OR

9	a)	Describe the production of the Cemented carbide using powder metallurgy in detail with neat flow chat process.	L3	CO4	6 M
	b)	Draw and explain Mechanical pulverization and Atomization.	L3	CO4	4 M

UNIT-V

10	a)	Explain the different stages involved in manufacturing of ceramics using uniaxial pressing and slip Casting process with neat diagrams.	L3	CO5	6 M
	b)	With help of flow chart discuss sol-gel process to produce SiO_2 nanoparticles.	L3	CO5	4 M

OR

11	a)	What is meant by composite materials and explain any one manufacturing method with neat sketch.	L2	CO5	6 M
	b)	Define nanomaterials and list out the applications.	L3	CO5	4 M

Code: 23ME3302

PVP 23

II B.Tech - I Semester – Regular / Supplementary Examinations
NOVEMBER 2025

MATERIAL SCIENCE AND METALLURGY
(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 space lattice in a crystal structure of engineering materials.	L1	CO1
1.b)	What is Gibbs phase rule ? and Write its importance.	L2	CO1
1.c)	Write the function of P,S and C in cast irons.	L3	CO2
1.d)	State the difference between wrought and cast aluminium alloy.	L3	CO2
1.e)	Define Martensite and Bainite phases in steels.	L1	CO3
1.f)	What is Austempering process?	L2	CO3
1.g)	Explain the terms compaction and sintering.	L2	CO4
1.h)	Why particle size distribution is important in the packing of powders?	L3	CO4
1.i)	Differentiate between ceramic and non-ceramic materials.	L2	CO5

1.j)	List the applications of gold nanoparticles in engineering fields.	L2	CO5

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	What is meant by packing factor. Derive the packing factor of BCC structure.	L3	CO1	5 M
	b)	Explain the Eutectoid and Eutectic binary systems with help of phase diagrams.	L3	CO1	5 M
OR					
3	a)	Write a short note on point defects, line defects and surface defects with suitable diagrams.	L2	CO1	6 M
	b)	What are the condition's to form a solid solution based on Hume Rothery's rules.	L2	CO1	4 M
UNIT-II					
4	a)	Write the classification of tool steels. And explain in detail about Hot working and cold working tool steels as per AISI in view of industrial applications.	L3	CO2	5 M
	b)	What are the different types of brass and bronze alloys? Also mention its properties and application with help of microstructures.	L3	CO2	5 M
OR					

5	a)	With help of microstructures explain the chemical composition, properties and applications of cast iron.	L3	CO2	5 M
	b)	Draw the microstructures of aluminium alloys and label the different phases.	L3	CO2	5 M
UNIT-III					
6	a)	How alloying elements shows effect on Iron-Carbon diagram explain with cooling curves.	L3	CO3	4 M
	b)	In what way TTT diagram is differ from Fe-Fe$_3$C phase diagram, and draw the TTT for 0.8% steel.	L4	CO3	6 M
OR					
7	a)	Why tempering process is significant in heat treatment of steels? And mention the classification of tempering with respect to temperature range.	L3	CO3	4 M
	b)	Write a short note on surface hardening techniques with suitable diagrams.	L3	CO3	6 M
UNIT-IV					
8	a)	How are self-lubricating bearings produced?	L3	CO4	4 M
	b)	Explain the following processes (i) Infiltration (ii) Impregnation	L3	CO4	6 M

Code: 23ME3302

PVP 23

II B.Tech-I Semester-Regular / Supplementary Examinations-

November 2025

MATERIAL SCIENCE AND METALLURGY

(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
BL-Blooms Level CO-Course Outcome

Answer the following questions.

SCHEME OF EVALUATION

PART-A

Question No	Concept to cover	BL	CO	Marks	Total Marks
1.a)	Definition of space lattice	L1	1	1 Mark	2 Marks
	Crystal structures diagram			1 Mark	
1.b)	Gibbs phase rule	L2	1	1 Mark	2 Marks
	importance			1 Mark	
1.c)	P,S, C significance	L3	2	1 Mark	2 Marks
	Cast irons properties			1 Mark	
1.d)	Wrought aluminium alloy	L3	2	1 Mark	2 Marks
	Cast aluminium alloy difference			1 Mark	
1.e)	Martenisite and Bainite phases in steels explanation	L1	3	2 Marks	2 Marks
1.f)	Austempering process explanation	L2	3	2 Marks	2 Marks
1.g)	Compaction	L2	4	1 Mark	2 Marks
	sintering explanation			1 Mark	
1.h)	Particle size effect	L2	4	1 Mark	2 Marks
	and importance in packing effect			1 Mark	
1.i)	Ceramics and non-ceramics difference	L2	5	2 Marks	2 Marks
1.j)	Application of gold particles in engineering filed	L2	5	2Mark	2 Marks

PART-B					
		BL	CO	Marks	Total Marks
UNIT-1					
2	a) Packing factor definition and Bcc structure explanation and definition	L3	1	5 Mark	10 Marks
	b) Eutectiod and eutectic binary systems in the phase diagram with Figure	L3	1	5 Marks	
OR					
3.	a) Point defects, line defects, surface defects, slip and twinning explanation with figure	L2	1	6 Marks	10 Marks
	Hume Rothery 's rules and explanation	L2	1	4 Marks	
UNIT-II					
4.	a) Tool steels explanation, hot and cold work application	L3	2	5 Marks	10 Marks
	b) Brass and bronze alloys properties, applications	L3	2	5 Marks	
OR					
5.	a) Cast cast microstructure, white, gray etc with images	L3	2	5Marks	10 Marks
	b) Alimunium alloys and its alloys	L3	2	5 Marks	
UNIT-III					
6.	Iron carbon diagram explanation figure and cooling curve with the perspective of alloying elements	L3	3	4 Marks	10 Marks
	Why TTT diagram fe-fe3 c diagram deference with respect to time, TTT figure	L4	3	6 Marks	
OR					
7.	a)Tempering process explanation classification	L3	3	4 Marks	10 Marks
	b) Surface hardening , induction or case or carburizing any one method can be awarded from surface hardening	L3	3	6 Marks	
UNIT-IV					
8.	a) Procedure lubricating bearing production process	L3	4	4 Marks	10 Marks
	b) Infiltration and impregnation	L3	4	6 Marks	

	explanation				
OR					
9.	a) Flow chart process of powder metallurgy flow chart with perspective of cemented carbide	L3	4	6 Marks	10 Marks
	b) Mechanical Pulverization and atomization diagram with explanation	L3	4	4 Marks	
UNIT-V					
10.	a) Different stages of uniaxial processing and slip casting	L3	5	6 Marks	10 Marks
	b) Sol-gel process to produce sio2 nanoparticles	L3	5	4 Marks	
(OR)					
11.	a) Composite material definition and manufacturing method any one	L3	5	6 Marks	10 Marks
	b) Application of nano materials Nano material definition	L3	5	4 Marks	

PVP 23

Code: 23ME3302

II B.Tech-I Semester-Regular / Supplementary Examinations-

DECEMBER 2025

MATERIAL SCIENCE AND METALLURGY

(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

Answer the following questions.

PART-A

1. a) Define space lattice in a crystal structure of engineering materials ***L1 CO1 2M***

Ans) A space lattice is a three-dimensional, infinite array of points where each point has identical surroundings, representing the positions of atoms, ions, or molecules in a crystalline solid

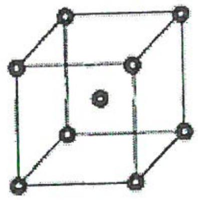


Fig.1. Crystal structure representation

1.b) what is gibbs phase rule? And write its importance L2, CO-1 2M

Gibbs' phase rule is a fundamental thermodynamic principle that relates the number of phases (P) in a system at equilibrium to the number of components (C) and the degrees of freedom (F) using the formula: $F = C - P + 2$.

1.c) Write the functions of P,S and C in cast irons. L3 CO-2 2M

Ans) The elements Phosphorus (P), Sulfur (S), and Carbon (C) play vital roles in determining the final properties and behavior of cast irons, from their fluidity during casting to their mechanical performance in application.

1.d) State the difference between wrought and cast aluminium alloy L3 CO-2 2M

The main difference is the manufacturing process: wrought alloys are formed by shaping the metal in a solid state (e.g., rolling, extruding, forging), while cast alloys are created by melting the metal and pouring it into a mold. This leads to differences in mechanical properties, with wrought alloys generally having higher tensile strength and ductility, and cast alloys often containing more internal defects but being more cost-effective for complex shapes.

1.e) Define Martensite and Bainite phases in steels L1 CO-3 2M

Martensite is a very hard and brittle, non-equilibrium phase formed in steel by a rapid, diffusionless transformation of austenite, resulting in a body-centered tetragonal (BCT) structure that traps interstitial carbon.

Bainite is a microstructure composed of ferrite and cementite phases, formed by a diffusional transformation at temperatures between those for pearlite and martensite, and is known for offering a balance of strength and toughness

1.f) what is Austempering process? L2 CO-3 2M

Austempering is a heat treatment process that improves the mechanical properties of ferrous metals like steel by heating them to form austenite, then rapidly quenching them in a bath to a temperature above the martensite start temperature

1.g) Explain the terms compaction and sintering L2 CO-4 2M

Compaction is the process of physically pressing loose metal or ceramic powder into a desired shape (a "green compact") at room temperature, typically using a die and punches.

Sintering is a subsequent heat treatment process where the compacted part is heated in a furnace to a temperature below the material's melting point.

1.h) why particle size distribution is important in the packing of powders? L3 CO-4 2M

Particle size distribution is important for powder packing because it determines how densely the powder packs together, which in turn affects its flowability, bulk density, and overall performance

1.i) Differentiate between ceramic and non-ceramic materials L2 CO-5 2M

Ceramic materials are inorganic, non-metallic solids known for their hardness, high heat resistance, and brittleness, while non-ceramic materials include metals, which are often durable but prone to corrosion, and plastics, which can be organic, weaker, and susceptible to heat.

1.j) List the applications of gold nanoparticles in engineering fileds L2 CO-5 2M

Gold nanoparticles have diverse applications in various engineering fields, primarily due to their unique optical, electronic, and catalytic properties, along with their high surface area-to-volume ratio and ease of functionalization. Mainly used to capture the SEM images.i.e to find the microstructure of the materials

PART-B

UNIT-I

2. *a) what is meant by packing factor. Derive the packing factor of BCC structure L3, CO1 5M*

Ans)

Atomic packing is defined as the packing of atoms in a unit cell of the crystal structure of a material. Packing arrangement of atom depends on the following factors:

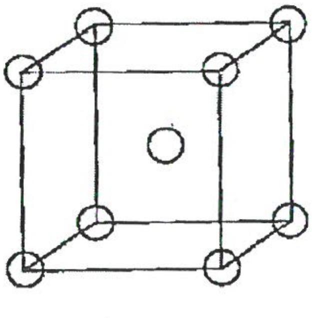
(i) The relative radius of the atoms involved

(ii) Character of bonding between atoms.

$$\text{APF} = \frac{\textit{Volume of atoms contained in each unit cell}}{\textit{volume of the unit cell}}$$

Body Centred Cubic (BCC):

It has one atom at the center of the cube along with atoms at each corner of the cube. Ex: Cr, W, Na, α - iron, γ - iron, v, Mo, Mn.



No. of atoms in B.C.C:

Each corner atom is shared by 8 adjoining cubes and the new center atom is not shared by any adjoining cube.

8 atoms at the corner × $\frac{1}{8}$ = 1 atom

1 center atom = 1 atom

Total = 2 atoms.

T find 'a' in terms of 'r':

From fig, xy = $\sqrt{a^2+a^2} = \sqrt{2a^2} = \sqrt{2}\,a$

Similarly, $(xz)^2 = (4r)^2 = (\sqrt{2}\,a)^2 + a^2 = 2a^2 + a^2 = 3a^2$

$$4r = \sqrt{3}\,a.$$

$$a = \frac{4r}{\sqrt{3}}$$

$$APF = \frac{no.of\ atoms \times volume\ of\ each\ atom}{volume\ of\ unit\ cell}$$

$$= \frac{2\times\frac{4}{3}\pi r^3}{a^3} = \frac{2\times 4\pi r^3}{3\times\left(\frac{4r}{\sqrt{3}}\right)^3}$$

$$= \frac{\pi}{8}$$

APF = 0.68

2.b) Explain the Eutectoid and Eutectic binary systems with help of phase diagrams L3 CO-1 5M

It is commonly found that many materials are highly miscible in the liquid state, but have very limited mutual miscibility in the solid state. Thus much of the phase diagram at low temperatures is dominated by a 2-phase field of two different solid structures- one that is highly enriched in component A (the α phase) and one that is highly enriched in component B (the β phase). These binary systems, with unlimited liquid state miscibility and low or negligible solid state miscibility, are referred to as eutectic systems

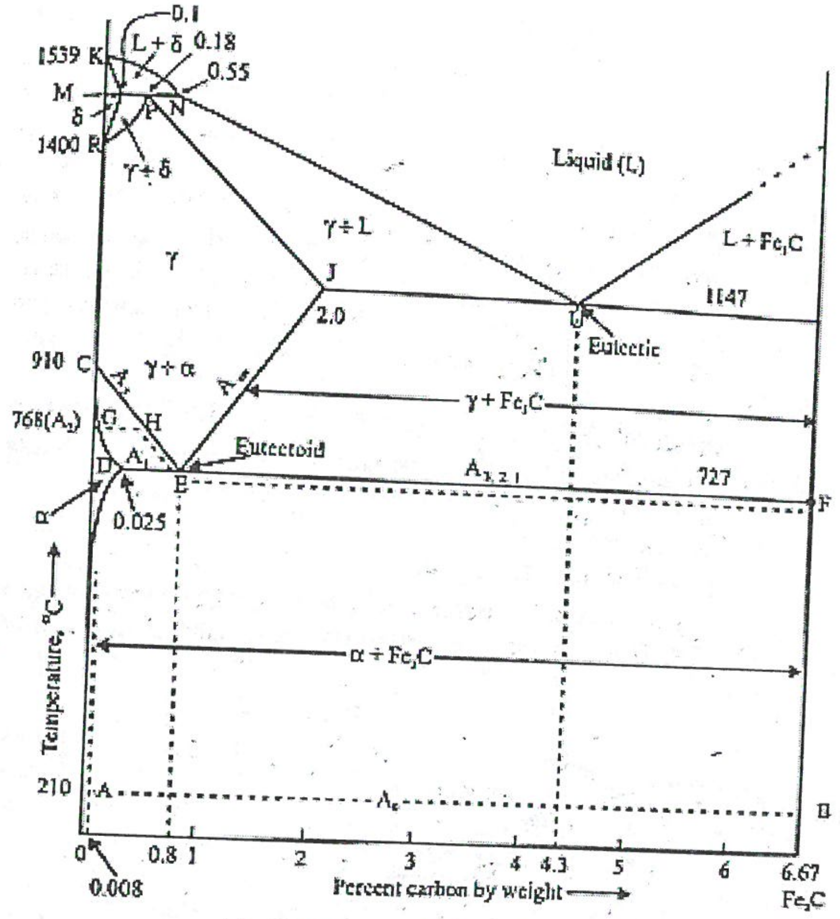


Fig. 9.1 : Iron-iron carbide equilibrium diagram.

From the FE Fe-3 c diagram eutectic and eutectoid points are presented.

Eutectic reaction: Liquid phase transforms into two solid phases (austenite and cementite) at the eutectic point.

Eutectoid reaction: One solid phase (austenite) transforms into two other solid phases (ferrite and cementite).

OR

3. **a) write a short note on point defects, line defects, and surface defects with suitable diagrams.** **L2, CO-1 6M**

Point, line, and surface defects are all types of imperfections in crystalline solids that affect their properties. Point defects are zero-dimensional flaws involving a single atom or lattice point, like vacancies or impurities.

Line defects are one-dimensional, such as dislocations (edge or screw), which are misaligned rows of atoms. Surface defects are two-dimensional, occurring at interfaces and boundaries like grain boundaries and twin boundaries.

Point defects

Description: Irregularities at a single point or a few points in the crystal lattice.

Examples:

Vacancy: A missing atom from its lattice site.

Interstitials: Extra atoms in spaces between lattice sites.

Substitutional: An atom on a lattice site is replaced by a different type of atom.

Schottky and Frenkel defects: Specific types of vacancies and interstitials in ionic crystals.

Line defects

Description: One-dimensional defects that run along a line within the crystal.

Examples:

Edge dislocation: An extra half-plane of atoms inserted into the crystal structure.

Screw dislocation: A spiral or helical arrangement of atoms around a central line.

Surface defects

Description: Two-dimensional defects that exist at the surface or interfaces between different regions of the crystal.

Examples:

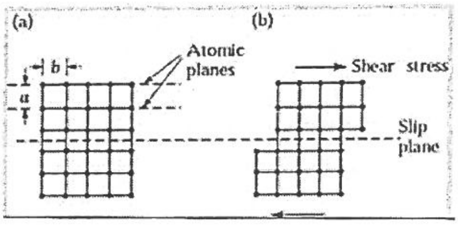
Grain boundaries: The interface where two different crystals (grains) meet.

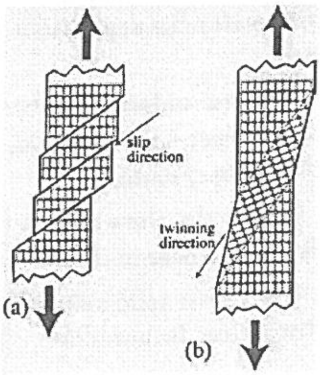
Twin boundaries: A boundary where the crystal structure on one side is a mirror image of the other.

Stacking faults: An error in the stacking sequence of atomic layers.

Slip and twin

1. **Slip is a permanent displacement of one part of crystal relative to the other part. slip involves sliding of one plane of atoms over the other.**
2. **The plane on which the slip occurs are called slip planes and the direction in which this occurs are called slip direction.**
3. **Slip occurs when shear stress applied exceeds a critical value.**





- Twinning is a process in which the atoms in a part of the crystal subjected to stress rearrange themselves so that the orientation of the part changes in such a way that the distorted part becomes a mirror image of the other part.
- The plane across which the two part are mirror images is called twinning plane or composition plane.
- Like slip, twinning also occurs along the certain crystallographic planes and directions.
- These planes and directions are called as twin planes and twin directions.
- The important role of twinning in plastic deformation is that it causes changes in plane orientation so that further slip can occur.

3.b) what are the conditions to form a solid solution based on Hume Rothery's rules L2 CO-1 4M

In formation of solid solutions, the solubility limit of solute in the solvent is governed by certain factors. These factors are known as Hume–Rothery's rules of solid solubility. They are as below :

(i) **Atomic size factor :** If the atomic sizes of solute and solvent differ by less than 15%, it is said to have a favourable size factor for solid solution formation. If the atomic size difference exceeds 15%, solid solubility is limited.

(ii) **Chemical affinity factor :** The greater the chemical affinity of two metals, the more restricted is their solid solubility and greater is the tendency of formation of a compound. Generally, wider the separation of elements in the periodic table, greater is their chemical affinity.

(iii) **Relative valency factor :** A metal of higher valency can dissolve only a small amount of a lower valency metal, while the lower valency metal may have good solubility for the higher valency metal.

(iv) **Crystal structure factor :** Metals having same crystal structure will have greater solubility. Differences in crystal structure limits the solid solubility.

For continuous solid solubility, atomic size difference should preferably be less than 8% with other factors favourable.

UNIT-II

4.a) Write the classification of tool steels. And explain in details about Hot working and cold working tool steels as per AISI in view of industrial applications. L3 CO2 5M

- Steel for making forming and cutting tools and dies for desired performance in terms of reliability and life should have a good combination of hardness, wear resistance, toughness, dimensional stability, and ease of manufacturing.
- In general, increasing the hardenability of the steel increases the maximum attainable hardness, wear resistance, and dimensional stability.
- Depending upon the hardening approach and application, tool steel are classified as

a) water hardening (plain carbon steel)
b) shock resisting (medium and low alloy steel)
c) cold work (oil hardening, high carbon-high chromium, medium alloy steel)
d) hot work (chromium, molybdenum, tungsten Steel)
e) high-speed steel (tungsten, and molybdenum high-speed steels)
f) and mold (low carbon steel).

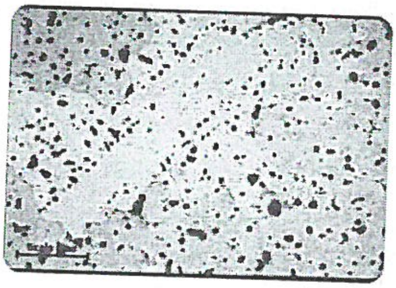
Note: explanation of any one method of above can be considered

4.b) What are the different types of brass and Bronze alloys? Also mention its properties and application with help of microstructures L3 CO2 5M

Ans) Copper and copper-based alloys, including brasses (Cu-Zn) and bronzes (Cu-Sn), are widely used in different industrial and societal applications.

- Some brass alloys include costume jewellery, locks, hinges, gears, bearings, ammunition casings, automotive radiators, musical instruments, electronic packaging, and coins.
- Bronze, or bronze-like alloys and mixtures, were used for coins over a longer period. It is still widely used today for springs, bearings, bushings, automobile transmission pilot bearings, and similar fittings and is particularly common in the bearings of small electric motors.
- Brass and bronze are common engineering materials in modern architecture and are primarily used for roofing and facade cladding due to their visual appearance.

Brass microstructure



Bronze microstructure

Bronze is applied in heavy-duty industrial applications like bearings and marine parts due to its strength and corrosion resistance, while brass is used for decorative and more malleable purposes like plumbing fixtures, musical instruments, and electrical fittings because of its gold-like appearance and ease of machining

Cartridge brass

Cartridge brass, a copper alloy containing about 30% zinc by weight, is easy to produce and is often cost effective because zinc generally costs less than copper. This most popular brass has attractive properties for terminals, springs, switches, contacts, and other connector components.

Applications : Radiator Tanks and cores, flashlight shells, lamp fixtures, fasteners locks, hinges, ammunition components, pins, rivets, buttons, plumbing accessories

GUNMETAL: gunmetal, also called G Metal, variety of bronze, formerly used for ordnance. Modern admiralty gunmetal is composed of 88 percent copper, 10 percent tin, and 2 percent zinc and is used for gears and bearings that are to be subjected to heavy loads and low speeds.

Gun metal also known as red brass is a type of bronze an alloy of copper 88%, tin 10%, zinc 2%. It is used for making guns. Gunmetal casts and machines are resistant to corrosion from steam and salt water and is used to make steam and hydraulic castings, valves, gears.

NAVEL BRASS

Navy brass: Naval brass is the classic marine, high-strength and corrosion-resistant alloy containing 60 percent copper, 75 percent tin and 39.2 percent zinc. It is widely used in marine construction where strong, corrosive-resistant and hard material is required and is suitable for both salt and fresh water applications.

BELL METALS

Bell metal is a hard alloy used for making bells and related instruments, such as cymbals. It is a form of bronze with a higher tin content, usually in approximately a 4:1 ratio of copper to tin. Therefore, the bell metal is an alloy of copper and tin in ratio 4:1.

PHOSPHOR BRONZE is a member of the family of copper alloys. It is composed of copper that is alloyed with 0.5–11% of tin and 0.01–0.35% phosphorus, and may contain other elements to confer specific properties (e.g. lead at 0.5–3.0% to form free-machining phosphor bronze). Alloyed tin increases the corrosion resistance and strength of copper, while phosphorus increases its wear resistance and stiffness.

Note: explanation of any two types from each case can be considered

5a) with help of microstructure explain the chemical composition, properties and applications of cast iron L3 CO-2 5M

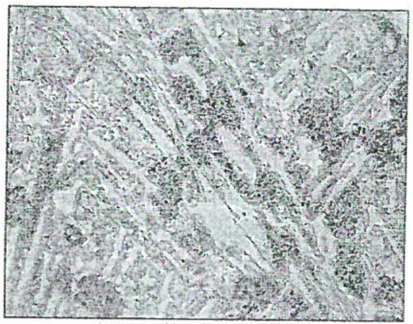
CAST IRONS:

- Cast iron is one of the oldest ferrous metals in commercial use. It is primarily composed of iron (Fe), carbon (C) and silicon (Si), but may also contain traces of sulfur (S), manganese (Mn) and phosphorus (P).
- It has a relatively high carbon content of 2% to 5%. It is typically brittle and nonmalleable (i.e. it cannot be bent, stretched or hammered into shape) and relatively weak in tension.
- Cast iron members tend to fracture with little prior deformation. Cast iron, however, has excellent compressive strength and is commonly used for structures that require this property.
  Cast
  irons can be divided into five groups, based on composition and metallurgical structure:
  ☐ Gray cast iron,
  ☐ White cast iron,
  ☐ Malleable cast iron,
  ☐ Compacted graphite iron and,
  ☐ Alloy cast iron.

WHITE CAST IRON

- White CIs are hard and brittle and cannot be machined easily. White CI is the only member of the CI family in which carbon is present only as carbides.

- Because of the absence of graphite, it has a light appearance. The presence of different carbides makes white CIs extremely hard and abrasion resistant, but also very brittle.
- The microstructure of white CI contains massive cementite (white) and pearlite. White cast iron derives its name from the white, crystalline crack surface observed when a casting fractures.
- Most white cast irons contain less than 4.3% carbon, with low silicon contents to inhibit the precipitation of carbon as graphite.
- It is used in applications where abrasion resistance is important and ductility not required, such as liners for cement mixers, ball mills, certain types of drawing dies and extrusion nozzles.
- White cast iron is generally considered unweldable.



White Cast Iron Microstructure

5b) Draw the microstructure of aluminium alloys and label the different phases

L3 CO-2 5M

ALUMINIUM AND ITS ALLOYS: PROPERTIES AND APPLICATIONS OF DURALUMIN

The aluminium may be easily alloyed with other elements like copper, magnesium, zinc, manganese, silicon and nickel to improve various properties. The addition of small quantities of alloying elements into other metals helps to converts the soft and weak metal into hard and strong metal, while still retaining its light weight.

Various aluminium alloys are

1. Duralumin
2. Magnalium
3. Hindalium
4. Duralumin:

It is an important wrought alloy. Its composition contains following chemical contents.

Copper = 3.5-4.5 %

Manganese = 0.4 - 0.7 %

Magnesium = 0.4- 0.7 %

Aluminium = 94 %

- Duralumin can be very easily forged, casted and worked because it possesses low melting point.
- It has high tensile strength, comparable with mild steel combined with the characteristics lightness of Al.
- It however possesses low corrosion resistance and high electrical conductivity.
- It is light in weight as compared to its strength in comparison to other metals.
- It can be easily hot worked at a temperature of 500°C. However after forging and annealing, it can also be cold worked.

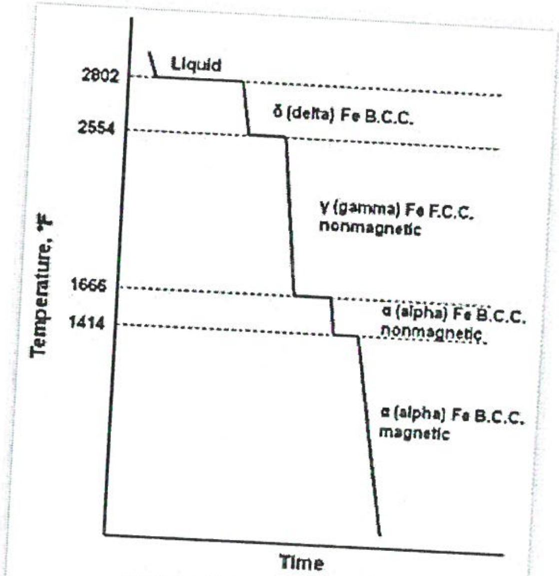
Applications

- Duralumin is used in the wrought conditions for forging, stamping, bars, sheets, tubes, bolts, and rivets.
- Due to its higher strength and lighter weight, this alloy is widely used in automobile and aircraft components.
- To improve the strength of duralumin sheet, a thin film of Al is rolled along with this sheet. Such combined sheets are widely used in air-craft industries.
- It is also employed in surgical and orthopedic work, non-magnetic work and measuring instrument parts constructing work.

UNIT-III

6.a) How alloying elements shows effects on Iron-Carbon diagram explain with cooling curves. L3 CO3 4M

Alloying elements affect the iron-carbon diagram by shifting phase boundary lines, which alters the temperatures at which transformations occur. Some elements expand the austenite field, promoting its formation, and are called gamma-stabilizers (e.g., nickel), while others contract it, favoring ferrite formation and are called alpha-stabilizers (e.g., chromium). On a cooling curve, this is observed as a change in the position and temperature of the "halts" or plateaus, where phase transformations take place.

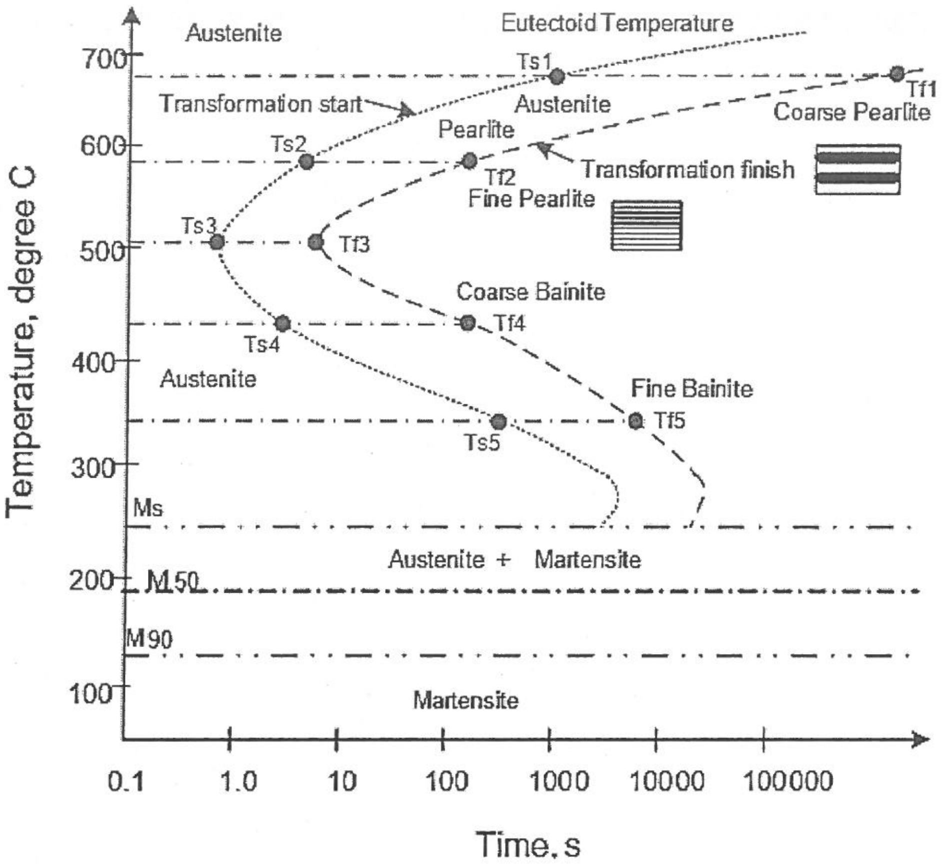


Cooling Curve for Pure Iron

6.b) In what way TTT diagram is different from Fe-Fe3c phase diagram, and draw the TTT for 0.8% steel L4 CO3 6M

The main difference is that the **Fe-Fe3C phase diagram** shows phase transformations under equilibrium conditions, while the **TTT (Time-Temperature-Transformation) diagram** illustrates the phases that form under non-equilibrium conditions based on how quickly cooling occurs. The TTT diagram includes time as a variable and shows how austenite transforms over time at a constant temperature, which is crucial for understanding practical heat treatment processess

- The temperature of transformation controls the nature of decomposed product (of austenite) which in turn decides the resultant properties of steel.
- The kinetics of austenitic transformation can be studied best at a constant temperature rather than by continuous cooling.
- The constant temperature transformation is also referred to as isothermal transformation which is studied by the following experiment.
- Davenport and Bain were the first to develop the TTT diagram of eutectoid steel. They determined pearlite and bainite portions whereas Cohen later modified and included M_S and M_F temperatures for martensite.
- There are number of methods used to determine TTT diagrams. The most popular method is salt bath techniques combined with metallography and hardness measurement with addition of this we have other techniques like dilatometry, electrical resistivity method, magnetic permeability, *in situ* diffraction techniques (X-ray, neutron), acoustic emission, thermal measurement techniques, density measurement techniques and thermodynamic predictions.
- TTT diagrams, also called as Isothermal *(temperature constant)* Transformation diagrams.
- For every composition of steel we should draw a different TTT diagram.

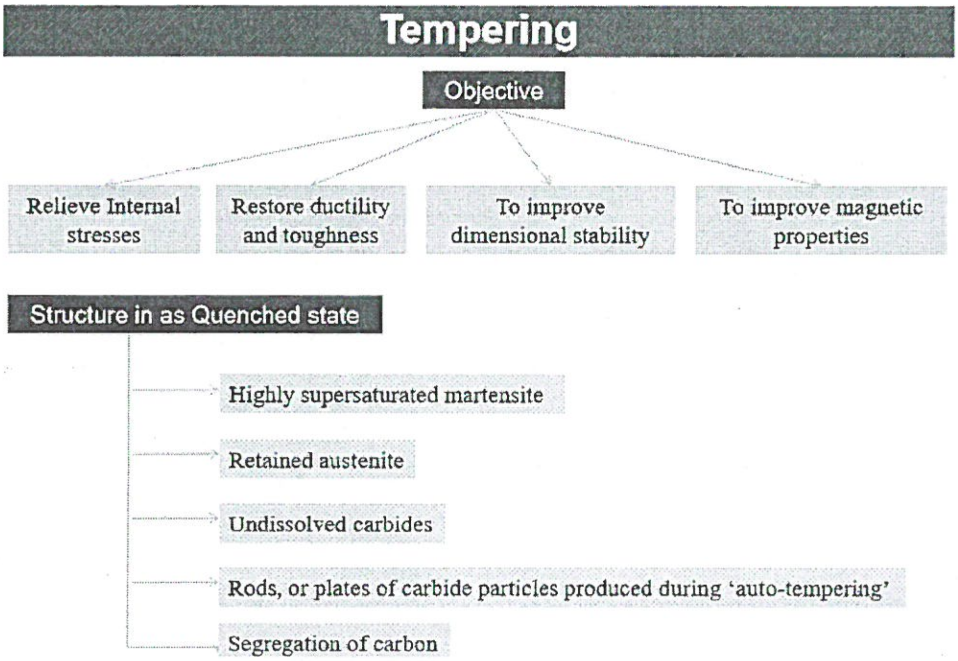


OR

7 a) Why tempering process is significant in heat treatment of steels? And mention the classification of tempering with respect to temperature range L3 CO3 4M

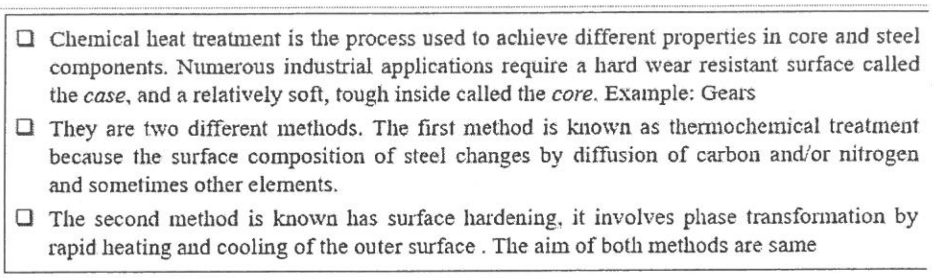
☐ The hardened steel is not readily suitable for engineering applications. It possesses following three drawbacks.

- ✓ Martensite obtained after hardening is extremely brittle and will result in failure of engineering components by cracking.
- ✓ Formation of martensite from austenite by quenching produces high internal stresses in the hardened steel.



Tempering is classified into three main types based on temperature: low-temperature (150-250^{0}C), medium-temperature (250-500^{0}c), and high-temperature (>500^{0}C). These ranges are used for different purposes, such as increasing hardness and wear resistance at lower temperatures, achieving a balance of toughness and hardness in the medium range, and increasing toughness for components like machine parts at higher temperatures.

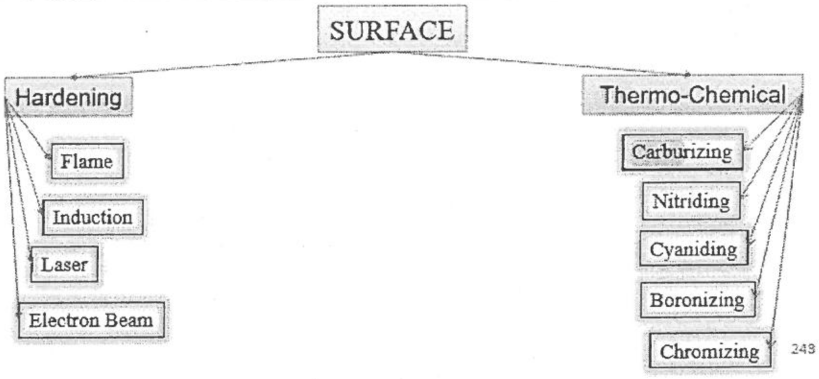
7b) Write a short note on surface hardening techniques with suitable diagrams L3, CO3 6M



❑ Chemical heat treatment is the process used to achieve different properties in core and steel components. Numerous industrial applications require a hard wear resistant surface called the *case*, and a relatively soft, tough inside called the *core*. Example: Gears

❑ They are two different methods. The first method is known as thermochemical treatment because the surface composition of steel changes by diffusion of carbon and/or nitrogen and sometimes other elements.

❑ The second method is known has surface hardening, it involves phase transformation by rapid heating and cooling of the outer surface . The aim of both methods are same



The main aim of this process is to make the only external surface of steel hard and inner core soft. It is the process of carburization i.e., saturating the surface layer of steel with carbon, or some other process by which case is hardened and the core remains soft.

Purpose of Case Hardening

To obtain a hard and wear resistance to machine parts.

By case hardening, it obtains a tough core.

To obtain a higher fatigue limit and high mechanical properties in the core.

Flame Hardening

Flame hardening is a surface-hardening method that involves heating a metal with a high-temperature flame, followed by quenching. It is used on medium carbon, mild or alloy steels or cast iron to produce a hard, wear-resistant surface.

Flame hardening uses direct impingement of an oxy-gas flame onto a defined surface area. The result of the hardening process is controlled by four factors: esign of the flame head Duration of heating Target temperature to be reached Composition of the metal being treated

Typical flame-hardening applications include: Blades, Gears, Rolls, Cams, Automotive components

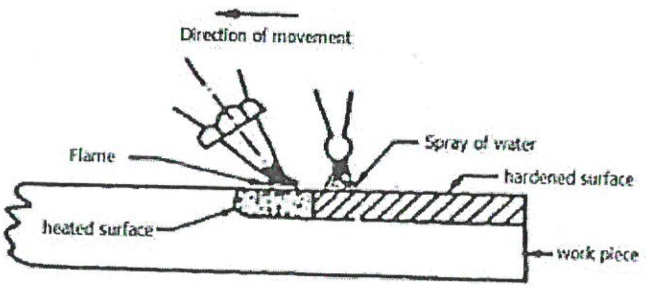


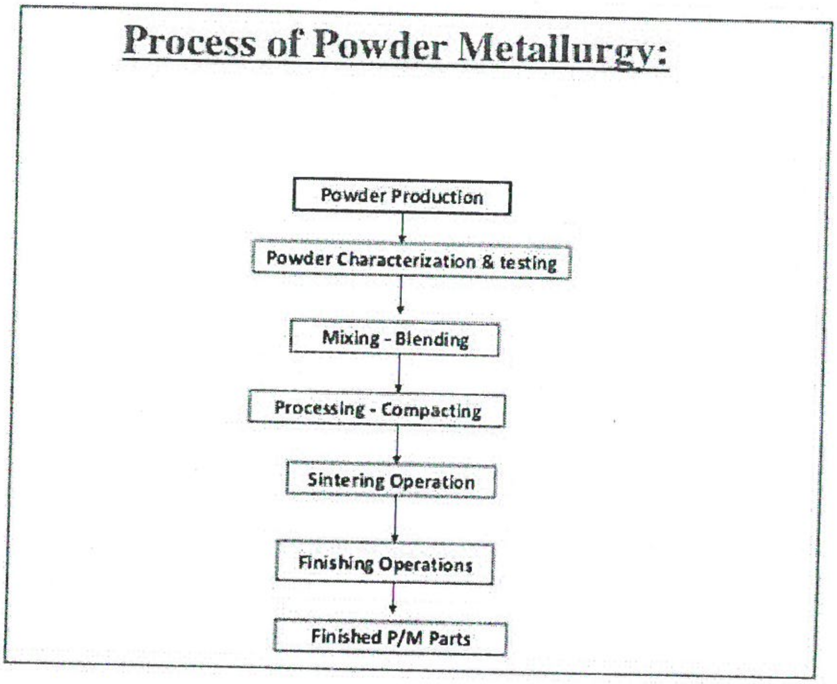
Fig: Principle of flame hardening

Note: Any one method can be awarded

UNIT-IV

8a) How are self-lubrication bearings produced? *L3 CO4 4M*

Self-lubricating bearings are produced through a process of powder metallurgy, which involves pressing metal or polymer powders into a desired shape, sintering them at high temperatures to create a porous structure, and then impregnating this porous material with a lubricant. Advanced methods like injection molding or laser surface texturing can also be used for other types of self-lubricating bearings.



Process of Powder Metallurgy:

8 b) Explain the following process **L3 CO4 6M**

(i) **Infiltration (ii) Impregnation**

(i) Infiltration

Definition:
Infiltration is the process of **introducing a molten metal** into the pores of a sintered powder metallurgy (P/M) part to **increase density, strength, and hardness.**

Working Process

1. A **sintered porous P/M part** (usually made of iron or copper alloys) is placed in contact with a **slug of lower-melting metal** such as copper, bronze, or brass.
2. The assembly is heated above the melting point of the infiltrant metal but **below the melting point of the base P/M compact**.
3. The molten metal flows by **capillary action** into the interconnected pores of the part.
4. As the molten metal fills the pores, the **density increases**, porosity decreases, and the part becomes much stronger.
5. After infiltration, the part is cooled and attains **superior mechanical properties** such as tensile strength, fatigue strength, and wear resistance.

(ii) Impregnation

Definition:
Impregnation is the process of **filling the pores of a sintered P/M part** with a **liquid substance** such as oil, resin, polymer, or lubricant to provide **self-lubrication, sealing, or corrosion resistance.**

Working Process

1. Sintered P/M parts are placed in a tank containing the impregnating material (oil, polymer resin, wax, etc.).
2. Vacuum or pressure is applied to force the liquid into the **open surface-connected pores**.
3. The part absorbs the liquid through capillary action.
4. Excess surface material is drained off, and the part is dried.
5. The impregnated part retains the liquid in its pores during operation, slowly releasing it as needed.

OR

9 a) Describe the production of cemented carbide using powder metallurgy in detail with neat flow chart process L3 CO4 6M

Powder metallurgy (PM) is a metal-forming process that involves compacting metal powders into a shape and then heating them to just below their melting point to bond the powders together (**cemented carbide**). This process is also known as sintering.

PM is also recognized as being environmentally friendly as it produces harmless bi-products of nitrogen and hydrogen while also limiting production waste.

The steps involved in **cemented carbide production using PM** are:

Production

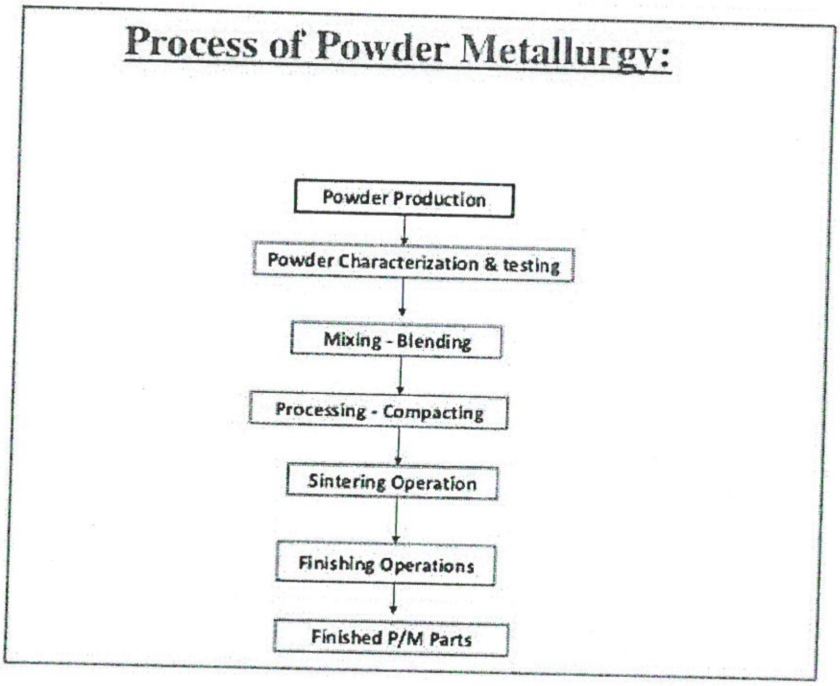
Powder can be produced using water atomization, where a thin jet of liquid metal is broken into drops by high-speed streams of atomized water.

Compacting

The powder is pressed into a specific shape or die using pressure compaction methods such as cold die compaction, iso-static pressing, or hot compaction.

Sintering: The compacted powder (is heated to just below its melting point to bond the powders together.

BASIC PROCESS IN POWDER METALLURGY



9 b) Draw and explain Mechanical pulverization and atomoization L3 CO4 4M

Mechanical pulverization is a process that breaks down solid materials into smaller particles using mechanical forces like crushing, grinding, impact, and shear. This size-reduction technique is used across many industries, from pharmaceuticals and food processing to metallurgy and recycling, to create powders with specific properties. Equipment like hammer mills, ball mills, and roller mills are used to perform this process on a large scale

Metal powders are produced by a variety of methods, including:

Atomization
A common method for mass production that involves converting molten metal into droplets that solidify into fine particles. Atomization can be achieved through gas, water, or centrifugal atomization.

UNIT-V

10 a) Explain the different stages involved in manufacturing of ceramics using uniaxial press and slip casting with neat diagrams L3, CO5, 6M

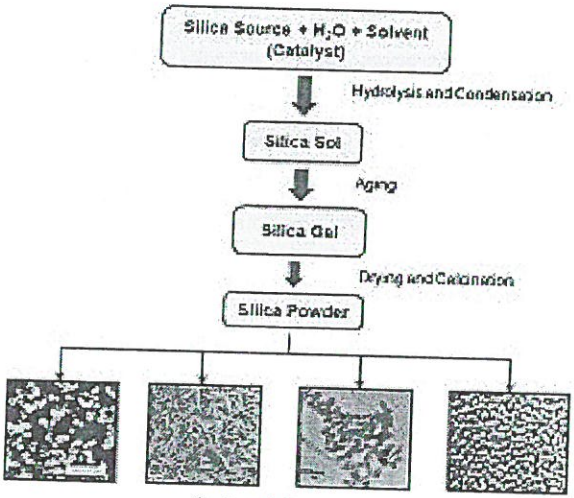
The manufacturing of ceramics generally involves common steps of material preparation, forming, drying, and sintering, but the specifics of the forming stage differ significantly between uniaxial pressing and slip casting.

Stage	**Uniaxial Pressing**	**Slip Casting**
1. Raw Material Preparation	Raw ceramic powders are mixed with minimal additives (binders, lubricants) and are often spray-dried into a free-flowing, granular powder.	Raw ceramic powders are mixed with a liquid (usually water) and deflocculants to form a stable, low-viscosity liquid suspension called a "slip".
2. Forming/Shaping	The prepared dry powder is loaded into a rigid die (usually made of steel or tungsten carbide). Pressure is then applied in a single axial direction using a ram or punch to compact the powder into a "green body" shape.	The slip is poured into a porous mold, typically made of plaster of Paris (gypsum). The mold's capillary action absorbs the liquid from the slip, causing a solid layer of particles to build up against the mold wall.
3. Removal of Excess Material	Not applicable; the die cavity is completely filled and compacted to form a solid piece.	For hollow parts (drain casting), excess slip is poured out once the desired wall thickness is achieved. For solid parts (solid casting), the slip is left to fully solidify in the mold.
4. Demolding and Drying	The compacted "green body" is ejected from the reusable die using cams or a hydraulic system. The part is then dried to remove any remaining moisture without cracking.	The "green body" is removed from the mold after partial drying (it shrinks away from the mold walls, aiding release). It is then left to dry completely in a controlled environment.

5. Sintering/Firing	The dried green body is fired at a high temperature in a kiln. This process sinters the particles together, creating strong bonds and densifying the material into a hard, durable ceramic.	The dried green body is similarly fired at a high temperature. Sintering transforms the fragile material into its final dense and strong form.
6. Finishing	If tighter tolerances or a smoother surface are needed, the final product may undergo grinding, polishing, or machining after sintering.	Glazes may be applied before a second firing for aesthetic or functional purposes (e.g., creating a smooth, glossy, and waterproof surface for tableware or sanitary ware).

10 b) with help of flow chart discuss sol-gel process to produce Sio2 nanoparticles L3, CO-5, 4M

The sol-gel process for producing \(SiO2) nanoparticles involves five main steps: forming a sol (a colloidal suspension) through the hydrolysis of a silica precursor like TEOS, followed by a condensation reaction to create a gel. The gel is then aged, dried to remove solvents, and finally, calcined (heated) at high temperatures to eliminate remaining organic material and form the stable, solid \(SiO_{2}\) nanoparticles.



Sol-gel Process

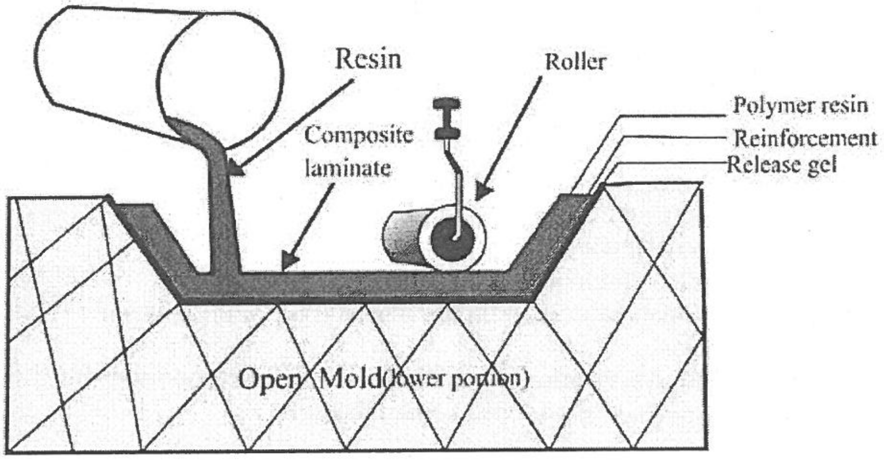
OR

11 a) what is meant by composites materials and explain any one manufacturing method with neat sketch L2 CO5 6M

Composites are materials made by combining two or more distinct materials (matrix and reinforcement) to achieve superior properties compared to individual components.

Hand Lay-Up Process

- **Description**: A simple and manual method for fabricating composite materials, typically used for low-volume production.
- **Steps**:
  1. A release agent is applied to the mold to prevent sticking.
  2. Fiber reinforcement (e.g., glass, carbon, or natural fibers) is placed on the mold.
  3. Resin (e.g., epoxy, polyester) is applied manually using brushes or rollers to saturate the fibers.
  4. Additional layers of reinforcement and resin are added as needed.
  5. The composite is left to cure at room temperature or under heat.
- **Applications**: Boat hulls, panels, tanks, and prototypes.
- **Advantages**:
  - Low cost.
  - Simple tools and setup.
  - Suitable for large parts.
- **Disadvantages**:
  - Labor-intensive.
  - Inconsistent quality due to manual handling.



Hand lay up process

11.b Define nanomaterial and list out the applications **L3, CO5, 4M**

Nanomaterials are materials that have structures, properties, or functionalities at the nanoscale, typically ranging from 1 to 100 nanometers (nm). At this scale, materials exhibit unique properties that differ significantly from their bulk counterparts due to quantum effects, increased surface area, and other nanoscale phenomena.

Applications of Nanomaterials

Nanomaterials are being used in a wide range of applications across various industries, such as:

1. **Electronics and Computing**
    - **Transistors**: Nanoscale transistors are used in faster, smaller, and more efficient electronic devices.
    - **Memory Storage**: Nanomaterials are used in advanced memory devices with higher storage capacities.
2. **Energy Storage and Conversion**
    - **Batteries**: Nanomaterials are used to improve the capacity and efficiency of batteries, such as lithium-ion and lithium-sulfur batteries.
    - **Solar Cells**: Nanostructured materials enhance the efficiency of solar panels by improving light absorption and conversion.
3. **Medicine**
    - **Drug Delivery**: Nanoparticles are used for targeted drug delivery systems that improve the precision and effectiveness of treatments.
    - **Diagnostics**: Nanosensors and nanoparticles are used in diagnostic imaging, enabling early detection of diseases like cancer.
    - **Wound Healing**: Nanomaterials are used in advanced wound dressings due to their antibacterial and regenerative properties.
4. **Environmental Remediation**
    - **Water Purification**: Nanomaterials such as nanofiltration membranes and photocatalysts are used to remove contaminants from water.
    - **Air Purification**: Nanocatalysts are employed in reducing air pollution by breaking down harmful gases.
5. **Textiles and Coatings**
    - **Water-Repellent Fabrics**: Nanomaterials are used to create fabrics with self-cleaning and water-repellent properties.
    - **Anti-Microbial Coatings**: Nanosilver and other nanoparticles are used in coatings to prevent microbial growth on surfaces.
6. **Automotive and Aerospace**
    - **Lightweight Materials**: Nanocomposites are used to create strong, lightweight materials for vehicles and aircraft, improving fuel efficiency and performance.
    - **Self-Healing Materials**: Nanomaterials enable the development of materials that can self-repair minor cracks and damages.