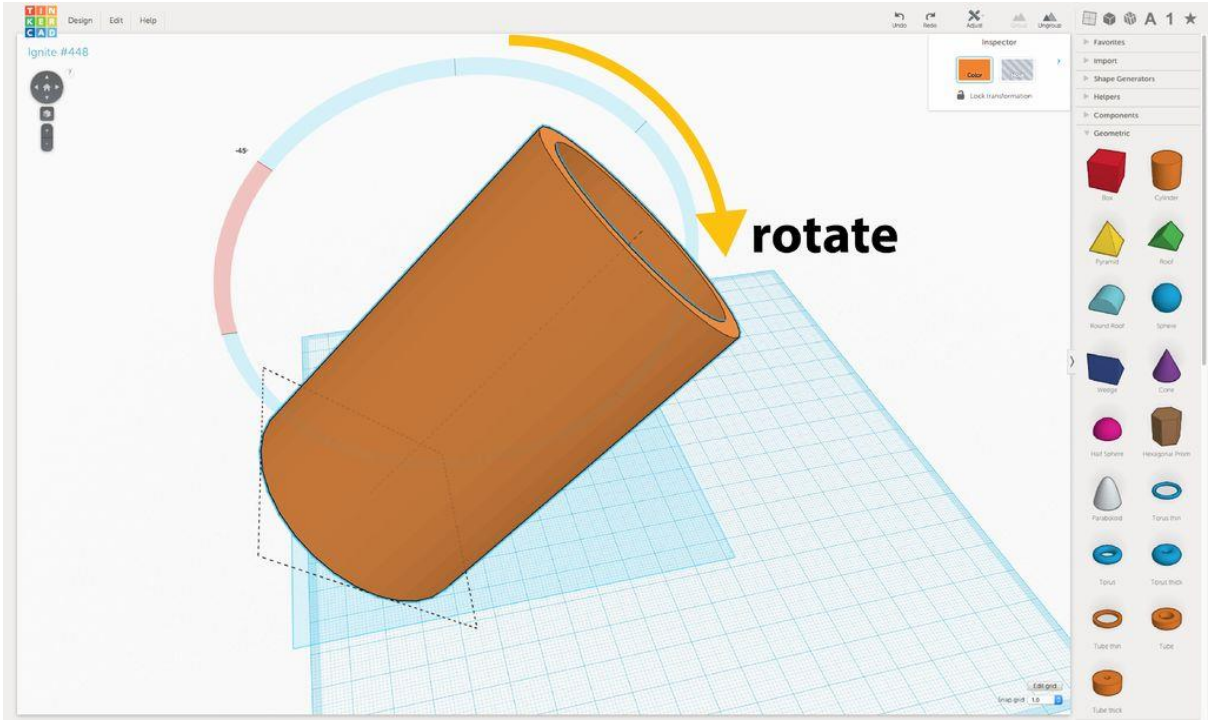


8. With both objects selected, click the Group button to create the tube.

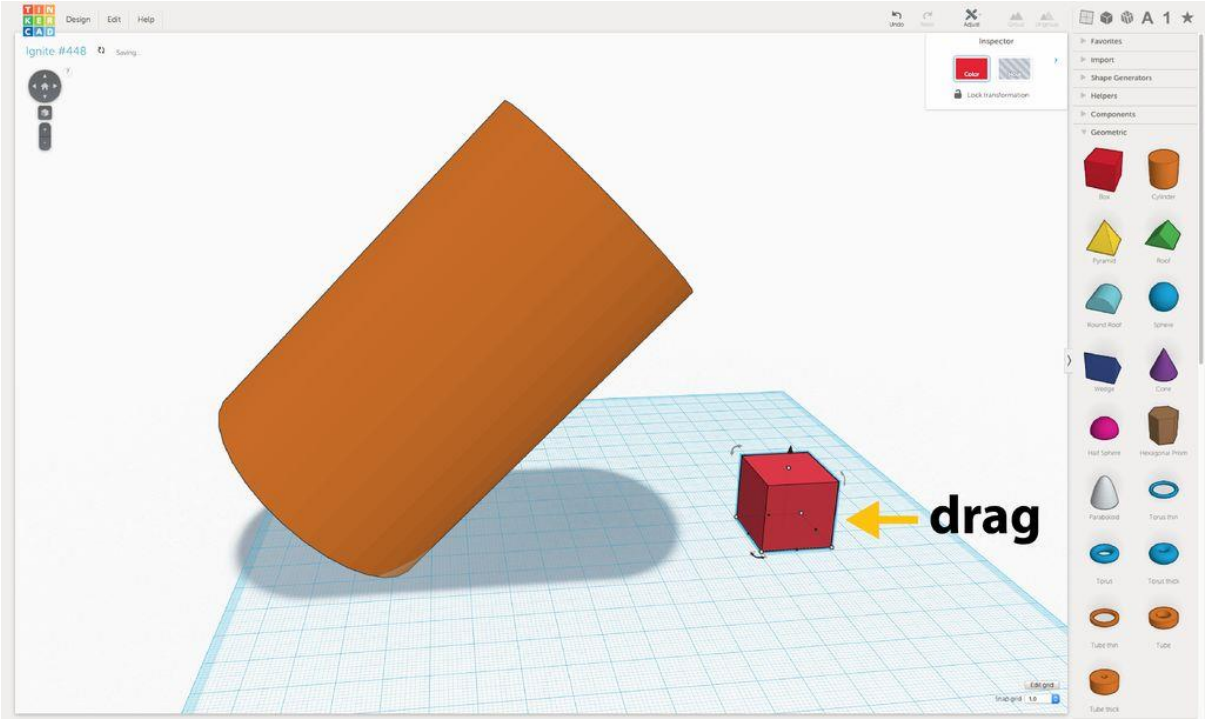


Rotate the Tube and Create a Platform

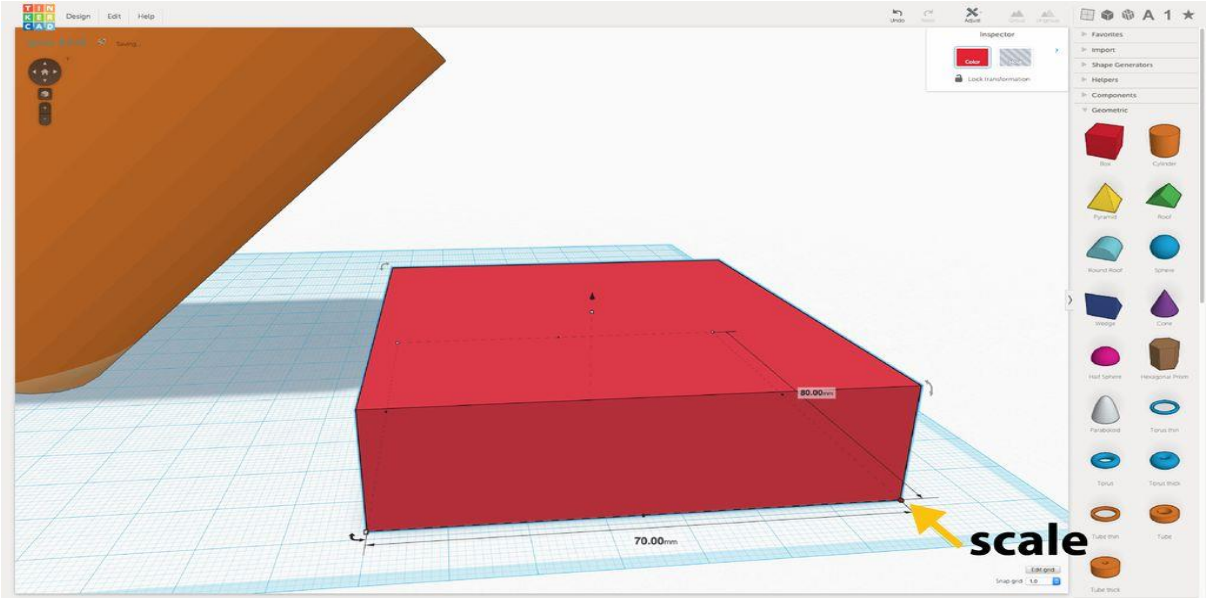
9. Select the cylinder and use the side arrow to rotate the cylinder to a 45-degree angle.



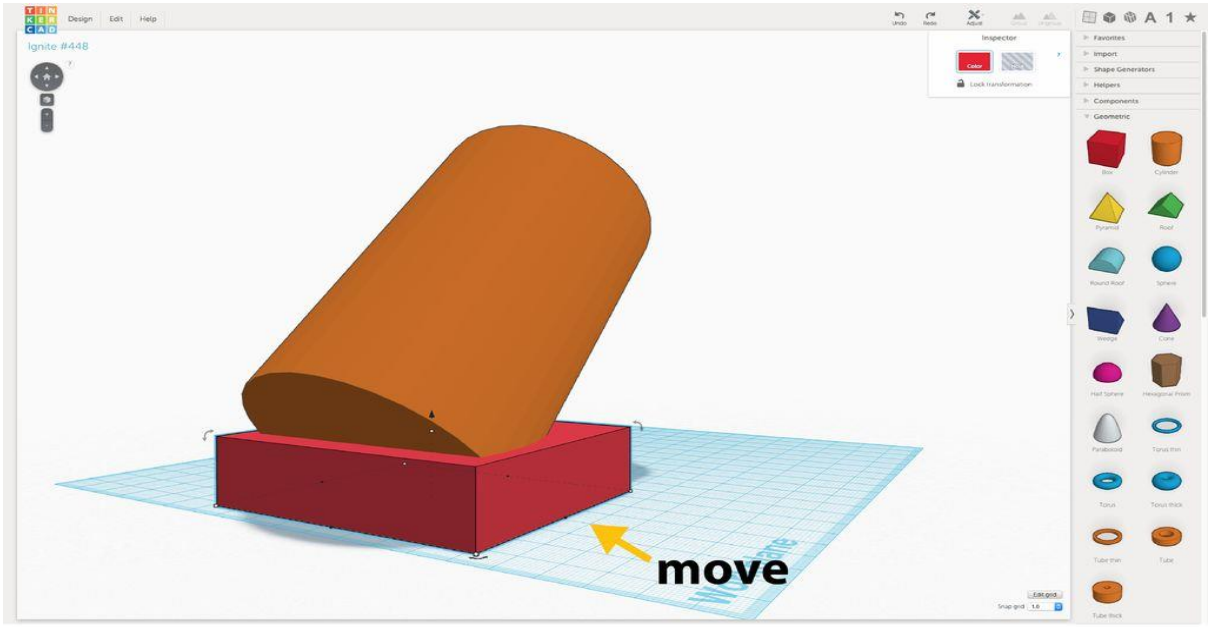
10. Drag and drop a cube onto the workplane.



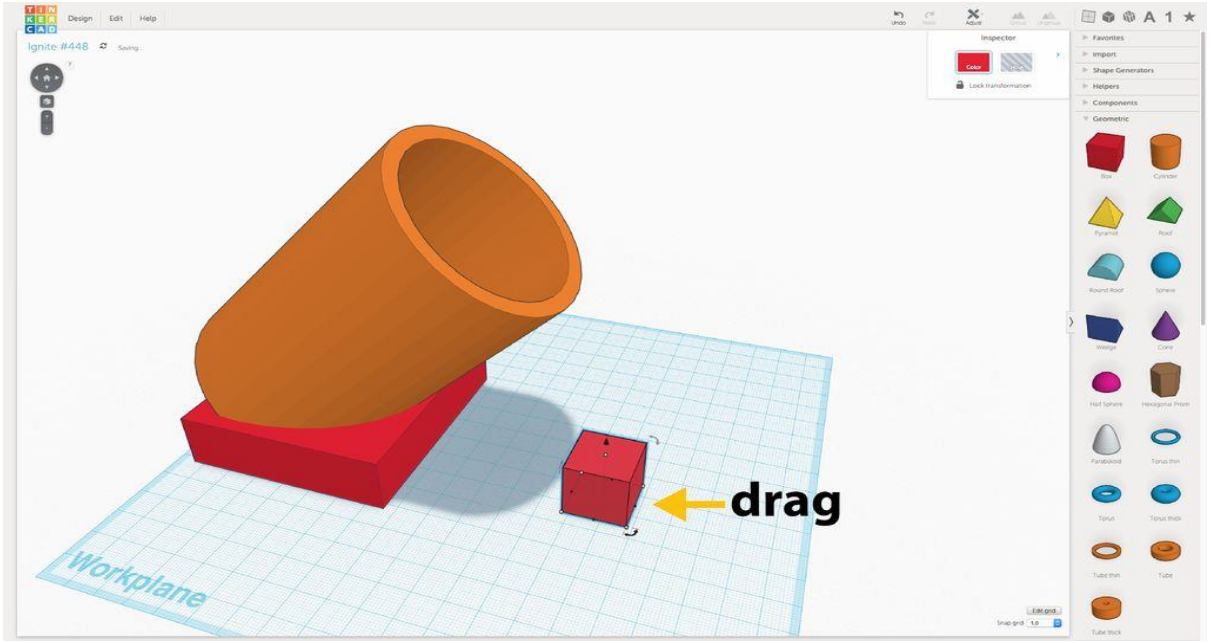
11. Use the scale handle to make it 80mm wide by 70mm deep. The shorter side should be the same side as the angle of the tube.



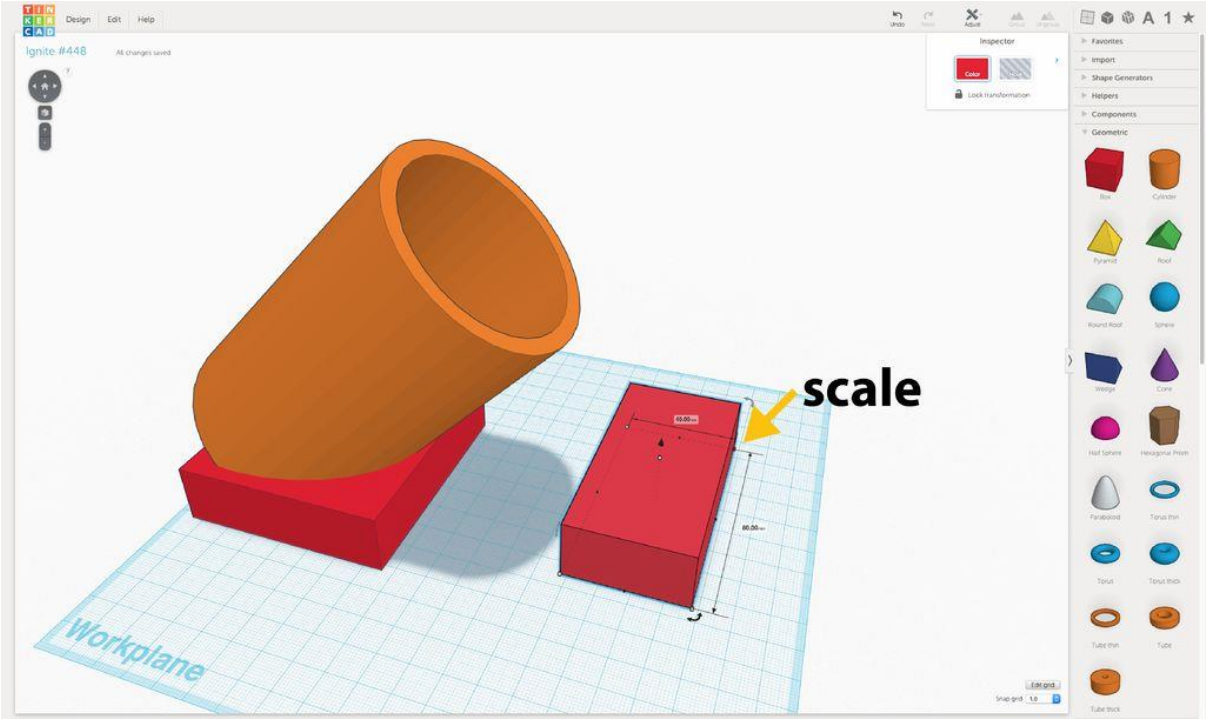
12. Move the box so that the tube rests on it.



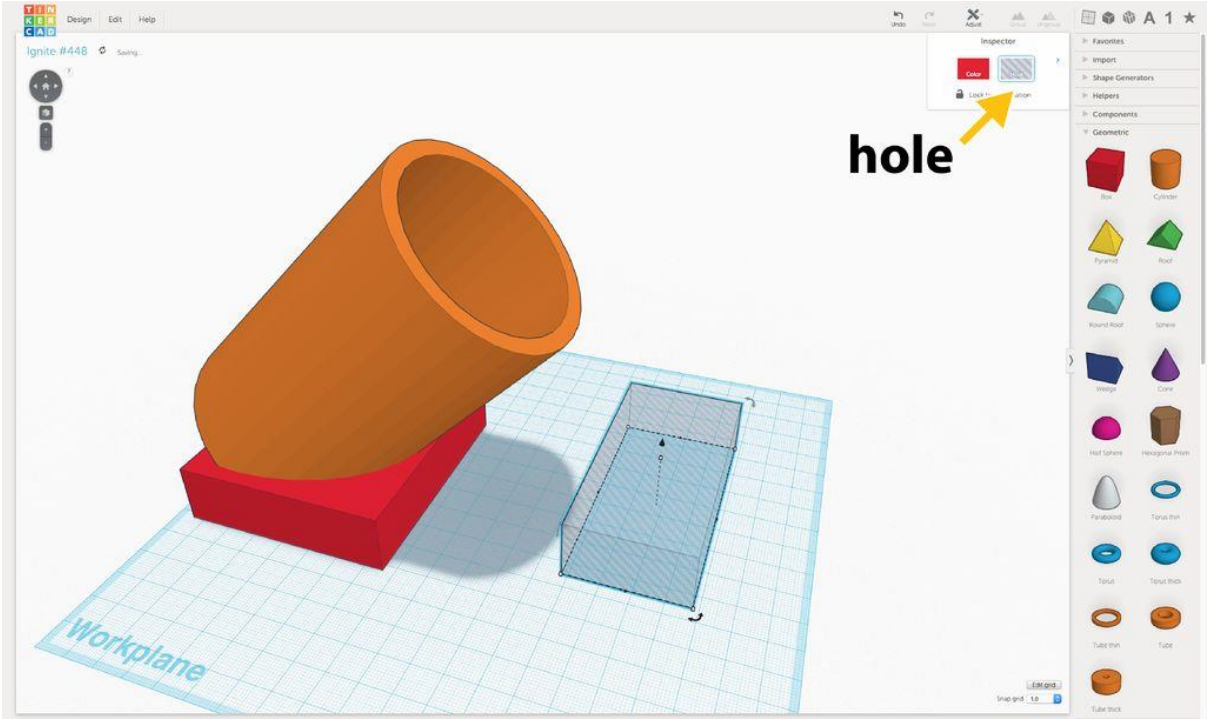
13. There will be a part of the tube sticking out on the bottom of the box, so now you'll make a box shape to cut that part off, giving you a flat bottom for the amplifier.
14. Drag and drop a cube onto the workplane.



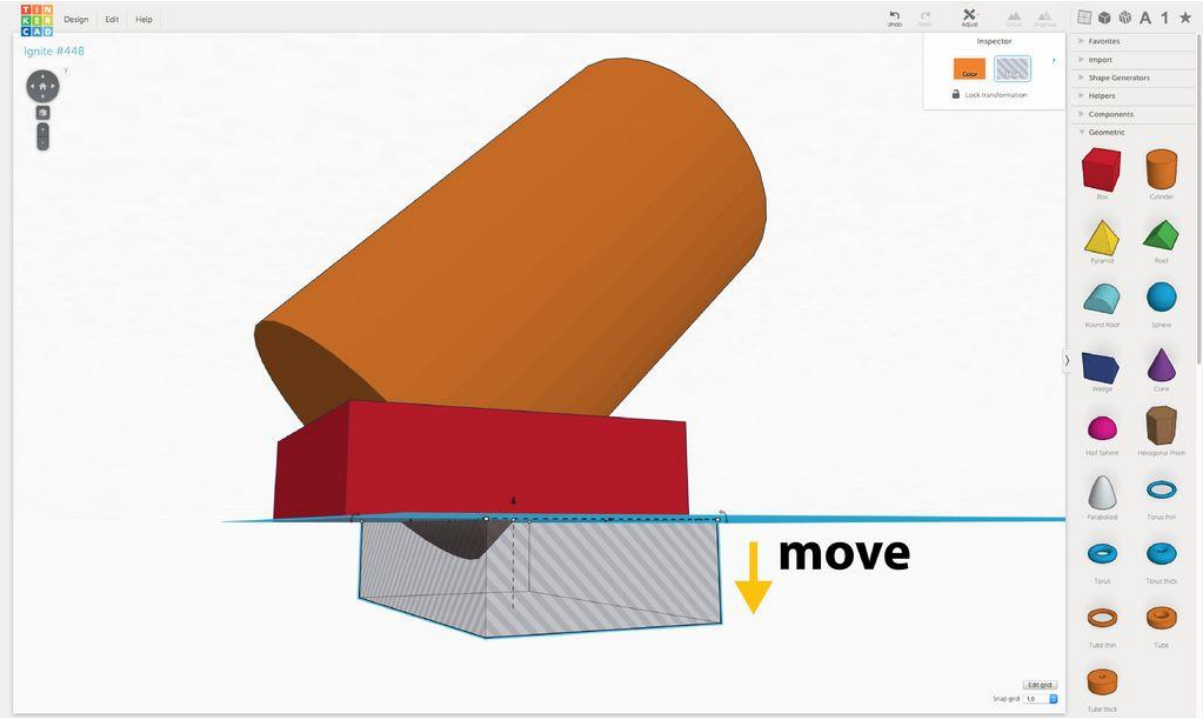
15. Drag the scale handle so that the box is 40mm X 80mm wide.



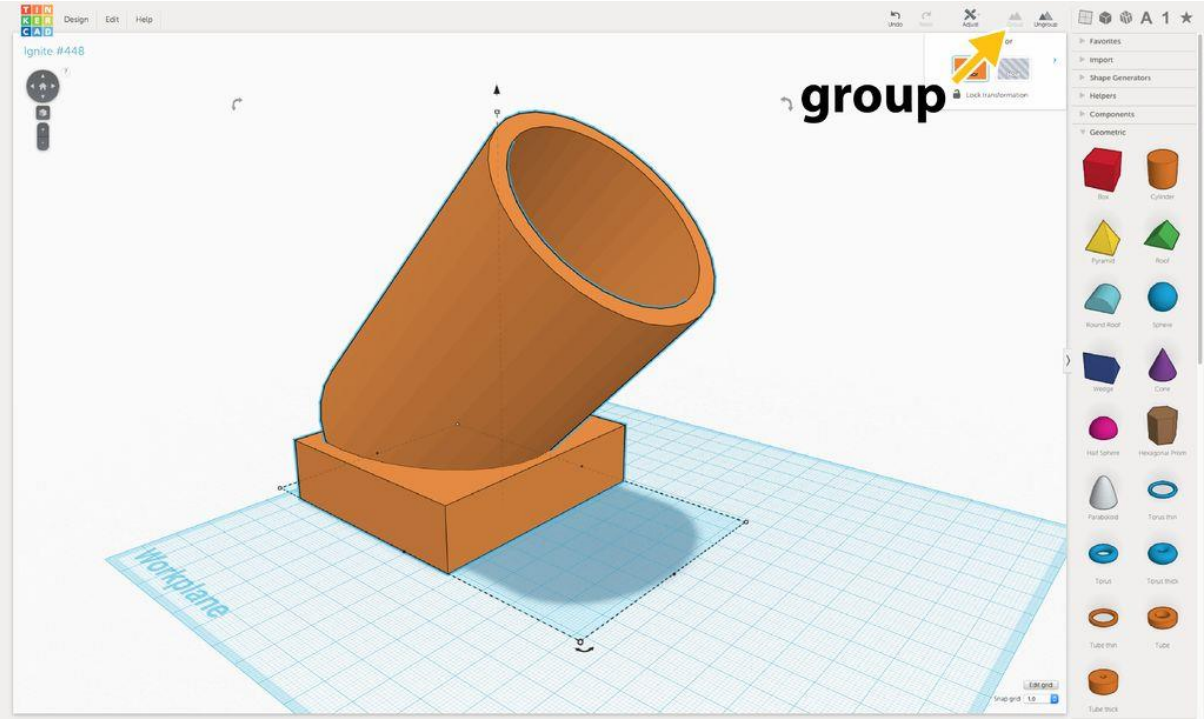
16. Click the Hole button in the Inspector- this will allow you to use the box shape to cut out the cylinder part on the bottom.



17. Move the box down, then move it over so that completely covers the tube part on the bottom.

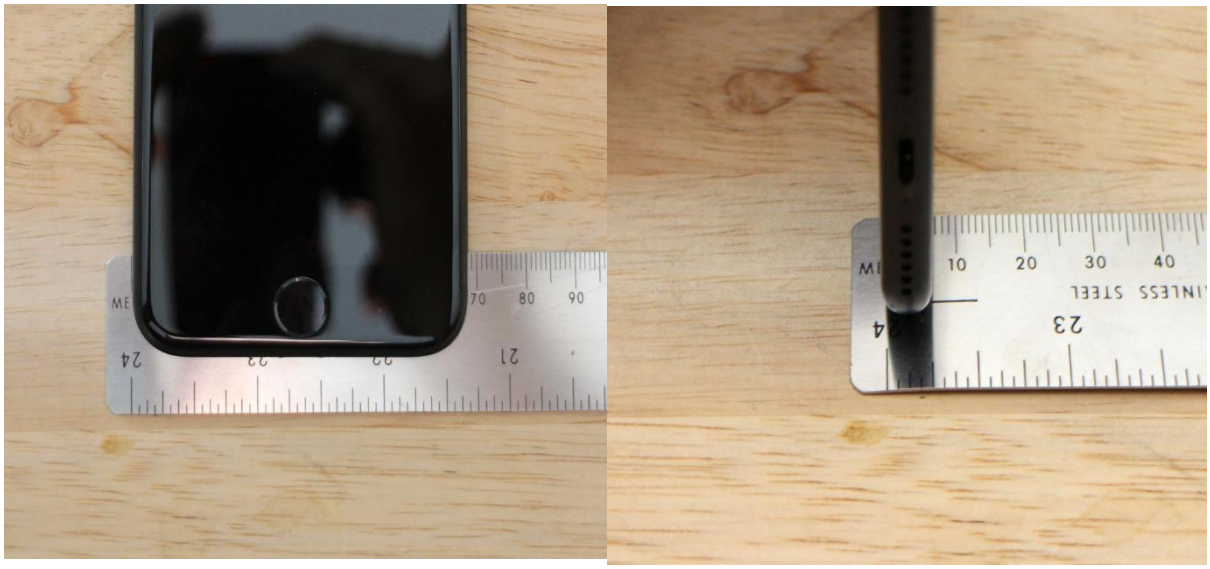


18. Select all components and click Group to subtract the piece below the plane.



Measure Your Phone

19. The amplifier works by making the sound from your phone's speaker bounce off the sides of the tube. That means the tube will need a cutout at the back to fit the phone in so that its speaker is inside the tube.



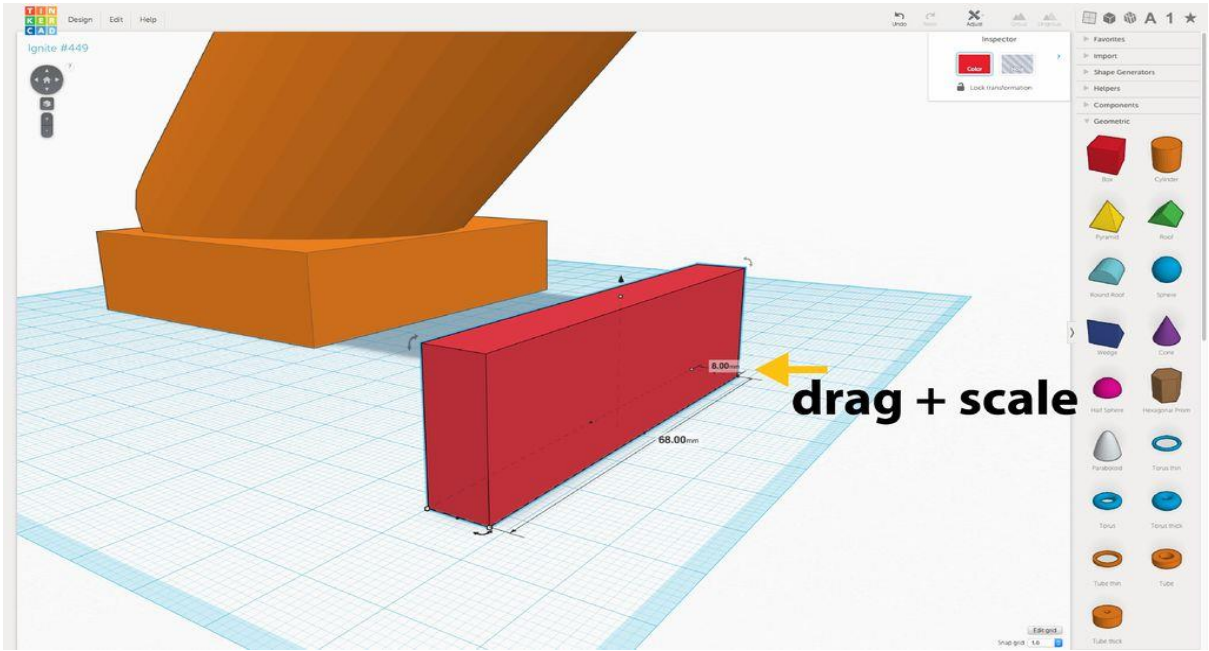
To make sure the cut out will be the right size, use a metric ruler (millimeters) to measure the thickness and width of the phone.

This phone is about 68mm wide by 7mm thick.

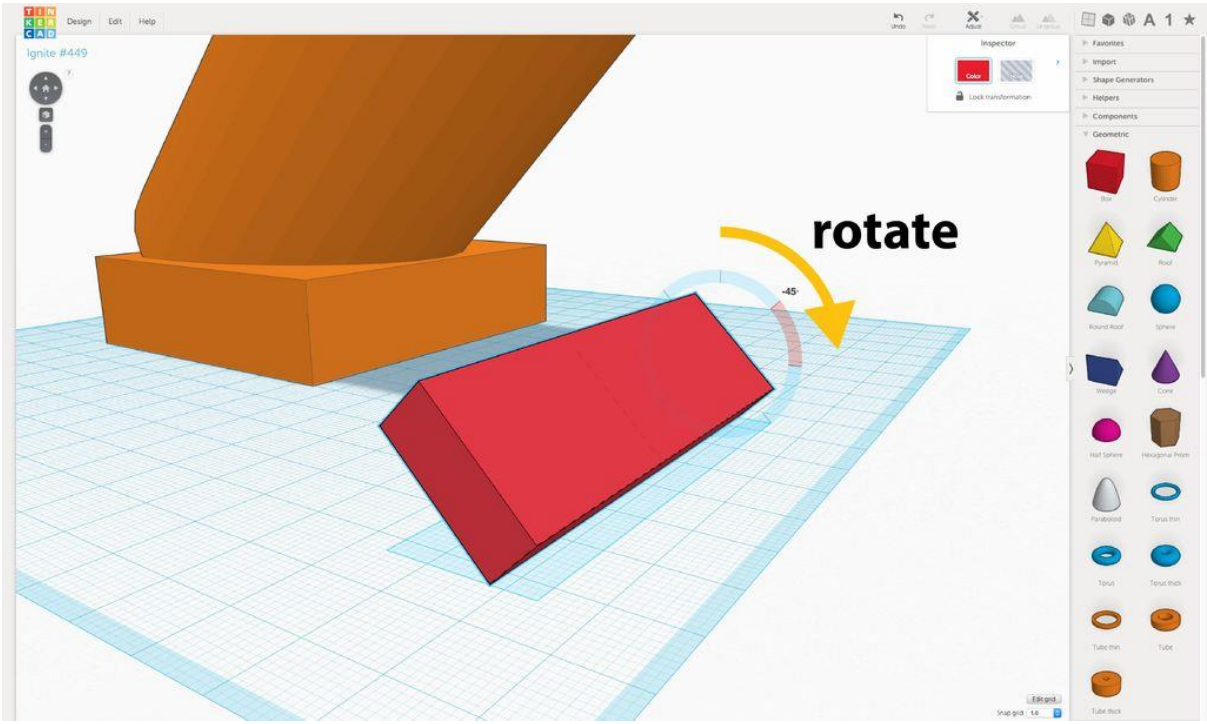
(You can also do a search for your phone model and "dimensions", and probably find the exact dimensions right away)

Make the Cut-out

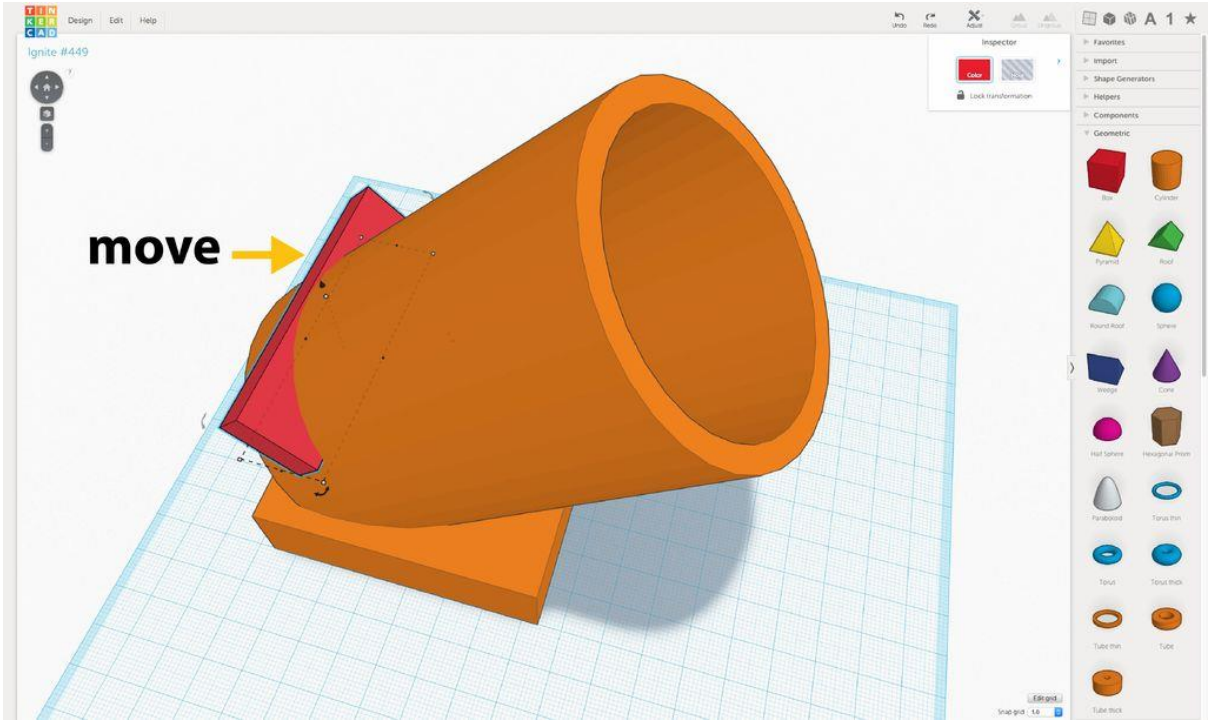
20. Drag a box to the workplane, then scale it so that it has the same width and thickness as the device you measured. Make the thickness slightly more (maybe .25mm) than the actual thickness of the device to make sure it doesn't fit too tightly.



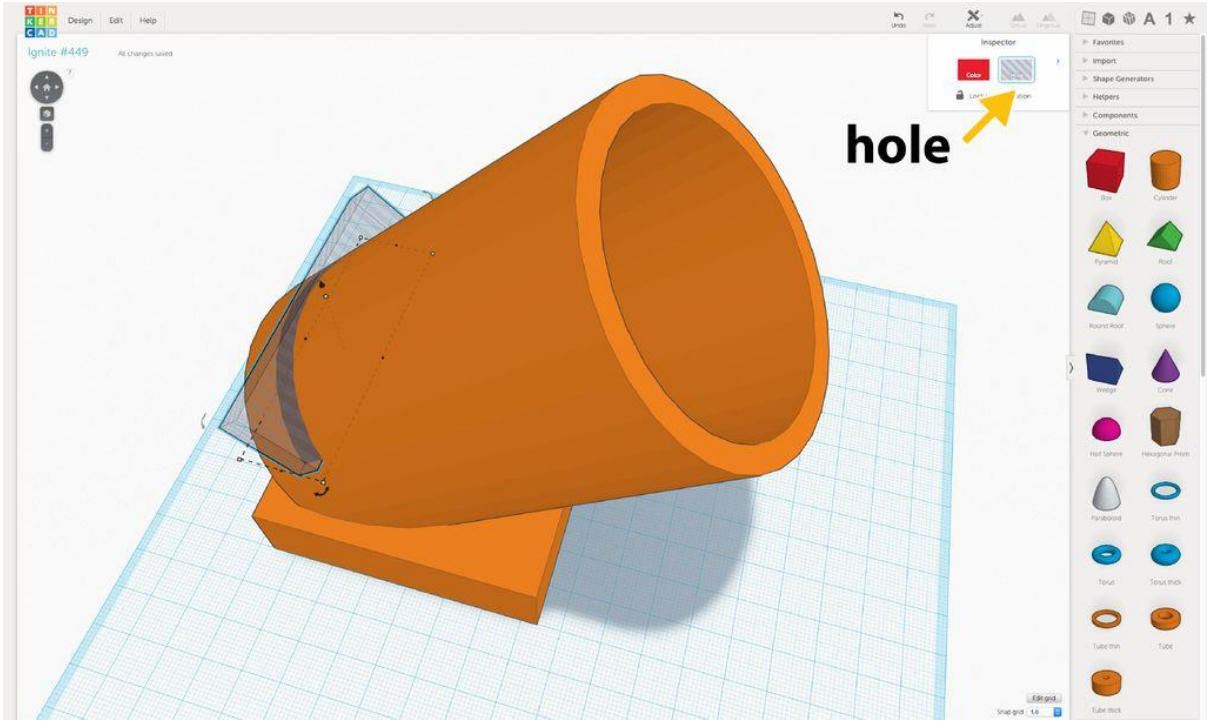
21. Rotate the box 45º so that the angle matches the tube.



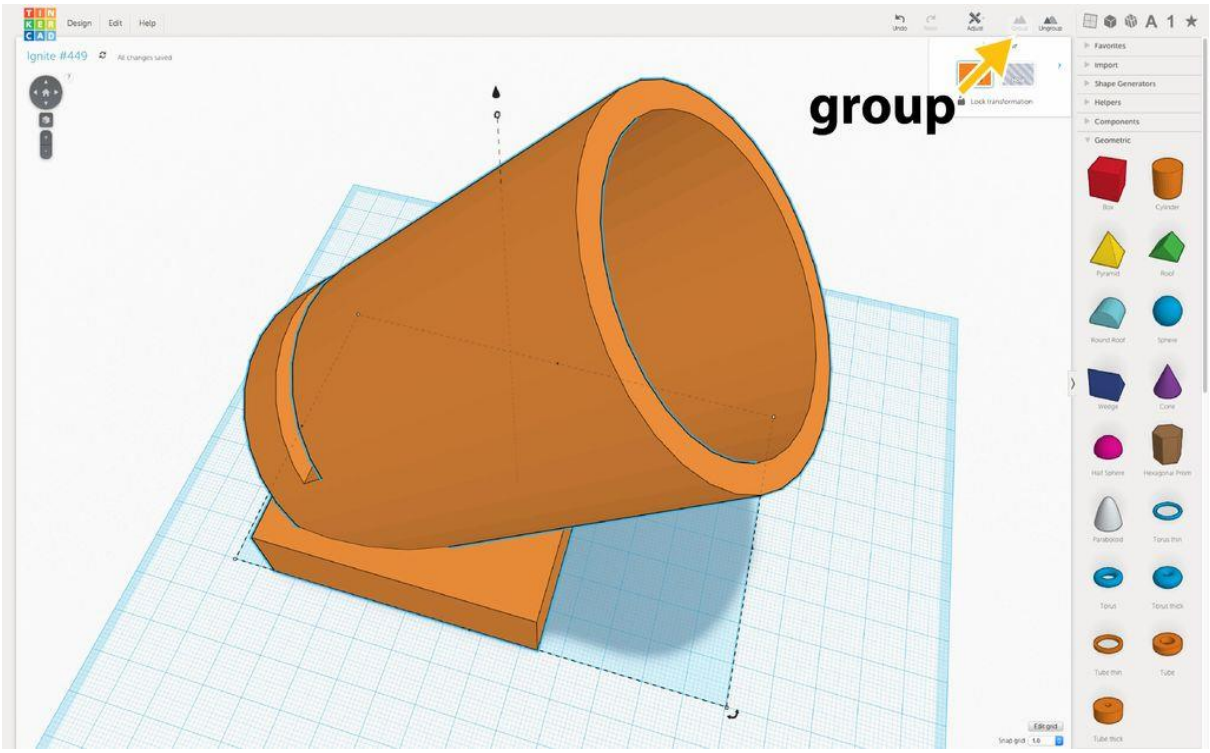
22. Move the box so that it intersects the tube near the back of it. Make sure the box is sticking out of the tube on 3 of its size as shown in the picture above.



23. With the box selected, click on the Hole button in the Inspector.

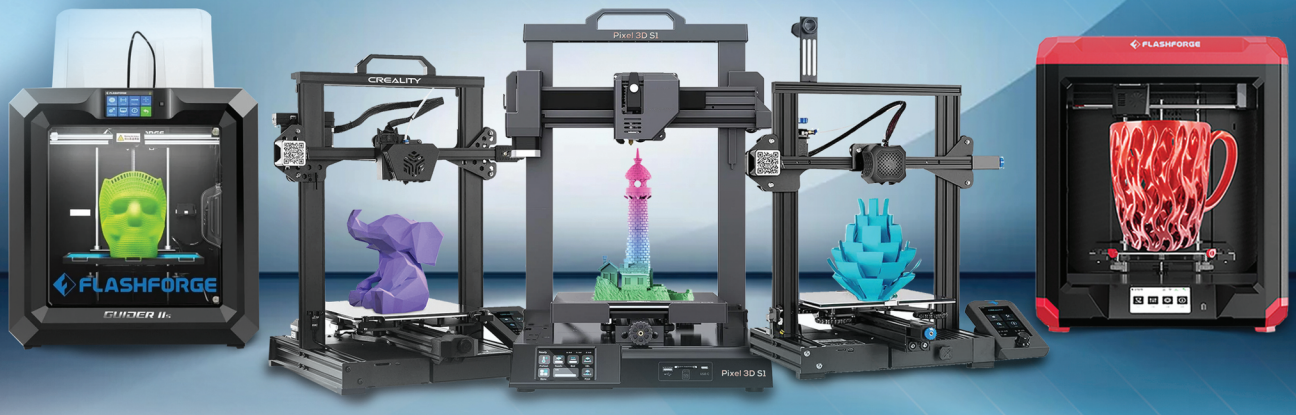


24. Group the amplifier and the hole to create the cutout.




UNIVERSAL ROBOTS


TOWER PRO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