PVP 23

Code: 23ME3401

II B.Tech - II Semester – Regular Examinations - MAY 2025

MANUFACTURING PROCESSES
(MECHANICAL ENGINEERING)

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)	Define casting and list its advantages.	L1	CO1
1.b)	What are the different types of patterns used in casting?	L1	CO1
1.c)	What are the different types of welding processes?	L1	CO1
1.d)	Differentiate between TIG and MIG welding.	L1	CO3
1.e)	Define bulk forming and give two examples.	L1	CO1
1.f)	What is recrystallization and how does it affect metal properties?	L1	CO1
1.g)	Define blanking and piercing.	L1	CO1
1.h)	What is spring back and how can it be minimized?	L1	CO1
1.i)	Define Additive Manufacturing.	L1	CO1
1.j)	List any four advantages of Additive Manufacturing.	L1	CO1

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Explain the steps involved in making a casting.	L2	CO1	5 M
	b)	Discuss different types of molding processes and their applications.	L2	CO2	5 M
OR					
3	a)	Describe the centrifugal casting process with a neat sketch.	L2	CO2	5 M
	b)	Illustrate the working of Cupola furnace with a neat sketch.	L2	CO2	5 M
UNIT-II					
4	a)	Discuss the importance of pre-heating and post-heating in welding.	L2	CO1	5 M
	b)	Illustrate the working of Submerged Arc Welding process with a neat sketch.	L2	CO3	5 M
OR					
5	a)	Explain the Electron Beam Welding process and its advantages.	L2	CO3	5 M
	b)	What are the differences between soldering, brazing and welding?	L2	CO3	5 M
UNIT-III					
6	a)	Explain the process of forging and its types.	L2	CO4	5 M
	b)	What is strain hardening? How is it removed?	L2	CO4	5 M

OR					
7	a)	Discuss different types of extrusion processes and their applications.	L2	CO4	5 M
	b)	Explain the defects in forging and their remedies.	L2	CO4	5 M
UNIT-IV					
8	a)	Explain the process of stretch forming with applications.	L2	CO4	5 M
	b)	Discuss different types of presses used in sheet metal forming.	L2	CO4	5 M
OR					
9	a)	What is high-energy rate forming? Explain its importance.	L2	CO1	5 M
	b)	Illustrate the spinning process along with applications.	L2	CO4	5 M
UNIT-V					
10	a)	What are the different types of materials used in Additive Manufacturing?	L2	CO1	5 M
	b)	Explain the working of Electron Beam Melting (EBM) in Additive Manufacturing.	L2	CO5	5 M
OR					
11	a)	What are the challenges and limitations of Additive Manufacturing?	L2	CO1	5 M
	b)	Discuss the applications of Additive Manufacturing in the aerospace and medical fields.	L2	CO1	5 M

SCHEME OF VALUATION

Code: 23ME3401 **PVP23**

II B.Tech. – II Semester- Regular Examinations- May 2025

MANUFACTURING PROCESSES
(MECHANICAL ENGINEERING)

Duration: 3 hours **Max Marks: 70**

PART-A

		BL	CO
1. a)	**Define casting and list its advantages.** Casting definition: 1M, Advantages of casting (any two): 1M	L1	CO1
1.b)	**What are the different types of patterns used in casting?** Name any four patterns: 2M	L1	CO1
1.c)	**What are the different types of welding processes?** Name any four welding processes: 2M	L1	CO1
1.d)	**Differentiate between TIG and MIG welding.** Any two differences between TIG & MIG welding: 2M	L1	CO3
1.e)	**Define bulk forming and give two examples.** Definition of bulk forming: 1M Two examples for bulk forming: 1M	L1	CO1
1.f)	**What is recrystallization and how does it affect metal properties?** Recrystallization: 1M Effect of recrystallization on metal properties: 1M	L1	CO1
1.g)	**Define blanking and piercing.** Definition of blanking: 1M Definition of piercing: 1M	L1	CO1
1.h)	**What is spring back and how can it be minimized?** Spring back: 1M **Minimizing spring back (Any two methods): 1M**	L1	CO1
1.i)	**Define Additive Manufacturing.** Definition of Additive Manufacturing: 2M	L1	CO1
1.j)	**List any four advantages of Additive Manufacturing.** Listing any four advantages of Additive Manufacturing: 2M	L1	CO1

PART-B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	**Explain the steps involved in making a casting.** Steps involved in making a casting: 5M	L2	CO1	5 M
	b)	**Discuss different types of molding processes and their applications.** Discussing any three molding processes with applications: 5M	L2	CO2	5 M
		OR			
3	a)	**Describe the centrifugal casting process with a neat sketch.** Describing centrifugal casting process: 3M	L2	CO2	5 M

		Sketch of centrifugal casting process: 2M			
	b)	**Illustrate the working of Cupola furnace with a neat sketch.** working of Cupola furnace: 3M Sketch of Cupola furnace: 2M	L2	CO2	5 M
		UNIT-II			
4	a)	**Discuss the importance of pre-heating and post-heating in welding.** Importance of pre-heating in welding: 2.5M Importance of post-heating in welding: 2.5M	L2	CO1	5 M
	b)	**Illustrate the working of Submerged Arc Welding process with a neat sketch.** Explaining Submerged Arc Welding process: 3M Sketch of Submerged Arc Welding process: 2M	L2	CO3	5 M
		OR			
5	a)	**Explain the Electron Beam Welding process and its advantages.** Explaining Electron Beam Welding process: 2M Sketch of Electron Beam Welding process: 2M Advantages of Electron Beam Welding process: 1M	L2	CO3	5 M
	b)	**What are the differences between soldering, brazing and welding?** Differences between soldering, brazing and welding: 5M	L2	CO3	5 M
		UNIT-III			
6	a)	**Explain the process of forging and its types.** Explaining forging process: 2M Explaining the types of forging: 3M	L2	CO4	5 M
	b)	**What is strain hardening? How is it removed?** Explaining strain hardening: 3M Removal of strain hardening: 2M	L2	CO4	5 M
		OR			
7	a)	**Discuss different types of extrusion processes and their applications.** Any four types of extrusion processes: 4M Applications: 1M	L2	CO4	5 M
	b)	**Explain the defects in forging and their remedies.** Explaining any four forging defects: 4M Their remedies: 1M	L2	CO4	5 M
		UNIT-IV			
8	a)	**Explain the process of stretch forming with applications.** Explaining stretch forming process: 2M Sketch of stretch forming process: 2M Applications of stretch forming process: 1M	L2	CO4	5 M
	b)	**Discuss different types of presses used in sheet metal forming.** Listing different presses used in sheet metal forming: 1M Discussing any four presses: 4M	L2	CO4	5 M
		OR			
9	a)	**What is high-energy rate forming? Explain its importance.** Explaining about high-energy rate forming: 3M Importance of high-energy rate forming: 2M	L2	CO1	5 M
	b)	**Illustrate the spinning process along with applications.** Explaining the spinning process: 2M Sketch of spinning process: 2M Applications of spinning process: 1M	L2	CO4	5 M

UNIT-V					
10	a)	**What are the different types of materials used in Additive Manufacturing?** Any five materials: 5M	L2	CO1	5 M
	b)	**Explain the working of Electron Beam Melting (EBM) in Additive Manufacturing.** Working of EBM in Additive Manufacturing: 3M Sketch of Electron Beam Melting: 2M	L2	CO5	5 M
OR					
11	a)	**What are the challenges and limitations of Additive Manufacturing?** Challenges of Additive Manufacturing: 2M Limitations of Additive Manufacturing: 3M	L2	CO1	5 M
	b)	**Discuss the applications of Additive Manufacturing in the aerospace and medical fields.** Applications of AM in the aerospace field: 2.5M Applications of AM in the medical field:2.5M	L2	CO1	5 M

KEY/ SOLUTIONS

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II B.Tech. – II Semester- Regular Examinations- May 2025

MANUFACTURING PROCESSES
(MECHANICAL ENGINEERING)

Duration: 3 hours **Max Marks: 70**

PART-A

1. a)	**Define casting and list its advantages.** **Casting** is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a **casting**, which is ejected or broken out of the mold to complete the process. **Advantages of casting**: **(Any two)** ▪ Molten material flows into any small section in the mould cavity and as such any intricate shapes, internal or external, can be made with the casting process. ▪ It is possible to cast practically any material, be it ferrous or non–ferrous. ▪ The necessary tools required for casting moulds are very simple and inexpensive. As a result, for trial production or production of a small lot, it is an ideal method. ▪ It is possible in casting process to place the amount of material where exactly required. As a result, weight reduction in design can be achieved. ▪ Castings are generally cooled uniformly from all sides and therefore they are expected to have no directional properties. ▪ There are certain metals and alloys which can only be processed by the casting and not by any other process like forging because of the metallurgical considerations. ▪ Casting of any size and weight, even up to 200 tons can be made.
1.b)	**What are the different types of patterns used in casting?** Single Piece Pattern (Solid Pattern), Split Pattern (Two-Piece Pattern), Match Plate Pattern, Cope and Drag Pattern, Loose Piece Pattern, Gated Pattern, Sweep Pattern, Skeleton Pattern.
1.c)	**What are the different types of welding processes?**

1	Arc Welding (Electric Arc Welding)	• Shielded Metal Arc Welding (SMAW / Stick Welding) • Gas Metal Arc Welding (GMAW / MIG Welding) • Gas Tungsten Arc Welding (GTAW / TIG Welding) • Flux-Cored Arc Welding (FCAW) • Submerged Arc Welding (SAW)
2	Gas Welding	• Oxy-Acetylene Welding (OAW)
3	Resistance Welding	• Spot Welding • Seam Welding • Projection Welding
4	Solid-State Welding	• Friction Welding (FRW) • Ultrasonic Welding • Diffusion Welding • Explosion Welding
5	Laser and Electron Beam Welding	• Laser Beam Welding (LBW) • Electron Beam Welding (EBW)
6	Thermite Welding	

1.d) Differentiate between TIG and MIG welding.

MIG Welding	TIG Welding
Metal inert gas (MIG) welding utilizes a consumable electrode that is continuously fed into the welding zone from a wire pool.	Tungsten inert gas (TIG) welding utilizes a non-consumable electrode (so it remains static and intact during welding).
The electrode itself melts down to supply necessary filler metal required to fill the root gap between base metals. So electrode acts as filler metal (no additional filler is required).	If required, filler metal is supplied additionally by feeding a small diameter filler rod into the arc. So filler metal is supplied separately.
Composition of electrode metal is selected based on parent metal. Usually, metallurgical composition of electrode metal is similar to that of base metal.	Electrode is always made of tungsten with small proportion of other alloying elements (like thorium).
It is suitable for homogeneous welding. It cannot be carried out in autogenous mode welding as filler is applied inherently.	It is particularly suitable for autogenous mode welding. However, it can also be employed for homogeneous or heterogeneous mode by supplying additional filler.
The electrode-cum-filler for MIG welding comes in the form of a small diameter (0.5 – 2 mm) and very long (several hundred meters) wire that is wound in a wire-pool.	TIG welding filler typically comes in the form of small diameter (1 – 3 mm) and short length (60 – 180 mm) rod.
Due to very large length, the filler electrode can be fed for a longer duration without replacement.	Due to short length, frequent replacement of filler is required. This interrupts the welding process unintentionally.
MIG welding is commonly carried out either in AC or in DCEP polarity so that electrode can be melted and deposited at a faster rate.	TIG welding is commonly carried out either in AC or DCEN polarity to increase electrode life.
Filler deposition rate is very high, so the process is highly productive.	Filler deposition rate is low. In this sense, it is not very productive.
MIG welding usually produce spatter. This causes loss of costly filler metal.	TIG welding is mostly free from spatter.
Quality and appearance of weld bead are not very good.	It can easily produce defect-free reliable joint with good appearance.
It does not lead to tungsten inclusion defect.	TIG welding sometimes leads to tungsten inclusion defect (occurred when a melted/broken part of the tungsten electrode gets embedded into weld bead).

1.e) Define bulk forming and give two examples.

- Bulk forming, also known as bulk metal forming, is a metalworking process where the raw material, typically in the form of a billet, slab, or rod, undergoes significant plastic deformation to change its shape and cross-sectional area.
- Examples of bulk forming processes include rolling, forging, extrusion, and wire drawing.

1.f) What is recrystallization and how does it affect metal properties?

- Recrystallization of metals is a metallurgical process where deformed grains are replaced by new, stress-free grains, which is typically achieved by heating the metal above a certain temperature.
- This process significantly affects metal properties, primarily by restoring ductility, reducing strength and hardness, and improving overall workability.

1.g) Define blanking and piercing.

	Blanking and piercing are sheet metal fabrication processes that utilize a punch and die to create desired shapes and holes, respectively. Blanking cuts out the desired shape from the sheet metal, with the remaining material as scrap. Piercing, on the other hand, removes the material from the sheet to create a hole, leaving the desired sheet metal as the final product.
1.h)	**What is spring back and how can it be minimized?** **Spring back** is a phenomenon in metal forming processes, especially in bending operations, where the metal tends to return partially to its original shape after the forming force is removed. It is caused by the elastic recovery of the material once the external force is no longer applied. **Methods to Minimize Spring Back: (Any two methods)** 1.**Over bending:** Intentionally bend the material slightly beyond the desired angle so that after spring back, the part settles into the correct angle. 2.**Bottoming or Coining:** A process where the punch presses deeply into the die cavity, stressing the material beyond its yield point across the entire cross-section, reducing spring back. 3.**Use of Appropriate Tooling:** Use smaller die radii and sharper punch angles to help control the material flow and reduce elastic recovery. 4.**Material Selection:** Choosing materials with lower yield strength and elastic modulus when possible can help reduce spring back. 5.**Heat Treatment:** Applying heat during or after forming (such as stress relief annealing) can help to reduce residual stresses and minimize spring back. 6.**Finite Element Simulation:** Predict spring back using simulation software and compensate for it in the die design.
1.i)	**Define Additive Manufacturing.** **Additive Manufacturing (AM)**, commonly known as **3D printing**, is a manufacturing process that creates three-dimensional objects by adding material layer by layer based on a digital model. Unlike traditional subtractive manufacturing methods, which remove material from a solid block (e.g., machining or milling), additive manufacturing builds up the object from the ground up/ bottom up approach.
1.j)	List any four advantages of Additive Manufacturing. • **Design Flexibility**: Complex and intricate designs that are difficult or impossible to achieve with traditional manufacturing can be easily produced. • **Reduced Waste**: Since material is added layer by layer, only the necessary amount is used, minimizing scrap and material waste. • **Rapid Prototyping**: Products can be quickly designed, tested, and modified, significantly speeding up the development cycle. • **Customization**: Items can be tailored to individual specifications (e.g., medical implants, footwear) without the need for retooling or special equipment.

PART-B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	**Explain the steps involved in making a casting.** The **casting process** involves several key steps to produce a metal part by pouring molten metal into a mold and allowing it to solidify. Here are the main steps: **1. Pattern Making:** • A **pattern** is created to replicate the shape of the desired casting. • It is usually made of wood, plastic, or metal. • The pattern includes allowances for shrinkage and machining. **2. Mold Making:** • The pattern is used to create a **mold cavity** in sand or another mold material. • Molds can be **expendable (sand)** or **permanent (metal)**. • The mold includes features like the cavity, sprue, runners, and risers to guide the molten metal. **3. Core Making (if needed):** • **Cores** are used to create internal cavities or complex geometries in the casting. • Made separately and placed inside the mold cavity before pouring. **4. Melting and Pouring:** • The required metal is melted in a furnace. • The **molten metal** is poured into the mold through the sprue and runners. **5. Cooling and Solidification:** • The molten metal **cools and solidifies** inside the mold, taking the shape of the cavity. • Cooling time depends on the size and complexity of the casting and the type of metal used. **6. Shakeout:** • Once the metal has solidified, the mold is **broken or opened** to remove the casting. • For sand casting, this involves breaking the sand mold. **7. Cleaning and Finishing:** • The casting is **cleaned** to remove sand, scale, and excess metal (e.g., from gates or risers). • Finishing processes like grinding, machining, or heat treatment may be applied. **8. Inspection:** • The final casting is **inspected** for defects using visual checks, dimensional measurements, or non-destructive testing	L2	CO1	5 M
	b)	**Discuss different types of molding processes and their applications.** **Green Sand Moulding:** Green sand is the moulding sand which has been freshly prepared from silica grains, clay and mois ture. In a green sand mould, metal	L2	CO2	5 M

is poured immediately and the castings taken out. These are most commonly used and are adapted for rapid production whereas the moulding flasks are released quickly. They require less floor space as no storage is involved. As the mould is produ ced, the casting is prepared. Thus it is the least expensive of all. Also the tendency for hot tearing of the castings is less in green sand moulds. Mould erosion is common in these types of moulds. The permeability of these moulds should be properly controlled otherwise blow holes and gas inclusions are likely to form.

Dry Sand Moulds:

These are the green sand moulds which are completely dried by keeping in an oven from 150 to 350°C for
8 to 48 hours depending on the binders in the moulding sand. These moulds generally have higher strengths than the green sand mould and are preferred because they are less likely to be damaged during handling. These are generally used for medium to large castings. Better surface finish and dimensional accuracy can be achieved by dry sand mould. The main disadvantages are the likely distortion of the mould caused during the baking process; susceptibility to hot tearing of castings and longer production cycles. Also this is more expensive than the green sand mould.

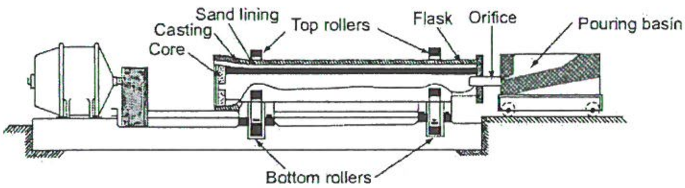
Skin Dried Mould:

Though the dry sand mould is preferable for large moulds because of the expense involved, a compromise is achieved by drying only the skin of the mould cavity with which the molten metal comes into contact, instead of the full mould. The skin is normally dried to a depth of 15 to 25 mm, using either torches or by simply allowing them to dry in atmosphere. This can also be done in pit moulding. However, pouring of metal should be completed immediately after the drying process such that moisture from the undried portion would not penetrate the dried skin.

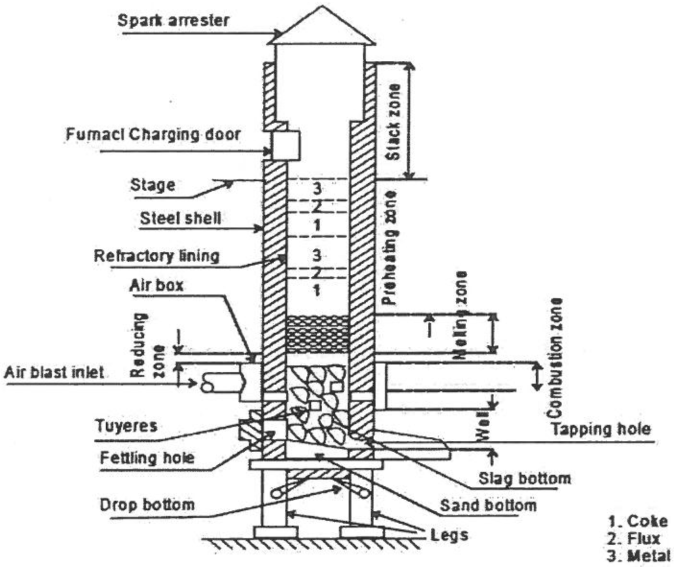
Plaster moulding:

Also called rubber plaster moulding (RPM), is a specialized casting process used for producing non–ferrous (aluminium and copper base alloys) castings by pouring liquid metal into moulds made of Plaster of Paris (gypsum). In this process, Plaster of Paris ($CaSO4.½H2O$) is mixed with water to form a slurry with additives such as ceramic talc, fiberglass, clay, silica flour, fly ash, etc., with water and then poured over the pattern. The additives are used to enhance the mould properties such as green and dry strength, permeability, and castability. The slurry is allowed to preset to a rubbery consistency which allows it to be stripped from the pattern but which is sufficiently strong to return to the shape it had when on the pattern. The preset mould is then ignited to burn off the volatile content in the set gel and baked at about 120 to 260°C. This step results in a hard and rigid mould containing microscopic cracks. Cores can also be made using similar process. Cores, if required, are then placed in the drag half. The cope half is then aligned with the drag half and locating pins on cope going into the matching pin holes in the cope. This assembling process can be done while the moulds are still hot or after they have cooled to

		room temperature depending on mould complexity. Dried plaster moulds have extremely low permeability of about 1 to 2 AFS. In view of this low permeability, gravity pouring is rarely employed and a vacuum assist is usually required for the pouring of moulds. **Pit Moulding:** Pit moulding is used for large and heavy castings weighing up to 150 tons where using a moulding flask for the process becomes almost impossible and too expensive for the amount of handling is concerned. The pit is normally formed in the foundry floor with sand. The pit acts as a drag where the cavity is formed. Pattern is placed in the pit and the sand is rammed around it to form the drag cavity. A separate cope can then be used above the pit which will be at the floor level. The cope can be constructed with bricks and normally houses the pouring cup and sprue. Vent pipes will be added into the pit to facilitate the escape of gases. This is a slow process and requires a lot of time to complete the mould. **Loam Moulding:** Loam sand contains many ingredients like fine sand particles, finely ground refractories, clay, graphite and fibre reinforcements. Loam soils generally have better drainage than clay soils. They retain water easily. Organic matter such as chopped straw is added to the sand to provide good ventilation. Loam moulds are generally employed for making large castings without using the expensive full patterns and moulding flasks. They use skeleton patterns and sweeps to reduce the cost of patterns. Objects such as large cylinders, chemical pans, large gears, round bottoms, kettles and other machining parts are produced in loam moulding. Big moulds are constructed using brick framework that will be lined with loam sand and dried. Sweeps, etc. are used for getting the requisite profile of the casting.			
OR					
3	a)	**Describe the centrifugal casting process with a neat sketch.** This is a process where the mould is rotated rapidly about its central axis as the metal is poured into it. Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies. The slag, oxides and other inclusions being lighter, gets separated from the metal and segregates toward the centre. This is normally used for the making of hollow pipes, tubes, hollow bushes, etc., which are axi-symmetric with a concentric hole. Since the metal is always pushed outward because of the centrifugal force, no core needs to be used for making the concentric hole. The axis of rotation can be horizontal, vertical or any angle in between. Very long pipes are normally cast with horizontal axis whereas short pieces are more conveniently cast with a vertical axis. First, the moulding flask is properly rammed with sand to confirm to the outer contour of the pipe to be made. Any end details, such as spigot ends, or flanged ends are obtained with the help of dry sand cores located in the ends. Then the flask is dynamically balanced so as to reduce the occurrence of undesirable vibrations during the casting process. The finished flask is mounted in between the	L2	CO2	5 M

		rollers and the mould is rotated slowly. Now the molten metal in requisite quantity is poured into the mould through the movable pouring basin. The amount of metal poured determines the thick ness of the pipe to be cast. After the pouring is completed, the mould is rotated at its operational speed till it solidifies, to form the requisite tubing. Then the mould is replaced by a new mould machine and the process continues. Metal moulds can also be used in the true centrifugal casting process for large quantity production. A water jacket is provided around the mould for cooling it. The casting machine is mounted on wheels with the pouring ladle which has a long spout extending till the other end of the pipe to be made. To start, the mould is rotated with the metal being delivered at the extreme end of the pipe. The casting machine is slowly moved down the track allowing the metal to be deposited all along the length of the pipe. The machine is continuously rotated till the pipe is completely solidified. After wards, the pipe is extracted from the mould and the cycle repeated.  			
	b)	**Illustrate the working of Cupola furnace with a neat sketch.** Cupola consists of a cylindrical steel shell with its interior lined with heat resisting fire bricks. It consists of drop doors at the bottom after closing which a proper sand bed could be prepared. This sand bed provides the necessary refractory bottom for the molten metal and the coke. Immediately above the sand bed is the metal tapping hole which is initially closed with clay called 'bot' till the molten metal is ready for tapping. Above the metal tap hole normally in a position opposite to it is the slag hole through which the slag generated during the melting process is tapped. Above the slag hole is the wind box which is connected to the air blowers supplying the requisite air at a given pressure and quantity. The air enters the cupola through the tuyeres. A little above the charging platform is the charging hole in the shell from where the charge consisting of a combination of pig iron, scrap iron, coke and fluxes, is put into the cupola. The refractory lining above the charge door need not necessarily be as thick as that below, since it is not exposed to much heat, To operate the cupola, first, the drop doors at the bottom are closed and a sand bed with a gentle slope towards the tap hole is rammed. Then a coke bed of suitable height is prepared above the sand bottom and ignited through the tap hole or any other hole. When the coke bed is properly ignited, alternate layers of charge, flux and coke are alternately fed into the cupola through the charge door maintaining the necessary proportions and rate of charging. The charge is then allowed to soak in the heat for a while, and then the air blast is turned on. Within about 5 to 10 minutes, the molten metal is collected near the tap hole. When enough	L2	CO2	5 M

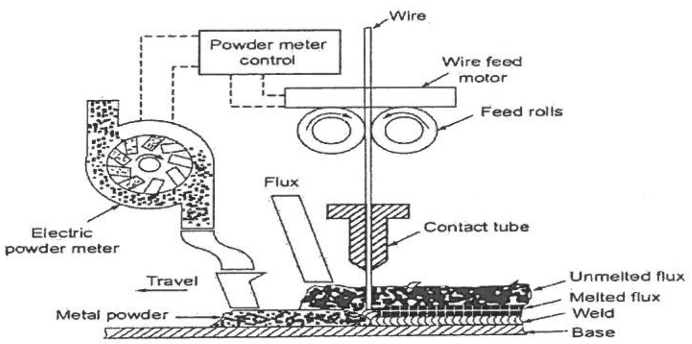
molten metal is collected in the well of the cupola, the slag is drained off through the slag hole before opening the tap hole. The molten metal is collected in the ladles and then transported to the moulds into which it is poured with a minimum time loss. The charge needed to produce cast iron, essentially consists of pig iron, cast iron scrap and steel scrap when alloy cast iron is needed. The proportions of these depend on their chemical compositions and on the final chemical composition of cast iron desired. The fluxes are added in the charge to remove the oxides and other impurities present in the metal. The flux most commonly used is lime stone ($CaCO_3$) in a proportion of about 2 to 4% of the metal charge. Some of the other fluxes that may also be used are dolomite, sodium carbonate and calcium carbide. The flux is expected to react with the oxides and form compounds which have low melting point and also are lighter. As a result, the molten slag tends to float on the metal pool and thus, can very easily be separated



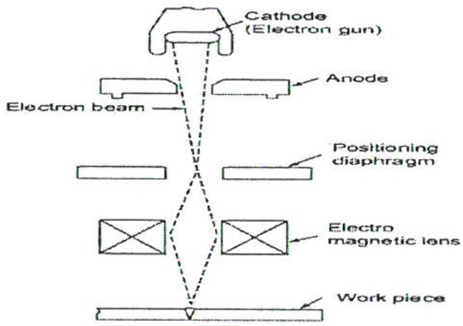
UNIT-II

4	a)	**Discuss the importance of pre-heating and post-heating in welding.** Pre-heating and post-heating are essential practices in welding that significantly influence the quality, integrity, and durability of welded joints. These thermal treatments help control the temperature before and after welding, minimizing the risk of defects and ensuring optimal metallurgical properties. **Importance of Pre-heating in Welding** **1. Reduces Thermal Shock:** Pre-heating raises the temperature of the base metal before welding, reducing the temperature gradient between the welding arc and the workpiece. This helps minimize thermal shock, which can cause cracking. **2. Slows Cooling Rate:** By starting at a higher temperature, the cooling rate after welding is reduced. This is especially important in materials prone to forming brittle microstructures (e.g., martensite in carbon steels).	L2	CO1	5 M

		3. Minimizes Risk of Hydrogen Cracking: Slower cooling allows hydrogen, which may have been introduced during welding, to diffuse out of the weld zone, reducing the risk of hydrogen-induced cracking. **4. Enhances Weld Penetration and Fusion:** Pre-heated materials generally respond better to the welding arc, leading to improved fusion and deeper penetration, particularly in thick sections. **5. Improves Metallurgical Properties:** In materials like high-strength steels and alloy steels, pre-heating helps maintain favorable mechanical properties and reduces hardness in the heat-affected zone (HAZ). **Importance of Post-heating in Welding** **1. Hydrogen Removal:** Post-heating (also known as hydrogen bake-out) is often used to keep the weld area at an elevated temperature immediately after welding to allow hydrogen to escape, reducing the risk of delayed cracking. **2. Stress Relief:** Post-heating can be part of a stress-relief heat treatment to reduce residual stresses developed during welding. This is especially critical for thick sections, restrained joints, or pressure vessels. **3. Microstructure Control:** It helps transform the microstructure into more stable phases, reducing brittleness and enhancing ductility and toughness. **4. Prevents Cracking:** By controlling the cooling rate after welding, post-heating reduces the chances of solidification and liquation cracking, particularly in materials sensitive to such defects. **5. Compliance with Codes and Standards:** Many engineering codes (e.g., ASME, AWS) mandate post-weld heat treatment (PWHT) for certain materials and thicknesses to ensure safety and reliability			
	b)	**Illustrate the working of Submerged Arc Welding process with a neat sketch.** The submerged arc welding (SAW) is used for doing faster welding jobs. It is possible to use larger welding electrodes (12 mm) as well as very high currents (4000 A) so that very high metal deposition rates of the order of 20 kg/h or more can be achieved with this process. Also, very high welding speeds (5 m/min) are possible in SAW. Some submerged arc welding machines are able to weld plates of thickness as high as 75 mm in butt joints in a single pass. Though submerged arc welding can be used even for very small thicknesses, of the order of 1 mm, it is more economical for larger welds only. The arc is produced while the consumable electrode wire which is continuously fed into the weld zone as in GMAW. The welding zone is completely covered by means of a large amount of granulated flux which is delivered ahead of the welding electrode by means of a welding flux feed tube. The arc occurring between the electrode and the work piece is completely submerged under the flux and not visible from outside. A part of the flux melts and forms the slag, which covers the weld metal. The unused flux is collected and reused. Since the arc is completely submerged in the flux, there is no spatter of the molten metal. Since this process uses loose granulated flux to cover the joint, it is not possible to carry out in any position other than the flat or down	L2	CO3	5 M

		hand position. The out of position welds are difficult to carry, also because of the large metal pools that are generated in the SAW process. The electrode wires normally used are of sizes 1.6, 2, 2.5, 3.15, 4, 5, 6.3, and 8 mm. The wires should be smooth with no surface imperfections or contaminants. Since the wire feed rate is normally very high, it is not possible to manually feed the wire into the joint. submerged arc welding produces large amount of molten weld metal which takes some time for solidification. The weld metal backing is normally used. The backing plates can be with or without grooves. The most commonly employed are the copper plates which can be cooled with internal running water, when necessary. Normally for thin plates, plain copper backing plates without any cooling water would be enough. Pure copper, because of its high thermal conductivity, would remove heat quickly from the molten weld pool and allow it solidify fast. For welding plates that are less than 3 mm thick, copper backing plates without grooves are used. For thicker plates, grooves with a depth of 0.5 to 1.5 mm and width of 6 to 20 mm are made for providing the necessary support to the molten metal. The type of edge preparation and joint design used with submerged arc welding is slightly different from the other arc welding processes because of the larger deposition rates and deeper penetrations involved.  			
		OR			
5	a)	**Explain the Electron Beam Welding process and its advantages.** The heat source in Electron-Beam Welding (EBW) for melting the joint is a focused beam of high velocity electrons. The electron beam upon impinging the work piece releases the necessary heat by converting its kinetic energy The cathode (heated filament) within the electron gun is the source of a stream of electrons. These electrons are accelerated towards the anode because of the large potential difference that exists between them. The potential differences that are used are of the order of 30 kV to 175 kV. The higher the potential difference, higher would be the acceleration. The current levels are low ranging, between 50 mA to 1000 mA. Depending on the accelerating voltage, the electrons would travel at the speed of 50,000 to 200,000 km/s. The depth of penetration of the weld depends on this electron speed which in turn is dependent upon the accelerating voltage. The electron beam is focused by means of an electromagnetic lens so that the energy is	L2	CO3	5 M

released in a small area. When the high velocity electron beam strikes the work piece all the kinetic energy is converted to heat. As these electrons penetrate the metal, the material that is directly in the path is melted and a keyhole is formed melting the metal around the beam. As the beam traverses, the keyhole would also travel along with the molten metal being pushed back which when solidified, forms the joint.



***Advantages of Electron-beam welding*:**

- The penetration of the beam is high.
- The depth-to-width ratios between 10:1 and 30:1 can be easily realised with electron-beam welding.
- It is also possible to closely control this penetration by controlling the accelerating voltage, beam current and beam focus.
- The process can be used at higher welding speeds typically between 125 to 200 mm/s.
- Filler metal or flux are not needed to be used in this process.
- The heat liberated is low and also is in a narrow zone, thus the heat affected zone is minimal as well as weld distortions are virtually eliminated.

b) **What are the differences between soldering, brazing and welding?**

S.No.	Welding	Soldering	Brazing
1	Welding joints are strongest joints used to bear the load. Strength of the welded portion of joint is usually more than the strength of base metal.	Soldering joints are weakest joints out of three. Not meant to bear the load. Use to make electrical contacts generally.	Brazing joints are weaker than welding joints but stronger than soldering joints. This can be used to bear the load up to some extent.
2	Temperature required is 3800°C in welding joints.	Temperature requirement is up to 450°C in soldering joints.	Temperature may go to 600°C in brazing joints.
3	To join work pieces need to be heated till their melting point.	Heating of the work pieces is not required.	Work pieces are heated but below their melting point.
4	Mechanical properties of base metal may change at the joint due to heating and cooling.	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost negligible.

5	Heat cost is involved and high skill level is required.	Cost involved and skill requirements are very low.	Cost involved and sill required are in between other two.
6	Heat treatment is generally required to eliminate undesirable effects of welding.	No heat treatment is required.	No heat treatment is required after brazing.
7	No preheating of workpiece is required before welding as it is carried out at high temperature.	Preheating of workpieces before soldering is good for making good quality joint.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.

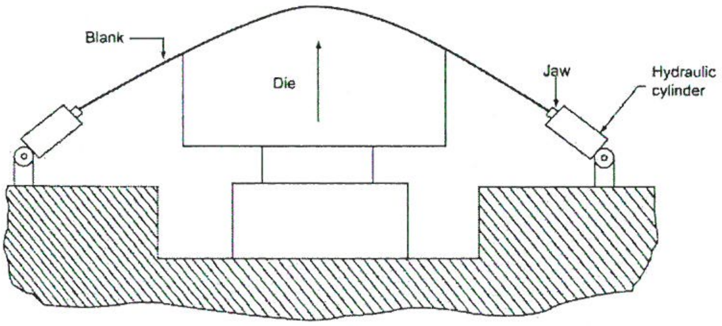
L2 CO3 5 M

UNIT-III

6	a)	**Explain the process of forging and its types.** Forging is the operation where the metal is heated and then a force is applied to manipulate the metal in such a way that the required final shape is obtained. This is the oldest of the metal-working processes known to mankind since the copper age. Forging is generally a hot-working operation though cold forging is used sometimes. **Forging Types:** There are four types of forging methods, which are generally used. **Smith Forging**: This is the traditional forging operation done openly or in open dies by the village blacksmith or modern shop floor by manual hammering or by power hammers. **Drop Forging**: This is the operation done in closed impression dies by means of the drop hammers. Here the force for shaping the component is applied in a series of blows. **Press Forging**: Similar to drop forging, the press forging is also done in closed-impression dies with the exception that the force is a continuous squeezing type applied by the hydraulic presses. **Machine Forging**: Unlike the drop or press forging where the material is drawn out, in machine forging, the material is only upset to get the desired shape.	L2	CO4	5 M
	b)	**What is strain hardening? How is it removed?** **Strain hardening**, also known as **work hardening**, is the process by which a metal becomes stronger and harder as it is **plastically deformed**. When a ductile metal is subjected to mechanical stress beyond its elastic limit, dislocations in its crystal structure multiply and interact, making further deformation more difficult. **Mechanism:** 1. During plastic deformation (e.g., rolling, drawing, bending), dislocations move through the metal's crystal lattice. 2. As deformation continues, dislocations begin to pile up and interact with each other, creating internal barriers to movement. 3. This increased dislocation density **impedes further dislocation motion**, increasing the material's **yield strength and hardness**, but reducing **ductility**.	L2	CO4	5 M

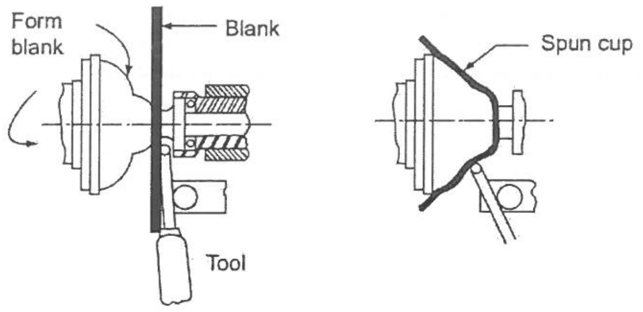
		Strain hardening can be reversed or removed by a process called **annealing**, which involves heating the metal to a specific temperature and then cooling it. Annealing Stages: **1. Recovery**: • Relieves some of the internal stresses. • Dislocation density does not change significantly. • Minor improvements in ductility. **2. Recrystallization**: • New strain-free grains nucleate and grow within the deformed structure. • Occurs at a specific **recrystallization temperature** (typically 0.3–0.5 times the melting temperature in Kelvin). • Restores ductility and reduces strength and hardness. **3. Grain Growth** (if heating continues): • Recrystallized grains grow larger. • Strength may decrease further, but ductility increases.			
		OR			
7	a)	**Discuss different types of extrusion processes and their applications.** Extrusion is a metal forming process used to create objects of a fixed cross-sectional profile by forcing material through a die. There are several types of extrusion processes, each suited for specific materials, products, and performance requirements. **1. Direct (Forward) Extrusion**: The billet and ram move in the same direction. It is one of the most common extrusion methods. **Applications:** • Solid and hollow aluminum profiles • Structural components • Window frames, rails, and beams **2. Indirect (Backward) Extrusion**: The die moves against a stationary billet. This reduces friction and can be more energy-efficient. **Applications:** • Tubes and cylinders • Thin-walled components • Precision parts **3. Hydrostatic Extrusion**: The billet is surrounded by a pressurized liquid, and pressure is transmitted uniformly. It reduces friction and is suitable for brittle materials. **Applications:** • High-strength materials (e.g., titanium, high carbon steel) • Fine wire and rod production • Aerospace and defense components **4. Impact Extrusion**: Used in high-speed operations where a punch strikes a slug to form the desired shape. Typically cold and used for soft metals. **Applications:** • Cans and containers	L2	CO4	5 M

		• Battery cases • Small electrical components			
	b)	**Explain the defects in forging and their remedies.** Though the forging process generally gives superior quality products compared to other manufacturing processes, still there are some defects that are likely to come if proper care is not taken in the forging-process design. A brief description of such defects and their remedial methods is given below: **Unfilled Sections** In this, some sections of the die cavity are not completely filled by the flowing metal. The causes of this defect are improper design of forging die or using faulty forging techniques. **Cold Shut** This appears as a small crack at the corners of the forging. This is caused mainly by the improper design of the die wherein the corner and fillet radii are small as a result of which the metal do not flow properly into the corner and ends up as a cold shut. **Scale Pits** This is seen as irregular depressions on the surface of the forging. This is primarily caused because of the improper cleaning of the stock used for forging. The oxide and scale present on the stock surface gets embedded into the finished forging surface. When the forging is cleaned by pickling, these are seen as depressions on the forging surface. **Die Shift** This is caused by the misalignment of the two die halves, making the two halves of the forging to be of improper shape. **Flakes** These are basically internal ruptures caused by the improper cooling of the large forging. Rapid cooling causes the exteriors to cool quickly causing internal fractures. This can be remedied by following proper cooling practice. **Improper Grain Flow** This is caused by the improper design of the die, which makes the flow of metal not following the final intended directions.	L2	CO4	5 M
		UNIT-IV			
8	a)	**Explain the process of stretch forming with applications.** In stretch forming, the complete deformation is carried out in plastic state only. The material is first brought into plastic state by stretching, hence the name stretch forming. In the process, the sheet is held in the jaws of hydraulic cylinders and is stretched beyond elastic limit. Then the sheet is brought into contact with the die, so as to give it the shape of the die. Stretch forming is comparatively simple and inexpensive because it uses a single die. Many complicated shapes cannot be obtained but the component can have either singly curved or doubly curved surface. Also if the component is to have any holes, they may be punched after stretch forming otherwise the holes are likely to be enlarged. The physical properties are generally improved by the uniform stretching of the metal. The sheet used in stretch forming should have uniform thickness, otherwise the thinner portions are likely to be overstretched.	L2	CO4	5 M

		 **Applications of Stretch Forming:** *1. Aerospace Industry* • **Aircraft skins**: fuselage panels, wing skins, and engine cowlings. Materials like aluminum and titanium are shaped into smooth, aerodynamic curves. Ensures minimal stress concentrations and high strength-to-weight ratio. *2. Automotive Industry* • **Body panels and trim parts** for concept cars or custom builds. Used when large, smooth, contoured panels are needed (e.g., hoods, doors). Sometimes used in high-end or specialty vehicles, not mass production. *3. Architecture* • Curved metal panels for **building facades**, **roofing**, and **decorative structures**. Enables the creation of modern, sleek, and complex geometries. *4. Rail and Transportation* • Stretch forming is used for **train and tram panels** where aerodynamic shaping and surface quality are critical. *5. Shipbuilding* • Some specialized curved parts of ships and submarines, particularly with aluminum structures			
	b)	**Discuss different types of presses used in sheet metal forming.** Sheet metal forming involves shaping metal sheets into desired forms using various tools and presses. Presses are essential in this process as they apply the necessary force to shape the metal. Here are the different types of presses commonly used in sheet metal forming: **1. Mechanical Presses** These presses use a mechanical flywheel powered by an electric motor to generate force. • **Crank Press:** The most common type, where a crankshaft drives the ram. • **Knuckle Joint Press:** Offers slow, powerful pressing near the bottom of the stroke—ideal for coining and embossing. • **Eccentric Press:** Uses an eccentric shaft instead of a crankshaft, offering smooth operation. **2. Hydraulic Presses** These use hydraulic cylinders to apply force through fluid pressure. • **Single-acting hydraulic press:** Applies force in one direction. • **Double-acting hydraulic press:** Applies force in both directions (useful for deep drawing).	L2	CO4	5 M

		• **Triple-action hydraulic press:** Has a blank holder, punch, and ejector—used in complex deep drawing operations. **3. Pneumatic Presses:** These use compressed air to generate force. **Advantages:** • Fast operation • Lower cost compared to hydraulic presses **Limitations:** • Lower force capacity • Less precise than mechanical or hydraulic presses **4. Servo Presses (Electromechanical Presses)** These are powered by electric motors with programmable motion profiles. **Advantages:** • Precise control of speed, stroke, and force • Energy-efficient and low maintenance • Capable of handling complex forming operations **Limitations:** • Higher initial cost • Requires skilled operation and programming **5. Toggle Presses** A mechanical press that uses a toggle mechanism to amplify force near the end of the stroke. **Advantages:** • High force application near bottom dead center • Good for applications requiring high-pressure finishing **Limitations:** • Limited stroke length and speed variability **6. Hydroforming Presses** Use high-pressure hydraulic fluid to form sheet metal into a die. **Advantages:** • Can create complex shapes with uniform thickness • Reduces the need for welding or joining **Limitations:** • Specialized equipment • High setup costs			
OR					
9	a)	**What is high-energy rate forming? Explain its importance.** **High-energy rate forming (HERF)** is a group of metal forming processes that use high rates of energy delivery typically in a very short time duration to deform materials into desired shapes. These processes rely on the application of force at extremely high velocities, which distinguishes them from conventional forming methods. **Common HERF Methods** 1. **Explosive forming** – Uses the detonation of explosives to form metal sheets into dies. 2. **Electromagnetic forming** – Utilizes electromagnetic forces to shape conductive materials. 3. **Electrohydraulic forming** – Employs underwater spark discharges to create shock waves that form the metal. 4. **High-velocity impact forming** – Uses high-speed projectiles or rams. **Importance of High-Energy Rate Forming**	L2	CO1	5 M

		1. **Forming Complex Shapes:** HERF can create intricate and deep-draw shapes that are difficult or impossible to achieve using traditional methods. 2. **Improved Material Properties:** High strain rates can lead to work hardening and finer grain structures, improving strength and performance of the formed parts. 3. **Better Material Utilization:** These processes often require less trimming and waste, improving efficiency and reducing costs. 4. **Enhanced Formability:** Materials that are difficult to form under normal conditions (like high-strength alloys) may become more ductile under high strain rates. 5. **No Need for Heavy Tooling:** In some HERF methods, especially explosive and electromagnetic forming, lighter and cheaper tooling can be used, reducing setup costs. 6. **Applications in Aerospace and Defense:** HERF is widely used for forming components that require high strength-to-weight ratios, such as aerospace panels, missile parts, and satellite components.			
	b)	**Illustrate the spinning process along with applications.** Spinning is the process used for making cup shaped articles which are axisymmetric. The process of spinning consists of rotating the blank, fixed against the form block and then applying a gradually moving force on the blank so that the blank takes the shape of the form block. The setup essentially consists of a machine similar to a centre lathe. In the head stock of the spinning machine, a hard wood form block which has the shape of the desired part is fixed. The blank is held against the form block by means of the freely rotating wooden block from the tail stock. After proper clamping, the blank is rotated to its operating speed. The spinning speed depends on the blank material, thickness and complexity of the desired cup. Then the hard wood or roller type metallic tool is pressed and moved gradually on the blank so that it conforms to the shape of the form block. The manipulation of spinning tools is a highly skilled art. The tool is to be moved back and forth on the blank so that no thinning takes place anywhere on the blank. Spinning is comparable to drawing for making cylindrical shaped parts. Because of the simple tools used in spinning, it is economical for smaller lots. But the time required for making a cup is more in spinning and also more skill is required in the process. Thus, it is not suitable for large scale production. Complicated shapes and re-entrant shapes are not feasible by drawing but can be made by spinning using the sectional and collapsible form blocks. Large parts are much more easily made in spinning than by drawing. When sheet thickness is more, for example, in making the dished ends of pressure vessels, cold spinning is not sufficient. Then the blank is heated to the forging temperature and so the process is called 'hot spinning'. Also in hot spinning, the tools are mechanically manipulated because of the higher magnitudes of forces required.	L2	CO4	5 M

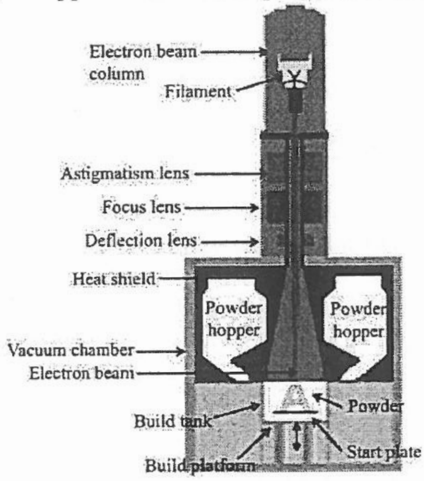
		 			
		UNIT-V			
10	a)	**What are the different types of materials used in Additive Manufacturing?** Additive Manufacturing (AM), also known as 3D printing, uses a wide variety of materials depending on the printing technology and the intended application. These materials can be broadly classified into several categories: **1. Polymers (Plastics):** Most common materials used, especially in consumer-grade 3D printers. • **Thermoplastics**: o **PLA (Polylactic Acid)** – Biodegradable, easy to print, low cost. o **ABS (Acrylonitrile Butadiene Styrene)** – Strong, durable, slightly higher melting point. o **PETG (Polyethylene Terephthalate Glycol)** – Good strength and chemical resistance. o **Nylon (Polyamide)** – Flexible, strong, wear-resistant. o **TPU/TPE (Thermoplastic Polyurethane/Elastomer)** – Rubber-like flexibility. • **Thermosets**: o Used mainly in **vat photopolymerization** (e.g., SLA, DLP) processes. o Examples: epoxy, acrylic-based resins. o Characteristics: high detail resolution, brittle. **2. Metals:** Used in industrial AM for functional and structural components. • **Titanium and its alloys (e.g., Ti-6Al-4V)** – Lightweight, high strength, corrosion-resistant. • **Aluminum and its alloys** – Lightweight, good mechanical properties. • **Stainless Steel** – Durable, corrosion-resistant, widely used. • **Tool Steels** – Hard and wear-resistant, used in molds and dies. • **Nickel-based superalloys (e.g., Inconel)** – High-temperature performance. • **Cobalt-Chromium alloys** – Biocompatible, used in medical and dental applications. **Common metal AM processes**: Powder Bed Fusion (PBF), Directed Energy Deposition (DED), Binder Jetting. **3. Ceramics:** Used for high-temperature or biocompatible applications. • **Alumina (Al_2O_3)** • **Zirconia (ZrO_2)** • **Silicon carbide (SiC)**	L2	CO1	5 M

		• **Hydroxyapatite** – Used in bone scaffolds. **Challenges**: Brittle nature, complex sintering processes. **4. Composites:** Mixtures of two or more materials to enhance properties. o Polymer matrix composites with: Carbon fiber, Glass fiber, Kevlar • Metal matrix composites – Metal reinforced with ceramic or other particles. **Advantages**: Improved strength, stiffness, thermal and chemical resistance. **5. Bio-Materials:** Used in bioprinting and tissue engineering. • **Hydrogels** – Water-rich, biocompatible materials (e.g., alginate, gelatin). • **Biodegradable polymers** – e.g., PLA, PCL (polycaprolactone). • **Living cells** – In bio-inks for tissue and organ printing. **6. Sand and Foundry Materials:** Used in Binder Jetting for casting molds. • Silica sand • Furan or phenolic resins – Used as binders. **7. Concrete and Cementitious Materials:** Used in large-scale 3D printing (e.g., construction). • Mortar-based mixes • Fiber-reinforced concrete			
	b)	**Explain the working of Electron Beam Melting (EBM) in Additive Manufacturing.** Electron Beam Melting (EBM) is an advanced Additive Manufacturing (AM) technology used primarily for metal 3D printing, especially in aerospace and medical applications. It is a powder bed fusion process that utilizes an electron beam as the energy source to melt and fuse metal powder layer by layer to build a solid part. Working of Electron Beam Melting (EBM): 1. Preparation • A 3D CAD model is sliced into layers using specialized software. • A vacuum chamber is prepared because the electron beam requires a vacuum to operate efficiently. • Metal powder, such as titanium or cobalt-chrome, is evenly spread on the build platform in a thin layer using a rake or roller. 2. Preheating • The electron beam preheats the entire powder bed to a high temperature (but below the melting point) to: o Minimize residual stresses o Prevent powder repulsion due to electrostatic forces 3. Melting and Fusion • The electron beam, controlled by electromagnetic coils, selectively scans the powder layer according to the cross-sectional geometry of the part. • The beam melts the powder, which quickly solidifies to form a solid metal layer.	L2	CO5	5 M

- This process continues layer by layer, with each new layer of powder being added and melted onto the previous one.

4. Cooling and Post-processing

- Once the build is complete, the entire build remains at a high temperature and cools down slowly in the vacuum chamber to reduce thermal stresses.
- The part is then removed from the powder bed, and excess powder is cleaned off.
- Post-processing like heat treatment, machining, or surface finishing may be applied for desired properties and tolerances.



OR

11	a)	**What are the challenges and limitations of Additive Manufacturing?**	L2	CO1	5 M

Additive Manufacturing (AM), also known as 3D printing, offers many advantages such as design flexibility, material efficiency, and rapid prototyping. However, it also comes with several **challenges and limitations** that can hinder its broader adoption, especially in industrial settings. These challenges span across technical, economic, and regulatory domains:

1. Material Limitations:

- **Limited material selection:** Not all materials are available or suitable for AM. Metals, polymers, ceramics, and composites have different degrees of printability.
- **Material properties:** Printed parts may not match the mechanical properties of traditionally manufactured counterparts, especially in terms of strength, durability, or fatigue resistance.

2. Surface Finish and Accuracy:

- **Surface roughness:** AM parts often require post-processing to improve surface finish, especially for metal parts.
- **Dimensional accuracy:** Warping, shrinkage, or residual stresses can affect dimensional tolerances, requiring calibration or compensation strategies.

3. Speed and Scalability:

- **Slow production rates:** AM is typically slower than traditional manufacturing processes like injection molding or CNC machining, especially for large batch production.
- **Size constraints:** Most 3D printers have limited build volumes, which restricts the size of parts that can be produced in one piece.

		4. Cost Factors: • **High machine costs:** Industrial-grade 3D printers, especially for metal AM, are expensive to purchase and maintain. • **Material costs:** Specialized materials (e.g., metal powders or high-performance polymers) can be significantly more expensive than bulk materials used in conventional manufacturing. • **Post-processing costs:** Additional time and resources are needed for processes like heat treatment, surface finishing, and support removal. **5. Design and Software Limitations:** • **Complexity in design tools:** Advanced software is required to design for AM, especially when leveraging design freedoms like lattice structures or topology optimization. • **Skill gap:** Engineers and designers often lack training in AM-specific design principles, limiting the effective use of the technology. **6. Mechanical Properties and Reliability:** • **Anisotropy:** Properties of AM parts can vary depending on the build direction, which may lead to inconsistent performance. • **Porosity and defects:** Some AM processes can result in internal voids or weak inter-layer bonding, reducing structural integrity. **7. Standards and Certification:** • **Lack of industry standards:** AM is still evolving, and there is a lack of standardized testing and quality assurance methods. • **Certification hurdles:** Especially in regulated industries like aerospace or medical, certifying AM parts can be complex and time-consuming. **8. Environmental and Safety Concerns:** • **Material waste and recycling:** Although AM is often praised for low waste, support structures and failed prints still contribute to material waste. • **Health risks:** Powders and fumes used in AM can pose health hazards, requiring proper handling and ventilation. **9. Intellectual Property (IP) Concerns:** • **Digital file vulnerability:** Design files can be easily copied or modified, raising IP protection issues. • **Counterfeit risk:** AM can potentially be used to produce unauthorized copies of proprietary parts.			
	b)	**Discuss the applications of Additive Manufacturing in the aerospace and medical fields.** **Aerospace Applications of Additive Manufacturing:** 1. **Lightweight Components** o AM allows for the design of lightweight structures with complex internal geometries (e.g., lattice structures) that maintain strength while reducing mass. o Example: GE Aviation's 3D-printed fuel nozzles for jet engines are 25% lighter and five times more durable than traditionally manufactured parts. 2. **Design Optimization and Complexity** o Topology optimization tools can be combined with AM to produce parts that are stronger and more efficient, often impossible to manufacture through traditional methods.	L2	CO1	5 M

- Components like brackets, ducting, and heat exchangers benefit from these optimizations.

3. **Rapid Prototyping and Tooling**
   - AM accelerates the design-to-test cycle, enabling engineers to quickly iterate and improve designs.
   - Custom tooling and jigs can also be produced on-demand, reducing lead times.
4. **Supply Chain Efficiency**
   - AM can reduce reliance on long supply chains by enabling localized production of spare parts, especially for aging aircraft.
   - It also decreases the need for inventory by producing parts on demand.
5. **Repair and Maintenance**
   - AM techniques like Directed Energy Deposition (DED) are used for repairing high-value components such as turbine blades.

Medical Applications of Additive Manufacturing:

1. **Customized Implants and Prosthetics**
   - AM enables the production of patient-specific implants (e.g., cranial plates, hip joints, spinal cages) tailored to individual anatomy using data from CT or MRI scans.
   - Titanium and biocompatible polymers are commonly used materials.
2. **Bioprinting and Tissue Engineering**
   - 3D bioprinting allows the creation of scaffolds for tissue regeneration and, in experimental phases, the printing of tissues and organs using cells and biomaterials.
   - This has potential for regenerative medicine and drug testing.
3. **Surgical Planning and Simulation**
   - Anatomical models of organs, bones, or tumors are printed from patient imaging data to assist surgeons in planning complex procedures and improving accuracy.
   - These models are also valuable for education and training.
4. **Dental and Orthodontic Applications**
   - Customized dental implants, crowns, bridges, and aligners can be manufactured with high precision using AM.
   - This reduces turnaround time and improves patient comfort.
5. **Medical Devices and Instruments**
   - AM supports the design and production of lightweight, ergonomic, and highly customized medical tools and instruments.
   - These include surgical guides and cutting templates, enhancing precision during procedures.