

EG 1003 3D Printing Guide

EG 1003 Introduction to Engineering and Design
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BEFORE YOU BEGIN:

- Have you shown and explained your design to a TA?
- Have you saved it as an STL file, with the units set to MILLIMETERS?
- Does it have every feature you want it to have?
- Have you thought about how you would like to print it? (e.g. material or color choices, supports, orientation)
- FOR THINGIVERSE FILES: Do you know for certain that this part is the right one for your application? Do you know if it needs to be scaled or adjusted?

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1 What is 3d Printing?

3D printing is one of many ways to make a part. You are probably familiar with traditional, or reductive, manufacturing, in which a part is made using tools such as lathes, mills, drills, and saws that cut away pieces of a large block of raw material such as aluminum or wood. 3D printing is additive manufacturing, because it produces an object by building it up in layers from the raw materials.

3D printers are also an example of CAM, computer aided manufacturing. 3D designs made on a computer are translated into a set of instructions for the 3D printer to follow using software called a slicer. Once the instructions are given to the printer, the part is manufactured autonomously. A designer with a 3D printer can create complex designs digitally, and then have a physical prototype in the same day, without a workshop, machinists, or significant waste of material.

3D printing is used in several industries. Models made for games and films can be 3D printed into maquettes used for a variety of purposes such as lighting references and design review, a task usually done by hand in clay. Industrial designers use 3D printing to rapidly iterate product designs to improve ergonomics or add new features. 3D printing has the potential to make vehicles more efficient by creating parts in shapes that cannot be made through traditional manufacturing. New materials for printing (biomaterials, carbon fiber, conductive), larger scales for prints (building construction), and new domains (medicine) indicate that there are limitless applications for 3D printing.

There are still many limitations to 3D printing, especially at the consumer level. Just as inkjet or laser printers cannot guarantee that paper won't jam or toner won't leak, no 3D printer functions 100% of the time. In fact, the extra dimension adds extra problems. Expect to encounter jams, prints that look like spaghetti, and sometimes even solid blobs of plastic. 3D printing is a process that takes time, so it is still faster in some cases to do things by hand, especially for large, boxy objects. While 3D printing is sparking a new industrial revolution, remember that none of the traditional methods of prototyping and manufacturing are gone.

As a maker and an engineer, you will probably want to use the 3D printer on many projects. Remember that it is but one tool in your toolbox. This guide will help you begin to understand how to make the most of the 3D printers in the Makerspace and how to incorporate 3D printed parts into your projects.

2 Anatomy of a 3D Printer

1. Extruder - The extruder pushes plastic filament into the hot nozzle.
2. Nozzle - The nozzle melts and deposits plastic onto the 3D print.
3. Build Platform/Print Bed - Holds the 3D printed part in place during the print.
4. Blue Heat Plate Print Tape - Combines the characteristics of blue painters tape (easy to remove print) and Kapton tape (can handle high temperatures).
5. Leveling Knobs - Levels the bed so that the part is printed accurately. Too far from the plate prevents the filament from adhering, and too close to the plate prevents the filament from extruding.
6. Z Axis - Controls vertical displacement.
7. X and Y Axes - Controls horizontal displacement.
8. Filament Guide - Keeps the filament tangle-free as it is pulled into the extruder.
9. Filament Spool - Stores and dispenses fresh filament.
10. SD Card - Where the 3D printer's instructions are stored.
11. Monitor - Shows menu options and print progress.
12. Control Buttons - Allows menu navigation and printer control.

3 Anatomy of a 3D Print

1. Layers - 3D prints are made up of horizontal layers laid down one by one.
2. Shell/Wall - The outline of a layer.
3. Infill - The internal structure of a layer.
4. Roof and Floor - The topmost and bottommost layers of a print.
5. Overhang - A part of a print that is unsupported by a lower layer.
6. Support - Additional material added to a print to hold up overhangs.
7. Raft - Additional material added to the base of a print to hold print steady.
8. Anchor - Material extruded before a print to prime the extruder.
9. Scraper - Tool used to remove print from build platform.

4 3D Printer Settings

Most of the prints that will be performed for EG 1003 will have preset settings designed to save on print time while maintaining print quality. Some typical rules of the thumbs are summarized in a table below.

Use	Resolution	Infill	Walls	Speed
Draft	0.3mm	5%	2	120mm/s
Functional	0.2mm	7%	2	100mm/s
Finished	0.2mm	10%	2	70mm/s

Some other general principles to consider:

1. 2 color prints are easiest to complete with separate STL files for each part that has a different color.
2. Supports are usually necessary when printing overhang at an angle greater than 45 degrees from vertical.
3. Rotate, scale, and relocate the STL file as necessary in the slicing software.
4. Print scale and time to print are not linearly related. 50% prints can take less than a quarter of the time.
5. Reduce the speed to 30-40% when using flexible or dissolvable filaments.

5 Designing for Successful 3D Printing

Just as in any manufacturing process, 3D printers work best when certain practices are followed in the design process. Here are some basic ones to keep in mind for your designs.

- **Make a flat bottom:** A large flat bottom increases the adhesion between the build platform and the part, keeping the part from shifting around during a print.
- **Fillet bottom edges and sharp corners:** Filleting the bottom can reduce curling of the print and make it easier to remove the print with a scraper. Rounding other corners allows the printer to move more smoothly, improving print quality.
- **Oversize holes and undersize pegs:** Because of thermal expansion, holes and pegs tend to come out imperfectly. Leave at least 0.5mm tolerance between pegs and holes.
- **Avoid thin walls and thin columns:** Thin walls and column often do not come out well. The thickness of a thin wall should be a multiple of 0.35mm. Thin columns will usually come out distorted because they melt under the nozzle.
- **Use rounded fonts:** Fonts with sharp corners and thin sections will usually not be legible when 3D printed. Fonts such as Arial Round will be very clear. In addition, keep the text large or it will come out too blobby to read.
- **Keep overhangs close to 45 degrees:** Each layer of a 3D print needs to be supported from below. You can avoid adding additional supports to a print if all the overhanging parts are at no more than a 45 degree angle from vertical.
- **Cut parts into sections:** Large parts, parts without flat surfaces, or parts with large overhangs can be cut into easier-to-print sections to be glued together.

6 Filament

1. ABS - Same plastic used in LEGO pieces. Requires heated bed and ventilation. Less brittle, original plastic used for 3D printing.
2. PLA - Newer 3D printing plastic, biodegradable with fewer ultra fine particles (UFPs) so it does not require ventilation. Does not require heated bed, but has a greater coefficient of friction creating more stress for the extruder.
3. PVA - Dissolvable filament that can be used for supports, rafts, and internal parts that should be hollow. Can have issues with bonding to regular filament.
4. TPE - Flexible filament that is more resilient to damage.

Type	Ext Temp	Bed Temp	Notes
ABS	230	110	Heated Bed Required
PLA	210	45	No Heated Bed
PVA	160-180?	20-50?	Water Soluble
TPE	210-230?	20-50?	Flexible

Experimental PLA filaments:

Composite (Carbon Fiber, Wood, Ceramic), Conductive, Photochromatic, Thermochromatic

Brands:

- FlashForge
- Toner Plastics
- Inland
- HATCHBOX
- Gizmo Dorks
- BuMat
- SainSmart
- NinjaFlex

Important specifications:

1. 1.75 mm \pm .05mm diameter
2. 2.2 lbs or 1.1 lbs
3. Spool Diameter: 8" - Spool Width: 2.50" - Spool Hub Hole Diameter: 1.50"
4. Plastic bins and desiccant for storage

7 Maintenance

1. Bed leveling
2. Cleaning the extruder
3. Reapplying bed tape
4. Loading/unloading filament

8 Software

1. Printing Software

- (a) Makerware
- (b) ReplicatorG
- (c) Simplify3D
- (d) Flashforge

2. CAD Software

- (a) Solidworks
- (b) Inventor
- (c) Rhino
- (d) Tinkercad
- (e) Blender
- (f) OpenSCAD

9 Troubleshooting

Problem	Solution
First layer is peeling up or coming out stringy	<ol style="list-style-type: none"><li data-bbox="654 338 1442 407">1. Check if the part is printing on bad tape, and adjust bed position if it is.<li data-bbox="654 436 959 472">2. Try printing slower.<li data-bbox="654 501 1442 571">3. Level the bed using the program on the SD card with the knobs under the print bed.
Bottom of part is curling up	<ol style="list-style-type: none"><li data-bbox="654 653 1279 688">1. Restart print, checking first layer adhesion.<li data-bbox="654 718 1442 787">2. Increase the temperature of the bed, use a printer with plexiglass coverings installed.
Part comes off build platform	<ol style="list-style-type: none"><li data-bbox="654 863 1442 932">1. Restart print, checking first layer adhesion and reducing speed.<li data-bbox="654 961 1154 997">2. Change the settings to add a raft.
Print layers are shifted out of place	<ol style="list-style-type: none"><li data-bbox="654 1073 1019 1108">1. Pause and restart print.<li data-bbox="654 1138 1214 1173">2. Adjust build platform to realign print.<li data-bbox="654 1203 1122 1239">3. Restart print at a slower speed.
Layers are sagging	<ol style="list-style-type: none"><li data-bbox="654 1304 1414 1339">1. Reorient part in slicing software to reduce overhangs.<li data-bbox="654 1369 1295 1404">2. Add or increase supports in slicing software.

10 Research Questions

1. Best extruder and bed temperature for PLA, ABS, PVA, TPE/TPU?
2. Best software for 3d printer slicing/time?
3. Multiple prints on one bed/defined zones for completion?
4. Best software for 3d printing design, functionality, and compatibility?
5. Times to print with different speeds, infills, shells, colors?
6. Dissolvable filament for rafts/supports or infill for object?
7. How often do we need extruder maintenance, bed leveling?
8. Acetone finishing/joining?
9. Composite filaments?
 - (a) Carbon Fiber
 - (b) Conductive
10. Best brand of filament?

11 More Resources

1. The Additive Project:
Open source teaching tools and lesson plans for 3D printing projects.
<http://theadditiveproject.org/>
2. Tinkerine U:
Detailed video tutorials about 3D printing.
<http://u.tinkerine.com/en-ca>
3. MAKE: Magazine:
Project ideas, product reviews, and more.
<http://makezine.com>
4. Meshmixer:
Free software to make STL files more 3D printable.
<http://meshmixer.com>
5. 123Design:
Free 3D design software.
<http://www.123dapp.com/design>
6. Best 3D printer practices
7. Converting raster images to CAD files
8. Regular extruder cleaning
9. How to deal with an extremely clogged extruder

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