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3D Printing 101

What is 3D printing?

3D printing, also known as "Additive Manufacturing" and sometimes referred to as "Rapid Prototyping" is a type of manufacturing process where objects are built by adding material one layer at a time. The consumer printers we often see are the Fused Deposition Modeling (FDM) type where plastic filament is heated to a glass transition temperature, meaning that the plastic is heated just enough so that it can be extruded precisely by the printer.

There are other types of 3D printers aside from FDM such as Stereolithography (SLA), Digital Light Processing (DLP), Selective Laser Sintering (SLS) and more. Essentially the fundamental principal is the same for these technologies – adding material one layer at a time, though the methodology differs.

The early 3D printing technologies can be traced back to the 1980's with some traction gaining during the 1990's. 3D printing began to gather steam in the early 2000's with many innovations and finally came to consumer awareness in the late 00's and early 2010's. In 2019, 3D printing continues to break new ground on what seems like a weekly basis with new types of printers and new materials being 3D printed.

What can it do?

3D printing, at the consumer/pro-sumer level, can print one-piece objects from various plastics in the comfort of one's garage, bedroom or office. Consumer 3D printers that you can buy from retailers allow for an extremely high degree of precision at an unbelievable 0.0001 of an inch! 3D printers in general allow for someone to print objects that otherwise could not be manufactured or extremely hard to manufacture due to their design - in one solid piece and in just one print!

3D printing gives the consumer/pro-sumer and businesses a way to digitally design their ideas they have in their head and print it – in mere minutes in some cases! The ability for entities to rapidly produce and revise their ideas saves time, energy, waste, hassles and money.

And even more importantly, doing 3D printing in-house allows you to keep your intellectual property within your walls and not floating around the Internet or in some foreign country.

3D printing can print things such as household items, models, knick-knacks, replacement parts, prototypes… ultimately it comes down to the designer's imagination. At the business and industrial level, people are printing tools, parts for automobiles, bikes, motorcycles, aircraft and even biomedical implants.

Getting Started: Design & Slicing Software

It's easy to get started designing for 3D printing. All you need is a decently powered laptop or desktop PC and free software to start designing!

There are two types of software you need to 3D print; one type is called a "design/ CAD" software and the other is called a "slicer." In some cases, a program may contain both a CAD and a slicer. You do the designing of the object with design/ CAD software and then you will "slice" the object with a "slicer" program.

Free design/ CAD consumer software include AutoDesk 123D Design, SketchUp, TinkerCAD, Blender as well as the software that often comes free with the 3D printer.

Pro-sumers and professionals have software such as Solidworks and Inventor. All you need to do is download the different software, see which one works best for you and start learning.

Free "slicing" consumer software include MakerWare, Slic3r and Cura.

Again, you should try different ones to see which you like the best.

The digital design process has two steps; for the first step, you will design your object with one of the design/ CAD software. When you are done, you will save it in a particular type of file that can be used by the slicer program. When the slicer program analyzes that file, it "slices" the object layer by layer, creating the machine code that will be used by the printer. It is from that code a new file will be derived, one that the 3D printer can read and will be inserted into the printer via an SD card or by cable.

The FDM 3D Printer and 3D Printing

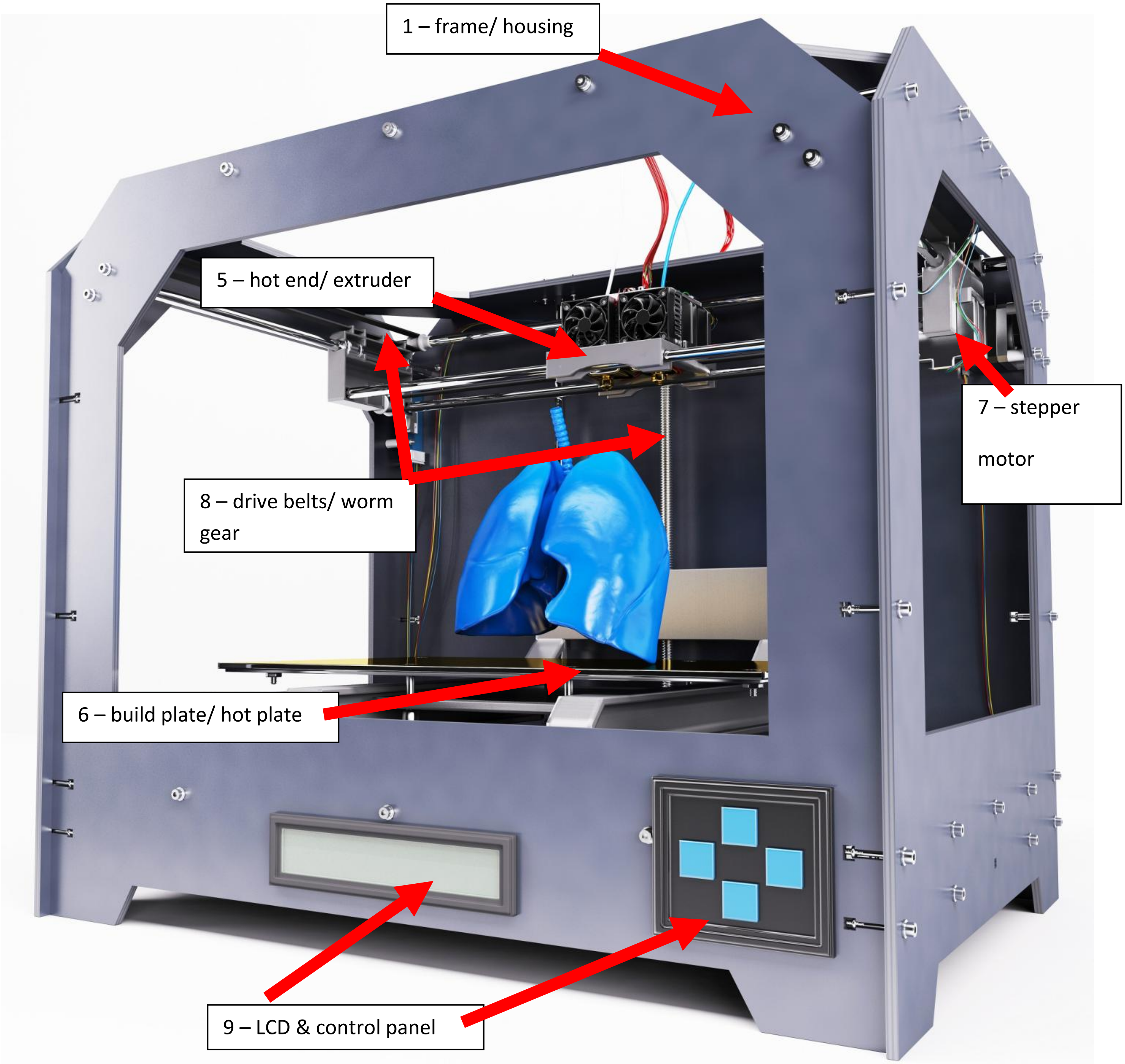
The FDM 3D printer that you may have seen is the most prevalent one for the consumer market. It looks a bit complex but truly, it's pretty simple! Here are the major components and what they do:

1. **frame/ housing** – holds the entire assembly
2. **power supply** – gives continuous power to all components of the 3D printer
3. **logic board** – this is the control center for the 3D printer, much like a computer motherboard
4. **wires** – wires that connect various components to the logic board
5. **hot end – extruder & nozzle** – this is the end that gets hot, melts the plastic and deposits it onto the build plate through the nozzle; a stepper motor pushes the filament through in precise amounts
6. **build/ hot plate** – this is the surface to which the plastic adheres; in some cases the plate gets got to help adhere certain types of plastics; not all printers have heated build plates
7. **stepper motors** – there precision motors control the X, Y and Z position of the extruder nozzle and the build plate (in some printers, the bed moves back and forth and the nozzle remains stationary)
8. **drive belts/ worm gear** – drive belts move the nozzle in the X and Y position and the worm gear raises or lowers the build platform in the Z direction
9. **control panel & LCD screen**– this is the interface where the user controls the 3D printer
10. **SD card slot** – this is where the user will insert the SD card containing the print files that the 3D printer will read
11. **filament** – while not part of the 3D printer, it is a long string of plastic rolled up on a spool

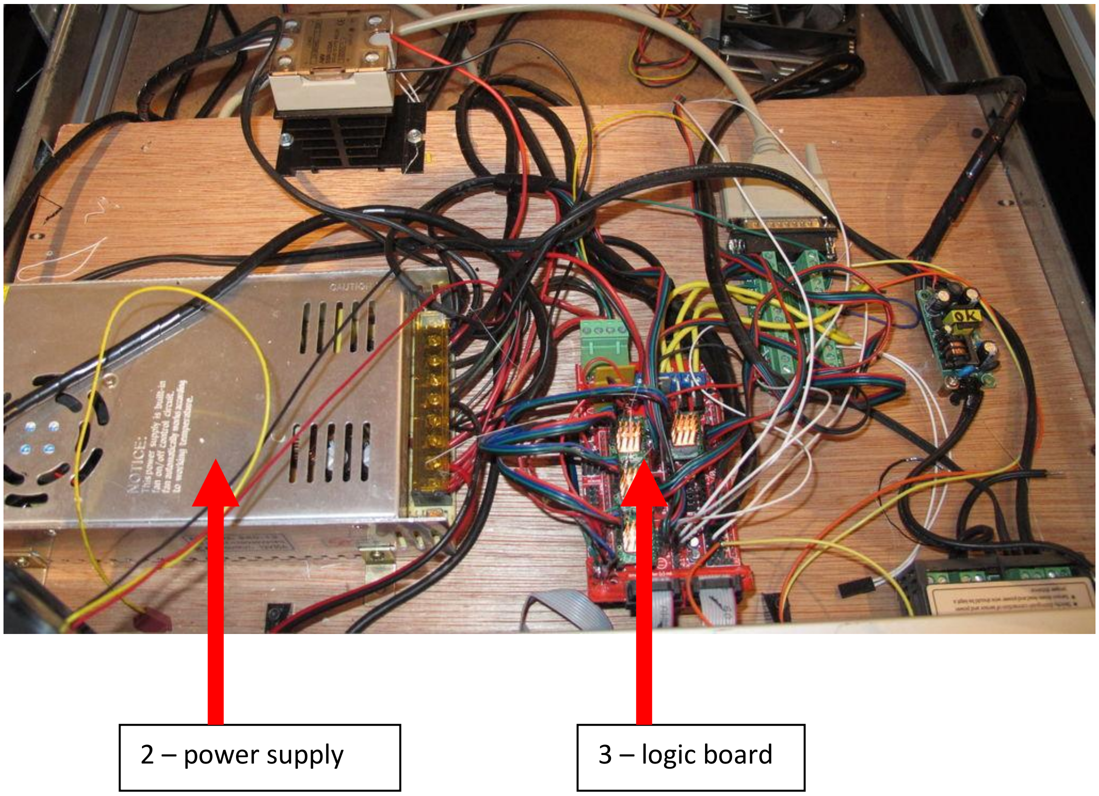
All of these components work together to bring you the wonderful technology of 3D printing! Here are the basic steps to a 3D print:

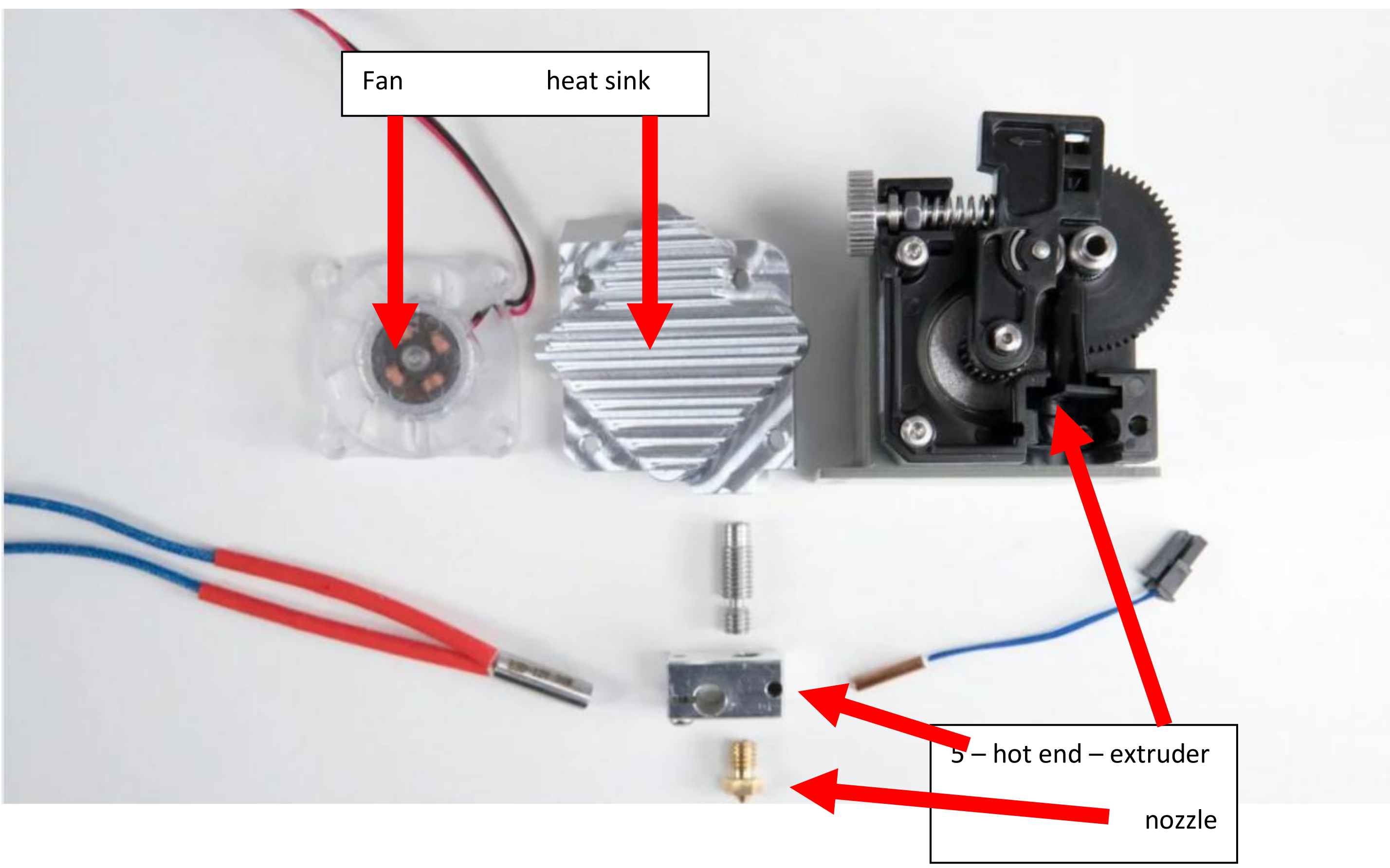
1. Design your object idea, slice it and put it onto an SD card
2. Insert the SD card into the 3D printer's SD slot, turn on your 3D printer and warm it up
3. Load filament and/ or level the 3D printer's print bed if needed
4. Start the print and watch it for the first few minutes to ensure that the object sticks to the build plate /hotplate
5. Once you are sure the first layer has stuck to the build plate, you can walk away and let it print; however, it is always good to check it every now and then to ensure everything is going smoothly
6. Once done, remove your object and enjoy seeing your idea come to life!

For the consumer market, 3D printers are an AMAZING technology to have. Sometimes they are not perfect…and there are many factors and variable one must consider in getting excellent, consistent prints; so when you are just beginning, don't be discouraged if the object comes out deformed, your printer stopped or you have a big glob of plastic on the end of your nozzle; this happens to all of us from time to time but you have to keep things in perspective – this AMAZING technology wasn't available for the consumer market 15 years ago and to have this level of precision and design capability in the comfort of your own hope is nothing short of a miracle!


1 – frame/ housing
5 – hot end/ extruder
7 – stepper motor
8 – drive belts/ worm gear
6 – build plate/ hot plate
9 – LCD & control panel

11 – filament


2 – power supply
3 – logic board


Fan
heat sink
5 – hot end – extruder
nozzle

Types of Materials

Currently for the consumer market, the major types of printing filament are ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic Acid) and PET (PolyEthylene Terephthalate). ABS is the strongest and is difficult to print with at times while PLA is easy to work with and a little less strong. PLA is recognized as food safe as well as PET and PETG. There are filaments that are flexible as well. There are also many other types of filament that infuse metal and wood powder into ABS or PLA so that it provides unique finishes and textures. The consumer market also has access to more exotic filament that contain carbon fiber to strengthen parts as well as conductive metal so that a person can print mini-circuit boards!

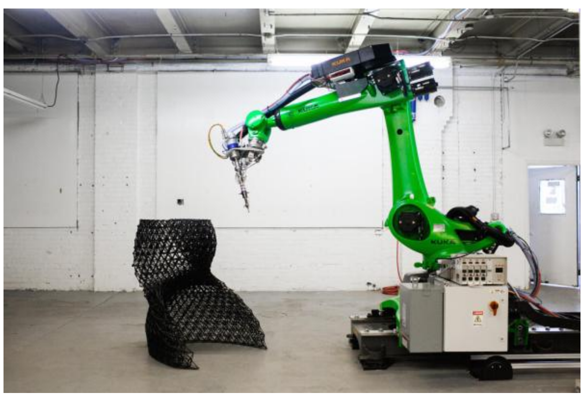
3D Printing Filament Comparison

V1.0 Feb 2017

Material	Print Temp (°C)	Bed Temp (°C)	Strength	Flexibility	Durability	Difficulty	Shrinkage	Soluble	Food Safe*	Blue Tape	Glue Stick	Typical Uses
ABS Acrylonitrile Butadiene Styrene	210-250	50-100	●●	●●	●●●	●●	[icon]	Acetone	No	[icon]	[icon]	Functional Parts
ASA Acrylonitrile Styrene Acrylate	240-260	100-120	●●	●	●●●	●●	[icon]	Acetone	No	[icon]	[icon]	Outdoor Use
Carbon Fiber Carbon Fiber and PLA blend	195-220	N/A	●●	●	●●●	●●	[icon]	No	No	[icon]	–	Functional Parts
Cleaning Cleaning Filament	150-260	N/A	–	–	–	●	–	–	–	–	–	Nozzle Cleaning / Unclogging
Color Changing PLA or ABS with color changing properties	210-220	N/A	●●	●●	●●	●	[icon]	No	No	[icon]	[icon]	Educational, Modelling
Conductive Conductive PLA or ABS	215-230	N/A	●●	●●	●	●	[icon]	No	No	[icon]	–	Electronics
Flexible, TPE, TPU Thermoplastic Urethane / Polyurethane	225-235	N/A	●	●●●	●●	●●●	[icon]	No	No	[icon]	[icon]	Elastic Parts, Wearables
FPE Flexible Polyester	205-250	75	●	●●●	●●●	●●	[icon]	No	Yes	–	[icon]	Flexible Parts
Glow-In-The-Dark Glow in the dark PLA or ABS	210-220	N/A	●●	●●	●●	●	[icon]	No	No	[icon]	–	Educational, Modelling
HIPS High Impact Polystyrene	210-250	50-100	●	●●	●●●	●●	[icon]	Solvent	No	[icon]	[icon]	Support Structures
Lignin (bioFila) Lignin and PLA plus additives	190-225	55	●●	●	●●●	●●●	[icon]	No	Yes	[icon]	[icon]	All Purpose
Magnetic PLA with powdered iron	195-220	N/A	●●	●●	●●	●●●	[icon]	No	No	[icon]	–	Educational, Experimental
Metal PLA / ABS Metal Powder and PLA or ABS blend	195-220	N/A	●●	●	●●●	●●●	[icon]	No	No	[icon]	–	Jewelry
nGen Similar to PETG	210-240	60	●●	●●●	●●●	●●	[icon]	No	Yes	[icon]	–	All Purpose
Nylon Polyamide	220-260	50-100	●●●	●●●	●●●	●●	[icon]	No	Yes	–	[icon]	All Purpose
PC Polycarbonate	270-310	90-105	●●●	●●●	●●●	●●	[icon]	Acetone	No	–	[icon]	Functional Parts
PC/ABS Polycarbonate ABS	260-280	120	●●	●	●●●	●●●	[icon]	No	No	–	[icon]	Functional Parts
PET (CPE) Polyethylene Terephthalate	220-250	N/A	●●●	●●●	●●●	●●	[icon]	No	Yes	[icon]	–	All Purpose
PETG (XT, N-Vent) Poly-Ethylene Terephthalate Glycol	220-235	N/A	●●	●●●	●●●	●●	[icon]	No	Yes	[icon]	–	All Purpose
PETT (T-Glase) PolyEthylene coTrimethylene Terephthalate	235-240	N/A	●●●	●●●	●●●	●●	[icon]	No	Yes	[icon]	–	Functional Parts
PLA Polylactic Acid	180-230	N/A	●●	●	●●	●	[icon]	No	Yes	[icon]	[icon]	Consumer Products
PMMA, Acrylic Polymethyl Methacrylate	235-250	100-120	●●	●	●●●	●●	[icon]	Acetone	No	[icon]	[icon]	Light diffusers, Modelling
POM, Acetal Polyoxymethylene	210-225	130	●●●	●	●●	●●●	[icon]	Chemical	No	–	[icon]	Functional Parts
PORO-LAY Rubber-elastomeric polymer with PVA	220-235	N/A	●●●	●	●●	●	[icon]	Water	Yes	[icon]	–	Experimental
PP Polypropylene	210-230	120-150	●●	●●●	●●	●●●	[icon]	No	Yes	[icon]	–	Flexible Components
PVA Polyvinyl Alcohol	180-230	N/A	●●●	●	●●	●	[icon]	Water	Yes	[icon]	–	Support Structures
Sandstone (Laybrick) Co-polyester and chalk powder	165-210	N/A	●	●	●	●●	[icon]	No	No	[icon]	–	Architectural Modelling
TPC Thermoplastic Copolyester	210-210	60-100	●	●●●	●●	●●●	[icon]	No	No	[icon]	–	Elastic Parts, Outdoor Use
Wax (MOLDLAY) Wax-like properties	170-180	N/A	●	●	●	●	[icon]	No	No	[icon]	–	Lost Wax Casting
Wood (Laywood) Wood PLA Blend	195-220	N/A	●●	●●	●●	●●	[icon]	No	No	[icon]	–	All Purpose (natural finish)

3D Printing – The Disruption is Here and Now!

3D printing today is what the PC of the late 70's and early 80's was to the world then; an interesting novelty that nerds dabbled with; 30 years later, the world has changed in so many ways because of the PC and the Information Technological revolution. 3D printing technology is being rapidly improved on many fronts and is already disrupting many industries; 3D printing is poised to change the way manufacturing is done across the globe as it spreads and become more user friendly. Every week some new innovation in 3D printing is announced and we are only just now seeing what this technology is capable of! 30 years from now, 3D printing will change the world in ways we can yet imagine - so it's a great time for anyone and everyone to learn about and become involved with 3D printing to be part of the revolution!



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