

3D Printing Basics

by **printeraction** on June 10, 2015

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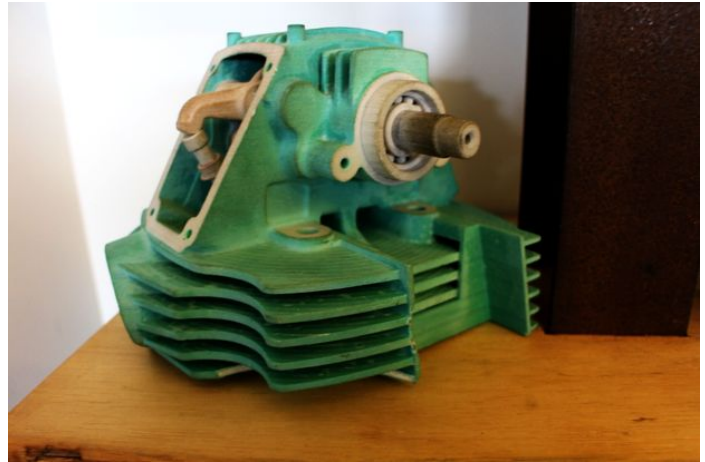
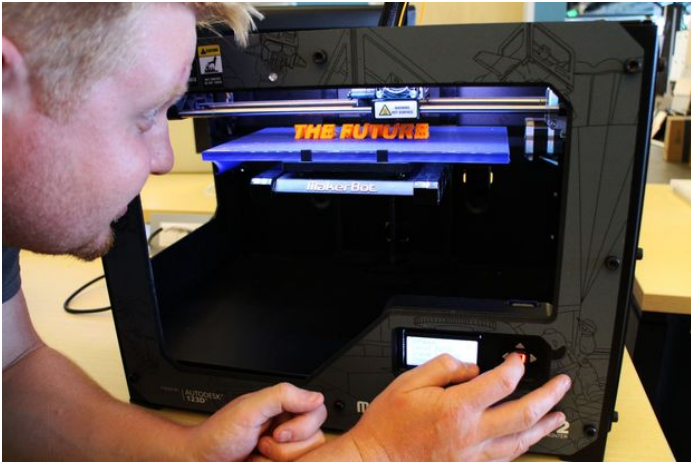
I'm an engineer, a musician, and an adventurer. I love building things and taking others apart to see how they work, because every creation is an adventure!

Intro: 3D Printing Basics

A 3D Printer is a manufacturing tool used to create three-dimensional artifacts that have been designed on a computer. 3D printers have a wide range of shapes, sizes, and types, but in essence they are all computer controlled additive manufacturing machines. Similar to how paper printers lay down ink in one layer to create an image, 3D printers lay down or cure material layer by layer to create a three-dimensional object.

3D printers have a huge range of applications; designers use them to test out product ideas, manufacturing companies use them to make complicated parts for assemblies, and makers use them for DIY fabrication for anything they can imagine. Although the different types and uses of 3D printers vary widely, all 3D printers can be simply described as tools; they allow people to make things that they weren't able to make before.

From this guide you will learn what 3D printers are, how they work, when they should be used, and how to design for them and use them. I'll also provide some resources on purchasing printers and 3D printing services. Once you're through it, hopefully you'll be able to print some things yourself!





Step 1: What is 3D Printing?

3D printers as machines fall under a couple different categories. They are controlled by a computer, making them CNC, or Computer Numerical Controlled, machines. Because of the way that 3D printers work, they are referred to as additive manufacturing machines. Instead of the machine cutting or drilling parts out of a block of raw material to form a certain shape (subtractive manufacturing), 3D printers add material bit by bit to form their work, making them additive manufacturing machines. To sum everything up, this means that 3D printers are machines controlled by computers that add material to create a shape that you tell it to create.

Compared to other CNC industrial machines, 3D printers are inefficient because they take on the scale of hours to make parts, while other machines, like injection molding machines, can produce stronger, more durable parts in minutes. Different 3D printers have different drawbacks and benefits, but most 3D printers produce relatively weak, small parts because of the way the parts are created. So why use 3D printing?

3D printers can be very inexpensive, so they allow anyone who has one to make anything very easily. They let designers go straight from ideas to reality, they allow for rapid iteration on designs, and they can create complicated geometries without much difficulty. In short, with just the push of a button, you can create whatever you imagine.





Step 2: Rapid Prototyping

Unlike most other CNC machines, 3D printers have very minimal associated setup costs or procedures. 3D printers can be used to produce custom designed parts relatively quickly and cheaply, making 3D printers one of the best rapid prototyping tools. Larger scale manufacturing machines may require precisely machined molds or fixtures for each new part, which means that they have more setup costs and steps required to produce content; they are set up to make hundreds or thousands of specific parts over and over again. Using a 3D printer, a part can be cheaply designed and made, and then its design can be modified, printed, and tested multiple times in rapid succession before the part reaches full scale production.



Step 3: Intricate Geometries

3D printing is a hands-off manufacturing process; just by pressing a button, whatever you design will be made. Other manufacturing methods, like the drill press, lathe, or milling machine, need to be operated by the maker. The workpiece needs to be aligned, measured, and machined by the user, which introduces human error into the making of the part. 3D printers, because of the way that they create parts, can make many parts with intricate geometries, including natural shapes like prosthetic limbs or animal models, or more complicated shapes like polyhedra or scale building replicas. 3D printers open up a lot of opportunity to makers just because they allow people to make things they feasibly couldn't before.



Step 4: Customized Content

As explained previously, 3D designs can be easily changed on the computer and then re-printed. This means that files can be customized for certain people or things, and printed easily, with no change to the setup of the machine. Being able to create personalized content is valuable for both small-scale manufacturing and for makers, because it allows them to create designs for specific people, or even produce designs that others give them. Personalized jewelry, custom fit prosthetics, and even 3D scans of people can be printed and modified to suit the end recipient.



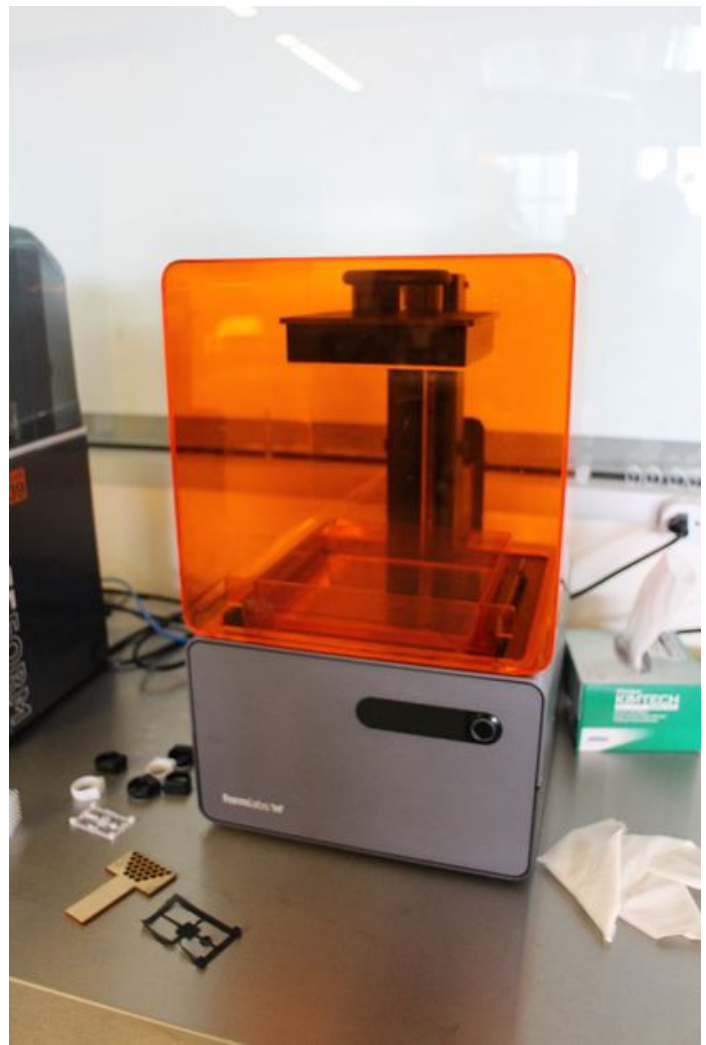


Step 5: How Does 3D Printing Work?

To understand more specifically how 3D printers work and how to design for them, you'll need to understand the different types of 3D printers on the market. Although the materials and methods with which parts are created varies widely, all 3D printers construct parts by adding material layer by layer, fusing each layer together to make a solid object.

There are a couple different types of 3D printing processes: some are more well suited for larger scale manufacturing, others allow for multiple materials or colors during prints, and some types of printers can even be built fairly easily because of the way that they work. I've included the most common types of 3D printers in this guide, there are a few other types of printers out there, but for the most part they stem from the following four.

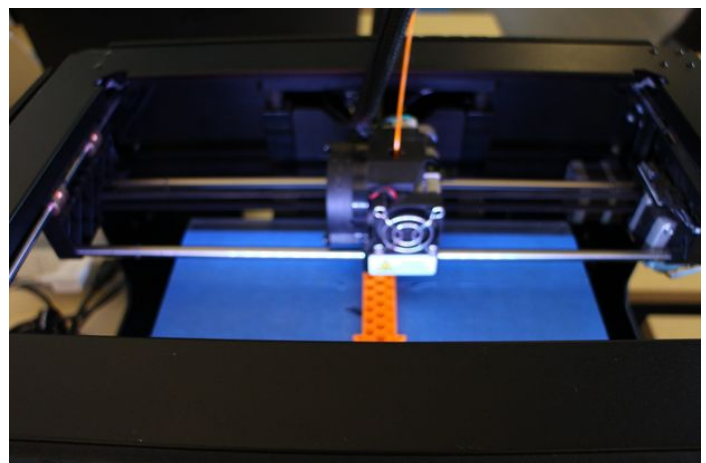




Step 6: Fused Deposition Modeling (FDM)

Fused Deposition Modeling is probably one of the most common types of 3D printing, and it is the easiest to understand. In this type of 3D printing, the material, usually ABS or PLA plastic, is melted down by the printer head and extruded onto the printer bed, similar to how ink is deposited onto a page on a paper printer. The extruder head of the printer lays down material layer by layer to build up a 3D model, and each layer fuses to the previous one as it cools.

FDM printers are very common desktop printers because they are inexpensive and easy to build. Their precision depends upon the quality of the motors that control the position of the extruder head relative to the build platform, and the fineness of the extruder head as it extrudes material. Because the material is built up layer by layer, printed parts tend to be weak along their horizontal cross sections. Additionally, any overhanging sections of 3D printed parts on FDM printers require support material to hold up the overhang. FDM printers with multiple extruder heads can print in a soluble support material that dissolves when immersed in certain chemicals, while those with single extruders print in a less dense material that can be broken off after the print is complete. Multiple extruder heads also allow FDM printers to print in multiple colors or materials, expanding their capabilities.

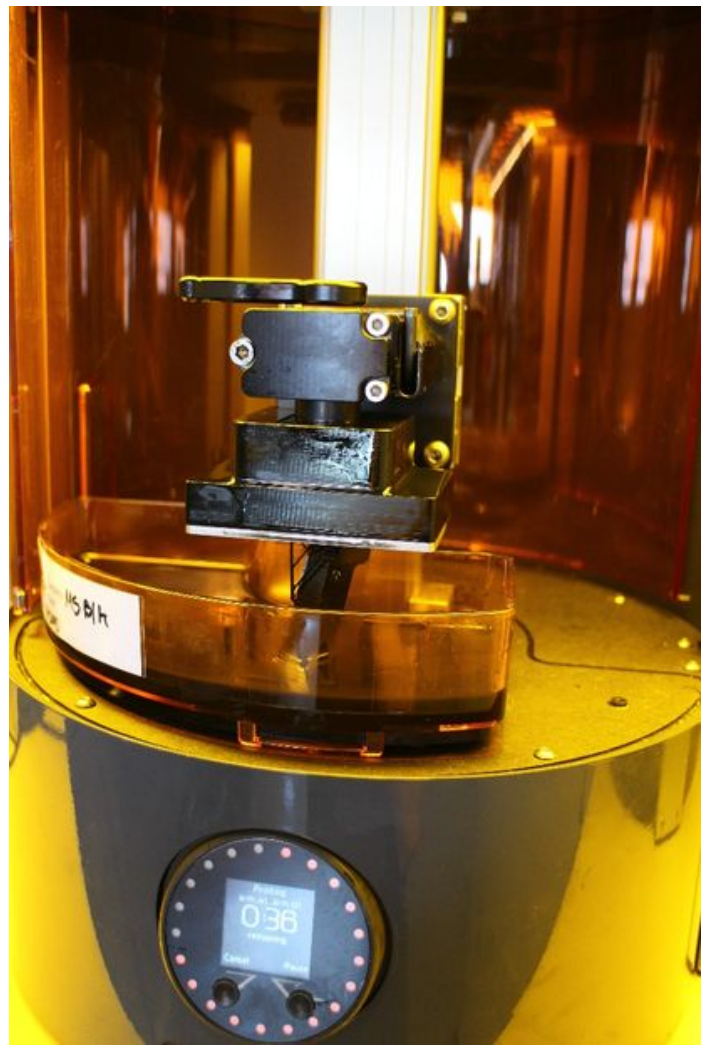




Step 7: Stereolithography (SLA)

Stereolithography is the oldest 3D printing method, in which a laser is used to solidify liquid resin with ultraviolet light. While FDM printers draw out the layers of filament to form the 3D model, the laser beam on an SLA printer draws out a slice of the part to cure the liquid resin layer by layer, generating the 3D part. While most other 3D printers print from the bottom of the part and work their way up, SLA printers can print from the top down. The laser and resin bath sit at the base of the printer, and the part is fixed to the bottom build platform and is drawn up as it prints.

SLA printers can be very fast and precise because of their nature. However, the resin itself is expensive, and because it is photocurable, needs to be stored in specialized containers. Most resins, when they cure, are usually very brittle, and cannot withstand much force, so SLA printing is usually useful when it comes to prototyping, but not production. Like FDM printers, SLA printers require support structures for printed parts, but their materials are limited because they can only print in cured resin, and cannot print multiple material types at once. However, the precision of SLA printers allows them to print very intricate, delicate structures.



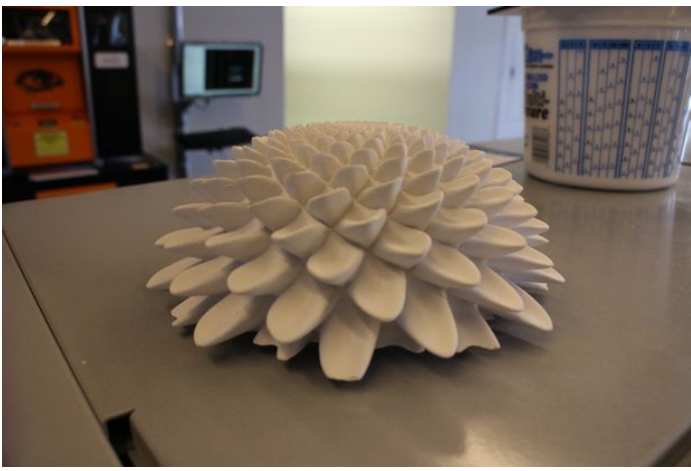


Step 8: Selective Laser Sintering (SLS)

Selective Laser Sintering is very similar to stereolithography in that a laser is used to solidify material and form a solid shape. The biggest difference between the two technologies is that while SLA printing uses liquid resin, laser sintering cures powdered material. Layers of powder are laid down onto a print bed, and the particles of each layer are cured by a laser. Selective Laser Sintering is advantageous in that it can support a wide range of materials, including plastics, glass, and some metals.

No support material is needed to print parts on an SLS machine because the parts are immersed in powder, so they can be used to create more complicated and precise parts than most other printers. However, they are usually only found in industry as they require high power lasers and can be very expensive.



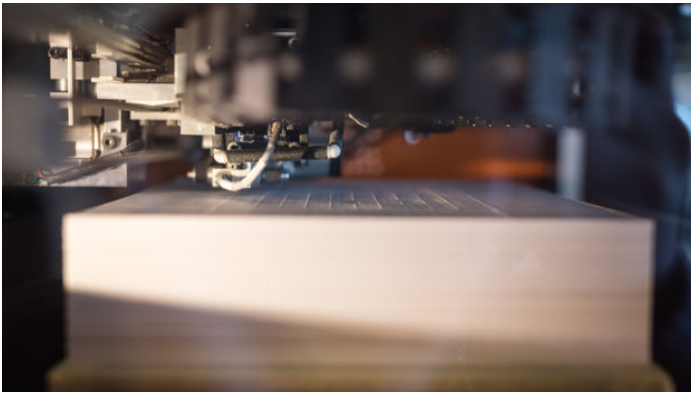


Step 9: Laminated Object Manufacturing (LOM)

In the Laminated Object Manufacturing process, a laser or knife is used to cut slices of the 3D model out of sheets of material. Each sheet of material is pulled over the previous sheet and cut out by the cutting tool, and then glue is laid down so that the next sheet will adhere to it. The printer thus generates stacks of sheet material cut out and fused together. Because LOM printers consist of stacks of paper, the paper can be printed on (in 2D) before used on the machine, meaning that these printers can actually be used to create colored 3D printed artifacts.

These printers have very low production costs because the raw materials are just reams of paper or plastic. They have the benefit of printing flexible, strong parts because of the material properties of the sheets. While the parts are strong, they are just stacks of paper, so they tend to wear easily and small part features can easily be peeled open. LOM machines are best at creating large parts with minimal small details. Each print requires a lot of post-processing to remove the part from the rest of the material. These printers usually generate a lot of waste because each part needs to be dug out of stacks of paper and the geometries of the parts created are restricted due to the way parts are manufactured.

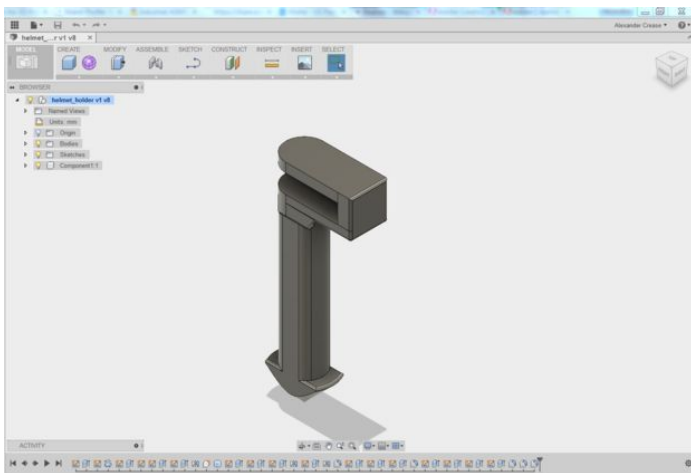


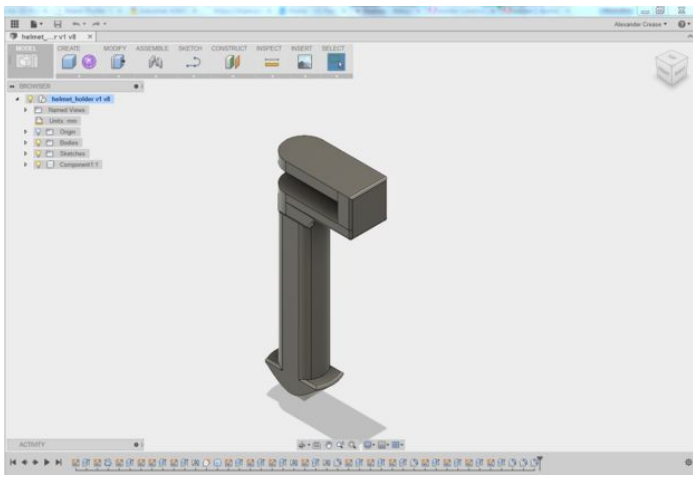


Step 10: 3D Design for 3D Printing

3D printers allow designers to go straight from concept ideas and designs to physical models. In order to do so, the object needs to be designed on a computer using some sort of 3D design software. Once a part is designed, it can be imported into software specific to the 3D printer in use, which will slice the part and send the printer a list of paths and directions used to create the part.

There are many different CAD (Computer Aided Design) programs out there to design 3D models for a variety of purposes. Design programs like Tinkercad or Autodesk 123D are free and great for beginners interested in 3D design and 3D printing, while programs like SolidWorks and Autodesk Inventor are used by professional engineers to design parts and assemblies for production. I'll cover some of the considerations necessary when designing a part to be 3D printed.







Step 11: Part Orientation

When designing for 3D printing, there are a few design guidelines and constraints that should be followed, as there are for any manufacturing process. One of the most important considerations during the design process involves designing with a build face in mind. All printers start building the part from the print bed, so remembering what face the part is being printed from is important. While determining optimal part orientation is slightly different on all printers, designing to optimize that orientation will minimize material usage, print time, and risk of print failure.

Reducing Print Time and Support Material

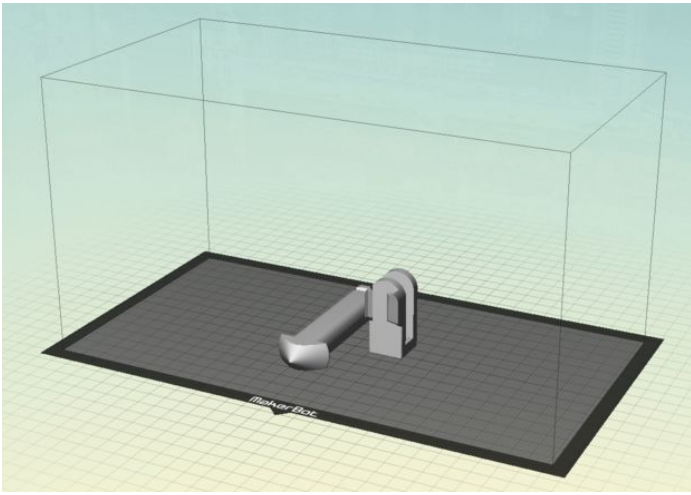
By orienting your part well, you can reduce the amount of support material needed, which can minimize material and print time. Support material can be hard to remove and creates a rough surface finish, which isn't the best if you want your part to look like a finished product. In order to remove the effects of the support material, parts need to be polished and sanded down, which may affect the tolerances of your part if it is interfacing with something else.

Part Strength

On most desktop printers, parts usually tend to break along cross-sections of the part that are parallel to the build plate. Material is laid down or cured layer by layer, and the layers don't fuse as well as they do in higher end printers, creating seams along the cross-sections of the part. This means that parts can shear easily along those planes if force is applied. If you know how and where force will be applied to your part, orient your part such that the direction of force is not along those cross-sectional planes.

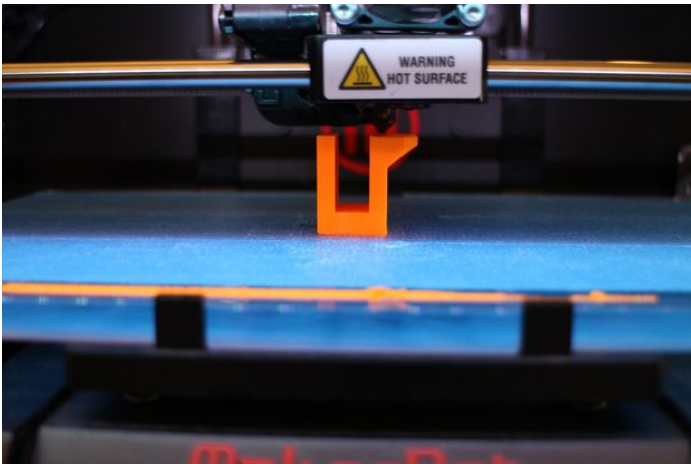
Build Adhesion

On most printers, primarily FDM machines, the 3D printed parts stick to the build plate as they are printing, and a very small contact area may result in the part falling off the build plate. The side of your part that has the most surface area on the same plane is usually the side you'll want to print on, although this can change depending on the features of a given printer.



Step 12: Overhangs and Arches

As I mentioned previously, most printers require printed support structures to hold up flat overhanging features of their parts. Because material is laid down layer by layer, most printers (primarily FDM and SLA printers) can handle up to about 45 degrees of overhang from the horizontal without requiring supports, and can also create features like vertical holes or round arches with minimal drooping. To avoid support material, note where the flat or low-angle overhangs are and either re-orient the part or make sure that they are supported by other part features, like angled overhangs or arches.



Step 13: Interfacing with Other Parts

Most 3D printers involve the heating and melting of plastic or resin, so parts tend to shrink slightly when they cool down. This means that printing parts like gears, sliders, or holders that will interface with other objects can be tricky.

Tolerances

If you are designing a part that will fit into or around something else, make sure you leave some clearance tolerance between the two parts. This tolerance will depend upon the printer you are using, so you may want to print out a few test pieces to try out the fit.

Holes

On many 3D printers, holes are never going to be as precise as they would be if you drilled or reamed them out. This is because the shrinking of the parts alters the size of the part slightly, and also because usually a cartesian-based printer is being used to make a circular hole. To ensure precise holes on your parts, design the hole to be slightly undersized (by a few thousandths of an inch) and then use a reamer to drill out the hole to the right size.

Threads

When designing parts that screws or nuts will screw onto, don't print the threads, because the tolerances may not be able to make them as precise as the threads on the components. To fix a screw to a 3D printed part, make the hole slightly smaller than the thread diameter of the component and tap the hole after the print is finished.

Part Corrosion

Most 3D printers use plastic that have relatively low melting points because the plastic needs to be feasibly heated and safe when hot. This is why ABS and PLA are commonly used for FDM machines. However, a low melting point means that they corrode very easily with applied friction. SLA printers usually produce very brittle parts because of the type of resin they require. 3D printed parts are usually not well suited for high speed or high force situations because features tend to rub off after a while, or parts break. Sliding, spinning, or moving parts will work when 3D printed, but will wear down.



Step 14: Related Technologies

CNC Machines

3D printers fall under a category of machines called "Computer Numerical Control" (CNC) Machines. CNC machines are machines whose operations are controlled by a computer. The machine controller gives the machine a CAD file, and the machine goes through a series of operations to create that object. CNC machines are usually much more precise and reliable than human-operated machines. 3D printers are additive manufacturing CNC machines because they are computer controlled and they add material to create a part. Other machines, like mills and lathes, are subtractive manufacturing machines because they remove material to make parts, just how you would cut up a piece of paper to make a shape.

Laser Cutters

Laser Cutters, like 3D printers, are another type of rapid prototyping CNC technology. Laser Cutters are very quick, efficient tools that use lasers to cut or etch flat material based on two dimensional CAD drawings. They can be used to make functional prototypes out of wood, plastic, and sometimes metal, among other materials, and can also be used to make works of art because of their rastering capabilities.

3D Scanners

A 3D scanner is another piece of technology that usually goes hand in hand with 3D printing. 3D scanners generate 3D CAD models of real world objects. To scan objects, 3D scanners map points on the object to distances from the scanner, and can thus generate a 3D representation of the object, which can be 3D printed or used for more design work.





Step 15: Resources

3D Printers

Desktop Printers

- **MakerBot:** A great FDM desktop 3D printer
- **FormLabs:** High resolution desktop SLA printer
- **RepRap:** A build-your-own FDM 3D printer kit
- **Ember:** An open source, efficient SLA printer
- **List of Common 3D Printers and Prices**

3D Printing Services

- **Shapeways:** An inexpensive 3D printing and design service
- **Ponoko:** An all around laser cutting and 3D printing service where you can make and sell your designs
- **i.materialize:** A 3D printing service that offers a wide range of design advice and materials
- **Sculpteo:** Another great 3D printing service with a wide range of materials and resources

3D Model Sites

- **Thingiverse:** A great site to share and find 3D printable designs
- **Pinshape:** Another 3D printable content sharing site
- **MyMiniFactory:** A site where you can buy and sell 3D printable designs
- **Shapeways:** Purchase parts that others have made via Shapeways

Free 3D Design Software

- **Autodesk 123D:** A group of free apps and programs designed to make 3D design easy
- **Tinkercad:** A very simple, free CAD program designed to create and print 3D content.
- **SketchUp:** Another simple, easy to learn CAD program
- **OpenSCAD:** A 3D design tool for programmers used to make easily modifiable designs
- **Blender:** A 3D design tool used to design biological and natural shapes

3D Printing News and Resources:

- **3Ders.org:** A 3D printing news and resources site
- **3Dprinter.net:** New 3D printing news and developments
- **3dPrintHQ.com:** An extensive 3D Printing glossary of terms
- **3D Printing SubReddit:** Great place for 3D printing questions, news, and content

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seamster says:

Wow, this is a really great article, thank you!

So informative, yet written in such a way that is very understandable.

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