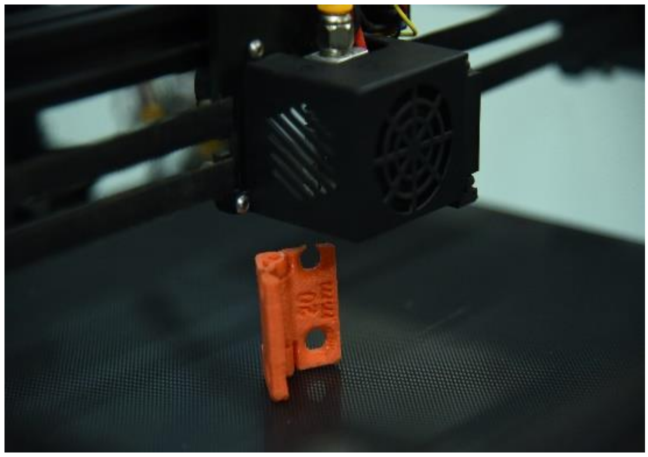
Draft Study Material



OPERATOR – PLASTIC 3D PRINITING

(Qualification Pack: Ref. Id. RSC/Q8009)

Sector: Rubber Industry

(Grade XII)

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION
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Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

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Date: 20 June 2024

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Module 1	Selection of Material for Fused Deposition Modelling

Module Overview
This module teaches students about choosing the right materials for 3D printing. FDM is a popular 3D printing method that uses melted plastic to create objects layer by layer. The module covers different types of plastics, like PLA and ABS, and their properties, such as strength, flexibility, and melting point. Students learn how these properties affect the final product's quality and usage. By understanding material selection, they can make informed decisions for successful 3D printing projects.

Learning Outcomes
After completing this module, you will be able to: • Understand different types of 3D Printing materials. • Identify key properties of different materials. • Develop skills to select appropriate materials for specific 3D Printing projects.

Module Structure
1.1 Brief Overview of Fused Deposition Modelling (FDM) technology 1.2 Role of materials in FDM process 1.3 Various materials used in FDM process

In the previous classes, we have gone through the concept and working of 3D printer. We have also studied various methods used for 3D printing such as Stereolithography, Laser Sintering, Digital light processing etc. One of which is Fused Deposition Method which was discussed in Unit 4 “3D Printing Technologies” of Class XI, of Operator- Plastic 3D Printing.

Imagine you have a hot glue gun loaded with plastic filament instead of glue sticks. FDM works kind of like that. The printer heats up the plastic filament until it's all melty. Then, it squirts out this melted plastic layer by layer, like drawing with a really precise hot glue gun. Each layer cools and hardens quickly, building up the object you're printing. It's like stacking layers of pancakes to make a tower, but with plastic instead of batter.

This method is great for making all sorts of things, from toys to prototypes, because it is relatively simple and affordable compared to other 3D printing techniques. Also, it allows for a lot of creativity and customization since you can design pretty much anything you want and then print it out in plastic.

1.1 BRIEF OVERVIEW OF FUSED DEPOSITION MODELING (FDM) TECHNOLOGY

Fused Deposition Modeling (FDM) is a type of 3D printing method used to make models, prototypes, and products. It is known for being fast, easy, and affordable for creating personalized items. The technology was invented by S. Scott Crump, one of the founders of Stratasys, back in the late 1980s. It became available for commercial use in 1990. Today, FDM is the most commonly used 3D printing technology and is also called extrusion-based additive manufacturing or FFF (Fused Filament Fabrication) as shown in Fig. 1.1.

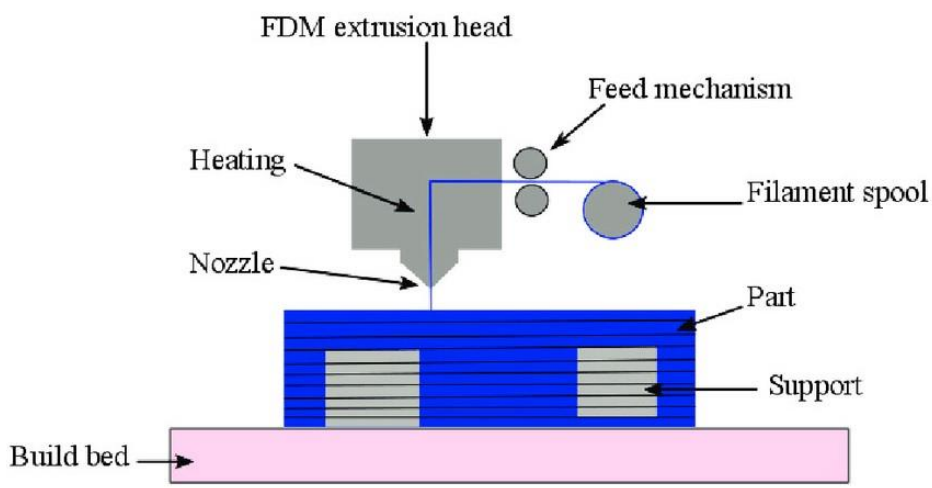


Fig1.1 Basic Procedure of FDM

Let us recall the general process of Fused Deposition Modelling technique used for 3D printing process:

The FDM (Fused Deposition Modeling) process works like this:

1. **Design Preparation**: The process begins with creation of digital 3D model using computer-aided design (CAD) software. This can be done using any design software such as TinkerCAD (an open source software), Pro/E (Used for model's mechanical designs) etc. The design such finalized should be downloaded in .stl file.

STL (stereolithography) file format is commonly used for 3D printing. It represents 3D surface geometry using a series of connected triangles. Each triangle is defined by three vertices in 3D space. .STL files can be generated by CAD software or created through 3D scanning. They are widely compatible across various 3D printing platforms and software applications. The format is renowned for its simplicity and efficiency in representing solid models for additive manufacturing.

2. **Conversion of. stl to G-Code**: The .stl file so downloaded will be now converted into G-code. This can be done using software "Cura" or any other such software. So, the file is now sliced into thin layers using slicing software, which generates the instructions (G-code) for the 3D printer.

G-code is the language that controls 3D printers, guiding them through the intricate process of creating objects layer by layer. It's essentially a set of instructions that tell the printer where to move, how fast to move, and when to extrude material.

Each line of G-code contains a specific command or instruction, such as moving the print head to a certain position, setting the temperature of the extruder or heated bed, or adjusting the flow rate of the filament.

The file is now ready to get printed. Before this, we must assure some arrangements in the 3D printer machine for smooth flow of work. They are:

3. **Material Loading**: A spool of thermoplastic filament, such as PLA or ABS, is loaded into the 3D printer. It depends on the used in which colour, the print is desired. Operator can used any of the colour in which the design desired to get printed. The filament is typically fed through a heated nozzle, where it melts and becomes malleable.

4. **Check at the basic settings of the 3D printer**: Some basic settings such as Nozzle temperature, Bed temperature, Levelling of the bed, Proper feed of filament etc.

Operator can use Secure Digital (SD) Card, USB or any other means on the basis of which the G code file of the design is be given to the 3D printer for printing.

5. **Layer-by-Layer Deposition**: As the printing starts, the 3D printer's nozzle moves along the X, Y, and Z axes according to the instructions from the slicing software. It deposits melted filament onto the build platform, layer by layer, following the shape of the sliced model.

6. **Material Cooling and Solidification**: As each layer is deposited, the melted filament quickly cools and solidifies, bonding to the previous layer. This process repeats until the entire object is built up layer by layer.

7. **Completion and Post-Processing**: Once printing is finished, the completed object may require post-processing steps such as removing support structures, sanding, or painting to achieve the desired finish

1.2 ROLE OF MATERIALS IN FDM PROCESS

In Fused Deposition Modeling (FDM), materials play a major role in determining the quality, functionality, and suitability of the printed objects. The choice of material significantly influences various aspects of the printing process, including print quality, mechanical properties, temperature resistance, and chemical compatibility.

Different thermoplastic polymers, such as PLA, ABS, PETG, and specialty filaments like woodfill or flexible materials, offer distinct characteristics that cater to specific application requirements. Moreover, high-performance materials like polycarbonate (PC) or polyether ether ketone (PEEK) provide enhanced mechanical strength and durability, expanding the range of potential applications for FDM technology.

Biocompatible and food-safe materials further broaden the scope of FDM applications, ensuring safety and compliance in medical, dental, and culinary industries. Ultimately, the careful selection of materials is essential for achieving desired outcomes in FDM, enabling the production of functional prototypes, customized products, and end-use parts with precision and reliability.

Materials play a very important role in Fused Deposition Modeling (FDM) as they directly influence the quality, properties, and functionality of the printed objects. Here are some key roles of materials in FDM:

1. **Print Quality**: The choice of material greatly impacts the overall print quality, including surface finish, layer adhesion, and detail resolution. Different materials may exhibit varying levels of shrinkage, warping, or stringing during printing, affecting the final appearance of the printed object.

2. **Mechanical Properties**: Materials determine the mechanical strength, stiffness, and flexibility of the printed parts. For functional prototypes, end-use parts, or engineering applications, it's important to select materials with appropriate mechanical properties to

ensure that the printed objects can withstand intended loads, stresses, or environmental conditions.

3. **Temperature Resistance**: Certain materials offer high temperature resistance, making them suitable for applications where the printed objects will be exposed to elevated temperatures or thermal stress. This is particularly important for functional parts used in automotive, aerospace, or industrial applications.

4. **Chemical Resistance**: Some materials are resistant to various chemicals, oils, solvents, or environmental factors, which is essential for applications where the printed objects will come into contact with corrosive substances or harsh environments.

5. **Biocompatibility**: In medical, dental, or biotechnological applications, selecting biocompatible materials is critical to ensure that the printed objects are safe for use within the human body or in contact with biological tissues or fluids.

6. **Aesthetic and Surface Finish**: Different materials offer varying degrees of smoothness, texture, and color options, allowing for customization and aesthetic considerations in product design and development.

7. **Cost and Availability**: The cost and availability of materials can influence material selection, particularly for large-scale production or cost-sensitive projects. Some materials may be more affordable or readily available than others, impacting the overall project budget and feasibility.

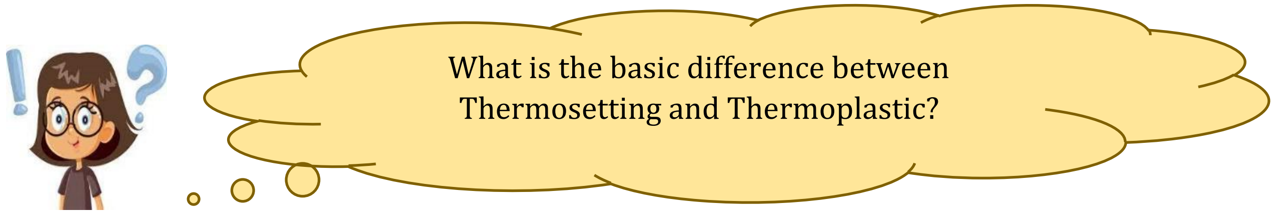
1.3 VARIOUS MATERIALS USED IN FDM PROCESS

To simplify the process of finding the ideal material for a specific part or product, let us start by examining the main types of plastics and the various 3D printing processes, ensuring they are best suited to particular cases.

1.3.1 Types of Plastic Materials

i. **Thermoplastics**: These are the most commonly used plastics in 3D printing. They can be melted and solidified repeatedly without undergoing chemical changes, making them suitable for recycling. Examples include PLA, ABS, and PETG.

ii. **Thermosetting**: These remain in a permanent solid state after curing and cannot be reshaped through melting. They are suitable for applications requiring high heat resistance and durability, such as aerospace components and automotive parts. Examples include epoxy resins and urethane resins.



1.3.2 Plastic 3D Printing Materials (FDM Process)

As we have already discussed, Fused deposition modeling (FDM), also known as Fused Filament Fabrication (FFF), is the most widely used form of 3D printing at the consumer level, fueled by the emergence of hobbyist 3D printers.

This technique is well-suited for basic proof-of-concept models, as well as for quick and low-cost prototyping of simple parts, such as parts that might typically be machined.

Consumer level FDM has the lowest resolution and accuracy when compared to other plastic 3D printing processes and is not the best option for printing complex designs or parts with intricate features. Higher-quality finishes may be obtained through chemical and mechanical polishing processes. Industrial FDM 3D printers use soluble supports to mitigate some of these issues and offer a wider range of engineering thermoplastics or even composites, but they also come at a steep price.

As the melted filament forms each layer, sometimes voids can remain between layers when they don’t adhere fully. This results in anisotropic parts, which is important to consider when you are designing parts meant to bear load or resist pulling. Various colour shades of the PLA filament roll are shown in Fig.1.2.

Fig1.2 PLA material used in FDM Process

1.3.3 Popular FDM 3D Printing Materials

Material	Properties	Applications
ABS (acrylonitrile butadiene styrene)	• Tough and durable • Heat and impact resistant • Requires a heated bed to print • Requires ventilation	• Functional prototypes
PLA (polylactic acid)	• The easiest FDM materials to print • Rigid, strong, but brittle • Less resistant to heat and chemicals • Biodegradable • Odorless	• Concept models • Looks-like prototypes
PETG (polyethylene terephthalate glycol)	• Compatible with lower printing temperatures for faster production • Humidity and chemical resistant • High transparency • Can be food safe	• Waterproof applications Snap-fit components
Nylon	• Strong, durable, and lightweight • Tough and partially flexible • Heat and impact resistant • Very complex to print on FDM	• Functional prototypes Wear resistant parts
TPU (thermoplastic polyurethane)	• Flexible and stretchable • Impact resistant • Excellent vibration dampening	• Flexible prototypes
PVA (polyvinyl alcohol)	• Soluble support material • Dissolves in water	• Support Material

HIPS (high impact polystyrene)	• Soluble support material most commonly used with ABS • Dissolves in chemical limonene	• Support Material
Composites (carbon fiber, kevlar, fiberglass)	• Rigid, strong, or extremely tough • Compatibility limited to some expensive industrial FDM 3D printers	• Functional prototypes Jigs, fixtures, and tooling

1.4 FRAMEWORK FOR CHOOSING THE RIGHT PLASTIC 3D PRINTING MATERIAL

With all these materials and 3D printing options available, how can you make the right selection?

Here's our three-step framework to choose the right 3D printing material and plastic 3D printer for your application.

Step 1: Define Performance Requirements

Plastics used for 3D printing have different chemical, optical, mechanical, and thermal characteristics that determine how the 3D printed parts will perform. As the intended use approaches real-world usage, performance requirements increase accordingly.

Requirement	Description	Recommendation
Low performance	For form and fit prototyping, conceptual modeling, and research and development, printed parts only need to meet low technical performance requirements. Example: A form prototype of a soup ladle for ergonomic testing. No functional performance requirements needed besides surface finish.	**FDM:** PLA
Moderate performance	For validation or pre-production uses, printed parts must behave as closely to final production parts as possible for functional testing but do not have strict lifetime requirements. Example: A housing for electronic components to protect against sudden impact. Performance	**FDM**: ABS

	requirements include ability to absorb impact, housing needs to snap together and hold its shape.	
High performance	For end-use parts, final 3D printed production parts must stand up to significant wear for a specific time period, whether that is one day, one week, or several years. Example: Shoe outsoles. Performance requirements include strict lifetime testing with cyclic loading and unloading, color fastness over periods of years, amongst others like tear resistance.	**FDM:** Composites

Step 2: Translate Performance Requirements to Material Requirements

Once you have identified the performance requirements for your product, the next step is translating them into material requirements—the properties of a material that will satisfy those performance needs. You will typically find these metrics on a material's data sheet.

Requirement	Description	Recommendation
Tensile strength	Resistance of a material to breaking under tension. High tensile strength is important for structural, load bearing, mechanical, or statical parts	**FDM**: PLA
Flexural modulus	Resistance of a material to bending under load. Good indicator for either the stiffness (high modulus) or the flexibility (low modulus) of a material	**FDM**: PLA (high), ABS (medium)
Elongation	Resistance of a material to breaking when stretched. Helps you compare flexible materials based on how much they can stretch. Also indicates if a material will deform first, or break suddenly.	**FDM**: ABS (medium), TPU (high)
Impact strength	Ability of a material to absorb shock and impact energy without breaking. Indicates toughness and durability, helps you figure out how easily a material will break when dropped on the ground or crashed into another object.	**FDM**: ABS, Nylon
Heat deflection temperature	Temperature at which a sample deforms under a specified load. Indicates if a material is suitable for high temperature applications.	**FDM**: ABS

Hardness (durometer)	Resistance of a material to surface deformation. Helps you identify the right "softness" for soft plastics, like rubber and elastomers for certain applications.	**FDM**: TPU
Tear strength	Resistance of a material to growth of cuts under tension. Important to assess the durability and the resistance to tearing of soft plastics and flexible materials, such as rubber.	**FDM**: TPU
Creep	Creep is the tendency of a material to deform permanently under the influence of constant stress: tensile, compressive, shear, or flexural. Low creep indicates longevity for hard plastics and is important for structural parts.	**FDM**: ABS

Step 3: Make a Selection

Once you translate performance requirements to material requirements, you will most likely end up with a single material or a smaller group of materials that could be suitable for your application.

If there are multiple materials that fulfil your basic requirements, you can then look at a wider range of desired characteristics and consider the pros, cons, and trade-offs of the given materials and processes to make the final choice.

Activities
Activity: Understanding of the materials used for FDM process. **Materials Needed:** 1. Notebook 2. Laptop/Desktop 3. Presentation software (e.g., PowerPoint, Google Slides). 4. Pen **Procedure:** 1.Accompanied by a teacher, make a trip to a shop specializing in FDM materials. 2.Observe the various types of materials utilized in the FDM process. 3.Choose three materials of interest. 4.Analyze and contrast the properties of the selected materials. 5.Create a presentation outlining the characteristics and comparisons of the chosen materials. 6.Engage in a group discussion with classmates to share insights and perspectives on the materials presented.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What is the most commonly used 3D printing technology for plastic manufacturing?
a) Stereolithography
b) Fused Deposition Modeling (FDM)
c) Digital Light Processing (DLP)
d) Laser Sintering

2. Which software is commonly used to convert .stl files to G-code for FDM 3D printing?
a) TinkerCAD
b) Cura
c) SolidWorks
d) None of the above

3. What is the role of thermoplastics in FDM 3D printing?
a) They remain in a permanent solid state after curing.
b) They can be melted and solidified repeatedly without undergoing chemical changes.
c) They are suitable for applications requiring high heat resistance.
d) They are compatible with lower printing temperatures for faster production.

4. Which material is known for being the easiest to print with in FDM?
a) ABS
b) PETG
c) PLA
d) Nylon

5. What is the primary purpose of soluble supports in industrial FDM 3D printing?
a) To increase the strength of the printed parts
b) To reduce the cost of printing materials
c) To mitigate issues related to layer adhesion
d) To remove support structures easily after printing

B. Fill in the Blanks:

1. Fused Deposition Modeling (FDM) is a type of __________ dimensional printing method used to make models, prototypes, and products.

2. The process of converting .stl files to G-code is typically done using most commonly _________ software such as Cura.

3. ________ is the most commonly used material for FDM 3D printing due to its ease of use and biodegradability.

4. _________ is the language that controls 3D printers, guiding them through the intricate process of creating objects layer by layer.

5. _________ plastic remain in a permanent solid state after curing and cannot be reshaped through melting.

C. Match the Following:

	Section A		**Section B**
1.	FDM	**A**	Software for converting. stl to G-code
2.	PLA	**B**	Fused Filament Fabrication
3.	Cura	**C**	Can be melted and solidified repeatedly without chemical changes
4.	Thermoplastics	**D**	Biodegradable and Odorless
5.	Soluble supports	**E**	Used in industrial FDM for easy removal of supports

C. Answer the Following

1. What are some factors that materials influence in FDM 3D printing?
2. Why is PLA commonly used in FDM 3D printing?
3. What role do soluble supports play in FDM 3D printing?
4. How does the choice of material impact the mechanical properties of printed parts?
5. What are some applications of FDM 3D printing materials like ABS, PLA, and PET?

Module 2 3D Printing Operations

Module Overview

This module introduces the process of creating objects using the Fused Deposition Modelling (FDM) method. It covers the basic steps of FDM, where a 3D printer melts plastic and deposits it layer by layer. Students will learn about designing 3D models and using slicing software to prepare these models for printing. The module also covers the essential functions of a 3D printer and common defects that can occur. By understanding these concepts, students can better plan and execute successful 3D printing projects.

Learning Outcomes

After completing this module, you will be able to:

- Understand generic process of the FDM 3D printing method.
- Understand the basics of designing 3D models for printing.
- Identify the basic functions and components of 3D Printer.

Module Structure

2.1 Generic Process of FDM method
2.2 Designing process
2.3 Slicing Software
2.4 Basic function of 3D printer
2.5 Defects in 3D printing

In the previous chapter, we have gained a foundational understanding of 3D printing, including selection of material to be used for FDM (Fused Deposition Modeling) process. Additionally, we have explored the various materials utilized in the 3D printing process.

Now, we will understand, how 3D printers actually work and discuss their operational processes. This chapter aims to provide a comprehensive understanding of the intricate mechanisms behind 3D printing, detailing the step-by-step operations involved in transforming digital designs into physical objects. By exploring the inner workings of 3D printers and the intricacies of their operations, readers will develop a deeper appreciation for this revolutionary manufacturing technology.

From the initial preparation of digital models to the final production of tangible items, we will uncover all the aspects that occurs within a 3D printer during the printing process. Through clear explanations and illustrative examples, you will gain insight into the complexities and capabilities of 3D printing technology, paving the way for further exploration and application in various industries and fields.

2.1 GENERIC PROCESS OF FDM PROCESS

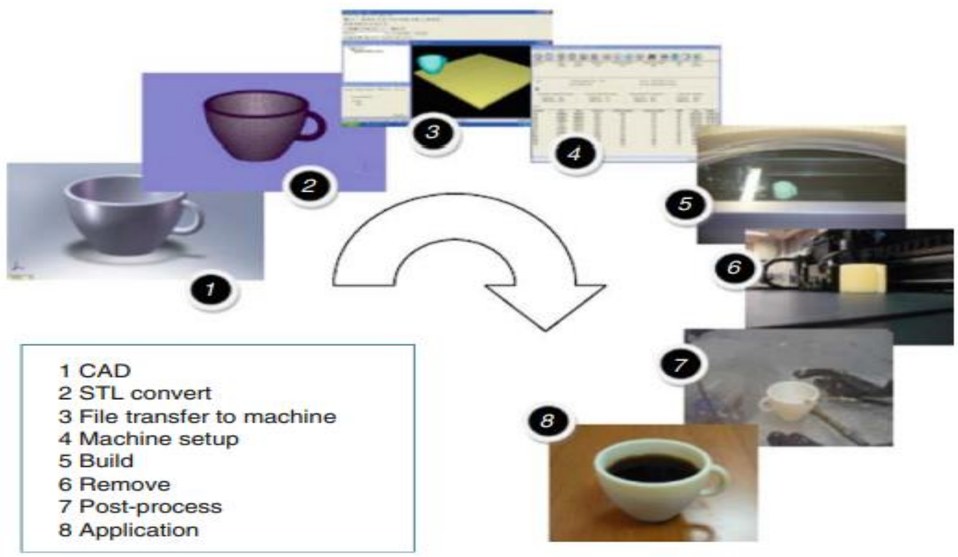


Fig 2.1 Generic Process of FDM

The generic process of FDM is shown in Fig. 2.1. It includes some basic steps which are needed to be followed. Although we have already covered these steps in previous chapters, but here more clarity of each step along with the hardware and software needed are discussed. So, let us break down each step of the generic AM process in more detail:

Step 1: CAD (Computer-Aided Design)

In this step, the process starts with the creation of a digital 3D model using CAD software. This software allows designers to create detailed representations of the desired object's geometry.

The CAD model must fully describe the external geometry of the part or object to be manufactured. It should include all the necessary features, dimensions, and specifications.

Designers can create CAD models from scratch or use reverse engineering techniques, such as laser scanning, to create digital representations of existing physical objects.

Hardware: Tinkercad, SketchUp, or Fusion 360 are some of the CAD software which are user-friendly and suitable for beginners.

Software: CAD software allows students to create 3D models by drawing shapes, extruding, and combining them to form objects. They can learn basic functions such as drawing lines, circles, and rectangles, and then extruding them to create 3D shapes.

Step 2: Conversion to .stl (Stereolithography) file

Once the CAD model is created, it needs to be converted into the .stl file format, which stands for Stereolithography or Standard Tessellation Language.

The .stl file describes the surface geometry of the CAD model using a series of connected triangles. It represents the outer boundary or shell of the 3D object.

Most AM machines accept .stl files as input, making it a de facto standard for transferring 3D models to the printing equipment.

Hardware: Same as in Step 1.

Software: Most CAD software can export models as .stl files directly. Students will learn how to export their 3D models as .stl files from their CAD software. For the basic we are going to use TinkerCAD (an open source software) as this allows us to download the sile into .stl format.

Step 3: Conversion of .STL file to G- Code and transfer it to the 3D printer

Our machine, 3D Printer, accepts and understands the design in G-Code. So, it becomes mandatory to understand about G-Code. We have already covered about G-Code in detail in previous grade.

In this step, after the .stl file is generated, it needs to be transferred to the AM machine for printing. This can be done through various methods, such as USB drives, network connections, or direct upload.

Hardware: Depending on the setup, students may use a computer connected to the AM machine or a USB drive or Card Reader to transfer the .stl file.

Software: For the conversion of .stl file to G-Code, Ultimaker Cura software is used.

Step 4: Machine Setup

Before starting the printing process, the Additive Manufacturing (AM) machine needs to be set up correctly. This involves configuring various parameters related to the build, such as material type, layer thickness, printing speed, and temperature settings.

Proper machine setup ensures that the printing process proceeds smoothly and produces high-quality parts.

Hardware: The 3D printer itself could be a desktop FDM printer and can be commonly used in classrooms.
Software: Most 3D printers come with their own software for machine setup. Students will learn how to load filament into the printer, set the print bed temperature, and adjust other settings using the printer's control interface or software.

Step 5: Build

Once the machine is set up, the actual printing process begins. The AM machine follows the instructions from the .stl file to build the object layer by layer.

The printing process is mostly automated, with minimal supervision required. However, operators may monitor the machine to ensure no errors occur, such as material depletion or mechanical failures.

Hardware: The 3D printer.

Software: No additional software required at this stage. Students will initiate the printing process using the controls on the printer itself.

Step 6: Removal

After the printing is complete, the finished parts need to be removed from the build platform. Depending on the type of AM technology used, this may involve manual removal or automated ejection.

Safety precautions should be taken during this step to prevent damage to the parts or injury to the operator. Some machines may have safety interlocks to ensure safe removal.

Hardware: Tools for removing the printed object from the print bed, such as a spatula or scraper.

Software: None.

Step 7: Postprocessing

Once removed from the machine, the parts may require post-processing to improve their surface finish or mechanical properties. This can include processes such as cleaning, sanding, polishing, or heat treatment.

Parts may also have support structures that need to be removed carefully without damaging the final part.

Hardware: Tools for removing the printed object from the print bed, such as a spatula or scraper.

Software: None.

Step 8: Application

Finally, the printed parts are ready for use or further application. Depending on the intended use, additional treatments such as painting, coating, or assembly with other components may be required.

The parts may be integrated into larger assemblies or used directly in end products, depending on the design requirements.

These steps outline the general process flow from digital design to physical realization using Additive Manufacturing technologies. Each step plays a crucial role in ensuring the successful fabrication of high-quality parts or objects.

Theoretically, you are now familiar with the process of how to use basic CAD software to design objects, to transfer files to a 3D printer, and also completing the printing process with minimal additional tools or software.

Let us understand and do hands on exercise of executing the overall process of 3D printing.

2.2 DESIGNING PROCESS

The basic first step to start the process is Designing, as the model which needs to be printed should be designed. We have already discussed before many times, that there is multiple software for designing models such as TinkerCAD, PTC Creo, CATIA etc.

As of all the options, we will go through TinkerCAD (as of beginner level). Let’s understand the TinkerCAD in a better way for designing.

2.2.1 Working with TinkerCAD

Tinkercad, which is a web– based software used to create and share 3D model files. What makes Tinkercad so great is how easy it is to use. If you can click and drag, then you can use Tinkercad!

Fig 2.2 TinkerCAD Logo

General Steps to start working with Tinkercad

1. Go through the website www. https://www.tinkercad.com/ (a window will open as shown in Fig. 2.3)

2. Click on Sign Up and follow the steps to create your own account. (as shown in Fig. 2.4).

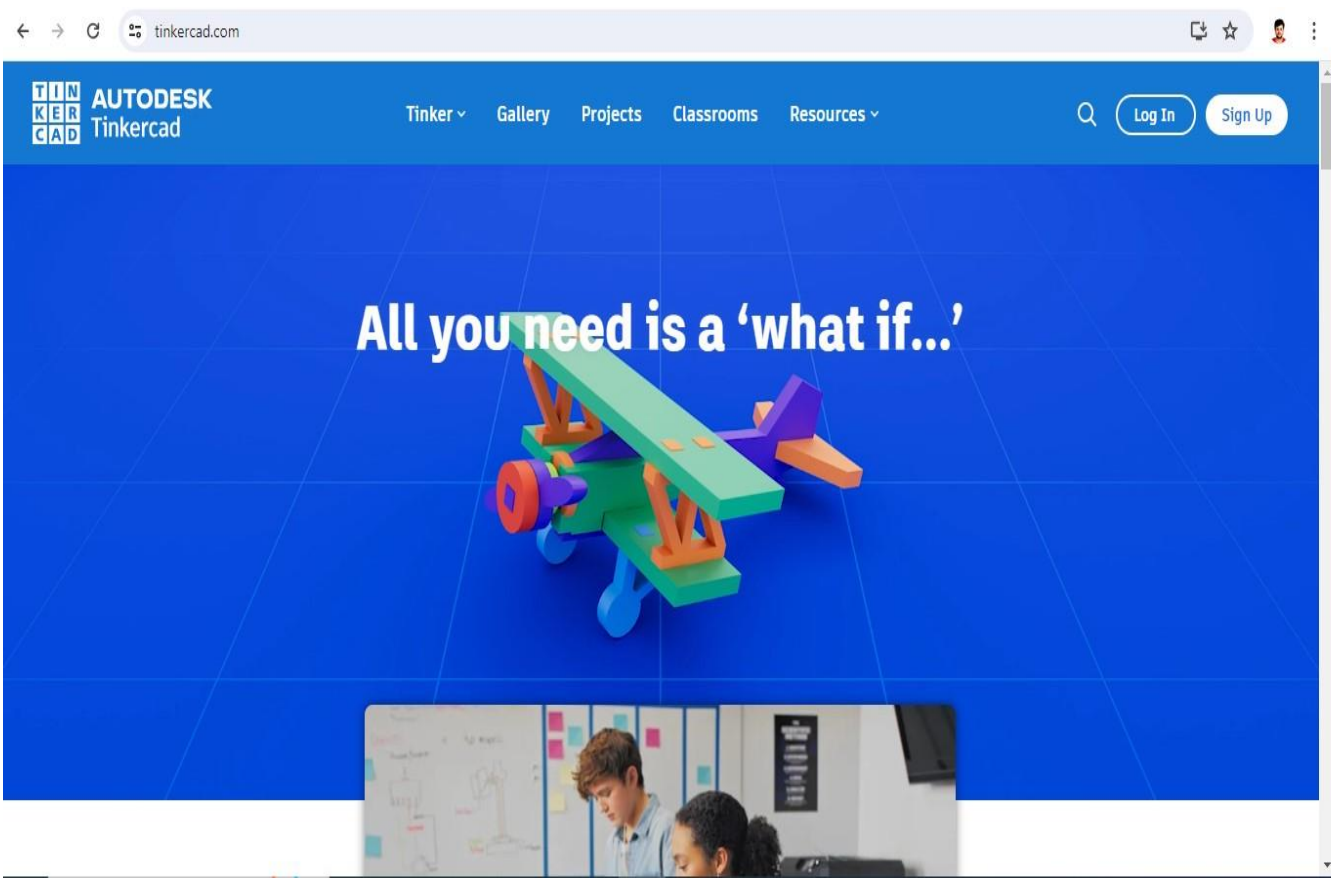


Fig 2.3 Webpage TinkerCAD website

Now, let us go through the actual workspace of Tinkercad.

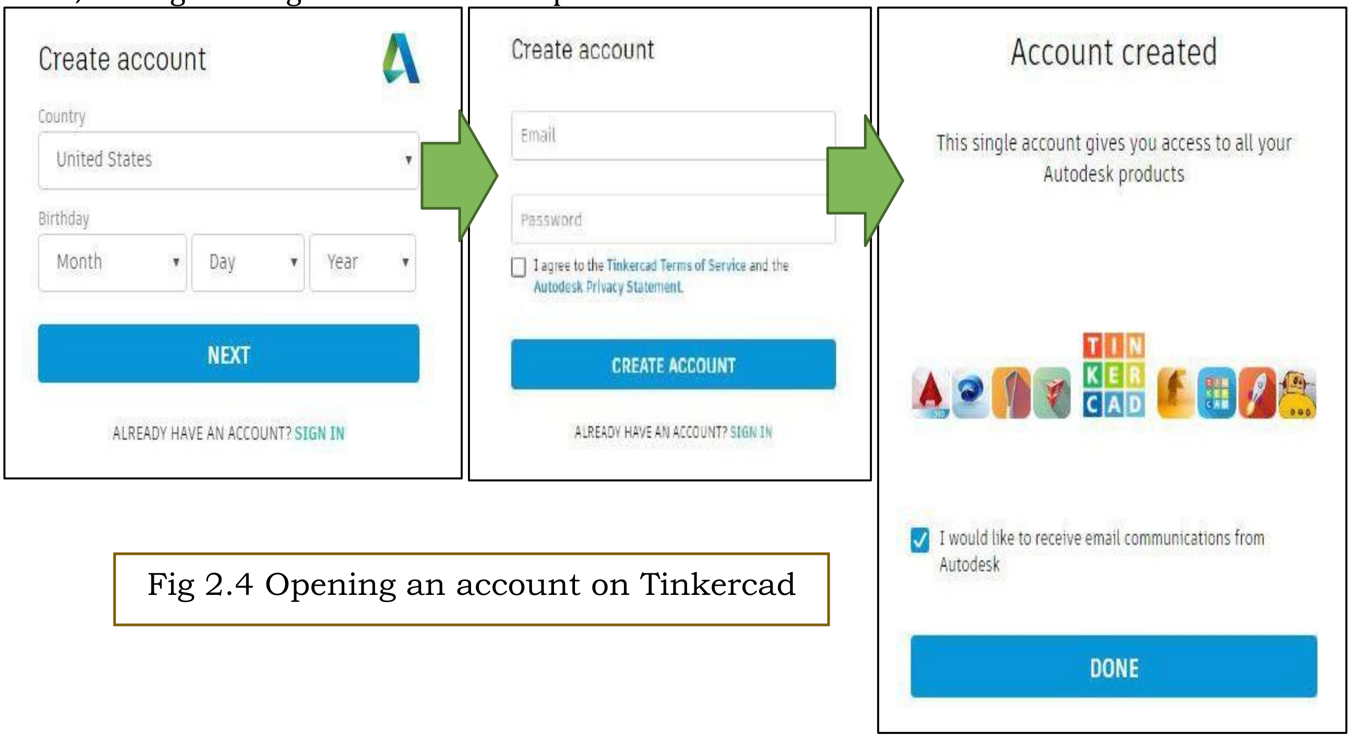


Fig 2.4 Opening an account on Tinkercad

Tinkercad workspace overview (shown in Fig. 2.5)

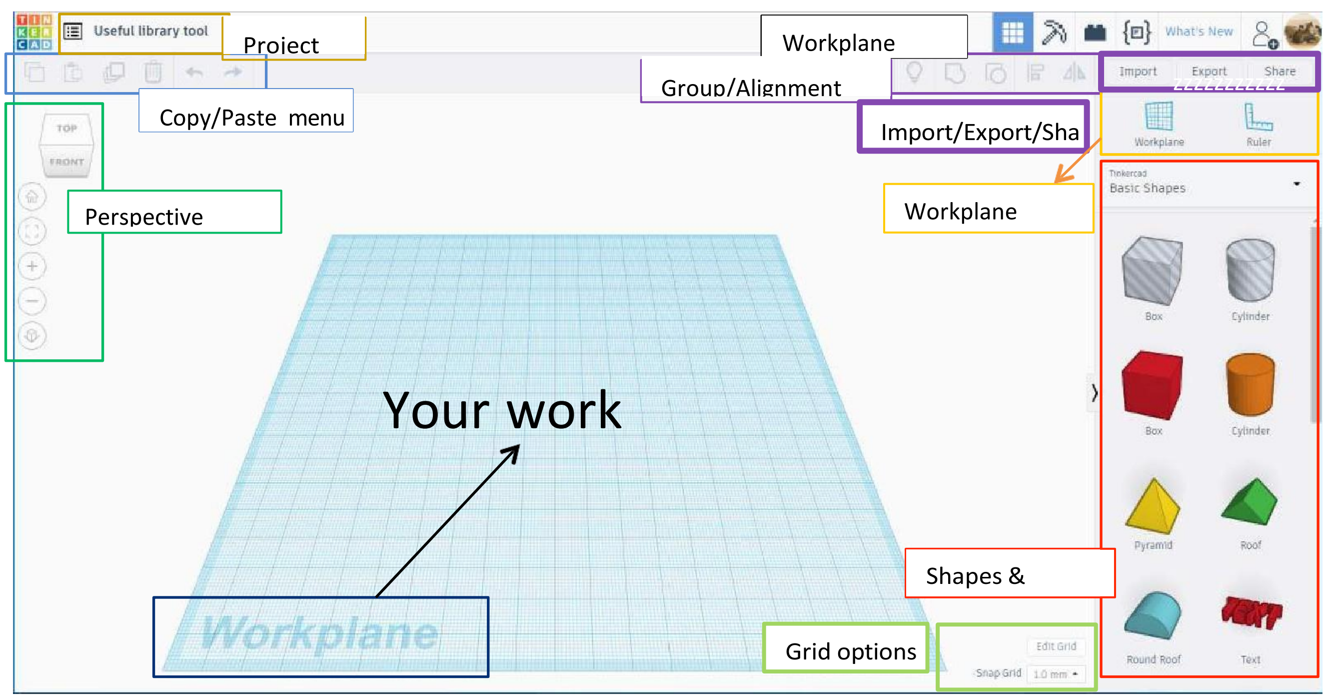


Fig 2.5 Tinkercad Workspace

Some Basic Tasks

I. Moving a shape or symbol from the basic shapes menu to your workplane (clicking and dragging) (as shown in Fig. 2.6)

1. Select which shape you would like to add to your workplane.
2. Move your mouse over the workplane where you would like to "drop" your shape.
3. Left click to "drop" shape and add it to the workplane

Note

Alternatively, you can left click and hold the shape you want, drag your mouse to where you want to put it on the Workplane and then let go of the left click button on the mouse to drop your shape.

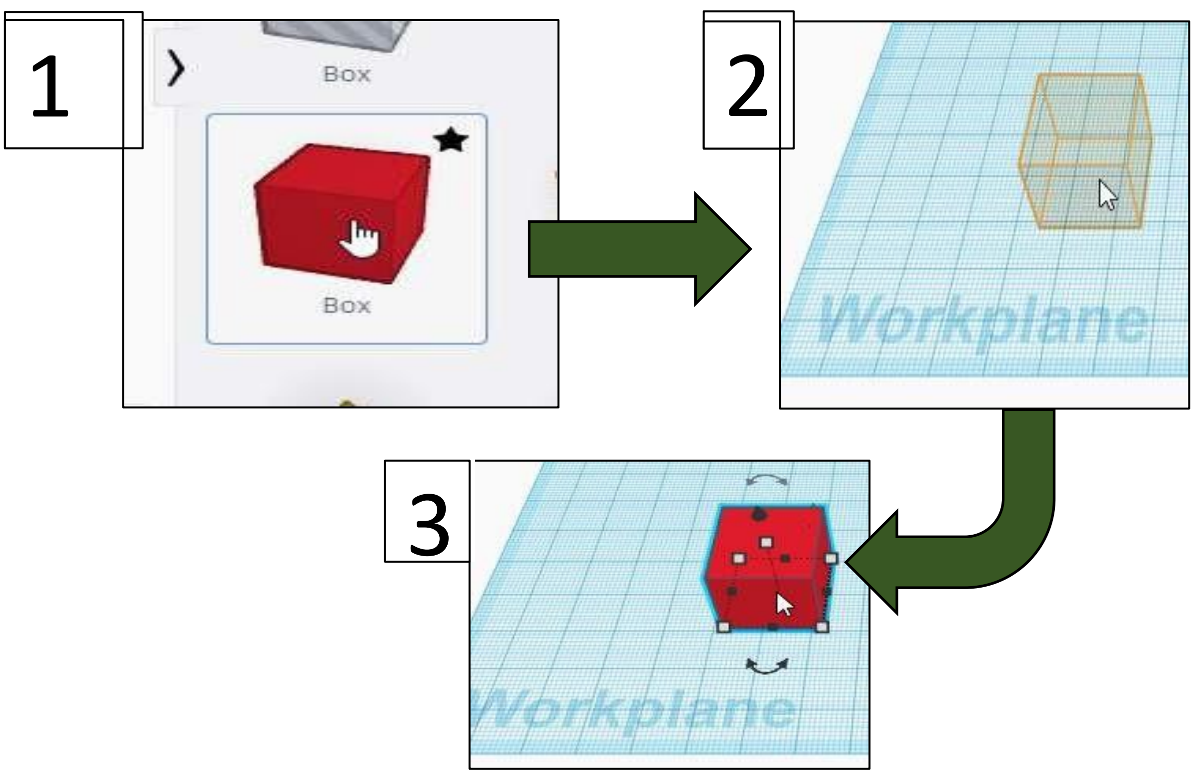
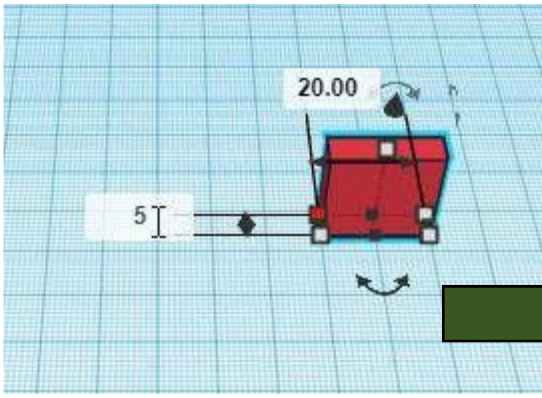


Fig 2.6 Steps for moving a shape

II. Resizing your shape

There are many different ways to edit your shape once it is on the workplane. (as shown in Fig. 2.7 (i) and 2.7 (ii))

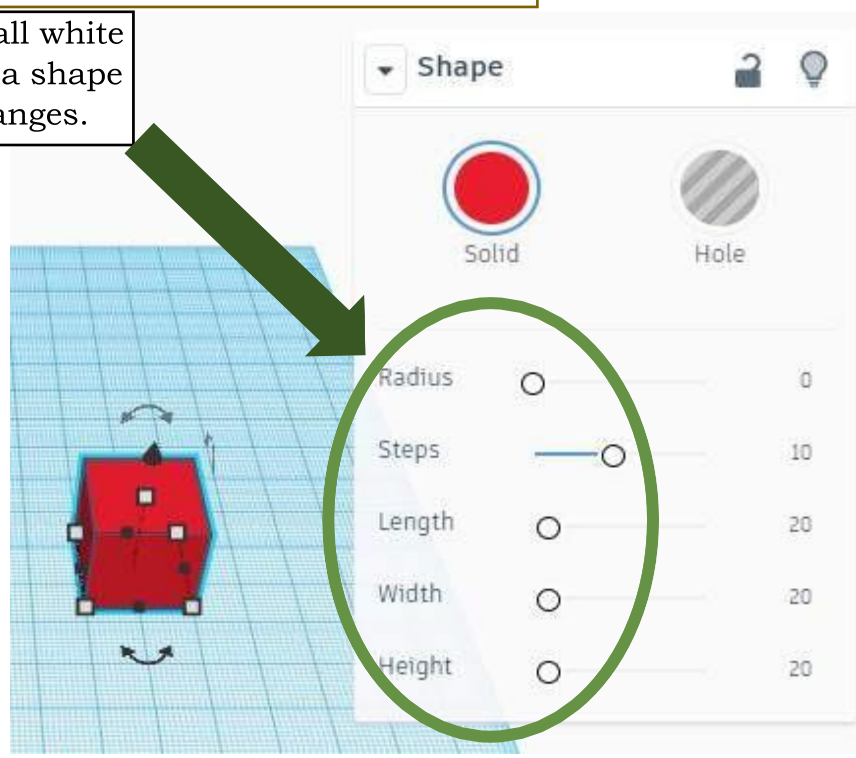


Once a shape is selected on the workplane, carefully click a small gray box to change a specific measurement of a shape by left clicking within the white text boxes that appear.

Note: Selected points will change color from gray (unselected) to red (selected).

Fig 2.7 (i) Steps for moving a shape

Click and drag the small white circles when you have a shape selected to make changes.



Note: Alternatively, you can left click and drag any of the points to change the size/shape of the object selected.

Fig 2.7 (ii) Steps for moving a shape

III. Moving a shape above or below the workplane (shown in Fig. 2.8)

a. You can move a shape above the workplane by clicking and dragging the cone–shaped handle above your shape. This function allows you to stack shapes on top of each other.

b. Remember to view your shape from the front to make sure it is not floating above the Workplane. This could mess up your 3D print if the base of your project is not touching the Workplane.

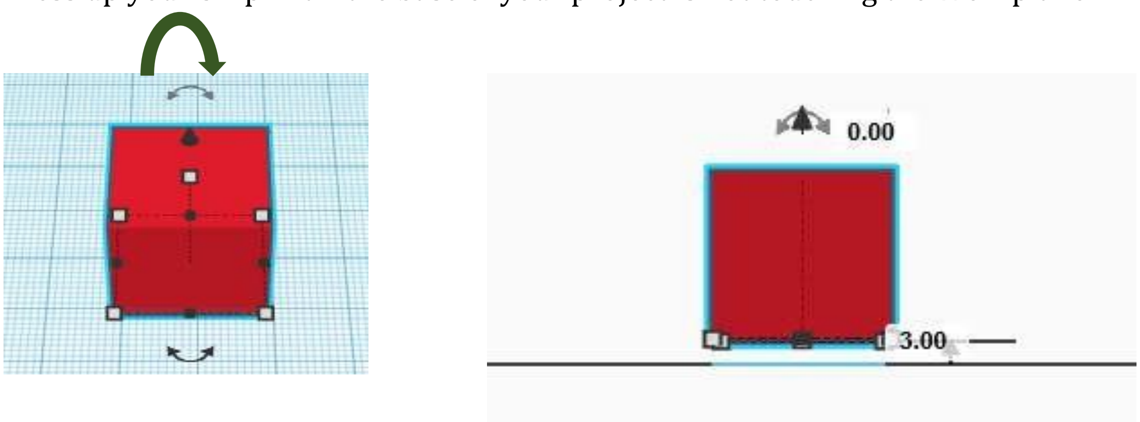


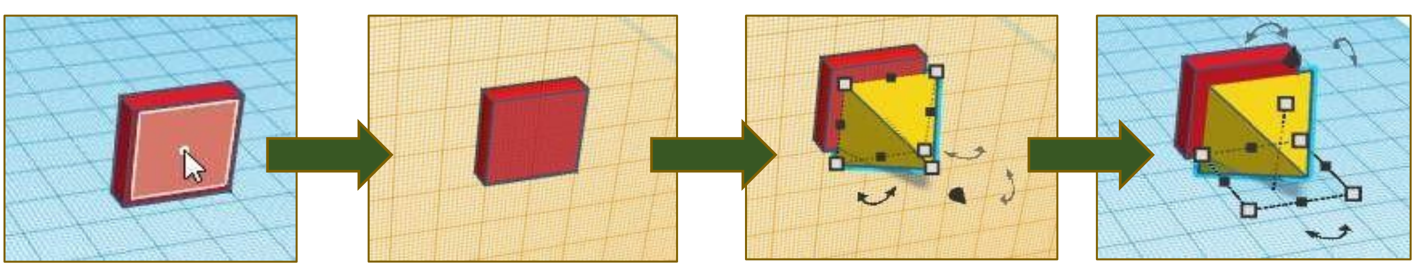
Fig 2.8 Moving a shape above or below the workplane

IV. The workplane button

If you would like to work or build on the side of a shape, you can change the Workplane to be the surface of a shape side by clicking this button and then clicking the side of a shape.

Try this!

1. Choose any shape such as a cuboid as shown in Fig 2.9(i).
2. Click the workplane button and select the side as shown in Fig 2.9 (ii). The side you have so selected, the workplane will be shifted as per that.
3. Select the prismoid and place on the selected sides as shown in Fig 2.9(iii) and 2.9(iv).



(i) **(ii)** **(iii)** **(iv)**

Fig 2.9 Using of workplace button

V. The Ruler

To use the ruler, click on the ruler button and then click where you would like the ruler to appear on the Workplane as shown in Fig. 2.10)

Once you have the ruler on the Workplane, you can select an object and then have the option to view the midpoint of the object selected or the endpoint

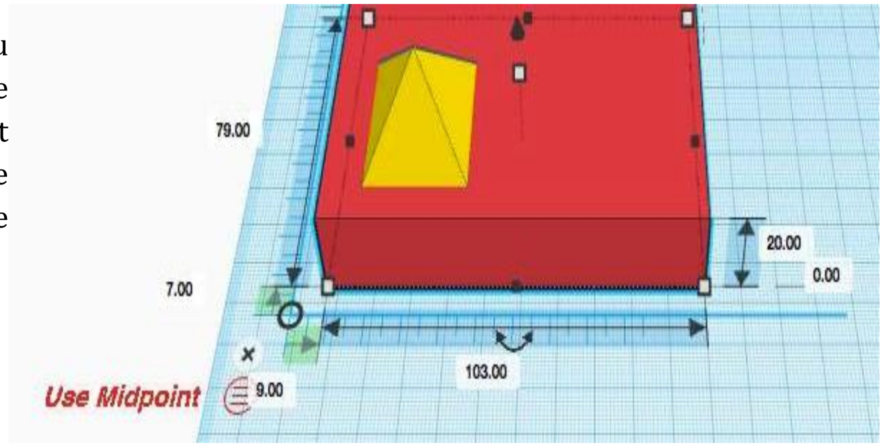
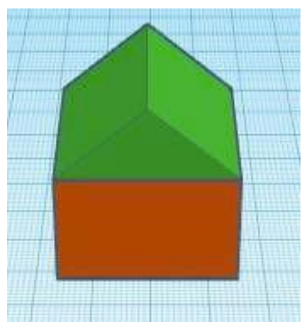


Fig 2.10 Using of Ruler

Activity 1: Design a basic House (With no specific dimensions)



Requirements: Laptop or Desktop with an internet connection.

Procedure:

(Refer Fig. 2.11 with steps mentioned)

1. Open browser and open "www.tinkercad.com".
2. Login and choose create 3D modelling.
3. Click and drag a "Box" shape from the Basic Shapes menu to your Workplane.
4. Change the size of your box to be the size of house that you prefer.
5. Change the area of your Workplane to the top of the box in order to add your roof.
6. Add a "Roof" shape on top of your box shape to make a house.
7. Change the color of your house

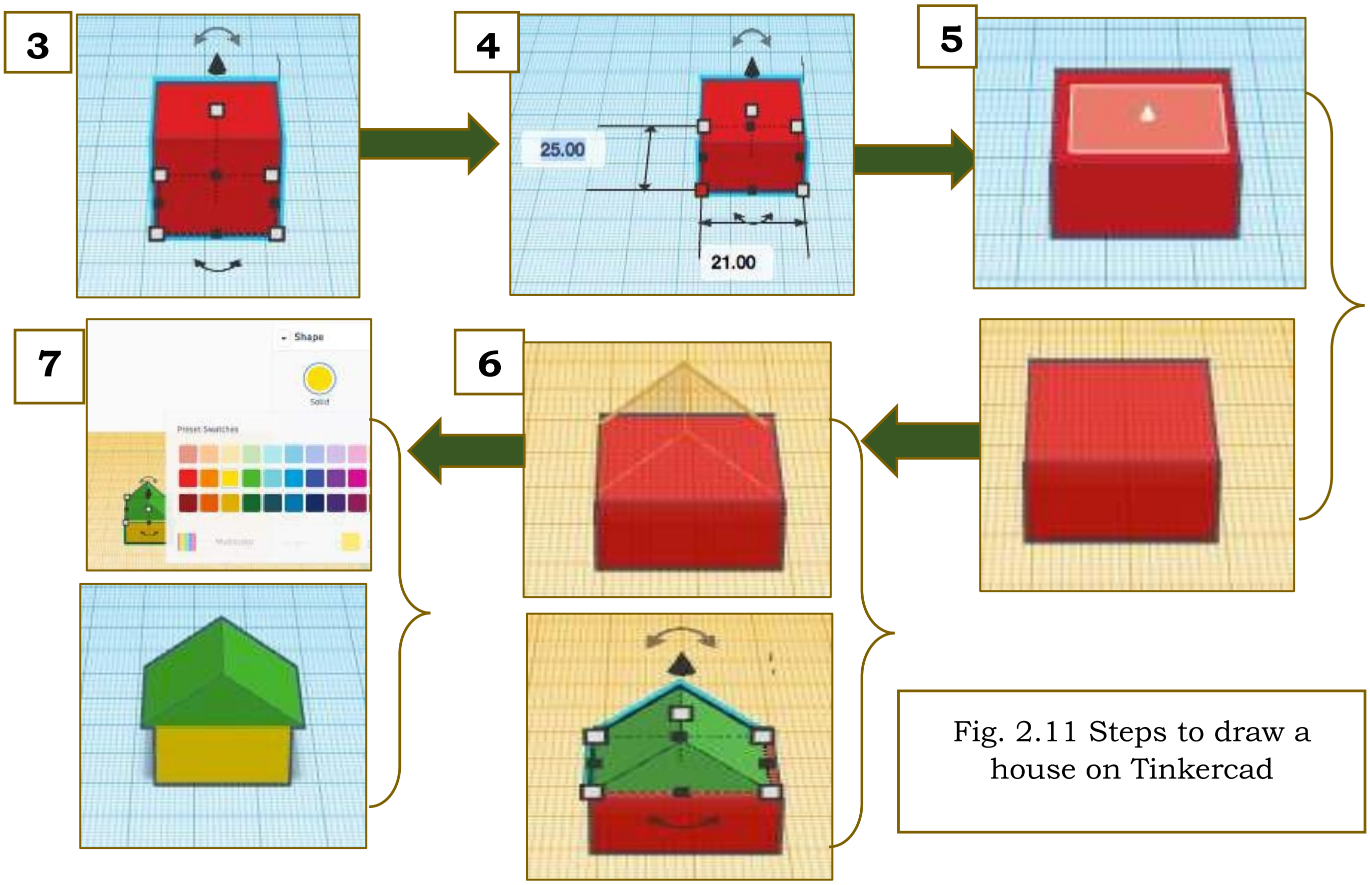


Fig. 2.11 Steps to draw a house on Tinkercad

<u>Activity 2</u>: Design a Keychain with your name

Requirements: Laptop OR Desktop with internet connection.

Procedure:

1. Click on the Create new design button (Refer fig. 2.12)

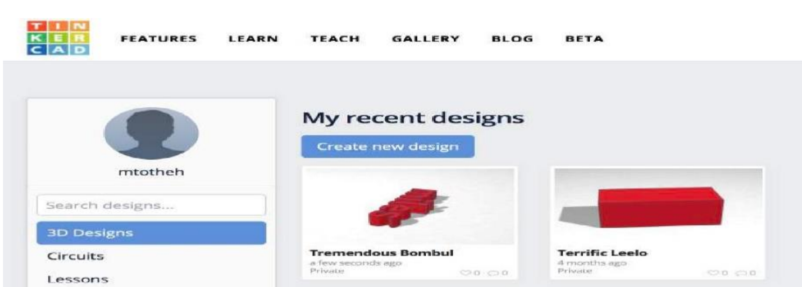


Fig 2.12 Choosing new design button

2. Click and drag a box onto the Workplane (Refer fig. 2.13)

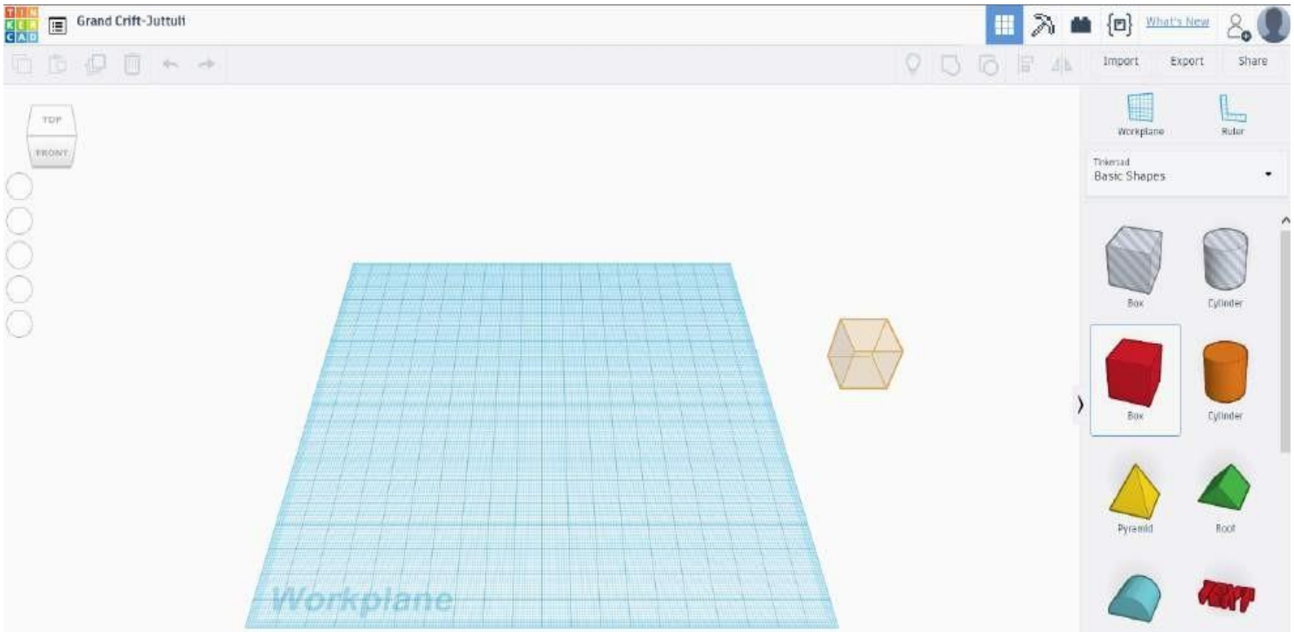


Fig.2.13 Drag a box

3. Click and drag the box into a rectangle, roughly 60mm long by 22mm wide. (Refer fig. 2.14)

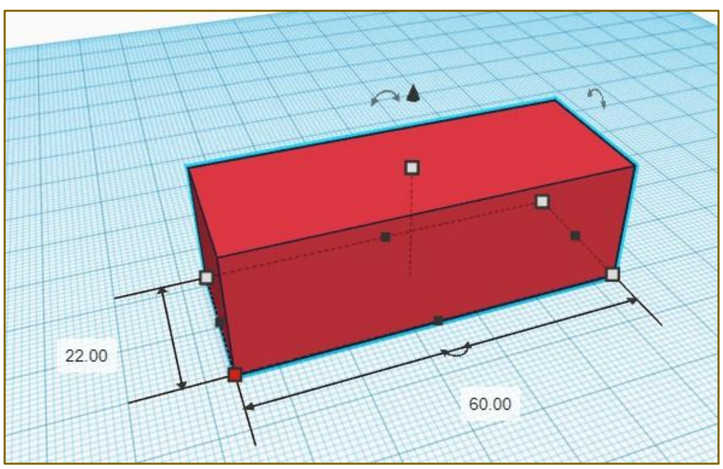


Fig.2.14 Box of mentioned depth and width

4. Grab the middle handle and reduce the height/thickness to around 2 mm. (Refer fig. 2.15)

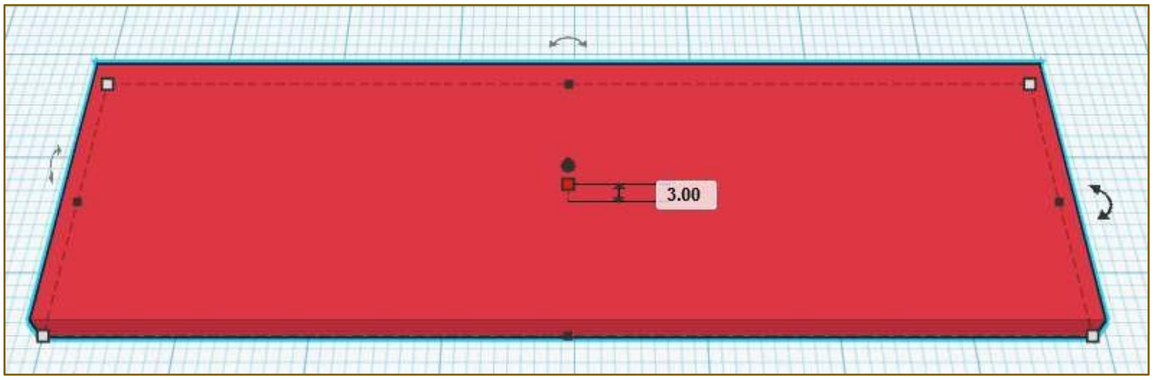


Fig.2.15 Reducing the height/thickness to 2mm

5. Click and drag the Text shape onto the Workplane. (Refer fig. 2.16)

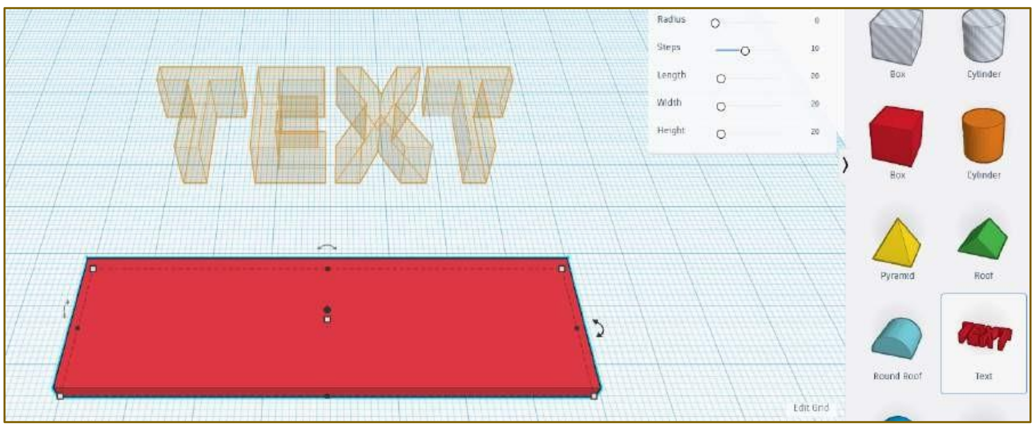


Fig.2.16 Dragging text into workplane

6. Type in your first name in the text box in the Shape menu appears. If your first name is long, you may need to click and drag the side of your box to make it longer. (Refer fig. 2.17)

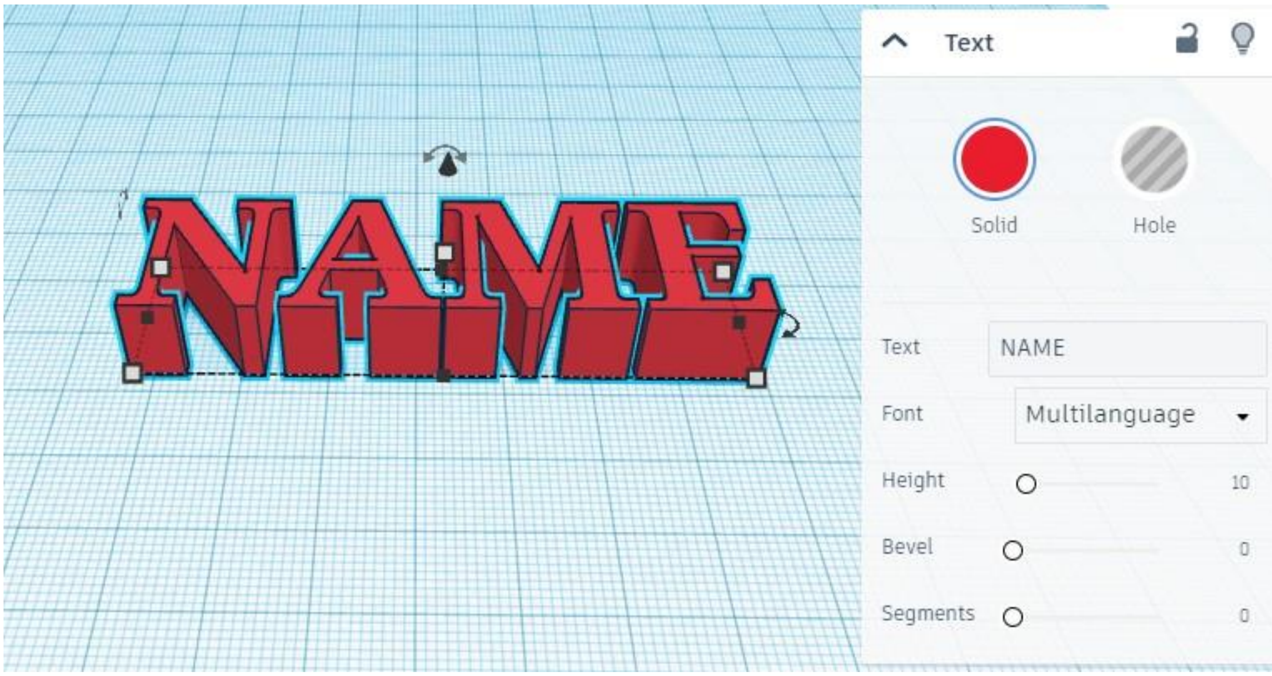


Fig.2.17 Insert your first name

7. Once you have typed you name, drag it on top of your box. Click your middle handle and decrease the thickness of your name to around 3mm. (Refer fig. 2.18)

Fig.2.18 Placing name over the box and adjusting its thickness

8. Scroll to the bottom of your Basic Shapes menu and drag a tube onto the Workplane. (Refer fig. 2.19)

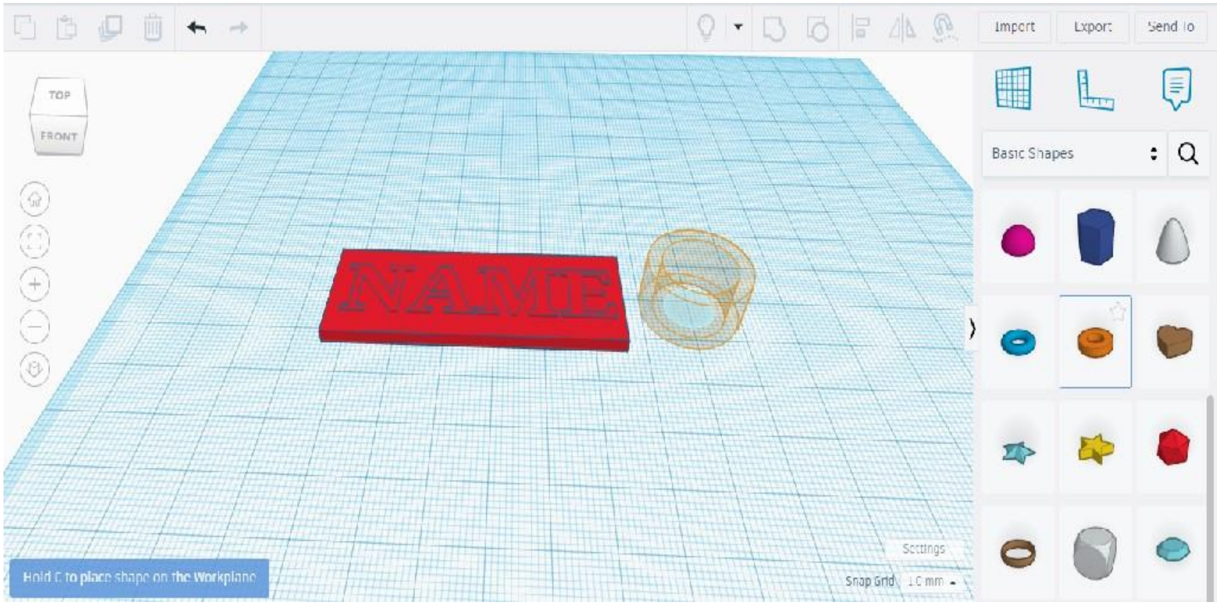


Fig.2.19 Selection of tube shape from the basic shapes

9. Click and drag the middle handle to reduce the thickness of the tube to around 2.50 mm and radius of approx. 15mm. (Refer fig. 2.20)

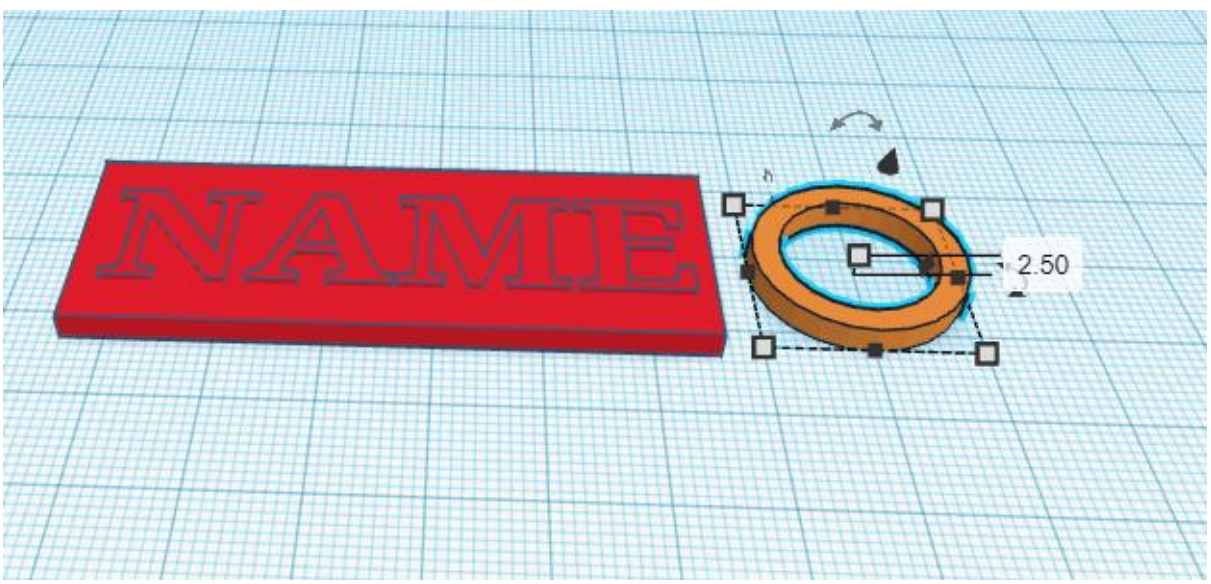


Fig.2.20 Selection of tube shape from the basic shapes

10. Drag your tube and place it so the bottom ¼ (or so) is inside your box. (Refer fig. 2.21)

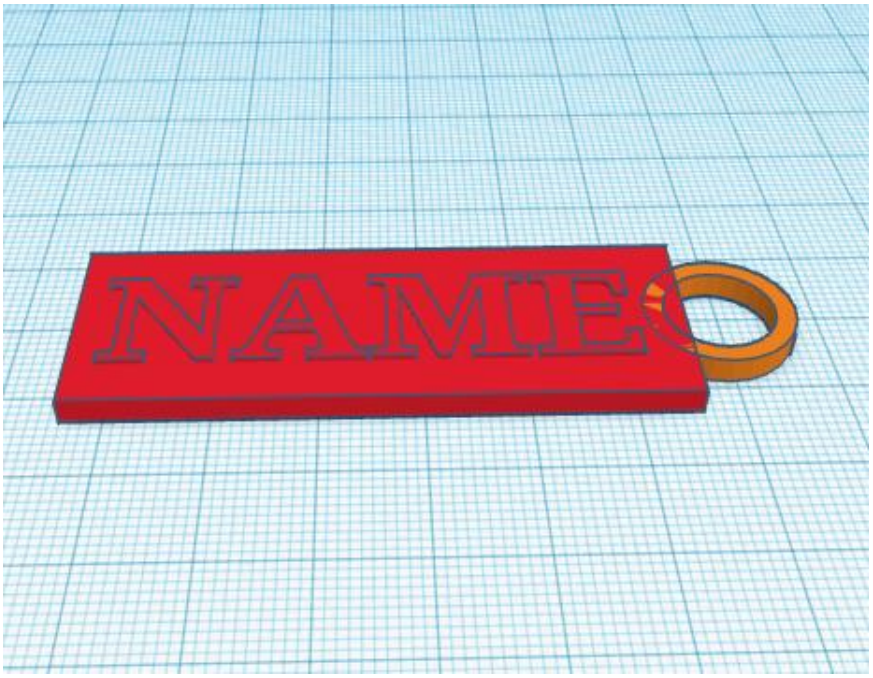


Fig.2.21 Blending the tube to the box to some extent

11. Click and drag a square around your entire design. (Refer fig. 2.22)

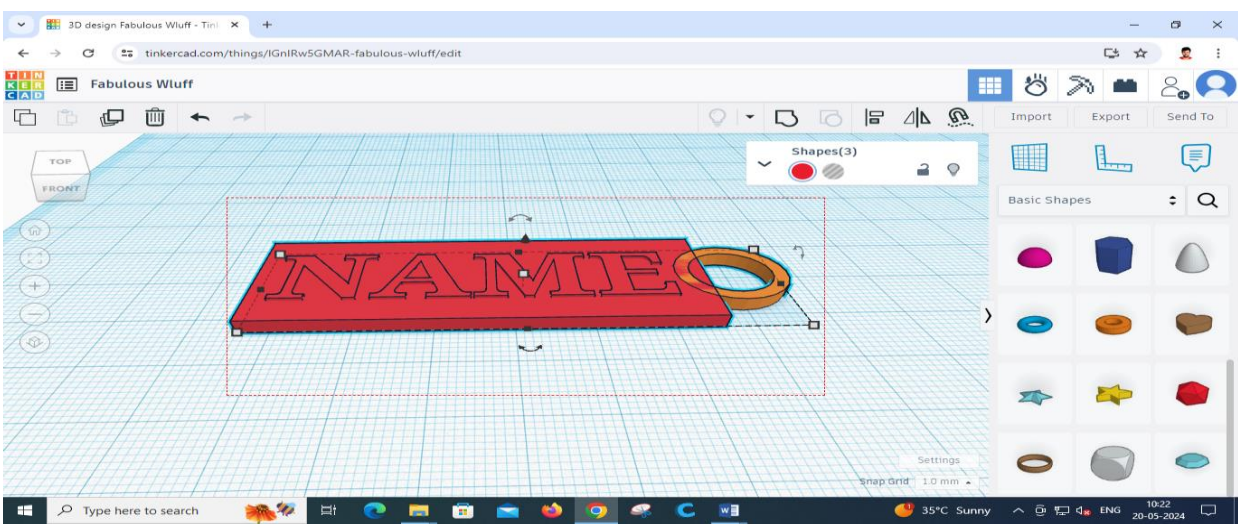


Fig.2.22 Selecting the overall design

14. Click on the Group button, which will connect all the pieces of your project together. (Refer fig. 2.23)

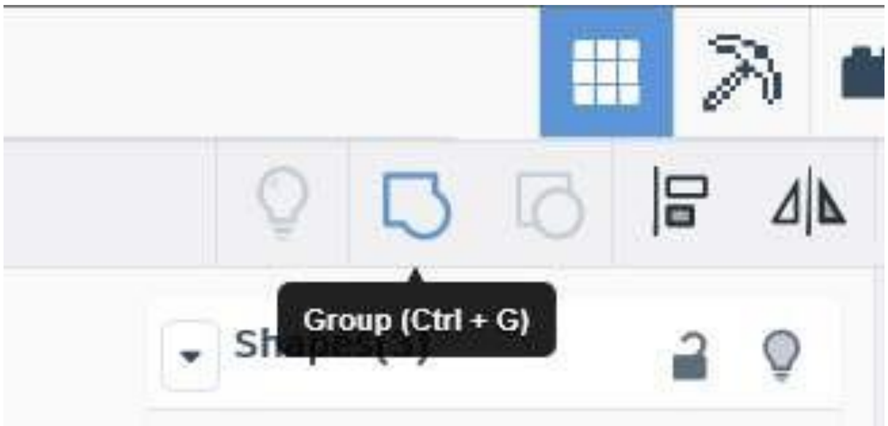


Fig.2.23 Finalizing the overall design by clicking the group button

15. Admire your finished keychain! (Refer fig. 2.24)

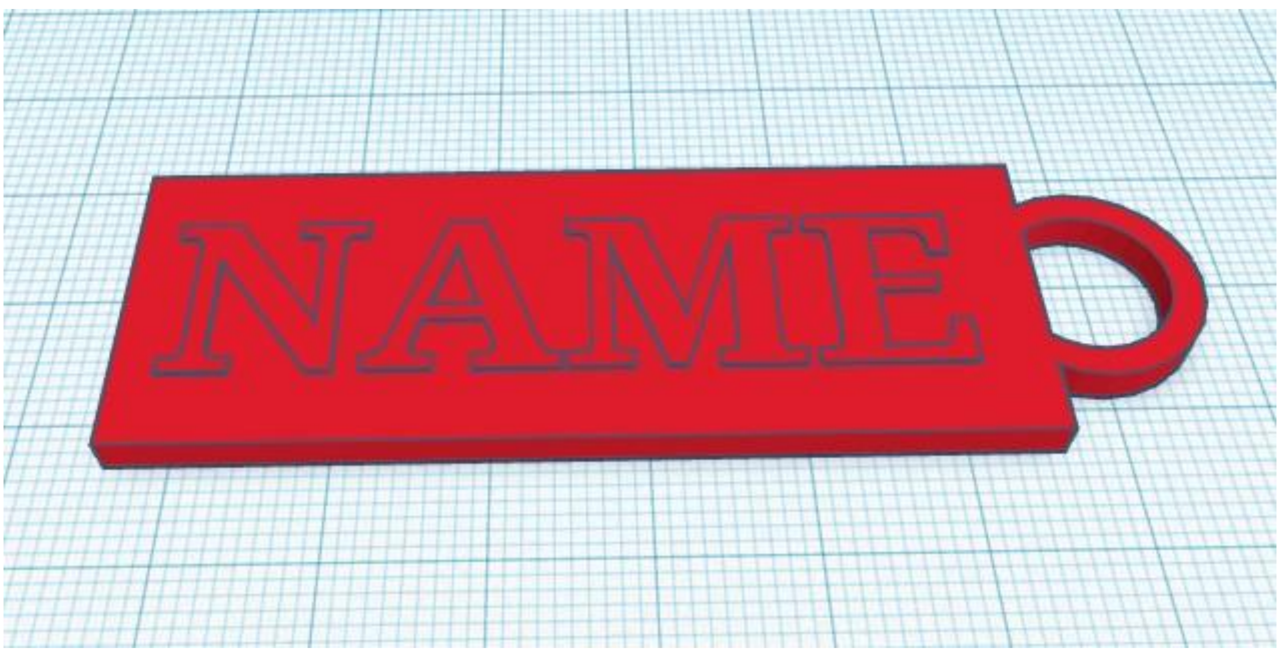


Fig.2.24 Keychain is ready

2.2.2 Changing your project name

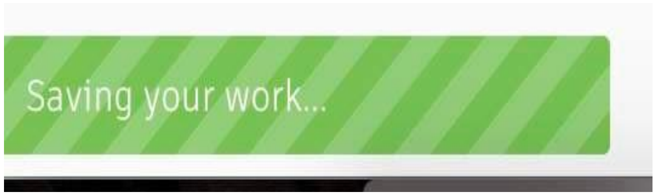
You will notice that Tinkercad automatically assigns any new project you create a name – usually something that sounds silly. You can change you project name by clicking on the Tinkercad–assigned project name in the upper left corner of your screen. (Refer fig. 2.25).

Once you click on the name, it becomes a highlighted text box that you can then type over and rename your project whatever you'd like.

Fig.2.25 Changing your project name

2.2.3 Saving your project

Saving a project, you create in Tinkercad, is easy because it is automatically done for you. When you choose to exit your project, you will see a small green bar appear at the bottom of the screen that says Saving your work. Note, until you download your project, it is saved in the cloud (servers at Tinkercad).



2.2.4 The Import/Export/Share Menu

Let us discuss each of them in detail with its options available:

1. Import

You will use the Import button to drag and drop a 2D or 3D file, or you can choose one that you have saved from your computer.

You can download files, that you want to modify, from 3D repository websites (like Thingiverse and MyMiniFactory) onto your computer and upload them into your Tinkercad account here. (Refer fig. 2.26)

You can also upload pictures saved from online that you want to turn into 3D objects (we'll cover this neat trick later)

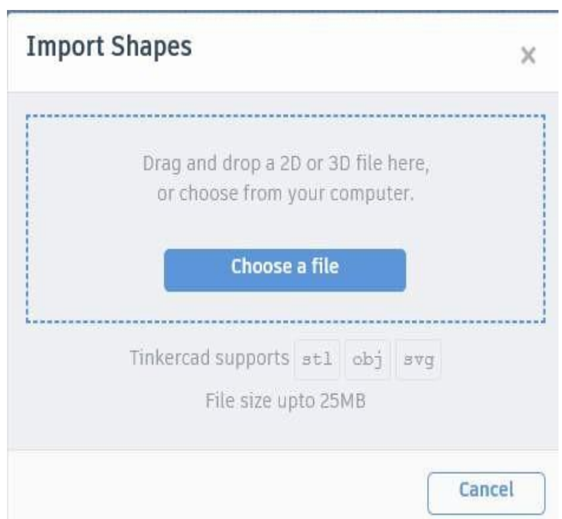


Fig.2.26 Import menu

2. Export

When you are completely finished with your project, you will likely want to save it outside of Tinkercad, for later 3D printing. When you're ready for this step, click on the Export button and follow these steps.

Once you click the Export button, a menu appears as shown in Fig. 2.27.

You can download the file in the given number of options such as .obj, .stl etc.

Every file format has their own specifications and reason to be chosen.

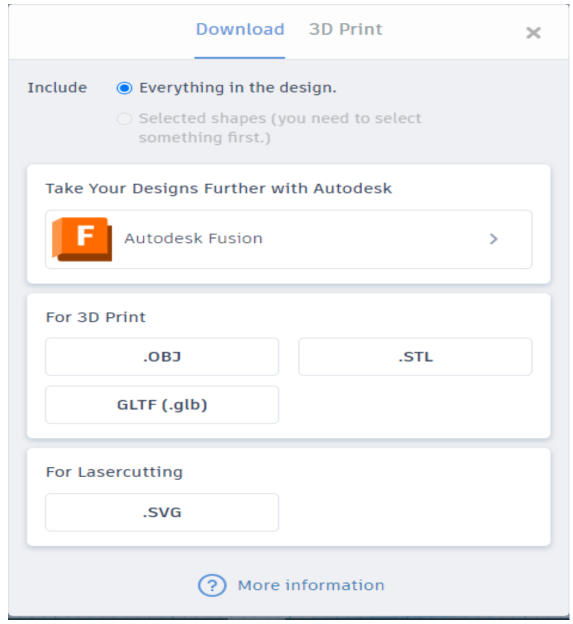


Fig.2.27 Export menu

My design is ready, but still I am confused which file format to be choose?

. stl or .obj?

Let us discuss these file formats in detail:

- **.stl**

.stl format is one of the most commonly used file formats for 3D Printing. This is due to the fact that most CAD software has the feature of exporting models in .stl format and most 3D Printers support it. Specifically, it is a file which "slices" a 3D model into a series of very thin 2D "layers." This output is then used to drive a stereolithography (or similar) machine which produces physical prototypes through layer–by–layer deposition. The file generates the surface geometry of the modeled object only.

- **.obj**

.obj format is considered to be more complex than .stl file for the fact that it is capable of representing texture, color and other CAD attributes of the three–dimensional object. .obj is also easily exported from most CAD tools and is supported by 3D Printers.

Which one to choose?

However, according to people's opinion on forums and 3D Printing enthusiast platforms, .stl seems to hold a top spot in the list of preference of file formats for 3D Printing. The main reason is that this type of file is simpler to use and most mesh repair tools work better with .stl files than .obj.

On the other hand, if you are willing to print a multi−colour 3D model, you would want to choose .OBJ file format.

Activity

Try this!

Design a 40 x 20 mm luggage tag with a hole, including your name, class, section, and the name of your school using Tinkercad.

2.3 SLICING SOFTWARE

Now, let us understand the next step included in the workflow of the 3D Printing process i.e. Slicing.

Slicing software is an essential tool in the 3D Printing workflow, acting as the intermediary between 3D model creation and the actual printing process. It converts 3D models into instructions that a 3D printer can understand and execute. This process is known as "slicing" because the software slices the 3D model into thin horizontal layers, generating a path for the printer to follow layer by layer.

We must also be aware of its role of slicing in designing. So, designing a 3D model typically involves using CAD (Computer-Aided Design) software. Popular CAD programs include AutoCAD, SolidWorks, Blender, and Tinkercad. These tools allow designers to create intricate and precise models. Once the design is complete, it needs to be exported in a format that slicing software can read, most commonly STL (Stereolithography) format.

2.3.1 Key Steps in Design and Slicing Workflow:

- **Model Creation**: Using CAD software, a designer creates a 3D model, ensuring all dimensions and geometries are accurate.
- **Exporting the Model**: The completed design is exported as an .stl file. The. stl format represents the surface geometry of the 3D object using a mesh of triangles.
- **Importing into Slicing Software**: The .stl file is imported into slicing software such as Cura, PrusaSlicer, or Simplify3D.

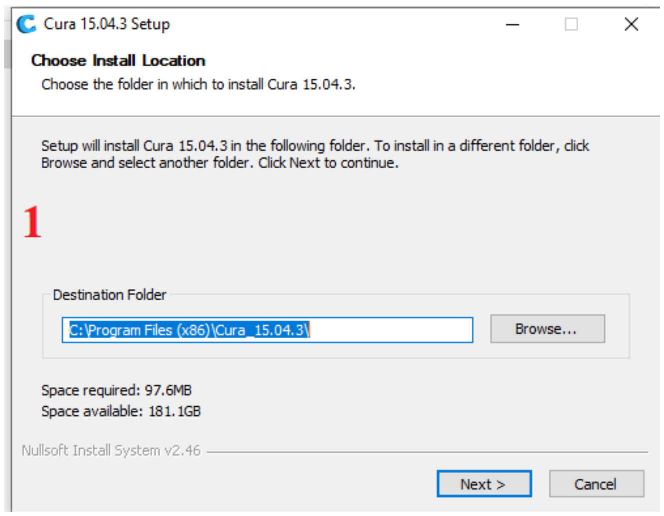
The most widely used software is Ultimaker Cura. Although the functioning of almost all the software is the same, so understanding the most relevant one will surely help you to understand the other software too. So, let us understand the 'Ultimaker Cura' slicing software in detail.

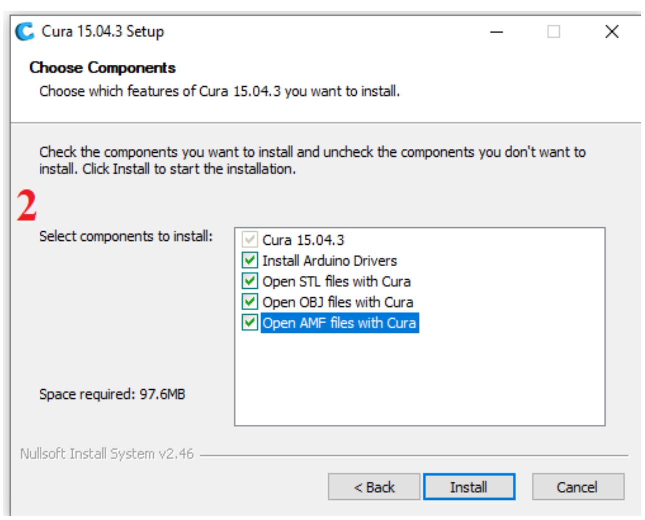
2.3.2 Ultimaker Cura

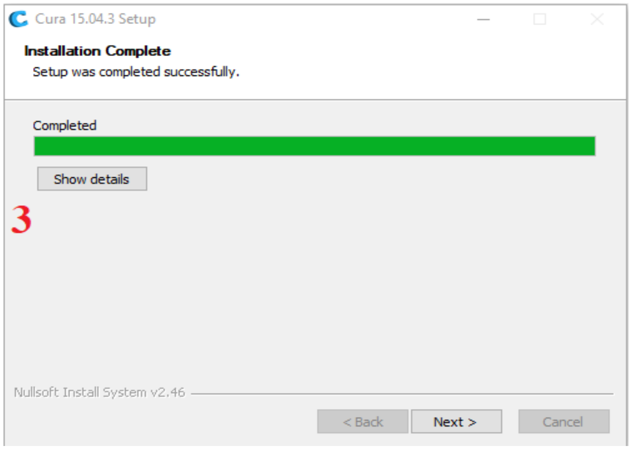
Let us go through the installation process and then we will continue with the technicalities.

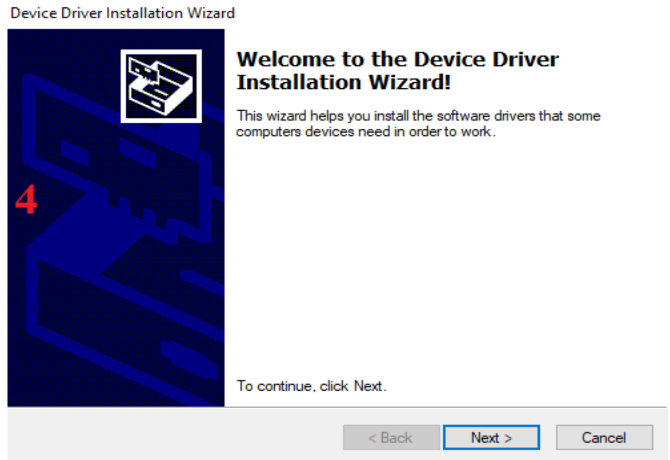
Installation of Cura software

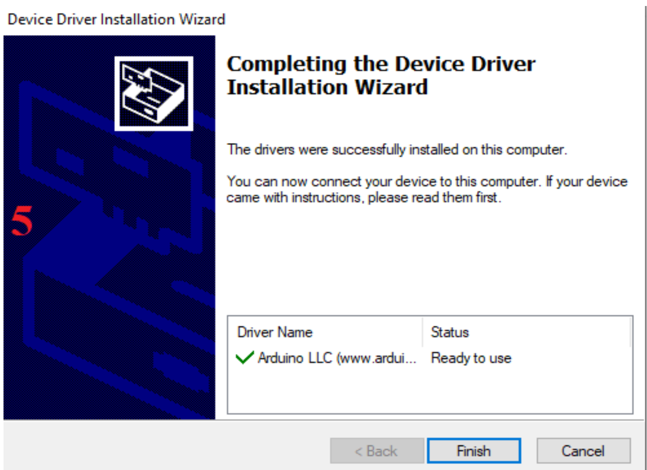
After clicking the Cura installation program, the page will pop up, and you can always click the next step to complete the installation.

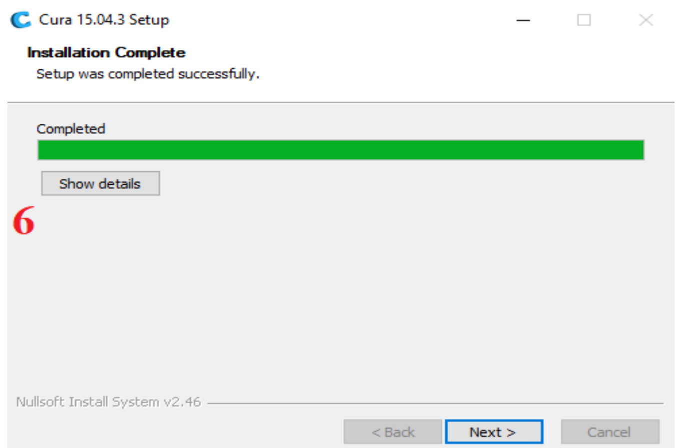


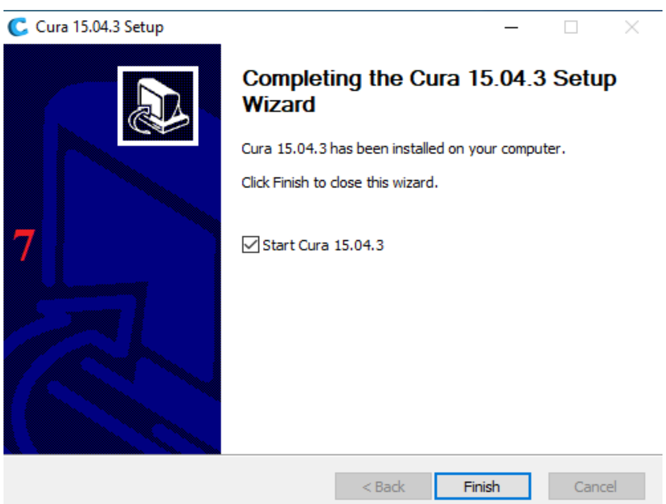


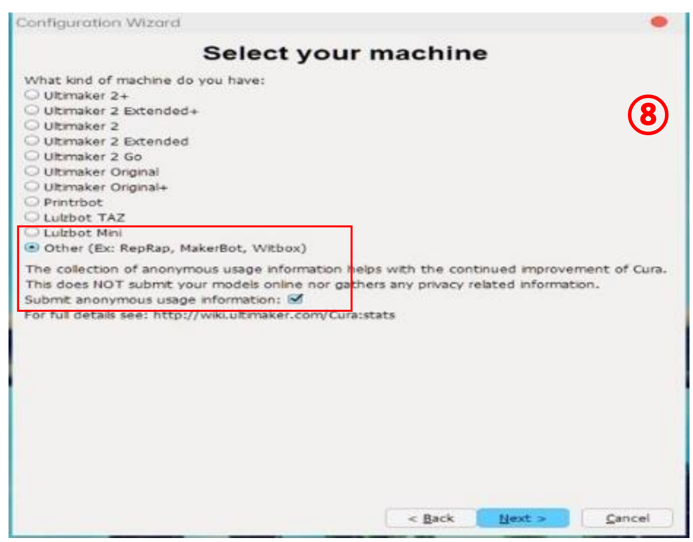

Cura 15.04.3 Setup
Installation Complete
Setup was completed successfully.
Completed
Show details
3
Nullsoft Install System v2.46
< Back
Next >
Cancel

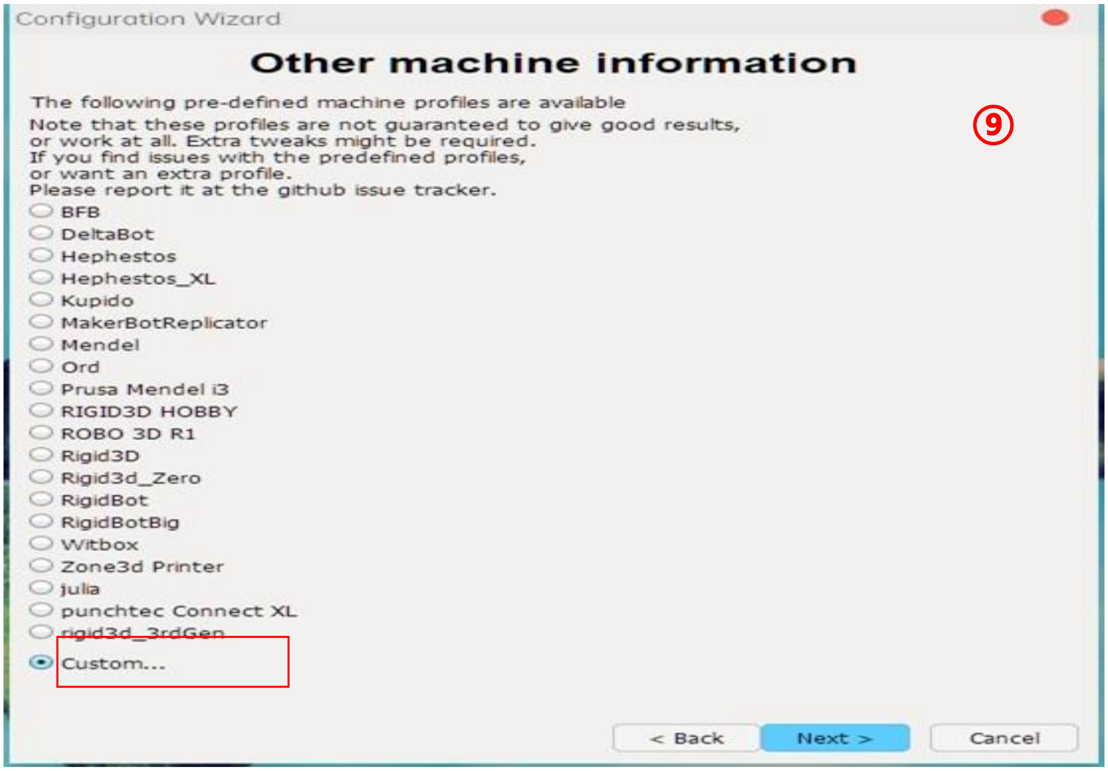

Device Driver Installation Wizard
4
Welcome to the Device Driver Installation Wizard!
This wizard helps you install the software drivers that some computers devices need in order to work.
To continue, click Next.
< Back
Next >
Cancel

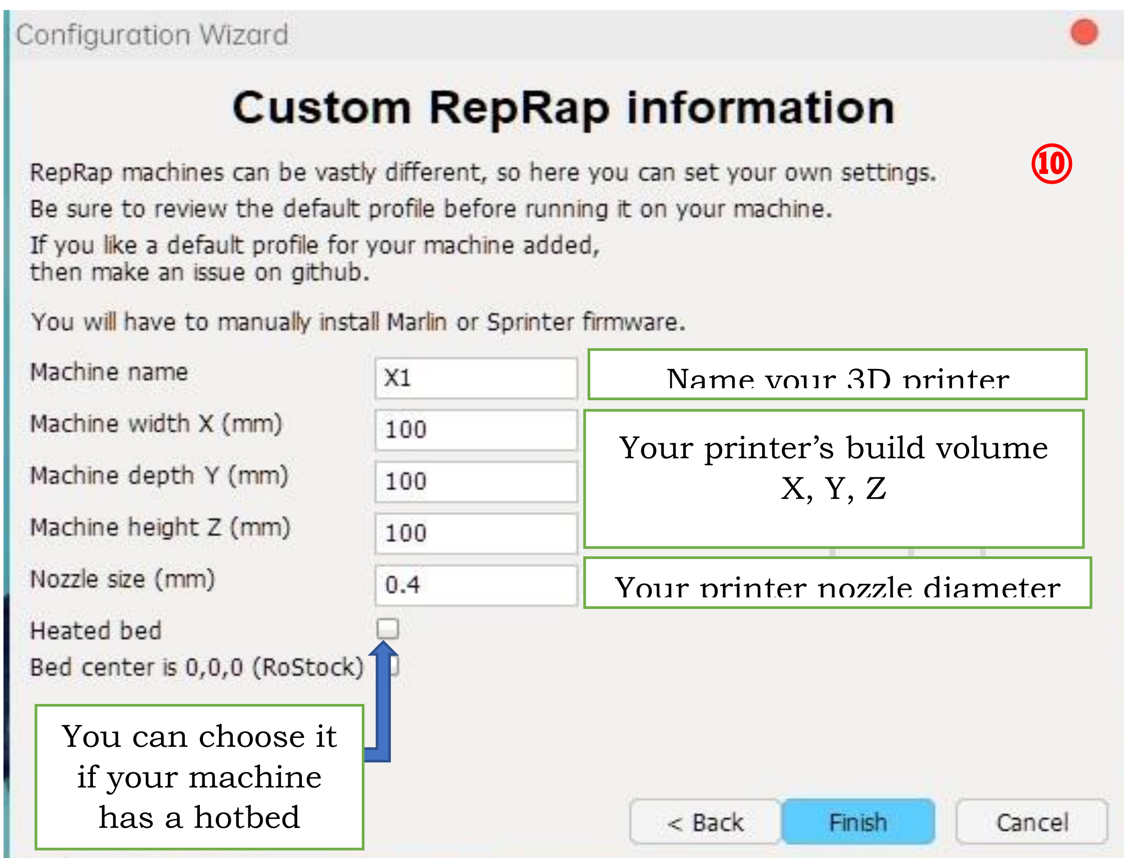

Device Driver Installation Wizard
5
Completing the Device Driver Installation Wizard
The drivers were successfully installed on this computer.
You can now connect your device to this computer. If your device came with instructions, please read them first.
Driver Name
Status
Arduino LLC (www.ardui...
Ready to use
< Back
Finish
Cancel


Cura 15.04.3 Setup
Installation Complete
Setup was completed successfully.
Completed
Show details
6
Nullsoft Install System v2.46
< Back
Next >
Cancel


Cura 15.04.3 Setup
Completing the Cura 15.04.3 Setup Wizard
Cura 15.04.3 has been installed on your computer.
Click Finish to close this wizard.
Start Cura 15.04.3
7
< Back
Finish
Cancel


Configuration Wizard
Select your machine
8
What kind of machine do you have:
Ultimaker 2+
Ultimaker 2 Extended+
Ultimaker 2
Ultimaker 2 Extended
Ultimaker 2 Go
Ultimaker Original
Ultimaker Original+
Printrbot
Lulzbot TAZ
Lulzbot Mini
Other (Ex: RepRap, MakerBot, Witbox)
The collection of anonymous usage information helps with the continued improvement of Cura.
This does NOT submit your models online nor gathers any privacy related information.
Submit anonymous usage information:
For full details see: http://wiki.ultimaker.com/Cura:stats
< Back
Next >
Cancel


Configuration Wizard
Other machine information
The following pre-defined machine profiles are available
Note that these profiles are not guaranteed to give good results, or work at all. Extra tweaks might be required.
If you find issues with the predefined profiles, or want an extra profile.
Please report it at the github issue tracker.
BFB
DeltaBot
Hephestos
Hephestos_XL
Kupido
MakerBotReplicator
Mendel
Ord
Prusa Mendel i3
RIGID3D HOBBY
ROBO 3D R1
Rigid3D
Rigid3d_Zero
RigidBot
RigidBotBig
Witbox
Zone3d Printer
julia
punchtec Connect XL
rigid3d_3rdGen
Custom...
< Back
Next >
Cancel
⑨


Configuration Wizard
Custom RepRap information
RepRap machines can be vastly different, so here you can set your own settings.
Be sure to review the default profile before running it on your machine.
If you like a default profile for your machine added, then make an issue on github.
You will have to manually install Marlin or Sprinter firmware.
Machine name
X1
Name your 3D printer
Machine width X (mm)
100
Machine depth Y (mm)
100
Machine height Z (mm)
100
Your printer's build volume X, Y, Z
Nozzle size (mm)
0.4
Your printer nozzle diameter
Heated bed
Bed center is 0,0,0 (RoStock)
You can choose it if your machine has a hotbed
< Back
Finish
Cancel
⑩

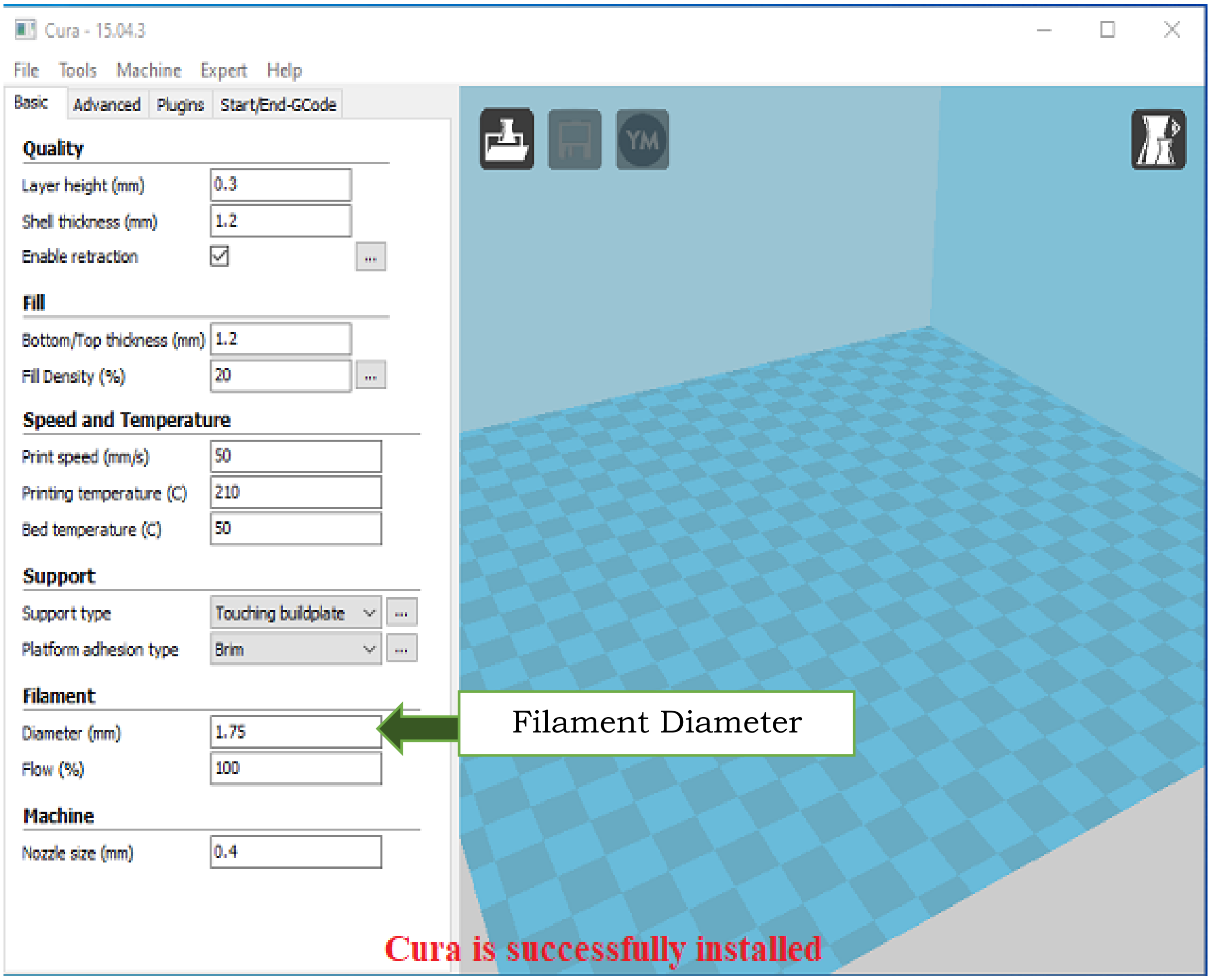
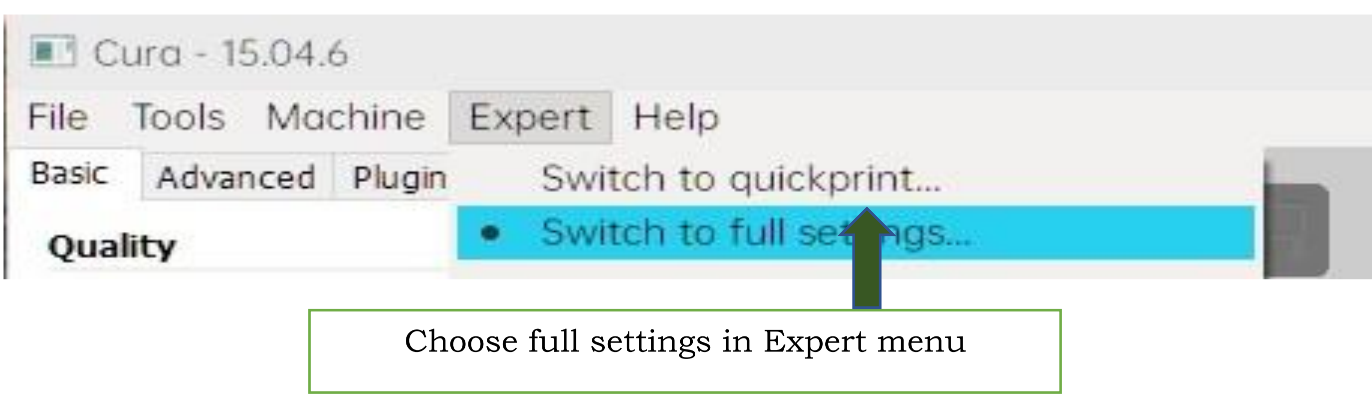
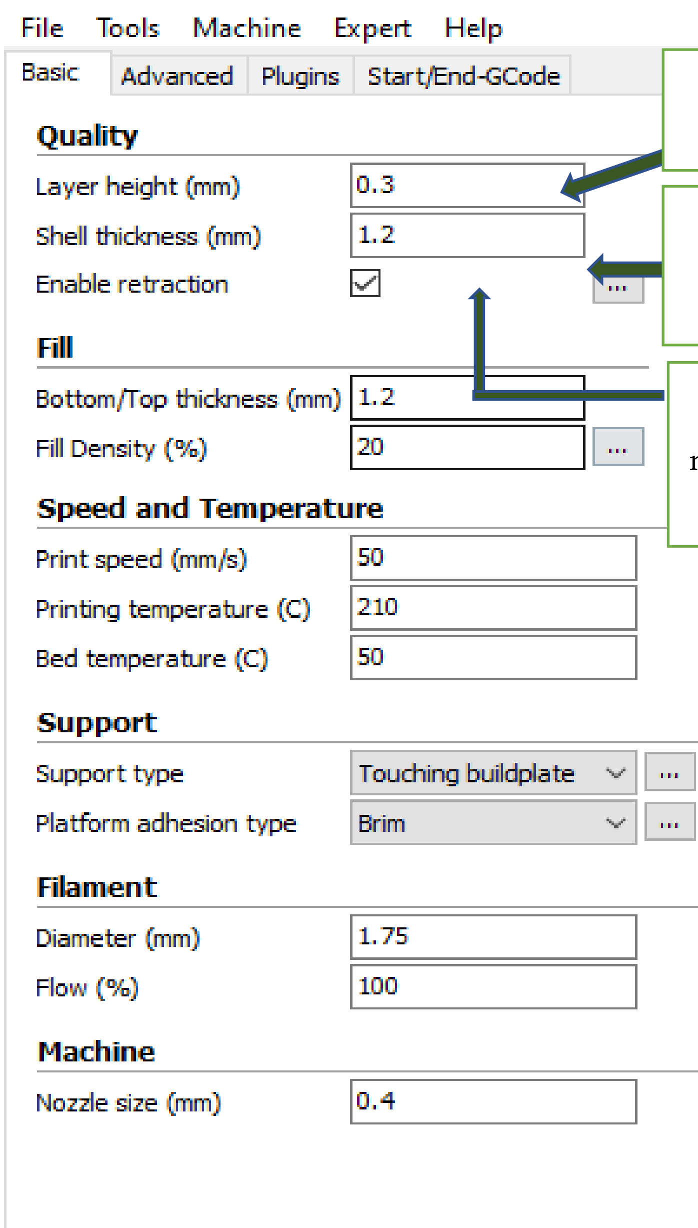


Fig. 2.27 Steps of installation of Cura software (General Procedure)

Hence from the above given steps, you will be successfully able to install Cura software, the only need is of Cura installation program.

Slice Setting for 3D printer Cura's interface to modify all the control parameters of the printing process.

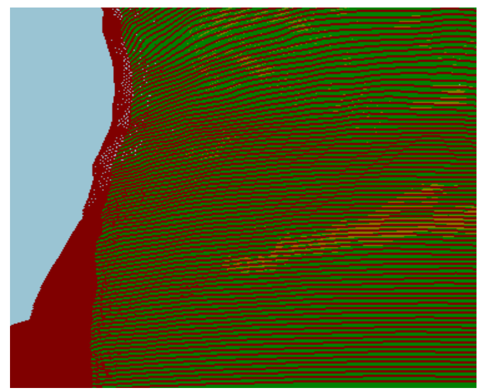




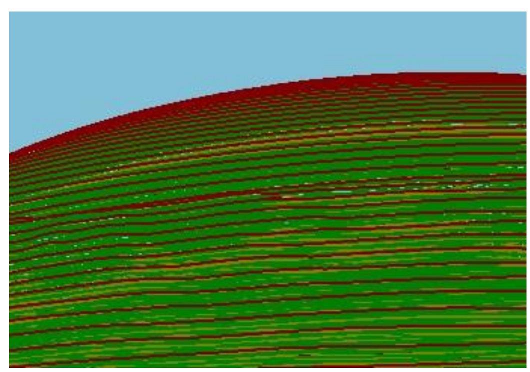
Layer thickness
0.1mm printing quality higher,

Shell thickness
0.4mm too thin, 1.2mm take more times to print, normally 0.8mm, Use integer times of the diameter of the

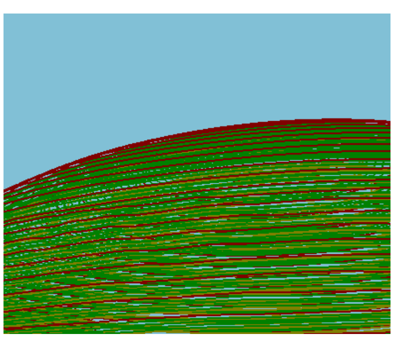
Enable Retraction
The purpose is not to let the material leak out when moving rapidly otherwise it will affect the appearance



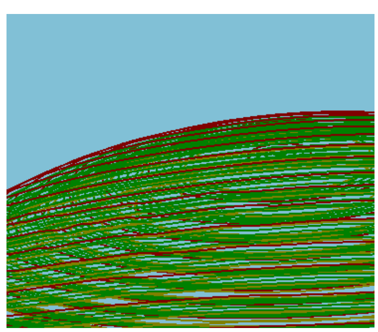
0.1 mm layer thickness



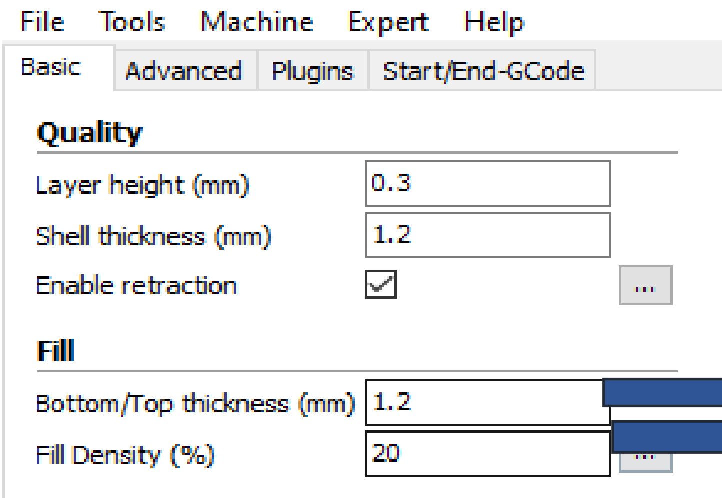
0.3 mm layer thickness



0.5 mm layer thickness



0.7 mm layer thickness

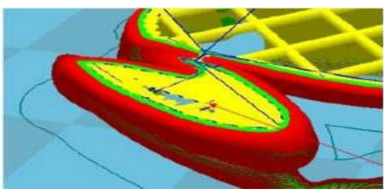


Bottom/top thickness

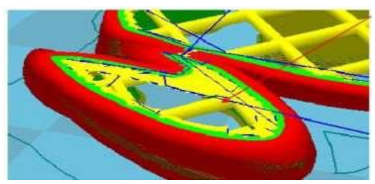
If the filling density is less than 20%, the thickness of 0.6 mm is very easy to cause holes on the top, and the value of 1 mm is generally better

Fill density

If high strength is not required, 10% is enough. For high strength, increase the filling ratio, but the printing time will increase



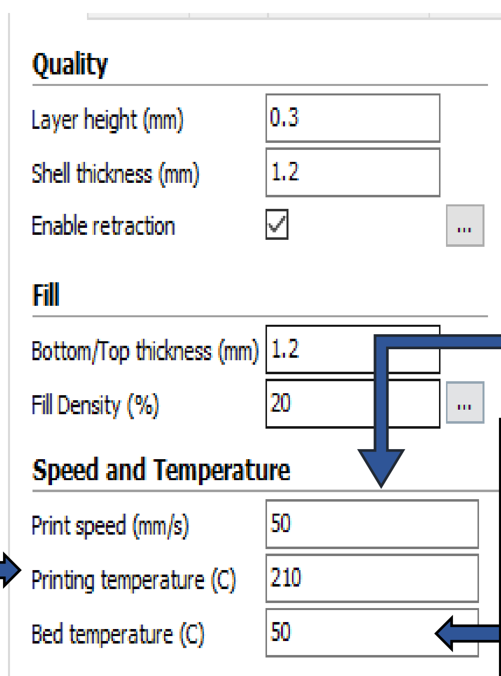
Bottom/Top thickness: 1mm



Bottom/Top thickness: 0.6mm

Print speed

This is the default speed. If the shell and filling speed are not set separately, the printing time is not directly proportional to the speed. If the speed is too fast, printing will easily cause quality problems. Generally speaking, 40mm / S is a better speed, According to the speed specifications of your printer

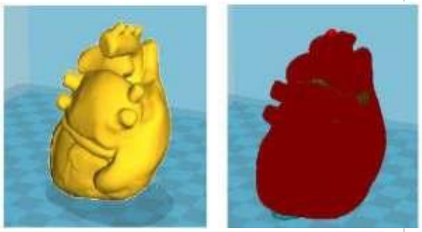


Print temperature

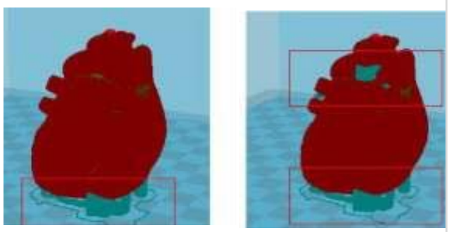
PLA starts to melt at 180 ℃, but the viscosity is relatively large, so it is difficult to squeeze. It is recommended to set the temperature at 190 ℃ -- 210 ℃, printing speed faster or layer thickness thicker, and set the printing temperature a little higher

Bed temperature

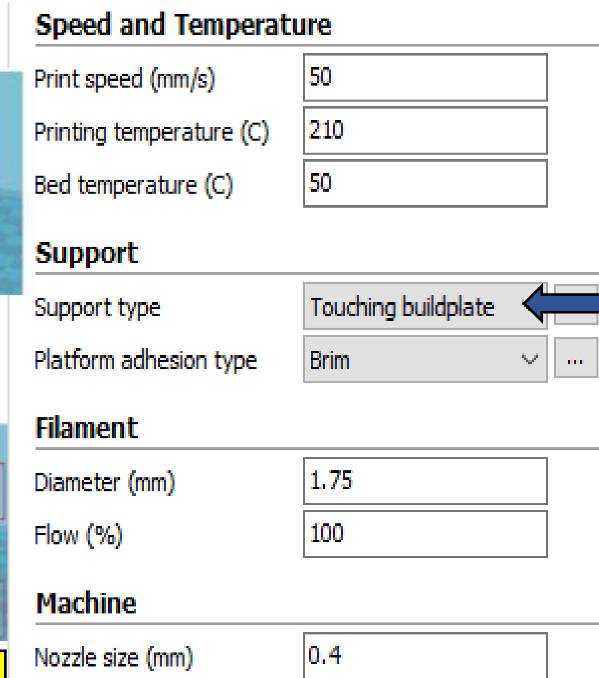
It ensures proper adhesion of the filament to the build platform. If the bed is too cold, the print might warp or detach mid-print. Conversely, an overly hot bed can make the filament too soft, resulting in a print that's difficult to remove or that has a warped base.



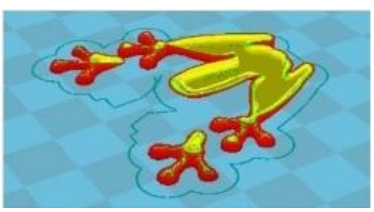
None Option in support type



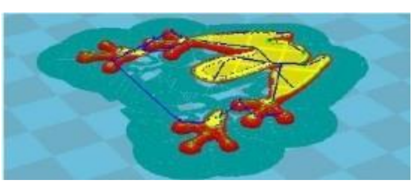
Touching everywhere Option in support type



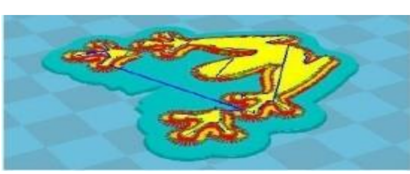
Support type
(None, touching, everywhere),
For the model with complex structure, it is usually necessary to add support. Usually choose Everywhere



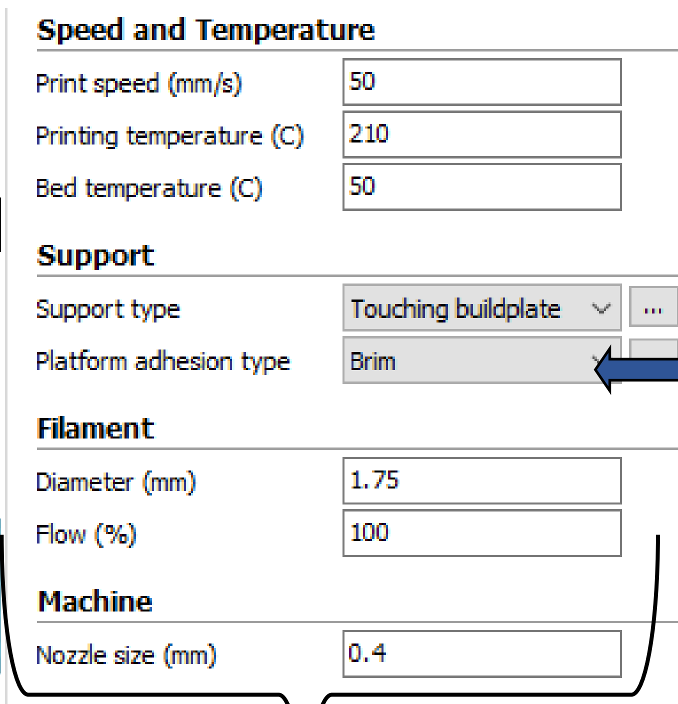
None



Brim



Raft



Platform adhesion type
(Brim,Raft, None)
Normally choose Brim help the model stick platform well.
You can also choose None if the platform leveling very well.

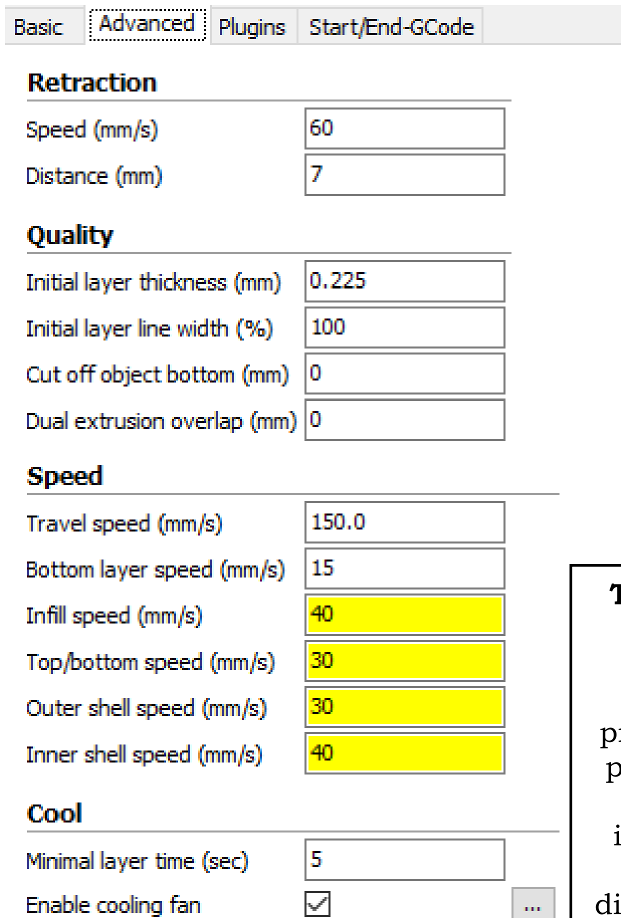
In the **filament section**, the diameter od the used filament needs to be entered.

Flow specifies the rate at which your printer will extrude material. It should be kept between 90-110%. Generally, 100%.

Also, the **nozzle size** must be mentioned as per attached in 3D printer

In the **Advanced** Section, Following are the options with their explanation,

0.3mm
It's to make the model easier to peel off.



Default is 100%

Top/Bottom, Outer and Inner shell speed

Speed at which outer shell is printed. If set to zero (0) then the print speed is used. Printing the outer shell at a lower speed improves the final skin quality. However, having a large difference between the inner shell speed and the outer shell speed will affect the quality in a negative way.

Here we have chosen, 30 which is not appropriate that's the reason of highlighting.

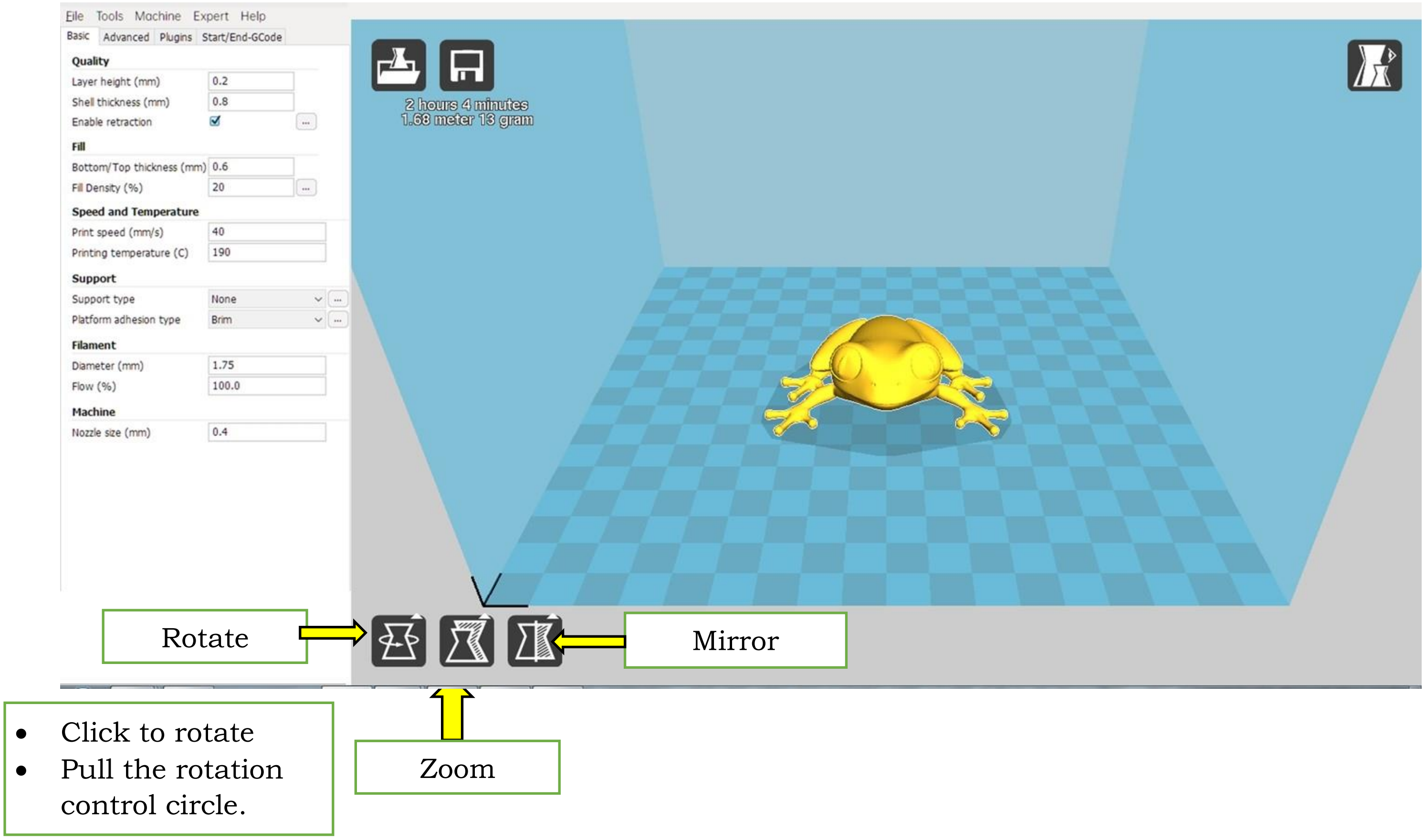
As we are traying to print more than 8.0mm^3 of filament per second. This might cause filament slipping. (Here we are printing 8.4mm^3 per second)

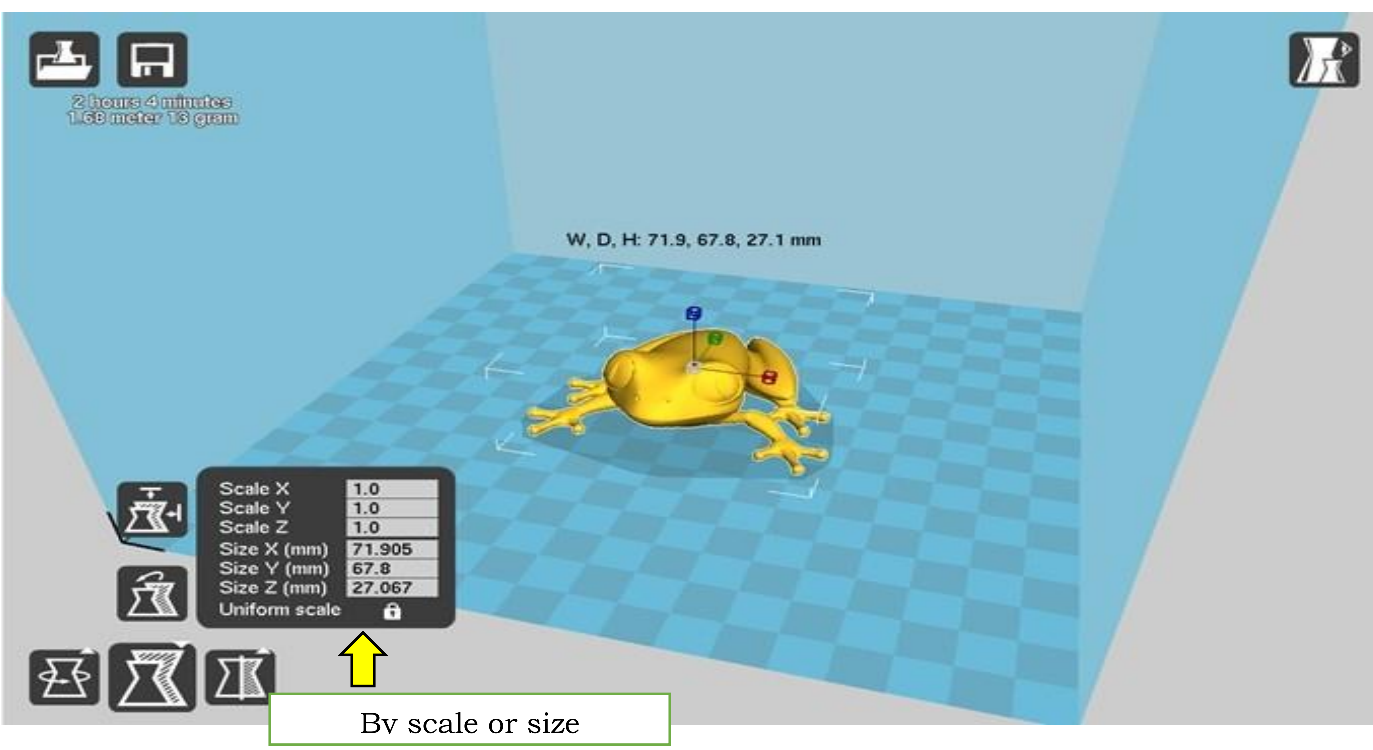
Use Cooling fan

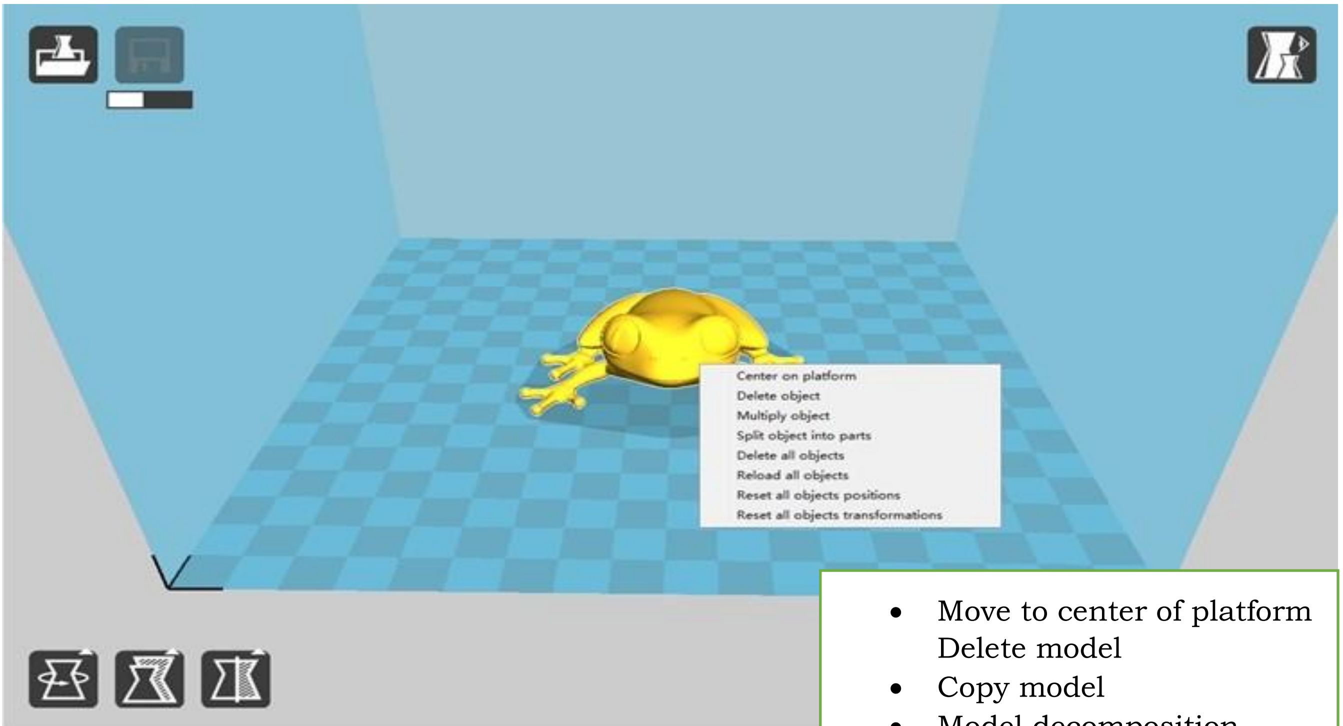
The minimum printing time of each layer, When the real printing time of the layer less Than 3 sec, the speed will be lower than the set speed.

Slice and Save

After all the parameters are set, load a 3D model file, save the sliced G- code file to the SD card, and then start printing.


File Tools Machine Expert Help
Basic Advanced Plugins Start/End-GCode
Quality
Layer height (mm) 0.2
Shell thickness (mm) 0.8
Enable retraction
Fill
Bottom/Top thickness (mm) 0.6
Fill Density (%) 20
Speed and Temperature
Print speed (mm/s) 40
Printing temperature (C) 190
Support
Support type None
Platform adhesion type Brim
Filament
Diameter (mm) 1.75
Flow (%) 100.0
Machine
Nozzle size (mm) 0.4
2 hours 4 minutes
1.68 meter 13 gram
Rotate
Mirror
Zoom
Click to rotate
Pull the rotation control circle.


2 hours 4 minutes
1.68 meter 13 gram
W, D, H: 71.9, 67.8, 27.1 mm
Scale X 1.0
Scale Y 1.0
Scale Z 1.0
Size X (mm) 71.905
Size Y (mm) 67.8
Size Z (mm) 27.067
Uniform scale
Bv scale or size



- Move to center of platform
  Delete model
- Copy model
- Model decomposition
- Delete all model
- Reload all model

Functionality of Slicing Software

Once the STL file is imported into the slicing software, several key processes take place:

- **Model Analysis**: The software examines the model for any errors or issues that could affect printing, such as non-manifold edges or holes in the geometry.
- **Orientation and Scaling**: The user can adjust the orientation, scale, and position of the model within the printer's build volume to optimize for print quality and material usage.
- **Layer Slicing**: The model is sliced into thousands of horizontal layers. Each layer represents a cross-section of the model at a specific height.
- **Path Generation**: The software calculates the precise path the printer's nozzle will follow to deposit material. This includes infill patterns, support structures, and perimeters.
- **Parameter Settings**: Users can adjust a wide range of printing parameters, such as layer height, print speed, temperature, and support material settings.

2.4 BASICS FUNCTIONS OF 3D PRINTER

So far, we've covered all aspects of the design process and slicing software. Now, the file we need for 3D printing is ready, and the G-code file is prepared. It's now essential to learn the basics of 3D printers, focusing on the common elements found in every FDM-based 3D printer.

It's crucial to ensure that the settings provided in Cura (or any other slicing software) are carefully configured, as they greatly impact the quality of the final product. Therefore, it's imperative to pay close attention to the settings in the slicing software.

2.4.1 Various basic setup before starting 3D printing process

When starting an FDM-based 3D printer, it's essential to configure several basic settings to ensure a successful print. Here are the fundamental settings to adjust:

1. **Printer Setup**
   - **Bed Leveling**: Ensure the print bed is level to provide a stable surface for the first layer.
   - **Nozzle Temperature**: Set the appropriate temperature for the filament type (e.g., PLA: 190-220°C, ABS: 220-250°C).
   - **Bed Temperature**: Adjust the bed temperature according to the filament type (e.g., PLA: 50-70°C, ABS: 80-110°C).
   - **Filament Loading**: Load the filament correctly, ensuring it feeds smoothly into the extruder.

2. **Printer Calibration**
   - **Extruder Calibration**: Check that the extruder is accurately dispensing the correct amount of filament.
   - **Step Calibration**: Ensure that the steps per millimeter for each axis (X, Y, Z) are correctly configured.
   - **Bed Adhesion**: Apply necessary adhesion aids (e.g., glue stick, painter's tape) if needed.

3. **Final Checks**
   - **Model Positioning**: Ensure the model is correctly oriented and positioned on the print bed.
   - **G-code Review**: Review the generated G-code to check for any potential issues.
   - **Preheat**: Preheat the nozzle and bed to the target temperatures before starting the print.

By carefully adjusting these settings, you can optimize the print quality and ensure successful 3D prints with your FDM printer.

Let us now go through the basic interface as shown in the display screen of 3D printer (Refer 2.28 (i), 2.28 (ii), 2.28(iii) and 2.28 (iv).

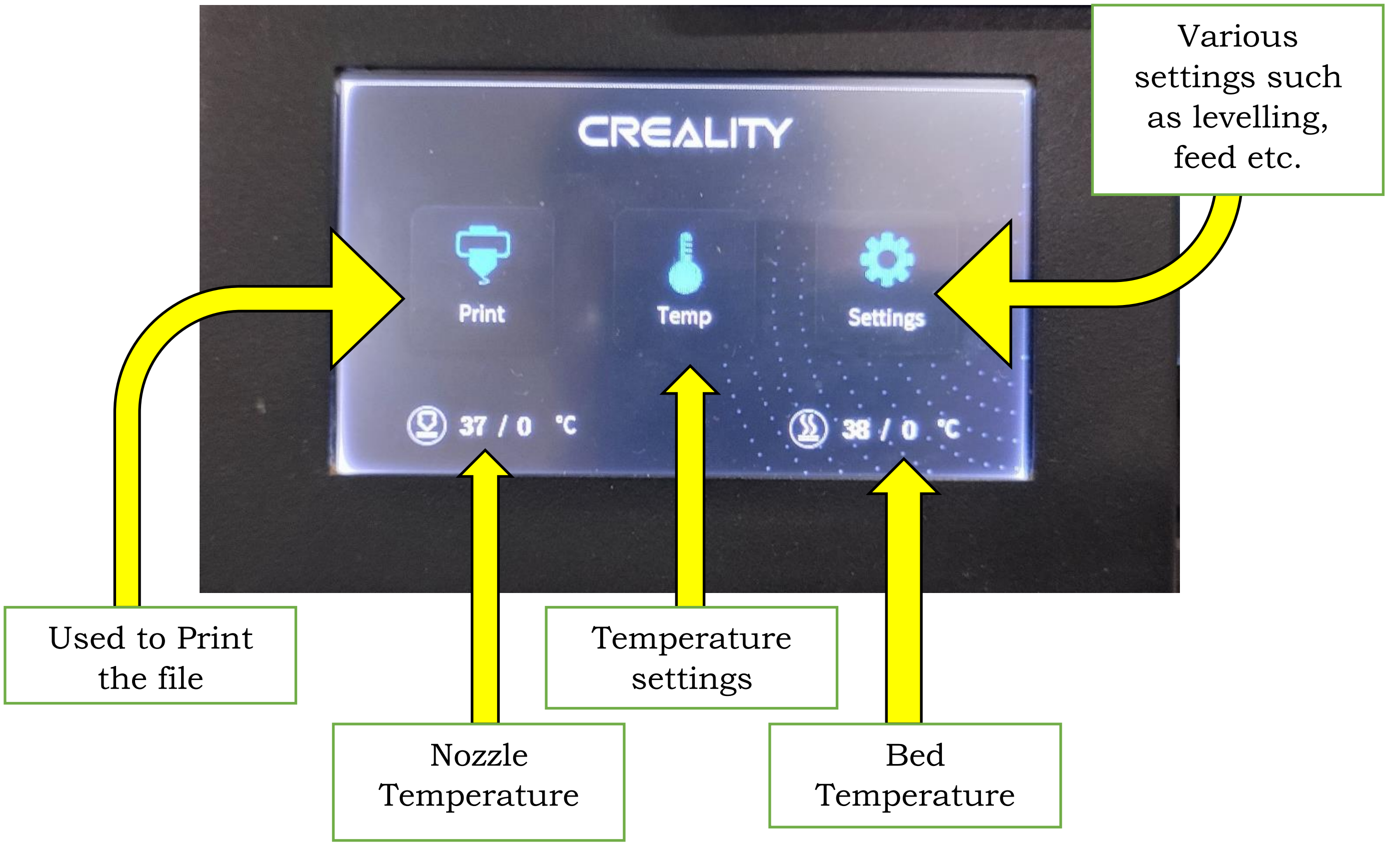


Fig. 2.28 (i) Basic Screen Menu of a 3D Printer

Once you will choose the first option that is print such screen will appear, which will show all the STL files that are stored in your card or pen drive or any other storage device connected to the 3d printer. As the storage devices doesn't contain any of the stl file do it is shown blank in the below given Fig. 2.28(ii).

Fig. 2.28 (ii) Screen showing .stl files on SD card

Like if you choose the choose the second option that is temperature, following such screen will appear as shown in Fig. 2.28(iii).

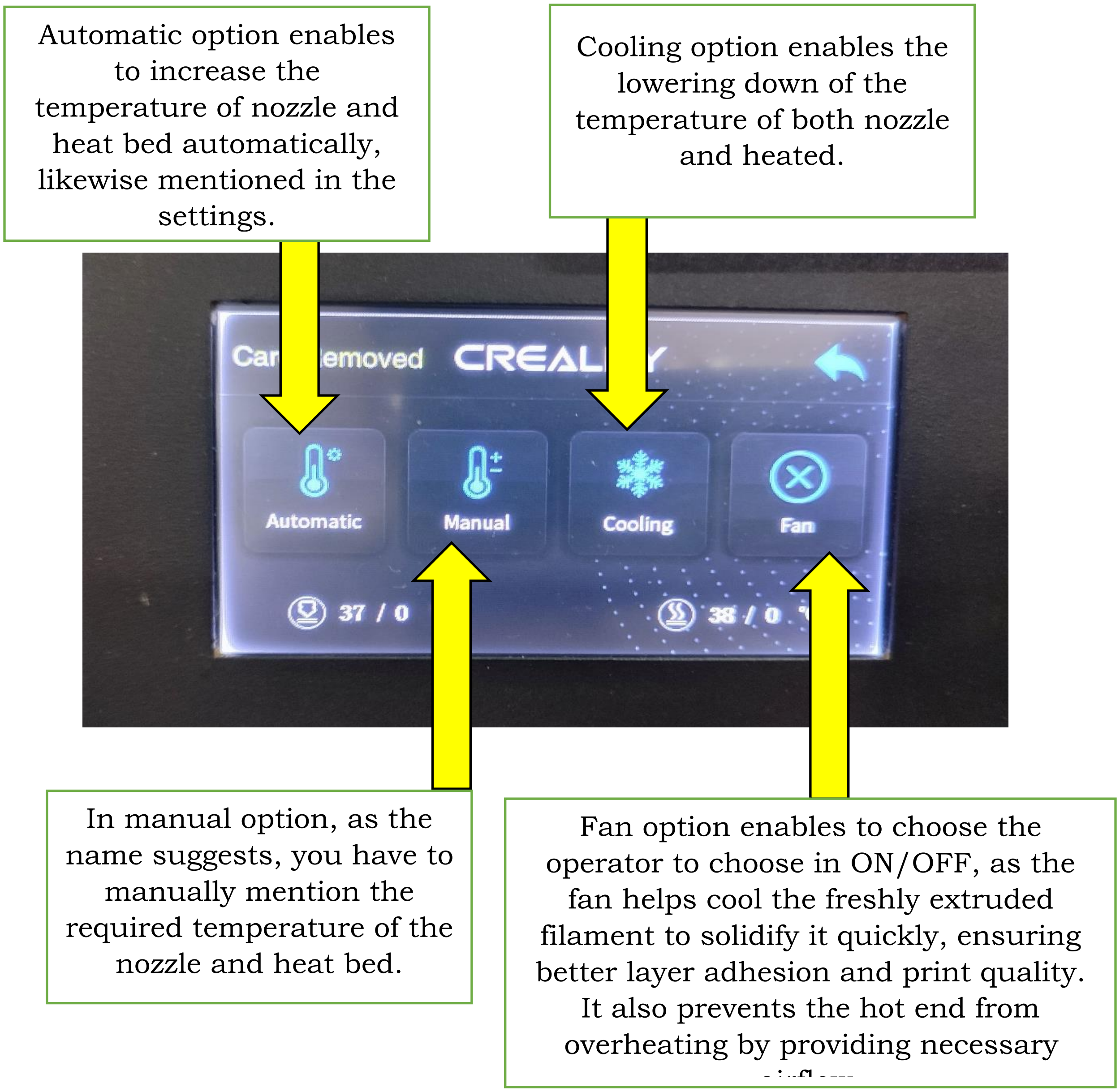


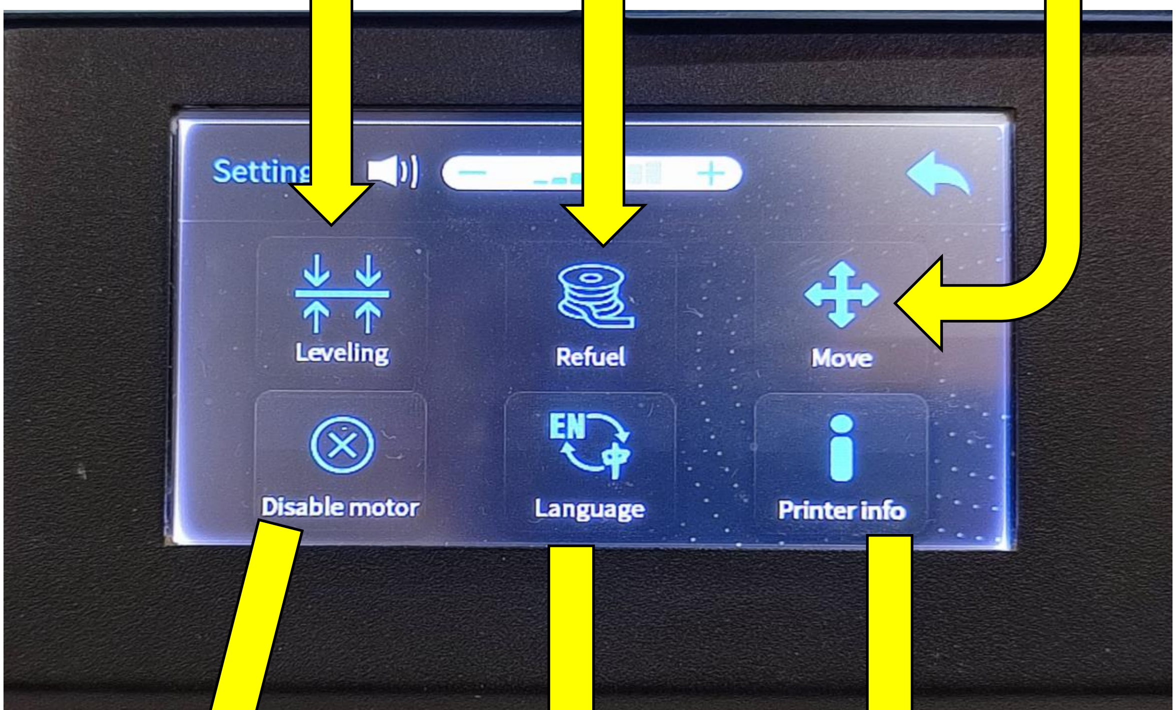
Fig. 2.28 (iii) Temperature menu

The third option which is Settings involves various options as shown in Fig 2.28(iv).

The leveling option in a 3D printer ensures the print bed is perfectly aligned, providing a uniform surface for the first layer to adhere properly. This can be achieved manually through adjustment knobs or automatically using this option.

This option enables to feed or extract the filament. Particularly this option is used while changing the filament. It will be also helpful when we have to check the proper extraction of the filament while printing.

This option enables the heated to move as per your instructions. Example: 10 mm down



As the name suggests, this option will disable the motor.

Enables to change the language of the 3d printing menu

This option will provide you information about the printer.

Fig. 2.28 (iv) Settings menu

Let's us take a quick view of the actual interface of various setting option individually, this may also vary on the basis of different 3d printer. (refer Fig. 2.29(i), 2.29(ii) and 2.29(iii).

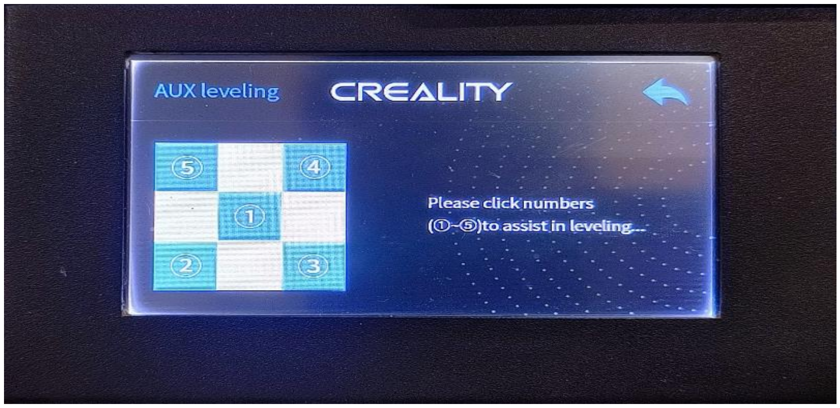


Fig. 2.29 (i) Levelling – Automatic - Settings Menu

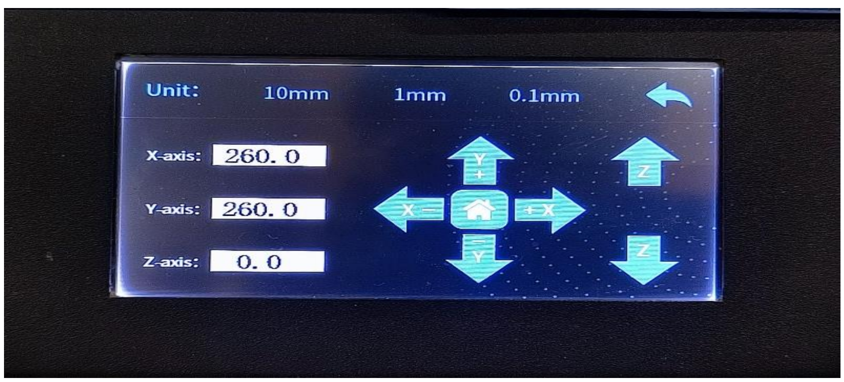


Fig. 2.29 (ii) Move Option in setting – Enable move the heat bed as per your preferences.

Fig. 2.29 (iii) Refuel option- Setting- Used to Retreat and feed the filament.

2.5 DEFECTS IN 3D PRINTING

3D printing with Fused Deposition Modelling (FDM) using PLA (Polylactic Acid) is popular due to its ease of use and biodegradability. However, various defects can occur during the printing process. Understanding these defects can help improve print quality and avoid common issues.
Following mentioned are some of the defects with its prevention tips which can sounds use

1. Warping

Warping happens when the edges of a printed object lift and curl away from the print bed. This is caused by uneven cooling and shrinking of the material. PLA is less prone to warping compared to other materials, but it can still occur, especially with larger prints. (Refer fig. 2.30)

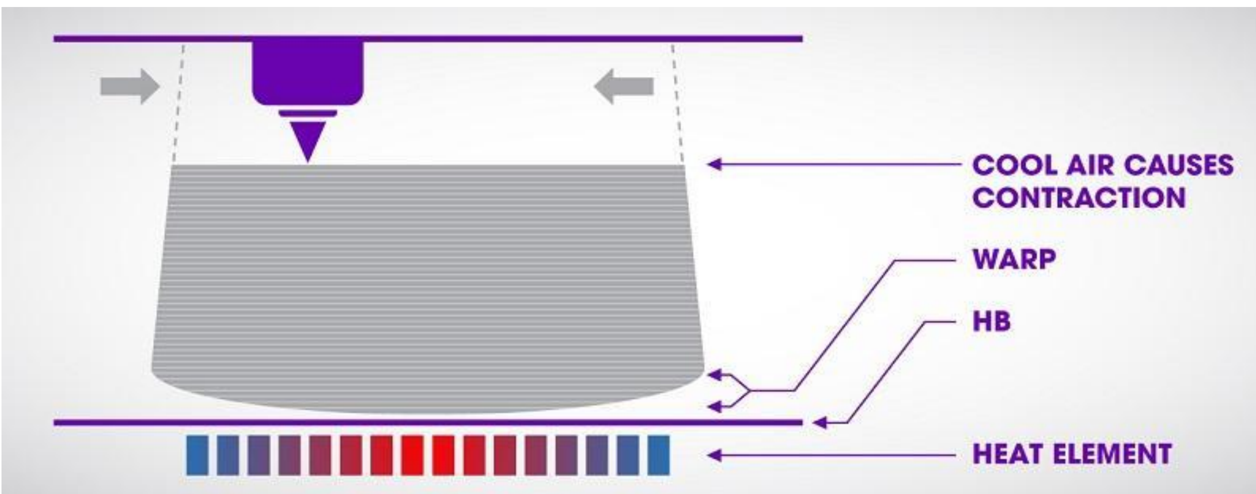


Fig. 2.30 Warping process

Prevention Tips

1. Use a heated bed.
2. Apply adhesive like glue stick or painter's tape to the bed.
3. Ensure proper bed leveling

2. Stringing

Stringing occurs when small strands of filament are left between parts of the print, resembling cobwebs. This happens when the extruder leaks filament while moving between different sections. (Refer fig. 2.31)

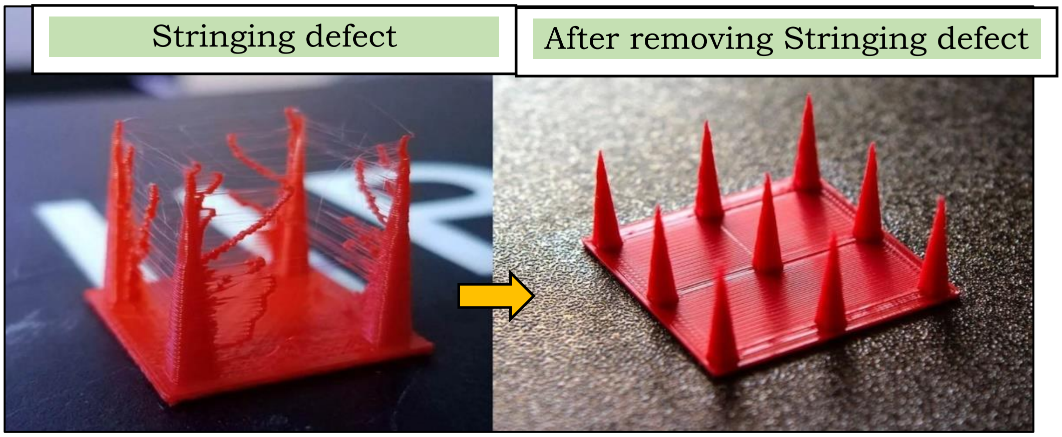


Fig. 2.31 Stringing

Prevention Tips

1. Increase retraction settings.
2. Reduce print temperature.
3. Adjust travel speed settings.

3. Layer Shifting

Layer shifting happens when the layers of the print become misaligned, resulting in a skewed object. This can be caused by loose belts, stepper motor issues, or the printer being bumped during printing. (Refer fig. 2.32)

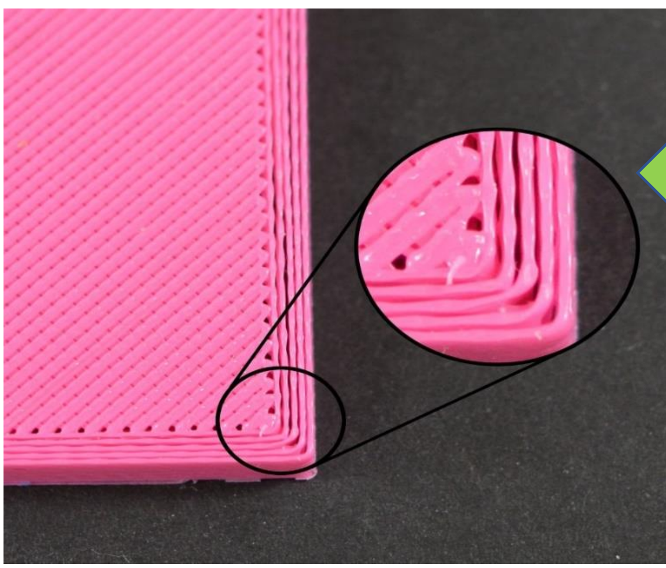
Fig. 2.32 Layer Shifting

Prevention Tips

1. Tighten belts and check pulley alignment.
2. Ensure the printer is on a stable surface.
3. Inspect and maintain stepper motors.

4. Under-Extrusion

Under-extrusion occurs when the printer is not able to push enough filament through the nozzle, leading to weak or missing layers. This can result from clogged nozzles, low print temperature, or issues with the extruder. (Refer fig. 2.33)



Missing layers due to improper discharge of filament through the nozzle.

Fig. 2.33 Stringing defect

Prevention Tips

1. Clean the nozzle regularly.
2. Increase the print temperature.
3. Check and maintain the extruder mechanism.

5. Over-Extrusion

Over-extrusion happens when too much filament is extruded, causing blobs and zits on the print surface. This can affect the print's accuracy and surface finish. (Refer fig. 2.34)

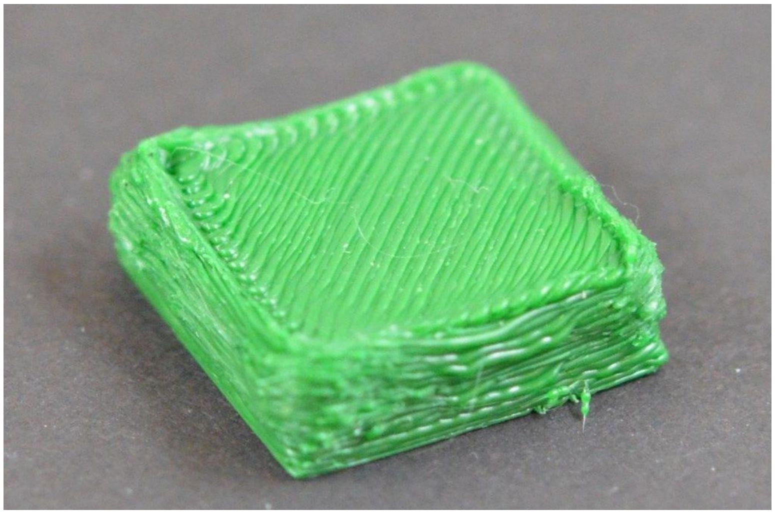


Fig. 2.34 Over- Extrusion

Prevention Tips

1. Reduce the flow rate or extrusion multiplier.
2. Calibrate the extruder steps (E-steps).
3. Lower the print temperature if necessary.

6. Layer Separation (Delamination)

Layer separation or delamination occurs when layers of the print do not adhere properly to each other, leading to cracks or gaps. This can be due to low print temperature or insufficient cooling. (Refer fig. 2.35)

Fig. 2.35 Layer seperation

Prevention Tips

1. Increase print temperature.
2. Ensure consistent cooling, but not excessive.
3. Check for proper bed adhesion.

7. Elephant's Foot

Elephant's foot is a defect where the bottom layers of the print are slightly bulged outward. This is caused by the weight of the object pressing down on the still-soft bottom layers. (Refer fig. 2.36)

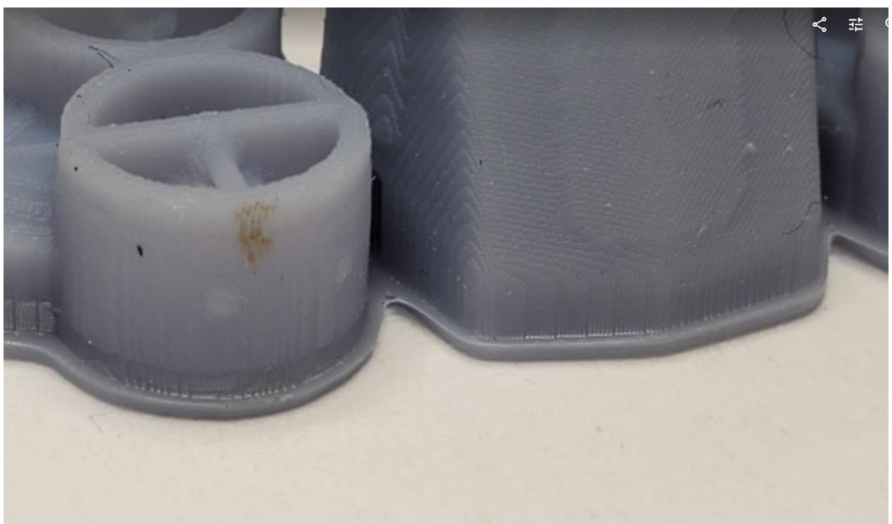


Fig. 2.36 Elephant's foot

Prevention Tips

1. Level the bed correctly.
2. Use a lower bed temperature.
3. Add a slight first layer height offset.

Activities
Activity 1: Design, Slice and Print. **Materials Required:** 1. Computer/Laptop with internet connection. 2. Cura slicing software 3. 3D printer 4. Filament such as PLA or ABS. 5. Notebook 6. Pen **Procedure:** 1. Open Tinkercad and create a design (e.g., keychain, mobile cover, luggage tag). 2. Save the design as an STL file. 3. Import the STL file into Cura slicing software. 4. Choose basic settings (layer height, print speed, infill). 5. Set advanced settings based on material (PLA, ABS, etc.). 6. Create the G-code file and save it. 7. Load the G-code into the 3D printer. 8. Start printing and watch for defects. 9. Remove the printed model. 10. Inspect for any issues. **Now your product which you've designed is ready to use!**
Activity 2: Mark the defects of the 3D Printer **Materials Required:** **1. Computer/Laptop with internet connection** **2. 3D Printer** **3. Filament** **4. Notebook** **5. Pen** **Procedure** 1. **While printing of any product, keenly observe the defects which may occur while printing or after the final print of the product.** 2. **Mention the names of the defect so seen.** 3. **Research on those defects, their reasons of occurring.**

4. **Also find the preventive measures for avoiding such kind of defects.**
5. **Prepare a Presentation on the above.**

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What is the first step in the generic FDM process?
a) Conversion to STL file
b) CAD (Computer-Aided Design)
c) Machine Setup
d) Postprocessing

2. Which file format is most commonly used for 3D printing?
a) .OBJ
b) .PDF
c) .STL
d) .JPEG

3.Which software is mentioned for slicing the .STL file into G-Code?
a) Tinkercad
b) Ultimaker Cura
c) SketchUp
d) Fusion 360

4. What is warping in 3D printing?
a) Misalignment of layers
b) Small strands of filament between parts
c) Edges of a printed object lifting and curling away from the print bed
d) Excess filament extrusion

5.Which tool is used in Tinkercad to place shapes onto the workplane?
a) Ruler
b) Text tool
c) Workplane button
d) Move tool

6.What is the function of the 'Export' button in Tinkercad?
a) To save the project to the cloud

b) To convert the model to a physical object
c) To download the file in various formats like. STL and .OBJ
d) To import a new model into the workspace

7. What causes layer shifting in a 3D print?
a) High print speed
b) Uneven cooling
c) Loose belts or stepper motor issues
d) Incorrect bed temperature
8.What is elephant's foot in 3D printing?
a) Layers becoming misaligned
b) Small strands of filament between parts
c) Excessive filament extrusion
d) Bottom layers bulging outward

B. Match the following

	Section A		**Section B**
1.	CAD Software	A.	Ultimaker Cura
2.	Slicing software	B.	Tinkercad
3.	File format for 3D printing	C.	PLA
4.	Common Filament type	D.	G-code

C. Fill in the Blanks

1. The STL file describes the surface geometry of the CAD model using a series of connected ______.
2. The printing process is mostly ______ with minimal supervision required.
3. Warping in 3D printing is caused by uneven ______ and shrinking of the material.
4. Under-extrusion can result from clogged nozzles or low print ______.

D. Answer the following
1. Explain the importance of bed leveling in 3D printing.
2. What are the steps involved in using Tinkercad to design a 3D model?
3. Describe how slicing software contributes to the 3D printing process.
4.What are some common defects in FDM 3D printing, and how can they be prevented?

Module 3 Post Processing Methods

Module Overview
This module covers the various methods of post-processing for Fused Deposition Modelling (FDM) 3D prints, such as sanding, painting, and smoothing. It also explains the need for post-processing, highlighting its importance in improving the appearance, strength, and functionality of 3D printed objects.

Learning Outcomes
After completing this module, you will be able to: • Understand he purpose and benefits of post-processing in enhancing the quality of 3D printed objects. • Identify appropriate post-processing techniques based on the material and desired finish.

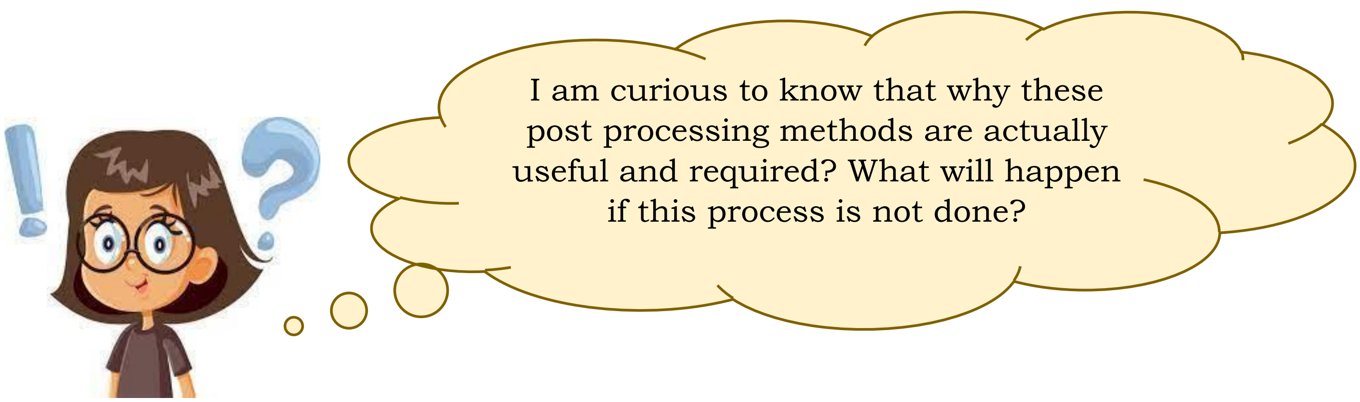
Module Structure
3.1 Methods of Post Processing 3.2 Need of Post processing method in FDM

Now that we have thoroughly covered the process of 3D printing, specifically Fused Deposition Modelling (FDM), it's time to move on to the crucial step of finishing your printed model. This final step i.e. the post processing, is vital in the design process because it ensures that your product achieves its best possible appearance and functionality. Post-processing enhances the surface quality and overall strength of your printed model, making it an essential part of creating a polished and durable final product.

As we are aware that, Fused Deposition Modeling (FDM) 3D printing is ideal for creating cost-effective prototypes quickly. However, FDM prints often have visible layer lines, so post-processing is essential to achieve a smooth finish. Additionally, certain post-processing techniques can enhance the strength of the prints, addressing the inherent weakness in FDM parts due to their layered construction.

Fig. 3.1 shows various post-processing methods on the product.

Fig. 3.1 Post processed FDM prints (from left to right): Cold welding, gap filling, unprocessed, sanded, polished, painted and epoxy coated.



The answer to the above question will be surely known once we will cover all the post processing methods and understand its importance.

3.1 Methods of Post Processing

Following are the methods of post-processing which are commonly used:

1. **Support Removal**

Imagine you've just finished 3D printing a model using Fused Deposition Modelling (FDM). The first step in post-processing is removing the support structures that were necessary for accurately creating complex parts. These supports come in two main types: standard and dissolvable. For example, if you printed a detailed figurine, you might have used standard supports that you need to manually remove or dissolvable supports that can be washed away in a special solution. Unlike other post-processing techniques that enhance the surface finish, support removal is essential and doesn't improve the model's appearance. Refer Fig. 3.2.

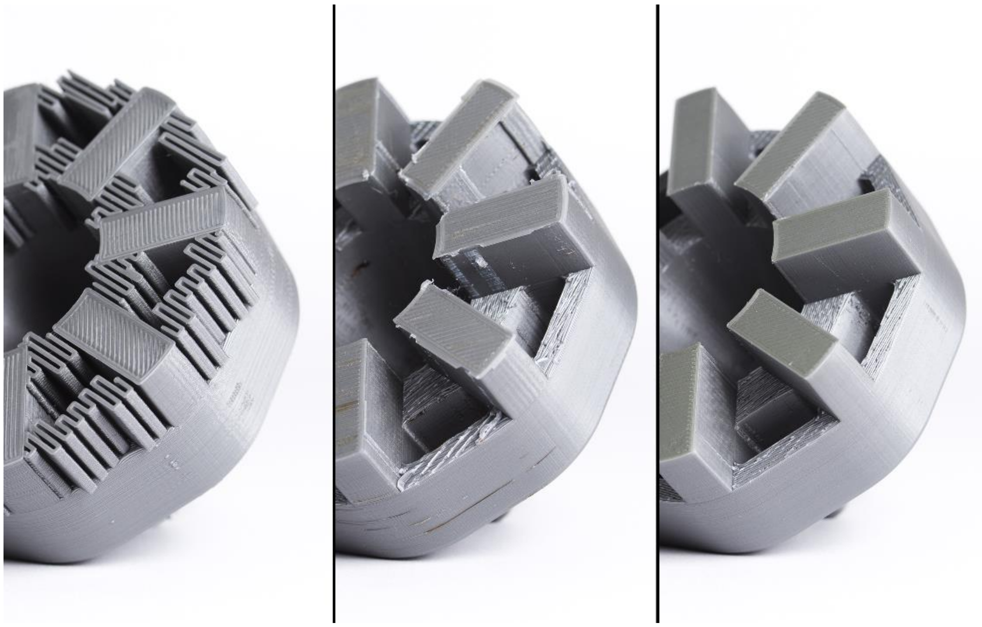


Fig. 3.2 Original print with support attached, poor support removal and good support removal (left to right)

Tool kit

1. Needle-nose pliers
2. Dental pick set

Process: Support material can generally be removed from the print with little effort, and cleaning of support material in hard-to-reach places (like holes or hollows) can be achieved with dental picks and needle-nose pliers. Well placed support structures, and proper print orientation, can greatly reduce aesthetic impact of support material on the final print.

PROS

1. Does not alter overall geometry of part.
2. Very quick.

CONS

1. Does not remove any layer lines, striations, or blemishes on the print surface.
2. If support structures leave behind excess material or marks, the accuracy and appearance of the print is diminished.

2. **Sanding**

Tool kit

- 150, 220, 400, 600, 1000, and 2000 grit sandpaper
- Tack cloth
- Toothbrush
- Soap
- Face mask

Process: After removing or dissolving the supports from your 3D print, the next step is to sand the part to make it smooth and remove any visible blemishes, like blobs or marks from the supports. The starting grit of sandpaper you use depends on the layer height and quality of your print:

Fig. 3.3 A sanded grey ABS print

- For layer heights of 200 microns or less, or if your print has no visible blemishes, start with 150-grit sandpaper.
- If your print has noticeable blemishes or was printed at a layer height of 300 microns or more, start with 100-grit sandpaper.

Continue sanding with increasingly finer grits of sandpaper, following this progression: 220 grit, 400 grit, 600 grit, 1000 grit, and finally 2000 grit. For the smoothest finish, you can sand up to 5000 grit. It's best to wet sand from start to finish, as this helps prevent friction and heat from damaging the part and keeps the sandpaper clean. After each sanding step, clean the print with a toothbrush and soapy water, then use a tack cloth to remove any dust. (refer Fig. 3.3)

Pro-tip: Always sand in small circular motions across the surface. Avoid sanding in straight lines either across or along the print layers, as this can create "trenches" in the part. If the print gets discoloured or has many small scratches from sanding, you can use a heat gun to gently warm the surface and smooth out some of the defects.

PROS

1. Produces an extremely smooth surface.
2. Makes other post-processing steps (like painting or polishing) easier.

CONS

1. Not recommended for prints with only 2 or fewer perimeter shells, as sanding can damage them.
2. Difficult to sand intricate surfaces or prints with small details.
3. Can reduce the accuracy of the print if too much material is removed by sanding too aggressively.

3. Cold Welding

Tool kit

1. Acetone
2. Foam applicator

Process: When the size of a print exceeds the maximum volume of the printer, the design is often broken down into smaller sections and assembled together after printing. For PLA and other materials, assembly can be done using Bond-O or an appropriate glue (glue selection will depend upon plastic). For ABS, multi-part assemblies can be "welded" together using acetone. The mating surfaces need to be brushed lightly with acetone, and firmly held together, or clamped, if possible, until the majority of the acetone evaporates. At this point, the two parts are chemically bonded to one another. (Refer Fig. 3.4).

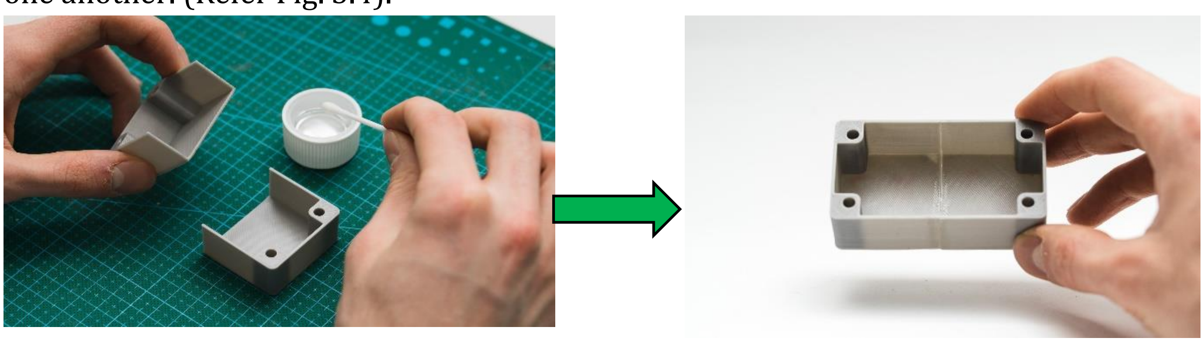


Fig. 3.4 Two grey ABS print halves attached together by cold welding

PROS

Pro-tip: Increasing the surface area the acetone contacts will increase the strength of the joint. This can be done by incorporating interlocking joints into the design.

1. Acetone will not alter the surface color of the print as much as other glues
2. Once dried, the joint will exhibit the properties of ABS, making further finishing simpler and uniform.

CONS

1. The joint formed by "welding" ABS pieces together with acetone is not as strong as a single piece print.
2. Excess use of acetone can aggressively dissolve the part, and negatively impact the resulting finish and tolerances.

4. Joining

If you'd like to print a large object but the build volume of your 3D printer is too small, you'll have to split the model, then assemble the pieces after they have been printed.

Fortunately, there are a lot of options for joining 3D printed parts. Gluing is the easiest method. Regardless of the glue or bonding agent you choose, please keep in mind that you'll probably need to (lightly) sand the surfaces that will be glued together, and after you've glued the pieces together, you may have to apply some filler to any large gaps at the seams of your assembled model.

Another method is "chemical welding" or "cold welding" but only for 3D printing materials that dissolve in a solvent. It's possible to apply a little bit of acetone. Just keep in mind, however, that acetone is a hazardous substance, and safety precautions need to take when storing and handling it. (For more on the precautions, see the smoothing section below).

For materials that aren't reactive to acetone, you could weld parts together with a soldering iron or 3D printing pen. Given its low melting point, it's possible to weld PLA simply by creating friction.

PROS

1. Inexpensive
2. Not time-consuming
3. Low skill-level required for gluing and chemical welding

CONS

1. Parts are weak at joining seam(s)
2. Can be messy
3. More skilled required for heat- or friction-based welding techniques

5. Priming and Painting

Priming is a post-processing technique that prepares a surface for painting. It simply means coating the part with either primer paint or primer spray, which acts as a base layer for the paint you will apply later.

Before applying the primer, it's best to sand your part with low- and then medium-grit sandpaper. This removes layer lines and smooths the surface. After sanding the part, apply two coats of primer, allowing it to dry between coats. Once everything is dry, you can start painting your 3D print using a brush or spray. If you want to achieve sharp colour intersections, use masking tape. (Refer Fig. 3.5).

Fig. 3.5 Spray Painting

Priming and painting are best done in a well-ventilated area or outdoors. Always wear a mask to avoid breathing in unwanted fumes.

PROS

1. Enhances the look and feel of a part
2. Provides a smooth surface finish
3. Works on all FDM materials

CONS

1. Relatively time-consuming
2. Can be costly due to the equipment needed (paints, sprays, sandpaper, masks, and brushes)
3. Some skill is required to achieve great results

6. Smoothing

Smoothing is a popular post-processing technique, especially for ABS prints. Acetone can melt ABS and therefore smooth away the layer lines visible on a part's surface. (Refer Fig. 3.6).

Fig. 3.6 Smoothing

The simplest method is to pour acetone into a large container (which can be plastic, but glass is recommended), then place your prints on a platform above the acetone. Close the container lid for 10-20 minutes so that the vapor can melt the outer layer of the parts. You want the vapor to be able to escape the container rather than build up, though. So, if the lid seals tightly, consider drilling a few holes beforehand. If you don't have an appropriate container, you can apply small amounts of acetone with a brush onto the surface of your 3D prints.

As for PLA, smoothing can't be done with acetone as it doesn't melt it, and it could even destroy the entire print by making it "gummy". PLA can be smoothed with chemicals like THF or MEK, but the results won't be as nice as acetone-smoothed ABS.

In case you have some, 3D prints made from PVB filament, you can use isopropyl alcohol to perform the smoothing.

PROS

1. Smooth and shiny surface
2. Acetone is relatively cheap
3. Quick to achieve

CONS

1. Acetone smoothing is only possible for ABS and ASA prints

2. Dimensional accuracy can be compromised
3. Risk of warping for larger prints

7. Polishing

This 3D printing post-processing technique is used to achieve the smoothest possible surface. You can polish 3D prints with plastic polishers and tools available at almost every hardware store. A microfiber cloth and a plastic polisher are all you need, but if you've got the enthusiasm and a few more dollars, using a Dremel tool will make this process even easier.

Before a part can be polished, you need to sand it properly, finishing with the finest sandpaper. After sanding, rinse your parts and make sure no particles left behind. If you're using a cloth, apply the polisher to the sanded part and move the cloth in a circular motion until you're satisfied with the result. A Dremel buffer will do much of the work for you, but make sure it's moving evenly along the surface.

PROS

1. Produces smooth and mirror-like surface
2. Inexpensive.

CONS

1. Dimensional accuracy can be compromised
2. Moderate skill-level required

3.2 NEED OF POST PROCESSING METHODS IN FDM PROCESS

The model produced or printed using FDM method often require post-processing to enhance their functionality, aesthetics, and overall quality. Here are the main reasons why post-processing methods are essential in the FDM process:

1. Improving Surface Finish

- **Layer Lines**: FDM prints typically exhibit visible layer lines, which can make the surface rough and visually unappealing.

- **Smoothing**: Techniques such as sanding, chemical smoothing, or applying fillers can significantly improve the surface finish, making the parts more aesthetically pleasing.

2. Enhancing Mechanical Properties

- **Strength and Durability**: Post-processing methods like annealing or coating can improve the mechanical properties of FDM parts, increasing their strength and durability.

- **Welding**: For larger objects printed in multiple pieces, welding techniques (such as using a soldering iron or chemical welding) can create strong, seamless joints.

3. Sealing and Water Resistance

- **Porosity**: FDM parts can be porous, which is problematic for applications requiring water or air-tightness.

- **Sealing**: Applying coatings or sealants can fill gaps and make the parts impermeable.

4. Removing Supports

- **Support Structures**: FDM prints often require support structures to print overhangs and complex geometries.

- **Removal**: Post-processing includes removing these supports and sanding down any marks left by them.

5. Improving Dimensional Accuracy

- **Warping and Shrinkage**: FDM parts can suffer from warping and shrinkage during the printing process, affecting their dimensional accuracy.

- **Machining and Trimming**: Post-processing steps like machining, trimming, or sanding can correct these issues, ensuring the parts meet precise specifications.

6. Aesthetic Enhancements

- **Colour and Finish**: Painting, dyeing, or applying surface coatings can enhance the visual appeal of FDM parts, making them suitable for display or consumer products.

- **Detailing**: Adding fine details through manual or automated processes can improve the overall look of the printed parts.

8. Functional Modifications

- **Adding Features**: Post-processing allows for the addition of functional features such as threaded inserts, magnets, or other hardware that cannot be printed directly.

- **Customization**: Parts can be modified or customized to fit specific applications or user requirements.

Activity
Activity: Smoothing and Painting a 3D Printed Part **Materials Required:** 1. 3D printed part (PLA or ABS) 2. Sandpaper (150, 220, 400 grit) 3. Toothbrush 4. Soapy water 5. Primer spray 6. Acrylic paint or spray paint 7. Brushes or spray can 8. Masking tape 9. Old newspapers or a large cloth (to protect your workspace) 10. Face mask **Procedure:** 1. Cover your workspace with old newspapers or a large cloth to protect it from dust and paint. 2. Wear a face mask to avoid inhaling dust and paint fumes. 3. If your 3D printed part has support structures, gently remove them using your hands or a small tool. 4. Start with 150-grit sandpaper to smooth out any rough areas. Sand in small, circular motions. 5. Move to 220-grit sandpaper to make the surface smoother. 6. Finish with 400-grit sandpaper for a fine, smooth finish. 7. Use a toothbrush dipped in soapy water to clean off the dust. 8. In a well-ventilated area, spray a light coat of primer over the entire part. Let it dry completely. 9. Apply a second coat if needed and let it dry. 10. Use masking tape to cover any parts you don't want to paint. 11. Paint your part with acrylic paint using a brush or spray paint in thin, even layers. Let each layer dry before adding another. 12. Remove the masking tape once the paint is dry.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following is a major reason for post-processing FDM prints?
a) Increasing print speed

b) Improving surface finish
c) Reducing material cost
d) Enhancing print color

2.What is the purpose of using acetone in the cold-welding process for ABS parts?
a) To smooth the surface
b) To chemically bond the parts together
c) To clean the parts
d) To remove supports

3.Which tool is not typically used for support removal in post-processing?
a) Needle-nose pliers
b) Dental pick set
c) Foam applicator
d) Tack cloth

5. Which of the following is a disadvantage of sanding in post-processing?
a) Produces an extremely smooth surface
b) Can damage prints with few perimeter shells
c) Makes painting easier
d) Can be done on intricate surfaces

6. What is the main benefit of priming before painting an FDM print?
a) It improves the structural strength
b) It provides a base layer for the paint
c) It smooths internal cavities
d) It reduces material cost

7. Which post-processing method is specifically recommended for ABS prints but not PLA prints?
a) Sanding
b) Priming and painting
c) Smoothing with acetone
d) Polishing

B. Fill in the Blanks

1. After removing supports from an FDM print, the next step is usually _______ to make the part smooth and remove visible blemishes.

2. ______ is a post-processing technique that prepares a surface for painting by coating the part with a base layer.
3. Applying coatings or sealants to FDM parts can improve ______ and make the parts impermeable.
4. To assemble larger prints that exceed the build volume of a printer, one common method is ______ the parts together.
5. For the smoothest finish during sanding, it is recommended to wet sand from start to finish to prevent ______ and heat from damaging the part.
6. ______ smoothing is a method commonly used for ABS prints to achieve a smooth and shiny surface.

C. Answer the Following

1. Explain why post-processing is essential for FDM prints.
2. What are the pros and cons of using sanding as a post-processing method?
3. Describe the process and benefits of priming and painting an FDM print.
4. How does chemical welding differ from traditional gluing in post-processing?
5. What precautions should be taken when smoothing ABS prints with acetone?
6. Why is polishing an important step in post-processing, and what are its benefits and drawbacks?

Module 4 Working Effectively with others

Module Overview
The module focuses on the importance of teamwork and communication. It covers aspects like team management, teamwork, resolving disputes, and handling conflicts. Students learn essential team-working skills and how to maintain good relationships with colleagues. The module also highlights the significance of building relationships in various settings and the use of diaries and log reports. Understanding the importance of site diaries ensures accurate documentation and smooth workflow in 3D printing projects.

Learning Outcomes
After completing this module, you will be able to: • Develop skills needed for working in a team. • Learn strategies for resolving disputes and managing conflicts within a team.

- Understand the importance of maintaining good relationships with colleagues.

Module Structure

4.1 Team Management
4.2 Team Work
4.3 Resolving Disputes
4.4 Conflict
4.5 Team Working Skills
4.6 Maintaining Good Relationship with colleagues
4.7 Where to build good relationships?
4.8 Diaries and Log reports
4.9 Importance of site diaries

Now that you are skilled in operating a 3D printer efficiently, is skill enhancement your only asset? The answer is NO, because many managerial skills are also required. One crucial skill is the ability to work effectively with others.

A skilled individual can work efficiently on their own, but when many skilled workers collaborate effectively, the quality and precision of the work are significantly elevated. The fundamental skill in both personal and professional contexts, essential for achieving collective goals and fostering a harmonious environment – Working effectively with others. It involves collaboration, communication, and the ability to navigate diverse perspectives and personalities. Effective teamwork is built on mutual respect, trust, and a shared vision. By valuing each team member's contributions and fostering an inclusive atmosphere, teams can leverage individual strengths to achieve superior outcomes.

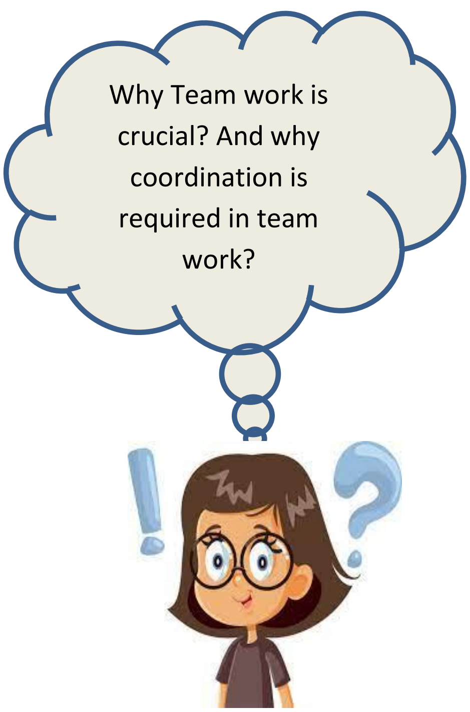
Clear and open communication is critical, ensuring that ideas, expectations, and feedback are exchanged constructively. Active listening, empathy, and adaptability are key components, helping to resolve conflicts and build stronger interpersonal relationships. In professional settings, effective collaboration can drive innovation, enhance productivity, and improve job satisfaction.

Moreover, working well with others involves recognizing and respecting cultural differences and diverse viewpoints. This diversity can be a powerful asset, bringing in varied ideas and approaches that can lead to more creative and effective solutions. Developing these skills requires ongoing effort and a willingness to grow and learn from experiences and interactions. Ultimately, the ability to work effectively with others not only contributes to individual and collective success but also creates a positive and supportive community, fostering a sense of belonging and shared purpose.

4.1 Team Management

There are some tasks which can't be done alone. Teamwork is the collaborative effort of a group to achieve a common goal or to complete a task in the most effective and efficient way. This concept is seen within the greater framework of a team, which is a group of inter dependent individuals who work together towards a common goal. And it should have similar objective and interests. As a plumber you may be employed with a construction company, Maintenance Company or you may free-lance with few others as a team. (Refer Fig. 4.1).

Fig 4.1 Team Management



Let's read a short story!

At Vidya Mandir School, a group of Class 8 students—Rahul, Priya, Aarav, Meena, and Aisha—were assigned to create a science project on sustainable living. Initially, they struggled with different ideas and poor communication. However, they decided to meet regularly, dividing tasks based on their strengths. Rahul handled the technical parts, Priya and Meena worked on the design, Aarav managed the timeline, and Aisha came up with innovative solutions. By listening to each other and working together, they built an impressive model of a sustainable village, showcasing solar energy and rainwater harvesting, winning praise for their teamwork and creativity.

To achieve the set of goals, the team management play major role and with help of different activities which actually bind a team member individually.

Characteristics of a Good/Effective Team

- **Elevating goal:** A goal which has been circulate/communicated with all.
- **Result driven structure**: The target has been combining fixed by all the team members. For getting it, they will fully commit.
- **Competent members**: Obtain the team target, each team member must have the necessary skill set.
- **Unified Commitment**
- **Collaborative Climate:** This will enhance the overall workability of the team members. A better leader can create such to keep their workers highly motivated to achieve their targets.
- **Standards of excellence:** In any organization, quality orientation play vital role to achieve success

4.2 Team Work

To obtain the team objective, sum of the attempts by each team member are called team work. In other words, team work is the backbone of any team**.**

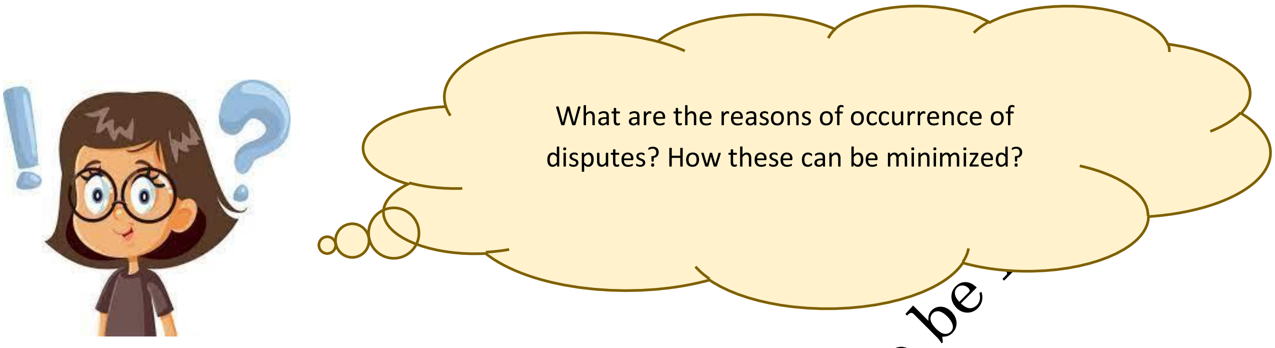
So, let us go through the pornts which every team member should keep in mind for a good team work. Following are such points:

1. Think about your team first.
2. Never underestimate your team member
3. Discuss – Before implementing any new idea, it must be discussed with each and every member on an open platform.
4. Avoid criticism–Stay away from criticism and making fun of your team members. Help each other and be a good team player.
5. Transparency must be maintained and healthy interaction must be promoted among the team members.
6. The team leader must take the responsibility of encouraging the team members to give their level best and should intervene immediately in cases of conflicts.

7. Avoid conflicts in your team. Don’t fight over petty issues and find faults in others. One should be a little adjusting with each other and try to find an alternative best suited to all the team members.
8. Rewards and Recognition – Healthy competition must be encouraged among the team member

4.3 Resolving Disputes

It is defined as an argument or disagreement, especially an official one between, for example, workers and employers or two countries with a common border.



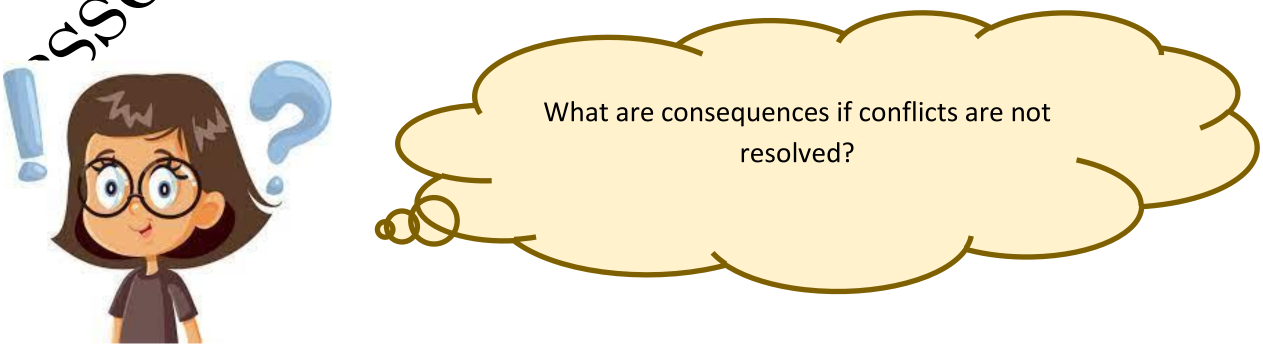
There are two ways of solving a dispute:

(a) Consensual process: Collaborative Law, Conciliation or Negotiation - It is a dialogue between two or more people or parties intended to reach a beneficial outcome.

(b) Litigation: Litigation or arbitration is the costliest and time -consuming way to resolve a dispute. Each party is represented by an attorney while witnesses and evidence are presented. Once all information is provided on the issue, the arbitrator makes a ruling which provides the final decision. The arbitrator provides the final decision on what must be done and it is a binding agreement between each of the disputing parties.

4.4 Conflict

Everyone, rich or poor, young or old, at workplace or even at home, if is in contact with others, faces one kind or the other type of conflict at many points of time. Conflict is a situation in which one person or a group perceives that its interests are being opposed or negatively affected by another person or group. Basically, it is a mismatch in the concerns of people involved in a particular activity.



4.4.1 How you can avoid conflict?

No one wants to be in a conflict situation. By adopting some minor attitudinal changes one can easily avoid conflicts. These are:

- **Focus on solution than problem** - Rather than dwelling on the past happenings and events, talk about how you want things to be.
- **Avoid blaming and criticizing others by using words –** 'you should…., you make me feel……'
- **Never give any personal comments**: If you do not like at any given point of time any action or reaction of any of your colleagues, do not comment on the person, and just talk about the behavior not about the person.
- Offer support and collaboration and make it obvious that you are a part of the solution.
- Recognize the positive intention.

4.4.2 Resolving Conflict

When a team oversteps the mark of healthy difference of opinion, resolving conflict requires respect and patience. There are the following ways of solving a conflict:

- Negotiation
- Mediation
- Arbitration
- Litigation

4.4.3 Preventing Conflict

Following are some tips to keep the conflict situations apart**:**

- **Dealing with conflict immediately** – avoid the temptation to ignore it.
- **Being open** –if people have issues, they need to be expressed immediately and not allowed to fester.
- **Practicing clear communication** – articulate thoughts and ideas clearly.
- **Practicing active listening –** paraphrasing, clarifying, questioning.
- **Practicing identifying assumptions** – asking yourself "why" on a regular basis.
- **Encouraging different points of view –** insist on honest dialogue and expressing feelings.
- **Not looking for blame** – encourage ownership of the problem and solution.
- **Demonstrating respect** – if the situation escalates takes a break and waits for emotions to subside.
- **Keeping team issues within the team** –talking outside allows conflict to build and fester, without being dealt with directly.
- To explore the process of conflict resolution in more depth, take our Bite -Sized Training session on Dealing with Conflict.

4.5 Team Working Skills

Team work is important because it helps us synergize, it complements our individual weaknesses, it does help in productivity and it helps one build new and better skills. Team work is an important part of a working culture. Good team works enhance effective and efficient achievement of an organization's work. Members of a team are more committed to work on goals that they helped to create. The most important thing about team work is that it enables individuals in the team to focus on one main objective. Team work is also important since everyone contributes their unique abilities, which make the result of their objective more diverse. Team work is generally important because it gives everyone a sense of belonging. Various team working skills are mentioned in Fig. 4.2.

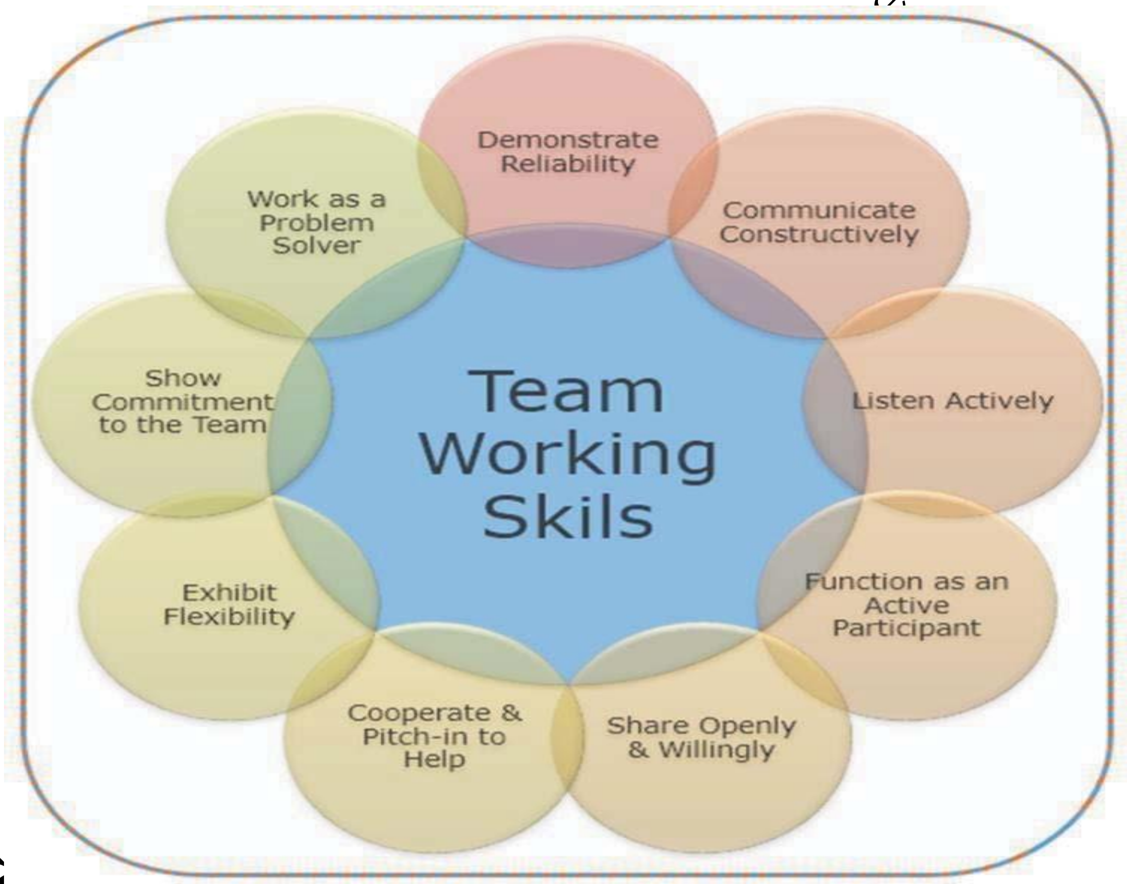


Fig 4.2 Team Working skills

Some of the skills that will help one in working effectively are as follows:

- **Demonstrates Reliability**
  A reliable team member who gets work done and does his fair share to work hard and meet commitments. He or she follows through on assignments. Consistency is key.
- **Communicates Constructively**
  Teams need people who speak up and express their thoughts and ideas clearly, directly, honestly, and with respect for others and for the work of the team. That's what it means to communicate constructively.
  Such a team member does not shy away from making a point but makes it in the best way possible — in a positive, confident, and respectful manner.

- **Listens Actively**
  Good listeners are essential for teams to function effectively.Teams need team players who can absorb, understand, and consider ideas and points of view from other people without debating and arguing every point. Such a team member also can receive criticism without reacting defensively.

- **Functions as an Active Participant**
  Good team players are active participants. They come prepared for team meetings and listen and speak up in discussions. They're fully engaged in the work of the team and do not sit passively on the side lines. Team members who function as active participants take the initiative to help make things happen, and they volunteer for assignments.

- **Shares Openly and Willingly**
  Good team players share. They're willing to share information; knowledge and experience. They take the initiative to keep other team members informed. Much of the communication within teams takes place informally. Beyond discussion at organized meetings, team members need to feel comfortable talking with one another and passing along important news and information day-to-day. Good team players are active in this informal sharing.

- **Cooperates and Pitches – into Help**
  Cooperation is the act of working with others and acting together to accomplish a job. Effective team players work this way by second nature. Good team players, despite differences they may have with other team members concerning style and perspective, figure out ways to work together to solve problems and get work done. They respond to requests for assistance and take the initiative to offer help.

- **Exhibits Flexibility**
  Teams often deal with changing conditions — and often create changes themselves. Good team players roll with the punches; they adapt to ever – changing situations. They don't complain or get stressed out because
  something new is being tried or some new direction is being set. In addition, a flexible team member can consider different points of views and compromise when needed. He or she doesn't hold rigidly to a point of view and argue it to death, especially when the team needs to move forward to decide or get something done. Strong team players are firm in their thoughts yet open to what others have to offer — flexibility at its best.

- **Shows Commitment to the Team**
  Strong team players care about their work, the team, and the team's work. They show up every day with this care and commitment up front.
  They want to give a good effort, and they want other team members to do the same.

- **Works as a Problem Solver**
  Teams, of course, deal with problems. Sometimes, it appears, that's the whole reason why a team is created — to address problems.
  Good team players are willing to deal with all kinds of problems in a solution – oriented manner.
  They're problem - solvers, not problem-dwellers, problem-blamers, or problem - avoiders. They don't simply rehash a problem the way problem – dwellers do. They don't look for others to fault, as the blamers do. And they don't put off dealing with issues, the way avoiders do.

- **Interact with colleagues, seniors within and outside the team**
  Interaction with seniors is extremely essential and should be done with lot of care. Seniors by virtue of a prolonged experience will offer guidance and support, which will also help to improve your skills. Interaction with seniors should be based on the principles of mutual respect and should not confrontational in nature. Good relationships are also often necessary if we hope to develop our careers. After all, if your boss doesn't trust you, it's unlikely that he or she will consider you when a new position opens up. Overall, we all want to work with people we're on good terms with.

4.6 Maintaining good relationship with colleagues

There are several characteristics that make up good, healthy working relationships:

- **Trust** – This is the foundation of every good relationship. If you trust the people you work with, you can be open and honest in your thoughts and actions, and you don't have to waste time and energy "watching your back."
- **Mutual Respect** – When you respect the people that you work with, you value their input and ideas, and they value yours. Working together, you can develop solutions based on your collective insight, wisdom and creativity.
- **Mindfulness**–This means taking responsibility for your words and actions. Those who are mindful are careful and attend to what they say, and they don't let their own negative emotions impact the people around them.
- **Welcoming Diversity** –People with good relationships not only accept diverse people and opinions, but they welcome them. For instance, when your friends and colleagues offer different opinions from yours, you take the time to consider what they have to say, and fact or their insights in to your decision - making.
- **Open Communication** –We communicate all day, whether we're sending emails and IMs, or meeting face – to -face. The better and more effectively you communicate with those around you, the richer your relationships will be. All good relationships depend on open, honest communication.

4.7 Where to build good relationships?

Although we should try to build and maintain good working relationships with everyone, there are certain relationships that deserve extra attention. Now next question arises how to build good work relationships> Here are some suggestions for that:

- Develop your people skills
- Good relationships start with good people skills.
- Schedule time to build relationships

- Appreciate others
- Be positive
- Avoid gossiping
- Listen actively

4.8 Diaries and Log Reports

Importance of log reports

A supervisor is the crew leader on a construction jobsite. It's up to him to plan, organize, and direct work in a safe, and timely, manner. All supervisors will experience conflict at some point, as well as safety violations and work place injuries. By keeping a daily record of all activities, your construction site supervisor can protect your business from arbitration and/or litigation.

4.8.1 What is a Daily Log?

The daily log is a book, or software program, into which a supervisor records the day's activities. Record keeping helps ensure project organization, as well as keeps tabs on day-to-day employee happenings. The daily log is essential because it keeps a consistent record, which could be useful if you're ever sued, and need to prove that your workers performed a safety inspection, or conflict wash and led immediately and efficiently.

Daily log sections include:

- Date and day plan
- Times of incidents
- Work performed
- Safety topics or any safety issue
- Problems and delays
- Employee conflict
- Equipment usage
- Materials purchased
- General management
- Drawing and maps studied with supervisor/team members/self

4.8.2 What is an Incident Report?

In order to understand the incident report, you'll first need to understand what constitutes an incident. There are two types of events that are considered "incidents."

An event that resulted in an injury. For example: An employee is handling materials and suffers a cut to the finger.

An event that resulted in a near-miss, otherwise known as an event that almost resulted in injury or damage. For example: An employee is handling materials and almost suffers a cut to the finger.

4.9 Importance of site diaries

Diaries: Each member of the project team is expected to keep a project diary. The diary contains summaries of the day's events in the member's own words. While interacting with senior's notedown the information, expectation as communicated by the seniors. They are used to keep track of any daily work activity, conversations, observations, or any other relevant information regarding the construction activities. Diaries can be referred to when disputes arise and a diary happens to contain information connected with the disagreement. Hand written diaries can be used as evidence in court.

Logs: Logs keep track of the regular activities on the job site such as phone logs, transmittal logs, delivery logs, and RFI (Request for Information) logs.

Daily Field Reports: Daily field reports are a more formal way of recording information on the job site. They contain information that includes the day's activities, temperature and weather conditions, delivered equipment or materials, visitors on the site, and equipment used that day. We should share these reports with our senior's one daily basis.

- The diaries and daily or other reports are meant to supplement each other and do not need to contain identical information.
- Minimize personal remarks, which may not be factual, about operations or personnel of the Contractor, Agency, or other organization. Such remarks may be used to demonstrate the inspect and was hostile and did not behave in a manner consistent with good faith.
- All entries should be clear, neat, and most importantly, legible.
- Summarize key points of any discussion of work activities with the contractor.

Activities
Activity: Observation of team work in your school/office **Material Required** 1. Notebook 2. Pen or pencil **Procedure** 1. Make a group or team. 2. Give some task to each other and perform as team. 3. Write down all task assign by the other team.

Activity: Prepare a daily log/activity in your school/office

Material Required

1. Notebook
2. Pen or pencil

Procedure

1. Make a book or software.
2. Record the all daily activities.
3. Check daily log sections.
4. Check the performance of the students/employee.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following is NOT a characteristic of a good/effective team?
a) Unified Commitment
b) Competitive Climate
c) Collaborative Climate
d) Standards of Excellence

2. What is the main foundation of a good relationship in a workplace?
a) Open Communication
b) Mindfulness
c) Trust
d) Welcoming Diversity

3. Which method is considered the most costly and time-consuming way to resolve a dispute?
a) Negotiation
b) Mediation
c) Conciliation
d) Litigation

4. Which skill involves taking the initiative to keep other team members informed?
a) Demonstrates Reliability
b) Shares Openly and Willingly

c) Functions as an Active Participant
d) Cooperates and Pitches In

5. What should a supervisor record in the daily log?
a) Personal opinions on team members
b) Plans for future projects
c) Employee conflicts and safety issues
d) Financial statements of the company

B. Fill in the blanks

1. Teamwork is built on mutual respect, trust, and a __________ vision.
2. Active listening, empathy, and adaptability help to resolve conflicts and build stronger __________ relationships.
3. A good team player is willing to deal with all kinds of problems in a __________ -oriented manner.
4. The daily log is essential because it keeps a consistent __________, which could be useful if you're ever sued.
5. Effective teamwork can drive innovation, enhance productivity, and improve job __________.

C. Answer the following questions:

1. What do you mean by Team Management and their importance?
2. Define the term team work?
3. What is a Daily Log?
4. What do you mean by Incident Report?
5. What are the methods of resolving a conflict?
6. What considerations you will keep in mind while resolving a conflict?

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Answer Key

Unit 1: Selection of material for Fused Deposition Modelling

A. Multiple Choice Questions

1. b) Fused Deposition modelling (FDM
2. c) Cura
3. b) They can be melted and solidified repeatedly without undergoing chemical changes.
4. c) PLA
5. d) To remove support structures easily after printing

B. Fill in the blanks

1. 3 or three
2. slicing
3. PLA
4. G-Code
5. Thermosetting

B. Match the following

1. B	2. D
3. A	4. C
5. D	

Unit 2: 3D Printing Operations

A. Multiple Choice Questions

1. b) CAD (Computer-Aided Design)
2. c). STL
3. b) Ultimaker Cura
4. c) Edges of a printed object lifting and curling away from the print bed
5. c) Workplane button
6. c) To download the file in various formats like. STL and .OBJ
7. c) Loose belts or stepper motor issues
8. d) Bottom layers bulging outward

B. Match the following

1. B	2. A
3. D	4. C

C. Fill in the blanks

1. Triangles	2. Automated
3. Cooling	4. Temperature

Unit 3: Post Processing Methods

A. Multiple Choice Questions

1. b) Improving Surface finish
2. b) To chemically bond the parts together
3. c) Foam applicator
4. b) Can damage prints with few perimeter shells
5. b) It provides a base layer for the paint
6. c) Smoothing with acetone

B. Fill in the blanks

1. sanding
2. priming
3. water resistance
4. joining
5. friction
6. Acetone

Unit 4: Working effectively with others

A. Multiple Choice Questions

1. b) Competitive Climate
2. c) Trust
3. d) Litigation
4. b) Shares Openly and Willingly
5. c) Employee conflicts and safety issues

B. Fill in the blanks

1. shared
2. interpersonal
3. solution
4. record
5. satisfaction

Further Readings

1. Atal innovation Mission -3D Printing
   https://aim.gov.in/3D-Printing.php

2. National Centre for Additive manufacturing
   https://ncam.in/