PVP 23

Code: 23ME2603

III B.Tech – II Semester - Regular Examinations – APRIL 2026

ADDITIVE MANUFACTURING

(Common for ALL BRANCHES)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.

2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	What are the advantages of SLA process?	L2	CO1
b)	Write any two applications in liquid based RP processes.	L2	CO1
c)	What are the process parameters that influence FDM process?	L2	CO2
d)	Write any two differences between LOM and SLA.	L2	CO2
e)	List the specifications of 3 dimensional printing (3DP) machine.	L2	CO3
f)	Why is 3DP most trending RP in powder based RP?	L2	CO3
g)	Define direct AIM.	L2	CO4
h)	List some direct rapid tooling techniques.	L2	CO4
i)	What are the general errors that usually generate in STL?	L2	CO5
j)	How does jewellery industry make use of rapid tooling applications?	L2	CO5

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Discuss about photo polymerization.	L2	CO1	5 M
	b)	List and explain the different process parameters of SLA technique.	L2	CO1	5 M
OR					
3	a)	Discuss a case study related to rapid prototyping in industrial applications.	L3	CO1	5 M
	b)	Discuss the classification of RP with a tree diagram.	L3	CO1	5 M
UNIT-II					
4	a)	Explain with a neat sketch the working principle of Fused Deposition Modelling (FDM) process.	L2	CO2	5 M
	b)	Write the materials used and applications of FDM process.	L2	CO2	5 M
OR					
5	a)	Explain the Laminated Object Manufacturing (LOM) process, including models, specifications, advantages and limitations.	L2	CO2	5 M
	b)	Write the case studies of FDM process.	L2	CO2	5 M
UNIT-III					
6	a)	Briefly explain the principle and process details in Selective Laser Sintering (SLS) and its applications with neat sketch.	L3	CO3	5 M

	b)	Discuss the materials, specifications used in SLS process.	L3	CO3	5 M
OR					
7	a)	Briefly explain Three Dimensional Printing (3DP) machine specifications, materials, advantages and disadvantages.	L3	CO3	5 M
	b)	What are the applications of 3D printing in detail?	L2	CO3	5 M
UNIT-IV					
8	a)	What is RT? What is the need of RT and classification of RT in additive manufacturing?	L2	CO4	5 M
	b)	Write any six differences between conventional tooling and rapid tooling.	L3	CO4	5 M
OR					
9	a)	Explain in brief about spray metal deposition indirect RT process.	L2	CO4	5 M
	b)	Discuss the process of making a rapid tool for spin casting. Assume your own example as product.	L3	CO4	5 M
UNIT-V					
10	a)	Explain the differences between valid and invalid tessellated models. Include atleast two examples for each type and discuss the potential impact of using an invalid model in rapid prototyping.	L3	CO5	5 M
	b)	List out the typical RP applications in engineering and analysis. Briefly describe each of them and illustrate them with examples.	L2	CO5	5 M

OR					
11	a)	Discuss about Newly Proposed RP Data Formats.	L3	CO5	5 M
	b)	What are the typical RP applications in aerospace industry?	L2	CO5	5 M

PVP 23

Code: 23ME2603

III B.Tech – II Semester - Regular Examinations – APRIL 2026

ADDITIVE MANUFACTURING
(Common for ALL BRANCHES)

Duration: 3 hours Max. Marks: 70

PART – A

1.a)	**What are the advantages of SLA process?** ➢ Any four advantages of SLA --------------- **4 × 0.5 = 2 Marks**
b)	**Write any two applications in liquid based RP processes.** ➢ Any Two Applications --------------- **2 × 1 = 2 Marks**
c)	**What are the process parameters that influence FDM process?** ➢ Any four FDM parameters --------------- **4 × 0.5 = 2 Marks**
d)	**Write any two differences between LOM and SLA.** ➢ Any two correct differences between LOM and SLA --------------- **2 × 1 = 2 Marks**
e)	**List the specifications of 3 dimensional printing (3DP) machine.** ➢ Any four specifications of 3DP machine --------------- **4 ×0.5 = 2 Marks**
f)	**Why is 3DP most trending RP in powder based RP?** ➢ Any four Reasons --------------- **4 ×0.5 = 2 Marks**
g)	**Define direct AIM.** ➢ Definition **2 Marks**
h)	**List some direct rapid tooling techniques.** ➢ Any four --------------- **4 ×0.5 = 2 Marks**
i)	**What are the general errors that usually generate in STL?** ➢ Any four --------------- **4 ×0.5 = 2 Marks**
j)	How does jewellery industry make use of rapid tooling applications? ➢ Any four --------------- **4 ×0.5 = 2 Marks**

PART – B

2	a)	**Discuss about photo polymerization.** ➢ Definition of photopolymerization **1 M** ➢ Principle / working process **1.5 M** ➢ Chemical reaction / curing explanation **1 M** ➢ Applications **1 M** ➢ Neat sketch / conclusion **0.5 M**	5 M
	b)	**List and explain the different process parameters of SLA technique.** ➢ Introduction to SLA parameters **0.5 M** ➢ Layer thickness **1 M** ➢ Laser power **1 M** ➢ Scan speed / hatch spacing **1 M** ➢ Build orientation / resin properties **1 M** ➢ Diagram / conclusion **0.5 M**	5 M
3	a)	**Discuss a case study related to rapid prototyping in industrial applications.** ➢ Introduction of industrial application **0.5 M** ➢ Product/problem description **1 M** ➢ RP technique used **1 M** ➢ Process explanation **1 M** ➢ Results/advantages obtained **1 M** ➢ Diagram/example/conclusion **0.5 M**	5 M
	b)	**Discuss the classification of RP with a tree diagram.** ➢ Definition/introduction **0.5 M** ➢ Liquid-based RP **1 M** ➢ Solid-based RP **1 M** ➢ Powder-based RP **1 M** ➢ Tree diagram **1 M** ➢ Examples/conclusion **0.5 M**	5 M
4	a)	**Explain with a neat sketch the working principle of Fused Deposition Modelling (FDM) process.** ➢ Definition of FDM **0.5 M** ➢ Principle of operation **1.5 M** ➢ Layer deposition process **1 M** ➢ Components/material flow **1 M** ➢ Neat sketch **1 M**	5 M

	b)	**Write the materials used and applications of FDM process.** ➢ Introduction **0.5 M** ➢ Materials used **2 M** ➢ Applications **2 M** ➢ Conclusion/examples **0.5 M**	5 M
5	a)	**Explain the Laminated Object Manufacturing (LOM) process, including models, specifications, advantages and limitations.** ➢ Definition and principle **1 M** ➢ Process explanation **1 M** ➢ Materials/specifications **1 M** ➢ Advantages **1 M** ➢ Limitations/sketch **1 M**	5 M
	b)	**Write the case studies of FDM process.** ➢ Introduction **0.5 M** ➢ Industrial examples/case studies **3 M** ➢ Benefits/results **1 M** ➢ Conclusion/examples **0.5 M**	5 M
6	a)	**Briefly explain the principle and process details in Selective Laser Sintering (SLS) and its applications with neat sketch.** ➢ Definition of SLS **0.5 M** ➢ Principle and process **2 M** ➢ Materials/components **0.5 M** ➢ Applications **1 M** ➢ Neat sketch **1 M**	5 M
	b)	**Discuss the materials, specifications used in SLS process.** ➢ Introduction **0.5 M** ➢ Materials used **2 M** ➢ Specifications/process parameters **2 M** ➢ Conclusion/examples **0.5 M**	5 M
7	a)	**Briefly explain Three Dimensional Printing (3DP) machine specifications, materials, advantages and disadvantages.** ➢ Definition/principle **0.5 M** ➢ Machine specifications **1.5 M** ➢ Materials used **1 M** ➢ Advantages **1 M** ➢ Disadvantages/sketch **1 M**	5 M
	b)	**What are the applications of 3D printing in detail?** ➢ Introduction **0.5 M** ➢ Industrial applications **3 M** ➢ Advantages/benefits **1 M** ➢ Conclusion/examples **0.5 M**	5 M

8	a)	**What is RT? What is the need of RT and classification of RT in additive manufacturing?** ➢ Definition of RT **1 M** ➢ Need of RT **1.5 M** ➢ Classification **1.5 M** ➢ Tree diagram/examples **1 M**	5 M
	b)	**Write any six differences between conventional tooling and rapid tooling.** ➢ Any six valid differences **5 M**	5 M
9	a)	**Explain in brief about spray metal deposition indirect RT process.** ➢ Definition **1 M** ➢ Working process **2 M** ➢ Advantages/applications **1 M** ➢ Sketch/conclusion **1 M**	5 M
	b)	**Discuss the process of making a rapid tool for spin casting. Assume your own example as product.** ➢ Product example/introduction **0.5 M** ➢ Tool making steps **2.5 M** ➢ Spin casting process **1 M** ➢ Advantages/applications **0.5 M** ➢ Sketch/conclusion **0.5 M**	5 M
10	a)	**Explain the differences between valid and invalid tessellated models. Include atleast two examples for each type and discuss the potential impact of using an invalid model in rapid prototyping.** ➢ Definition of tessellation **0.5 M** ➢ Valid tessellated model **1 M** ➢ Invalid tessellated model **1 M** ➢ Examples **1 M** ➢ Impact in RP/sketch **1.5 M**	5 M
	b)	**List out the typical RP applications in engineering and analysis. Briefly describe each of them and illustrate them with examples.** ➢ Introduction **0.5 M** ➢ Engineering applications **2 M** ➢ Analysis applications **1.5 M** ➢ Examples/illustrations **0.5 M** ➢ Conclusion **0.5 M**	5 M
11	a)	**Discuss about Newly Proposed RP Data Formats.** ➢ Need for new formats **1 M** ➢ AMF format **1 M** ➢ 3MF/STEP/IGES formats **2 M** ➢ Advantages/comparison **0.5 M** ➢ Diagram/conclusion **0.5 M**	5 M

	b)	**What are the typical RP applications in aerospace industry?** ➢ Prototype development **1 M** ➢ Lightweight components **1 M** ➢ Tooling/testing applications **1.5 M** ➢ Satellite/aerospace examples **1.5 M**	5 M

PVP 23

Code: 23ME2603

III B.Tech – II Semester - Regular Examinations – APRIL 2026

ADDITIVE MANUFACTURING

(Common for ALL BRANCHES)

Duration: 3 hours Max. Marks: 70

PART – A

1.a) **What are the advantages of SLA process?** 2M

- High accuracy and excellent surface finish
- Ability to produce complex geometries
- Good detail resolution (fine features possible)
- Transparent parts can be produced
- Faster than traditional prototyping methods

b) **Write any two applications in liquid based RP processes.** 2M

- Concept models and design validation
- Medical models (e.g., surgical planning, dental applications)

c) **What are the process parameters that influence FDM process?** 2M

- Layer thickness
- Extrusion temperature
- Build speed
- Raster angle and orientation
- Air gap
- Support structure design

d) **Write any two differences between LOM and SLA.** 2M

Feature	**LOM (Laminated Object Manufacturing)**	**SLA (Stereolithography)**
Material	Paper/plastic sheets	Liquid photopolymer resin
Process	Layer bonding using adhesive & cutting	UV laser curing of resin

e) **List the specifications of 3 dimensional printing (3DP) machine.** 2M

- Build volume
- Layer thickness/resolution
- Printing speed
- Type of material used (powder, resin, filament)
- Accuracy and tolerance
- Binder type (in powder-based systems)

f) **Why is 3DP most trending RP in powder based RP?** 2M

- Ability to print complex shapes without support structures
- Wide range of materials (metals, ceramics, polymers)
- Faster production for batch parts
- Cost-effective for prototypes and small production runs
- Minimal material wastage

g) **Define direct AIM.** 2M

Direct AIM refers to the use of additive manufacturing processes to directly produce functional end-use parts without requiring tooling or intermediate steps.

h) **List some direct rapid tooling techniques.** 2M

- Direct Metal Laser Sintering (DMLS)
- Selective Laser Melting (SLM)
- Electron Beam Melting (EBM)
- Laser Engineered Net Shaping (LENS)

i) **What are the general errors that usually generate in STL?** 2M

- Faceting errors (poor surface approximation)
- Gaps or holes in the model
- Overlapping or intersecting triangles
- Incorrect normal orientation
- Non-manifold edges

j) **How does jewelry industry make use of rapid tooling applications?** 2M

- Creation of intricate wax patterns for casting
- Rapid production of customized designs
- Reduced lead time for new collections
- High precision detailing for complex ornaments
- Cost-effective small batch production

PART – B

2 a) **Discuss about photo polymerization.** 5 M

Definition

Photopolymerization is a process in which a liquid resin or monomer changes into a solid polymer when exposed to light energy, usually **ultraviolet (UV) light** or visible light.

It is widely used in:

- 3D printing / Additive Manufacturing
- Dental fillings
- Coatings and inks
- Microelectronics
- Adhesives

Principle of Photopolymerization

The liquid photopolymer resin contains:

1. **Monomers/Oligomers** – basic building blocks
2. **Photoinitiator** – chemical that absorbs light
3. **Additives** – pigments, stabilizers, fillers

When UV light falls on the resin:

- The photoinitiator absorbs light energy
- Free radicals or ions are generated
- Polymer chains start forming
- Liquid resin becomes solid

Working Process

Step 1: Exposure to UV Light

UV laser or UV lamp is directed onto liquid resin.

Step 2: Initiation

Photoinitiator absorbs light and forms reactive species.

Step 3: Propagation

Monomer molecules join together to form long polymer chains.

Step 4: Termination

Reaction stops after polymer network formation.

Chemical Reaction

General reaction:

$$\text{Monomer} + \text{UV Light} \rightarrow \text{Polymer}$$

Types of Photopolymerization

1. Free Radical Photopolymerization

- Most common method
- Fast curing
- Used in stereolithography (SLA)

Advantages

- High speed
- Low cost

Limitation

- Oxygen inhibition may occur

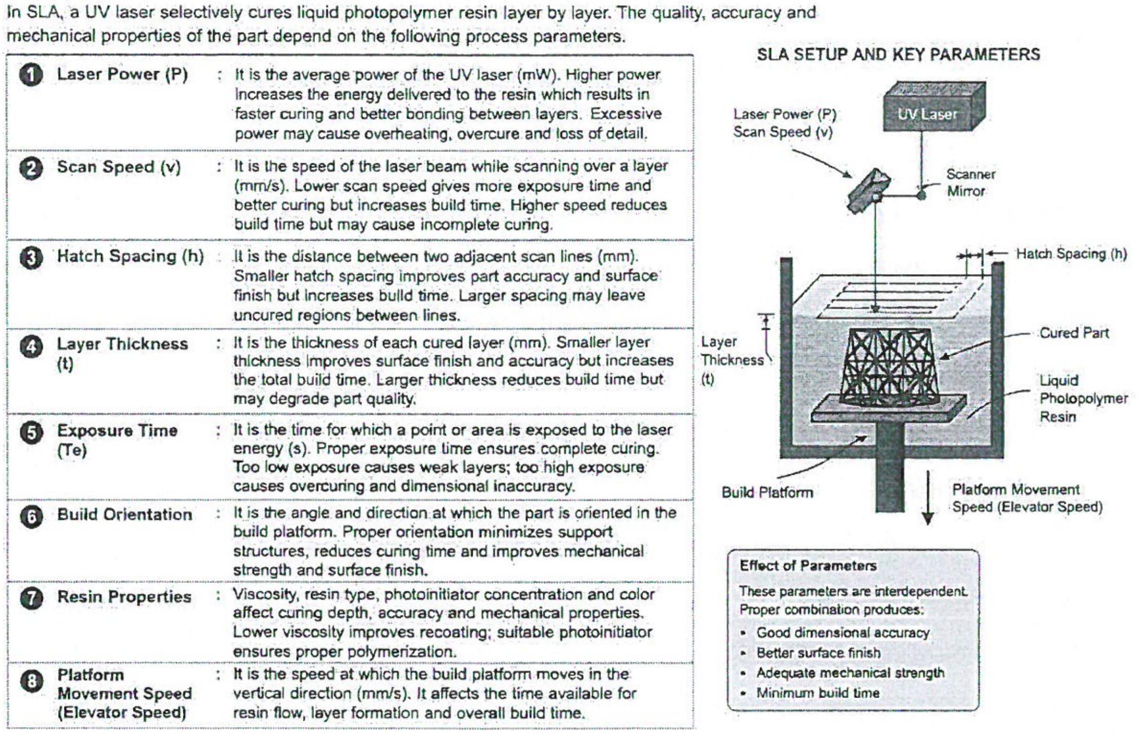
2. Cationic Photopolymerization

- Uses cations instead of free radicals
- Better mechanical properties
- Less shrinkage

Applications

- Coatings
- Electronics

b) List and explain the different process parameters of SLA technique. 5 M



In SLA, a UV laser selectively cures liquid photopolymer resin layer by layer. The quality, accuracy and mechanical properties of the part depend on the following process parameters.

❶	**Laser Power (P)**	It is the average power of the UV laser (mW). Higher power increases the energy delivered to the resin which results in faster curing and better bonding between layers. Excessive power may cause overheating, overcure and loss of detail.
❷	**Scan Speed (v)**	It is the speed of the laser beam while scanning over a layer (mm/s). Lower scan speed gives more exposure time and better curing but increases build time. Higher speed reduces build time but may cause incomplete curing.
❸	**Hatch Spacing (h)**	It is the distance between two adjacent scan lines (mm). Smaller hatch spacing improves part accuracy and surface finish but increases build time. Larger spacing may leave uncured regions between lines.
❹	**Layer Thickness (t)**	It is the thickness of each cured layer (mm). Smaller layer thickness improves surface finish and accuracy but increases the total build time. Larger thickness reduces build time but may degrade part quality.
❺	**Exposure Time (Te)**	It is the time for which a point or area is exposed to the laser energy (s). Proper exposure time ensures complete curing. Too low exposure causes weak layers; too high exposure causes overcuring and dimensional inaccuracy.
❻	**Build Orientation**	It is the angle and direction at which the part is oriented in the build platform. Proper orientation minimizes support structures, reduces curing time and improves mechanical strength and surface finish.
❼	**Resin Properties**	Viscosity, resin type, photoinitiator concentration and color affect curing depth, accuracy and mechanical properties. Lower viscosity improves recoating; suitable photoinitiator ensures proper polymerization.
❽	**Platform Movement Speed (Elevator Speed)**	It is the speed at which the build platform moves in the vertical direction (mm/s). It affects the time available for resin flow, layer formation and overall build time.

SLA SETUP AND KEY PARAMETERS

Effect of Parameters

These parameters are interdependent. Proper combination produces:

- Good dimensional accuracy
- Better surface finish
- Adequate mechanical strength
- Minimum build time

3 a) **Discuss a case study related to rapid prototyping in industrial applications.** 5 M

Rapid Prototyping (RP) is widely used in industries to quickly manufacture prototype models directly from CAD data. It reduces product development time, improves design accuracy, and lowers manufacturing cost.

This case study explains how an automobile company used **Stereolithography (SLA)** rapid prototyping technology to develop and test an **engine intake manifold** before mass production.

Problem Statement

An automobile manufacturer wanted to:

- Develop a new intake manifold design
- Reduce product development time
- Test airflow performance before manufacturing metal tooling
- Minimize design errors and production cost

Traditional machining methods required:

- High tooling cost
- Long manufacturing time
- Multiple redesign cycles

Hence, the company adopted **Rapid Prototyping**.

Rapid Prototyping Technique Used

Stereolithography (SLA)

In SLA:

A UV laser cures liquid photopolymer resin layer by layer.

CAD model is converted into STL format.

Prototype is fabricated automatically.

Working Procedure

Step 1: CAD Model Creation

Engineers designed the intake manifold using CAD software.

Step 2: STL Conversion and Slicing

The CAD model was converted into STL format and sliced into thin layers.

Step 3: Prototype Fabrication

The SLA machine produced the intake manifold prototype layer by layer using UV laser curing.

Testing Performed

The prototype was tested for:

- Airflow characteristics
- Dimensional accuracy
- Assembly fitting

- Surface finish
- Thermal behavior

Engineers identified design defects and modified the design quickly.

Results Achieved

Parameter	Traditional Method	Rapid Prototyping
Prototype Time	6–8 weeks	3–5 days
Development Cost	High	Reduced
Design Flexibility	Limited	Excellent
Design Modifications	Difficult	Easy
Product Accuracy	Moderate	High

Benefits Obtained

1. Reduced Development Time

Prototype was produced within days instead of weeks.

2. Lower Manufacturing Cost

No expensive tooling was required during design validation.

3. Improved Product Quality

Design errors were detected early.

4. Faster Design Iterations

Multiple prototype versions were tested quickly.

5. Better Communication

Physical models helped engineers and clients visualize the product.

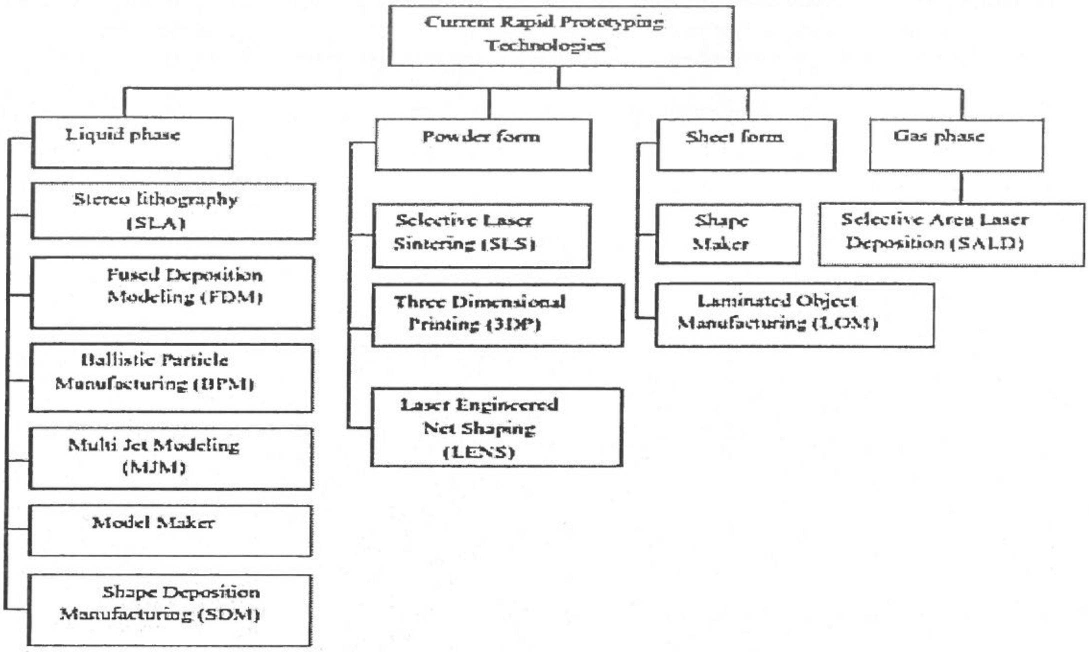
b) Discuss the classification of RP with a tree diagram. 5 M

Rapid Prototyping (RP) is a group of advanced manufacturing technologies used to create physical models directly from CAD data in a short time. RP processes are classified based on the method used for material addition and layer formation.

Classification of Rapid Prototyping

Rapid Prototyping processes are mainly classified into:

1. **Liquid-Based RP Systems**
2. **Solid-Based RP Systems**
3. **Powder-Based RP Systems**



4 a) **Explain with a neat sketch the working principle of Fused Deposition Modelling (FDM) process.** **5 M**

Fused Deposition Modelling (FDM) is a solid-based Rapid Prototyping (RP) process in which a thermoplastic material is melted and deposited layer by layer to create a 3D object directly from CAD data.

It is one of the most widely used 3D printing technologies due to its:

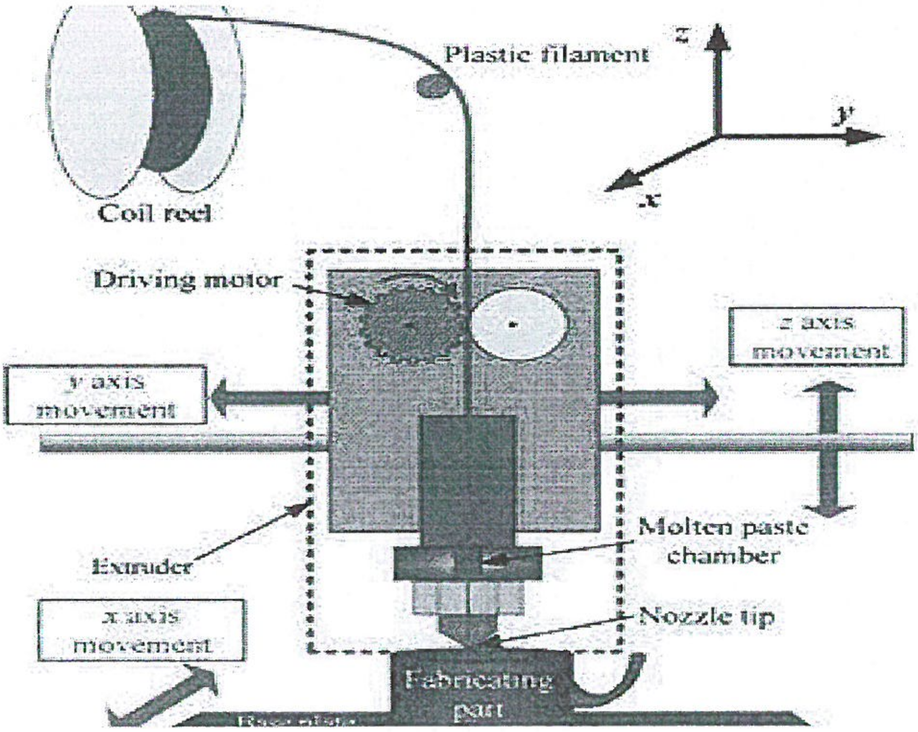
- Simplicity
- Low cost
- Ease of operation

Common materials used:

- ABS
- PLA
- Nylon
- Polycarbonate

Working Principle of FDM

In FDM, a thermoplastic filament is fed into a heated nozzle where it melts. The molten material is extruded through the nozzle and deposited layer by layer on a build platform according to CAD data. After one layer is completed, the platform moves downward and the next layer is deposited until the complete part is formed.



Step-by-Step Working Procedure

Step 1: CAD Model Preparation

- The component is designed using CAD software.
- Model is converted into STL format.

Step 2: Slicing

- STL file is sliced into thin layers using slicing software.

Step 3: Material Feeding

- Thermoplastic filament from spool is fed into the heated nozzle.

Step 4: Melting and Extrusion

- Nozzle heats the filament above melting temperature.
- Molten material is extruded through nozzle tip.

Step 5: Layer-by-Layer Deposition

- Extruder moves in X-Y direction and deposits material.
- Material solidifies immediately after deposition.

Step 6: Platform Movement

- Build platform moves downward after completion of each layer.
- Next layer is deposited over previous layer.

Step 7: Final Part Formation

- Repeated deposition forms the complete 3D object.

b) **Write the materials used and applications of FDM process.** **5 M**

Materials Used in Fused Deposition Modelling (FDM)

In the **Fused Deposition Modelling (FDM)** process, thermoplastic materials in filament form are used as raw materials. These materials are melted and deposited layer by layer to build the component.

Common Materials Used in FDM

Material	**Properties**	**Applications**
ABS (Acrylonitrile Butadiene Styrene)	Strong, durable, heat resistant	Automotive parts, functional prototypes
PLA (Polylactic Acid)	Biodegradable, easy to print	Educational models, prototypes
Nylon	Tough, flexible, wear resistant	Gears, machine components
Polycarbonate (PC)	High strength and heat resistance	Engineering applications
TPU (Thermoplastic Polyurethane)	Flexible and elastic	Rubber-like products
PETG (Polyethylene Terephthalate Glycol)	Good strength and chemical resistance	Food containers, mechanical parts
PVA (Polyvinyl Alcohol)	Water-soluble support material	Support structures
ULTEM	High temperature resistance	Aerospace and medical applications

---

Characteristics of FDM Materials

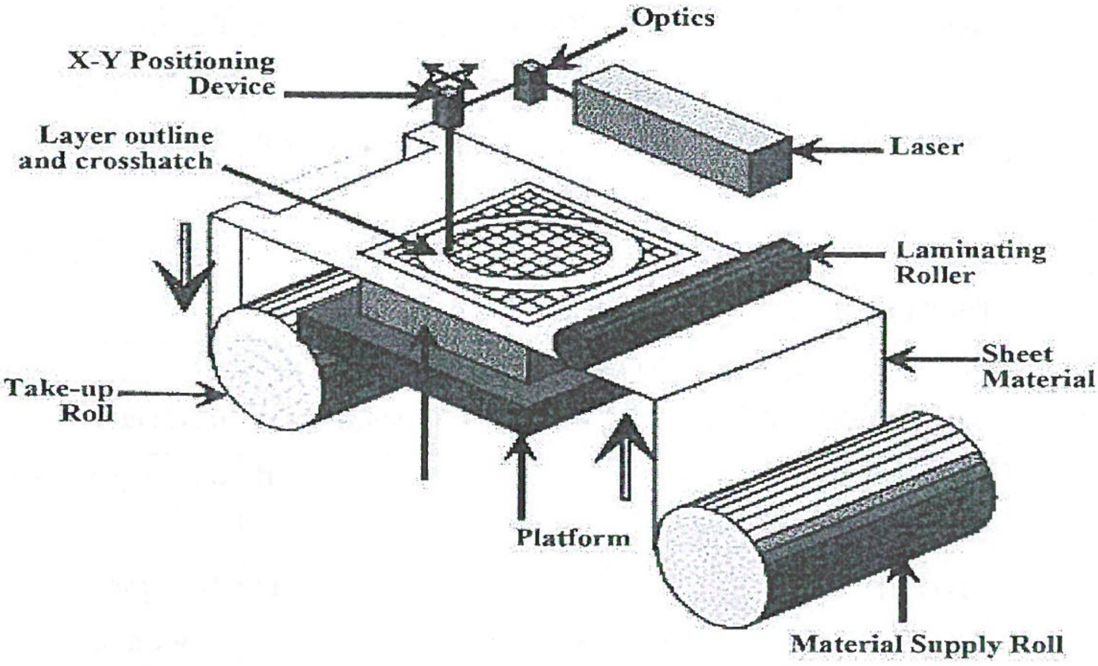
- Available in filament form
- Easy to melt and solidify
- Recyclable in some cases
- Different materials provide different mechanical properties

5 a) **Explain the Laminated Object Manufacturing (LOM) process, including models, specifications, advantages and limitations.** 5 M

Laminated Object Manufacturing (LOM) is a solid-based Rapid Prototyping (RP) process in which thin sheets of material such as paper, plastic, or metal are bonded layer by layer and cut according to the cross-sectional shape of the component.

Working Principle of LOM

1. A thin sheet of material is placed over the build platform.
2. Heated roller bonds the sheet to the previous layer.
3. Laser beam cuts the outline of the required shape.
4. Unwanted portions are cross-hatched for easy removal.
5. Platform moves downward and next sheet is laminated.
6. Process continues until the final part is formed.



Models / Materials Used in LOM

The following sheet materials are commonly used:

- Paper sheets
- Plastic sheets
- Metal foils
- Ceramic sheets
- Composite laminates

Specifications of LOM

Specification	Typical Value
Layer thickness	0.05 – 0.5 mm
Materials used	Paper, plastic, metal
Energy source	Laser beam
Build speed	Moderate to high
Accuracy	Medium
Surface finish	Moderate

Advantages of LOM

1. Low material cost
2. Faster fabrication for large parts
3. Minimal material wastage
4. No need for support structures
5. Suitable for large-sized models

Limitations of LOM

1. Lower dimensional accuracy
2. Poor surface finish compared to SLA
3. Difficulty in producing very complex shapes
4. Limited material strength
5. Post-processing may be required

Applications of LOM

- Concept models
- Architectural models
- Casting patterns
- Engineering prototypes
- Educational models

b) Write the case studies of FDM process. **5 M**

Case Study 1: Automotive Industry

Problem

An automobile company wanted to develop a new dashboard design quickly and economically.

Solution Using FDM

- CAD model of the dashboard was created.
- ABS material was used in the FDM machine.

- Prototype was fabricated layer by layer.

Results

- Prototype developed within 2 days
- Reduced design cost
- Easy modification of design
- Improved product development speed

Benefits

- Faster product testing
- Reduced tooling cost
- Better communication between designers and engineers

Case Study 2: Medical Industry

Problem

Doctors required patient-specific anatomical models for surgical planning.

Solution Using FDM

- CT scan data was converted into 3D CAD model.
- PLA material was used for printing.
- Exact human organ models were produced.

Results

- Improved surgical accuracy
- Reduced operation time
- Better understanding of complex anatomy

Applications

- Bone models
- Dental models
- Prosthetic components

Case Study 3: Aerospace Industry

Problem

An aerospace company needed lightweight prototype components for testing.

Solution Using FDM

- High-strength thermoplastic material like ULTEM was used.
- Functional prototype parts were manufactured.

Results

- Reduced manufacturing time
- Lightweight components obtained

- Cost-effective testing before final production

Benefits

- Material savings
- Faster design iterations
- Improved component performance

6 a) **Briefly explain the principle and process details in Selective Laser Sintering (SLS) and its applications with neat sketch.** **5 M**

Selective Laser Sintering (SLS) is a powder-based Rapid Prototyping (RP) process in which a high-power laser selectively fuses powdered material layer by layer to produce a solid 3D component directly from CAD data.

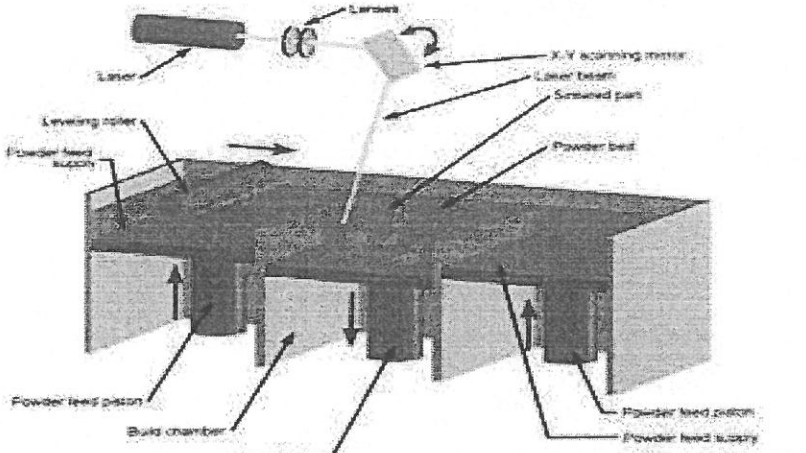
The laser heats the powder particles just below their melting point and bonds them together by sintering.

Principle of SLS

The principle of SLS is based on:

- Spreading a thin layer of powder material
- Selective sintering of powder using laser energy
- Layer-by-layer fabrication of the component

When the laser beam scans the powder surface, the powder particles fuse together to form the required cross-sectional shape.



Copyright © 2008 CustomPartNet

Working Process of SLS

Step 1: CAD Model Preparation

- 3D model is created using CAD software.
- Model is converted into STL format.

Step 2: Layer Slicing

- STL model is sliced into thin layers.

Step 3: Powder Deposition

- Powder supply piston raises powder material.
- Roller spreads a thin powder layer over build platform.

Step 4: Laser Sintering

- Laser beam scans selected areas.
- Powder particles fuse together according to CAD data.

Step 5: Layer Formation

- Build platform moves downward after each layer.
- New powder layer is spread.

Step 6: Repetition

- Process repeats until the complete part is formed.

Step 7: Part Removal

- Finished component is removed from unsintered powder.
- Cleaning and finishing operations are performed.

Materials Used in SLS

- Nylon
- Polyamide
- Polystyrene
- Metal powders
- Ceramic powders
- Glass-filled materials

Advantages of SLS

1. No support structures required
2. Can produce complex geometries
3. High material utilization
4. Good mechanical strength
5. Suitable for functional prototypes

Limitations of SLS

1. Expensive equipment

2. Rough surface finish
3. High power consumption
4. Post-processing required

Applications of SLS

Automotive Industry

- Engine components
- Air ducts
- Functional prototypes

Aerospace Industry

- Lightweight structural parts
- Complex aircraft components

Medical Industry

- Prosthetics
- Orthopedic implants
- Customized medical devices

Consumer Products

- Sports equipment
- Electronic housings
- Customized products

Tooling Applications

- Casting patterns
- Jigs and fixtures

b) **Discuss the materials, specifications used in SLS process.** 5 M

Selective Laser Sintering (SLS) is a powder-based Rapid Prototyping (RP) process in which powdered material is fused layer by layer using a laser beam to produce 3D components.

The performance of SLS mainly depends on:

- Type of material used
- Process specifications and parameters

Materials Used in SLS Process

In SLS, powdered materials are used. These materials should possess:

- Good thermal stability
- Proper particle size

- Good flow characteristics
- Ability to sinter under laser energy

1. Plastic Materials

a) Nylon (Polyamide)

- Most commonly used SLS material
- Good strength and flexibility
- Suitable for functional prototypes

Applications

- Automotive parts
- Consumer products

b) Polystyrene

- Easy to process
- Used for concept models

c) Glass-Filled Nylon

- Improved stiffness and strength
- Better thermal resistance

2. Metal Materials

a) Stainless Steel

- High strength
- Corrosion resistance

Applications

- Tooling components
- Engineering parts

b) Titanium

- Lightweight and strong
- Biocompatible

Applications

- Aerospace components
- Medical implants

c) Aluminum

- Lightweight material
- Good thermal conductivity

3. Ceramic Materials

- High temperature resistance
- Used for specialized engineering applications

Applications

- Heat-resistant components
- Electronic parts

4. Composite Materials

Examples:

- Carbon fiber reinforced powders
- Metal-ceramic composites

Advantages

- Improved mechanical properties
- Reduced weight

Specifications Used in SLS Process

The following process parameters/specifications affect the quality of SLS parts.

1. Layer Thickness

- Typical range: **0.05 mm to 0.15 mm**
- Thin layers improve accuracy and surface finish.

2. Laser Power

- CO_2 laser commonly used
- Typical power range: **25 W to 100 W**

Higher laser power increases sintering efficiency.

3. Scan Speed

- Determines laser movement speed over powder bed.
- Affects bonding strength and build time.

4. Powder Particle Size

- Typical size: **20–100 microns**
- Smaller particles improve surface finish.

5. Build Temperature

- Powder bed is heated near melting temperature.
- Reduces thermal distortion.

6. Build Volume

Typical machine size varies depending on application.

Example:

- 300 × 300 × 400 mm

7. Accuracy

- Typical dimensional accuracy: ±0.1 mm to ±0.3 mm

8. Surface Finish

- Surface roughness depends on powder size and laser settings.
- Usually rougher than SLA parts.

Important Specifications of SLS

Parameter	**Typical Value**
Layer Thickness	0.05 – 0.15 mm
Laser Type	CO_2 Laser
Laser Power	25 – 100 W
Powder Size	20 – 100 μm
Accuracy	±0.1 to ±0.3 mm
Build Temperature	Near melting point

7 a) **Briefly explain Three Dimensional Printing (3DP) machine specifications, materials, advantages and disadvantages.** 5 M

Three Dimensional Printing (3DP) is a powder-based Rapid Prototyping (RP) process in which a liquid binder is selectively sprayed onto layers of powder material to create a three-dimensional object layer by layer.

The process is similar to inkjet printing, but instead of ink on paper, binder is deposited on powder material.

Working Principle of 3DP

1. A thin layer of powder is spread over the build platform.
2. Inkjet print head sprays binder onto selected regions.
3. Powder particles bond together where binder is applied.
4. Build platform lowers after each layer.
5. New powder layer is spread and process repeats.
6. Final part is removed from loose powder.

Machine Specifications of 3DP

Specification	**Typical Value**
Layer Thickness	0.05 – 0.20 mm
Build Speed	High
Accuracy	Moderate
Build Material	Powder
Binder Type	Liquid adhesive
Build Volume	Depends on machine size
Printing Method	Inkjet deposition

Materials Used in 3DP

Various powder materials are used in 3DP process.

1. Plaster Powder

- Commonly used for concept models

2. Ceramic Powder

- Used for heat-resistant components

3. Metal Powder

Examples:

- Stainless steel
- Titanium
- Aluminum

Applications:

- Engineering parts
- Aerospace components

4. Polymer Powders

Examples:

- Nylon

- Polyamide

Used for functional prototypes.

5. Composite Materials

- Powder mixed with binders or fibers
- Improved mechanical properties

Advantages of 3DP

1. Fast manufacturing process
2. Low material wastage
3. Ability to produce complex geometries
4. No special tooling required
5. Multiple materials can be used
6. Suitable for colored prototypes

Disadvantages of 3DP

1. Lower mechanical strength
2. Rough surface finish
3. Post-processing required
4. Accuracy lower than SLA
5. Powder handling difficulties

Applications of 3DP

- Product development
- Medical models
- Architectural models
- Aerospace prototypes
- Automotive components
- Casting patterns

b) **What are the applications of 3D printing in detail?** 5 M

Major Applications of 3D Printing

1. Automotive Industry

3D printing is extensively used in automobile manufacturing for rapid prototyping and production of lightweight components.

Applications

- Engine components
- Dashboard prototypes
- Air ducts

- Custom spare parts
- Tooling and fixtures

Advantages

- Faster product development
- Reduced design cycle time
- Easy customization

Example

Car manufacturers print prototype vehicle parts before mass production.

2. Aerospace Industry

Aerospace industries use 3D printing for manufacturing lightweight and complex parts.

Applications

- Turbine blades
- Aircraft brackets
- Fuel nozzles
- Lightweight structural parts

Advantages

- Weight reduction
- Fuel efficiency improvement
- Reduced material wastage

Example

Aircraft companies manufacture titanium parts using metal 3D printing.

3. Medical and Healthcare Industry

One of the most important applications of 3D printing is in healthcare.

Applications

- Prosthetic limbs
- Dental implants
- Hearing aids
- Surgical instruments
- Anatomical models
- Customized implants

Advantages

- Patient-specific products
- Improved surgical planning
- Reduced medical costs

Example

Doctors use 3D printed heart and bone models before surgery.

4. Education and Research

Educational institutions use 3D printing for practical learning and innovation.

Applications

- Engineering models
- Science experiments
- Research prototypes
- Student projects

Advantages

- Hands-on learning
- Improved creativity
- Better visualization

5. Architecture and Construction

Architects use 3D printing for developing detailed building models.

Applications

- Building prototypes
- Interior design models
- Bridge models
- Construction components

Advantages

- Accurate visualization
- Reduced model preparation time

Example

Miniature building models are created for client presentations.

6. Consumer Products

3D printing is used for customized and low-volume consumer goods.

Applications

- Mobile covers
- Toys
- Jewelry
- Household items
- Footwear

Advantages

- Product personalization
- Fast production

7. Manufacturing and Tooling

Industries use 3D printing for manufacturing aids and tooling.

Applications

- Jigs and fixtures
- Molds and dies
- Casting patterns
- Functional prototypes

Advantages

- Reduced tooling cost
- Faster manufacturing setup

8. Défense and Military Applications

3D printing helps produce lightweight and emergency replacement parts.

Applications

- Weapon components
- Drone parts
- Customized equipment
- Spare parts in remote locations

9. Food Industry

Specialized 3D printers can print edible food items.

Applications

- Chocolates
- Cakes
- Customized food shapes

10. Fashion and Jewelry Industry

Used for creating artistic and customized products.

Applications

- Jewelry models
- Fashion accessories
- Designer footwear

11. Electronics Industry

3D printing is used in electronic product development.

Applications

- PCB prototypes
- Electronic casings
- Sensor housings

12. Bio-Printing Applications

Advanced 3D printing can print biological tissues.

Applications

- Artificial skin
- Tissue engineering
- Organ research

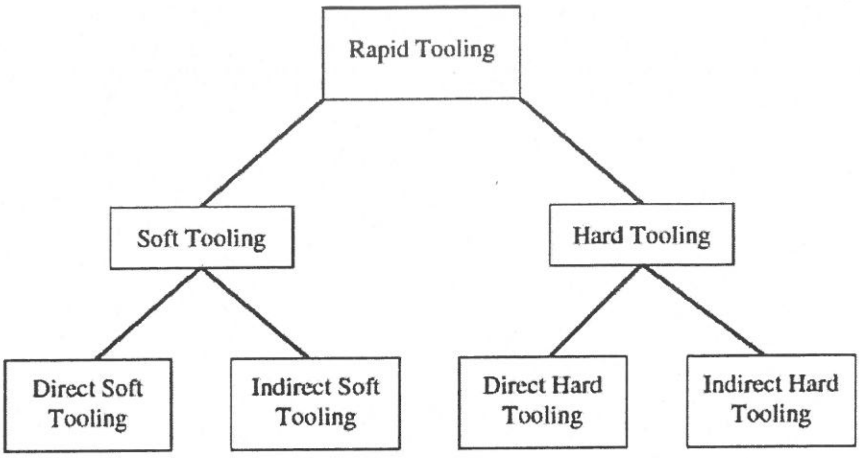
8 a) **What is RT? What is the need of RT and classification of RT in additive manufacturing?** 5 M

Rapid Tooling (RT) is the process of quickly manufacturing molds, dies, and tooling components using Rapid Prototyping (RP) or Additive Manufacturing (AM) techniques.
It reduces tooling time and manufacturing cost.

Need for Rapid Tooling (RT)

1. **Reduces product development time**
   - Tools can be manufactured quickly.
2. **Reduces manufacturing cost**
   - Less machining and tooling operations are required.
3. **Easy design modifications**
   - CAD model changes can be implemented easily.
4. **Produces complex shapes**
   - Complex tooling geometries can be manufactured.
5. **Suitable for prototype and small batch production**
   - Useful for customized products.

Classification of Rapid Tooling (RT)



Classification of Rapid Tooling

Rapid Tooling is classified into:

1. Indirect Rapid Tooling

In this method, RP models are first produced and then used to make tooling.

Examples

- RTV epoxy tooling
- Investment casting
- Spray metal tooling

2. Direct Rapid Tooling

In this method, tools are directly manufactured using additive manufacturing processes.

Examples

- Direct metal tooling
- Direct AIM
- LOM tools

b) Write any six differences between conventional tooling and rapid tooling. 5 M

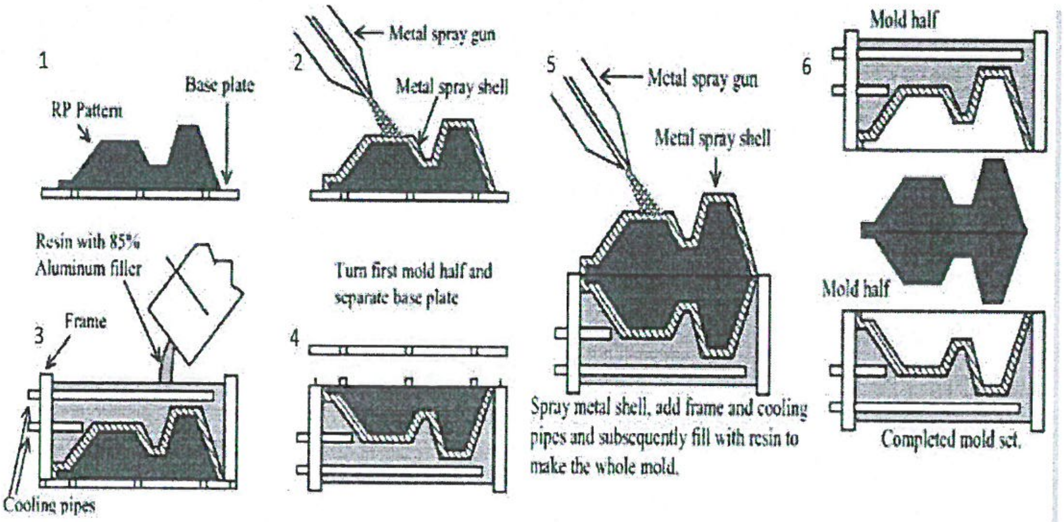
Conventional Tooling	Rapid Tooling
1. Tool manufacturing takes more time.	1. Tool manufacturing is very fast.
2. Uses conventional machining methods.	2. Uses additive manufacturing/RP techniques.
3. High manufacturing cost.	3. Lower tooling cost for prototypes.
4. Difficult to modify tool design.	4. Easy to modify using CAD data.
5. More material wastage occurs.	5. Minimal material wastage.

6. Suitable for mass production.	6. Suitable for prototype and small batch production.

9 a) **Explain in brief about spray metal deposition indirect RT process.** 5 M

Spray Metal Deposition is an **indirect rapid tooling (RT)** process in which molten metal is sprayed over a rapid prototype pattern to produce a metallic tooling surface.

It is mainly used for making molds, dies, and tooling inserts.



Working Principle

1. A master pattern is first produced using a Rapid Prototyping process.
2. Molten metal is sprayed onto the pattern surface using a spray gun.
3. Metal coating forms a shell around the pattern.
4. The metal shell is backed with epoxy or other support material.
5. Finally, the pattern is removed to obtain the tool cavity.

Process Steps

1. Prepare RP master pattern
2. Apply release agent
3. Spray molten metal on pattern
4. Build metal shell thickness
5. Fill backing material
6. Remove master pattern

Advantages

- Faster tooling production
- Good surface finish
- Lower tooling cost

- Suitable for prototype molds

Limitations

- Limited tool life
- Not suitable for very high-temperature applications
- Accuracy depends on spraying quality

Applications

- Injection molding dies
- Casting molds
- Prototype tooling
- Vacuum forming tools

b) **Discuss the process of making a rapid tool for spin casting. Assume your own example as product.** 5 M

Spin casting is a manufacturing process used to produce small and intricate components by pouring molten material into a rotating mold. Rapid tooling techniques are used to quickly manufacture molds for spin casting applications.

Example Product

Product Chosen:

Toy Car Wheel

A rapid tool is prepared for producing small toy car wheels using spin casting.

Process of Making Rapid Tool for Spin Casting

Step 1: CAD Model Preparation

- The toy wheel is designed using CAD software.
- Model is converted into STL format.

CAD Model → STL File

Step 2: Rapid Prototype Creation

- Prototype model of the wheel is fabricated using RP process such as:
    - SLA
    - FDM

This prototype acts as the master pattern.

Step 3: Mold Preparation

- Silicone rubber material is poured around the prototype.
- Mold is cured and hardened.

Step 4: Mold Cutting

- Mold is cut carefully into two halves.
- Runner and gate systems are prepared.

Step 5: Mounting in Spin Casting Machine

- Mold is mounted on rotating spin casting machine.

Step 6: Molten Material Pouring

- Molten metal/plastic/resin is poured into the rotating mold.
- Centrifugal force distributes material into all cavities.

Step 7: Cooling and Part Removal

- Mold is cooled.
- Finished toy wheel components are removed.

Materials Used

- Silicone rubber molds
- Zinc alloy
- Resin
- Low melting point metals

Advantages

1. Fast mold production
2. Low tooling cost
3. Suitable for small components
4. Good surface finish
5. Ideal for low-volume production

Limitations

1. Limited mold life
2. Not suitable for large products
3. Only low melting point materials can be used

Applications

- Toy parts
- Jewelry
- Decorative items
- Small engineering components
- Prototype products

10 a) **Explain the differences between valid and invalid tessellated models. Include atleast two examples for each type and discuss the potential impact of using an invalid model in rapid prototyping.** 5 M

A **tessellated model** is a 3D model represented using small triangular surfaces. In Rapid Prototyping and Additive Manufacturing, CAD models are converted into tessellated models such as STL files for fabrication.

A tessellated model may be:

1. **Valid tessellated model**
2. **Invalid tessellated model**

Valid Tessellated Model

A valid tessellated model is a properly formed 3D model in which all triangles are correctly connected without gaps or overlaps.

Characteristics

- Closed surface geometry
- No missing triangles
- Correct normal directions
- No overlapping surfaces
- Watertight model

Examples of Valid Models

Example 1: Solid Cube

- All triangular faces are properly connected.
- No holes or gaps exist.

Example 2: Cylindrical Part

- Entire curved surface is fully enclosed with triangles.

Invalid Tessellated Model

An invalid tessellated model contains errors in the triangular mesh, making it unsuitable for rapid prototyping.

Characteristics

- Holes or gaps in mesh
- Overlapping triangles
- Incorrect normal orientation
- Open boundaries
- Duplicate surfaces

Examples of Invalid Models

Example 1: Model with Missing Surface

- Some triangles are absent, creating holes.

Example 2: Overlapping Geometry

- Two surfaces intersect improperly.

Differences Between Valid and Invalid Tessellated Models

Valid Model	**Invalid Model**
Fully closed geometry	Contains gaps or holes
Correct triangle connections	Improper triangle connections
Suitable for RP processes	Causes RP errors
Proper surface normals	Incorrect normal directions
Accurate fabrication possible	Defective fabrication occurs
No overlapping surfaces	Overlapping/intersecting surfaces present

Impact of Using Invalid Model in Rapid Prototyping

Using an invalid tessellated model can create several manufacturing problems.

6. **Printing Errors**

- RP machine may fail during fabrication.

7. **Defective Parts**

- Holes and missing regions may appear in final product.

8. **Poor Surface Quality**

- Surface irregularities occur due to mesh defects.

9. **Dimensional Inaccuracy**

- Final part dimensions may differ from CAD design.

10. **Increased Manufacturing Time**

- Additional repair and correction steps are required.

11. **Material Wastage**

- Failed builds increase material consumption.

b) **List out the typical RP applications in engineering and analysis. Briefly describe each of them and illustrate them with examples.** 5 M

Rapid Prototyping (RP) is widely used in engineering and analysis for quick product development, testing, design verification, and manufacturing support. It helps reduce development time, cost, and design errors.

Typical RP Applications

1. Concept Modeling

Description

RP is used to create physical models of product concepts directly from CAD designs.

Purpose

- Visualize product appearance
- Verify shape and size

Example

- Mobile phone prototype
- Automobile body model

2. Functional Prototyping

Description

Functional prototypes are manufactured to test working performance and assembly.

Purpose

- Evaluate mechanical function
- Test fit and operation

Example

- Gear mechanism
- Engine air duct

3. Design Verification

Description

RP models help engineers verify product design before mass production.

Purpose

- Detect design errors
- Improve product quality

Example

- Machine component testing
- Plastic housing verification

4. Engineering Analysis

Description

RP models are used for engineering tests and simulations.

Purpose

- Structural analysis
- Flow analysis
- Thermal testing

Example

- Wind tunnel testing of aircraft models

- Fluid flow analysis in manifolds

5. Tooling Applications

Description

Rapid tooling is used to manufacture molds, dies, and casting patterns quickly.

Purpose

- Reduce tooling time
- Lower tooling cost

Example

- Injection molding dies
- Sand casting patterns

6. Medical Applications

Description

RP is used to create patient-specific medical models and implants.

Purpose

- Surgical planning
- Customized implants

Example

- Bone models
- Dental implants
- Prosthetic limbs

7. Reverse Engineering

Description

Existing components are scanned and reproduced using RP techniques.

Purpose

- Product redesign
- Spare part development

Example

- Turbine blade replication
- Old machine spare parts

8. Educational and Research Applications

Description

RP is used in engineering education and research laboratories.

Purpose

- Practical learning
- Product innovation

Example

- Student mini-projects
- Research prototypes

---

9. Architectural Models

Description

Architects use RP for building and structural models.

Purpose

- Better visualization
- Client presentation

Example

- Building models
- Bridge models

10. Aerospace and Automotive Applications

Description

Industries use RP for lightweight and complex component development.

Purpose

- Reduce development cycle
- Improve performance

Example

- Aircraft brackets
- Automotive dashboard prototypes

Advantages of RP Applications

1. Reduced product development time
2. Lower manufacturing cost
3. Easy design modification
4. Improved product quality
5. Better communication and visualization

11 a) **Discuss about Newly Proposed RP Data Formats.** 5 M

In Rapid Prototyping (RP) and Additive Manufacturing (AM), data formats are used to transfer CAD models to RP machines. The traditional STL format has some limitations such as lack of color, material, and accuracy information. Therefore, several new RP data formats have been proposed to improve manufacturing quality and data exchange.

Need for New RP Data Formats

The STL format has limitations:

- Stores only triangular geometry
- No color information
- No material information
- No texture details
- Large file size for complex models

To overcome these problems, new RP data formats were developed.

Newly Proposed RP Data Formats

1. AMF (Additive Manufacturing File Format)

Definition

AMF is an XML-based file format developed to improve STL limitations.

Features

- Supports curved surfaces
- Stores material properties
- Supports color and texture
- Multiple materials can be defined

Advantages

- Better accuracy
- Reduced file size
- Improved surface quality

Applications

- Multi-material 3D printing
- Complex engineering components

2. 3MF (3D Manufacturing Format)

Definition

3MF is a modern file format developed for efficient communication between CAD software and 3D printers.

Features

- Stores geometry, color, texture, and material data
- Compact file structure
- Better interoperability

Advantages

- Faster processing
- Improved printing reliability
- Supports full model information

Applications

- Industrial 3D printing
- Consumer product manufacturing

3. STEP Format

Definition

STEP (Standard for Exchange of Product Data) is an international standard for CAD data exchange.

Features

- Stores complete product information
- Supports assembly structures
- High geometric accuracy

Advantages

- Better CAD compatibility
- Accurate product representation

Applications

- Aerospace
- Automotive design

4. IGES Format

Definition

IGES (Initial Graphics Exchange Specification) is a neutral CAD data exchange format.

Features

- Transfers wireframe and surface models
- Used between different CAD systems

Advantages

- Easy data sharing
- Widely supported

Limitation

- Less suitable for direct RP compared to AMF and 3MF

5. CLI (Common Layer Interface)

Definition

CLI format stores layer-by-layer manufacturing information.

Features

- Contains slice data directly
- Reduces slicing time

Applications

- Layer manufacturing systems

Comparison of New RP Data Formats

Format	Main Feature	Advantage
STL	Triangular mesh	Simple format
AMF	Material & color support	Better accuracy
3MF	Complete manufacturing data	Efficient printing
STEP	Full CAD information	High precision
IGES	CAD data exchange	Interoperability
CLI	Layer data	Faster slicing

Advantages of Newly Proposed Formats

1. Better geometric accuracy
2. Material and color support
3. Reduced file size
4. Improved interoperability
5. Better support for complex models

b) What are the typical RP applications in aerospace industry? 5 M

Rapid Prototyping (RP) is widely used in the aerospace industry for fast product development, lightweight component manufacturing, testing, and design verification. RP helps reduce manufacturing time, cost, and material wastage while producing complex aerospace components with high accuracy.

Typical RP Applications in Aerospace Industry

1. Concept Modeling

Description

RP is used to produce physical models of aircraft components during the initial design stage.

Applications

- Aircraft body models
- Wing models
- Engine casing models

Benefits

- Better visualization
- Faster design evaluation

2. Functional Prototyping

Description

Functional prototypes are produced to test component performance before actual manufacturing.

Applications

- Turbine blades
- Air ducts
- Brackets

Benefits

- Early performance testing
- Reduced design errors

3. Wind Tunnel Testing Models

Description

Scaled aerospace models are produced using RP for aerodynamic testing.

Applications

- Aircraft wings
- Rocket structures
- UAV models

Benefits

- Improved aerodynamic analysis
- Reduced testing time

4. Lightweight Component Manufacturing

Description

RP helps manufacture lightweight parts with complex internal structures.

Applications

- Honeycomb structures
- Lightweight brackets
- Fuel nozzles

Benefits

- Weight reduction
- Improved fuel efficiency

5. Tooling Applications

Description

Rapid tooling is used to create molds, dies, and fixtures for aerospace manufacturing.

Applications

- Composite molds
- Assembly fixtures
- Casting patterns

Benefits

- Reduced tooling time
- Lower manufacturing cost

6. Spare Part Manufacturing

Description

RP enables quick manufacturing of replacement parts.

Applications

- Aircraft interior components
- Emergency spare parts

Benefits

- Reduced inventory
- Faster maintenance

7. Complex Geometry Production

Description

Aerospace industries use RP for components difficult to manufacture conventionally.

Applications

- Internal cooling channels
- Complex engine components

Benefits

- Design flexibility

- Improved component performance

8. Satellite and Space Applications

Description

RP is used in spacecraft and satellite component development.

Applications

- Satellite brackets
- Rocket nozzles
- Space vehicle parts

Benefits

- Reduced weight
- High precision manufacturing

Advantages of RP in Aerospace Industry

1. Reduced manufacturing time
2. Lightweight component production
3. Reduced material wastage
4. High dimensional accuracy
5. Faster product development
6. Ability to manufacture complex shapes

Limitations

1. High equipment cost
2. Limited build size
3. Expensive aerospace materials