CBCS SCHEME

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BME303

Third Semester B.E./B.Tech. Degree Examination, June/July 2024
Material Science and Engineering

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	List the three primary classifications of solid materials. Explain briefly the distinctive chemical features of each.	06	L2	CO1
	b.	Classify and briefly explain primary atomic bonds.	08	L2	CO1
	c.	Define unit cell of a crystal lattice. Name and sketch the various crystal structures (unit cells) commonly present in materials. Show the value of edge length (a).	06	L2	CO1
		OR			
Q.2	a.	Explain the following terms related to crystal structure: (i) Size of unit cell (ii) Coordination number (iii) Atomic packing factors	06	L2	CO1
	b.	Determine the Atomic Packing Factor (APF) for FCC structure (Unit Cell).	08	L2	CO1
	c.	Classify and briefly explain crystal lattice imperfections.	06	L2	CO1
		Module – 2			
Q.3	a.	Explain the term diffusion. State and briefly explain the various types of diffusion mechanisms.	08	L2	CO2
	b.	State and explain Fick's laws of diffusions.	08	L2	CO2
	c.	State and explain any two factors that influence diffusion process.	04	L3	CO2
		OR			
Q.4	a.	Define the following : i) Phase ii) Phase diagram iii) Phase equilibrium iv) Solubility limit.	04	L2	CO2
	b.	Explain 'Lever rule' for the construction of phase diagram.	06	L2	CO2
	c.	Name and explain the three invariant reactions that take place in Fe-Fe_3C phase diagram.	10	L2	CO2
		Module – 3			
Q.5	a.	Name and explain the various mechanisms by which the nucleation of solid particles in liquid metal occurs.	10	L2	CO3
	b.	Explain with suitable diagrams the process of precipitation hardening.	10	L2	CO3
		OR			
Q.6	a.	Explain briefly the following heat treatment processes : (i) Annealing (ii) Normalizing (iii) Tempering (iv) Nitriding	16	L2	CO3
	b.	What do you understand by critical radius for nucleation?	04	L2	CO2
		Module – 4			
Q.7	a.	Classify the various surface coating techniques used in surface engineering.	04	L1	CO4
	b.	Briefly explain Chemical Vapour Deposition (CVD).	10	L2	CO4
	c.	Write a note on Lubrication and binders.	06	L1	CO4
		OR			
Q.8	a.	Briefly explain the powder-metallurgy process using flow chart.	08	L2	CO4
	b.	State and briefly explain the various methods of atomization processes used for preparing the metallic powder.	12	L2	CO4

		Module – 5			
Q.9	a.	What is the Chemical Composition of grey cast iron? Show the microstructure by stating the various properties and uses of grey cast iron.	06	L2	CO5
	b.	Name the various alloying elements and their influence over steel alloys.	08	L2	CO5
	c.	How are copper alloys classified? Designate and state the properties and uses of copper alloys.	06	L2	CO5
		OR			
Q.10	a.	How composite materials are classified. State their constituents used.	06	L2	CO5
	b.	Name and briefly explain the various types of fibers and matrix materials used for Fiber Reinforces Plastics (FRP).	08	L2	CO5
	c.	Explain the process of obtaining Material data.	06	L2	CO5

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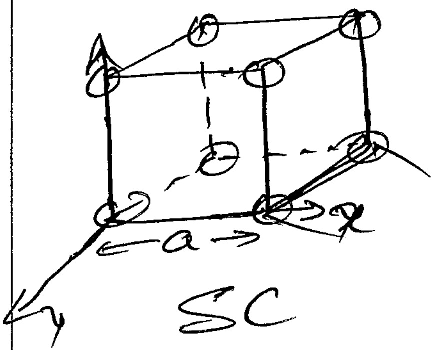
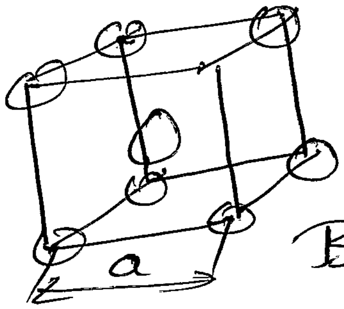
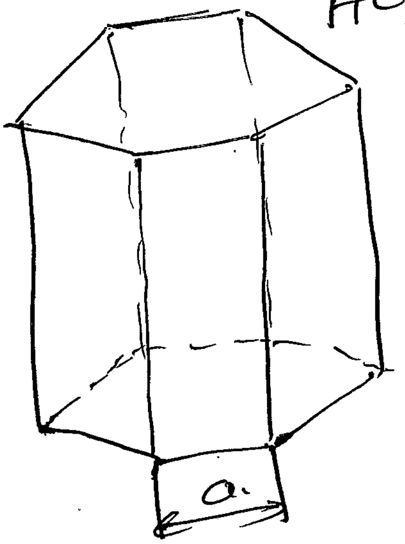
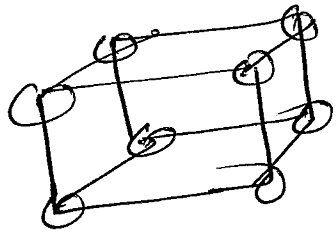
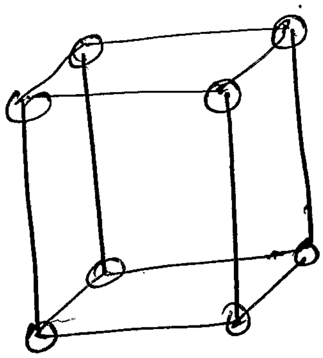
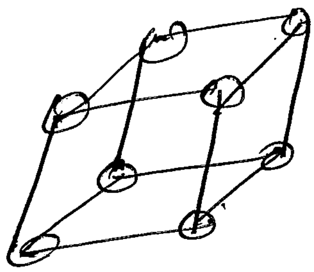
Q.No.	Solution and Scheme	Marks
1 a)	Solid materials have been Conventionaly classified in to three groups. Metals, Ceramics and polymers. based on chemical makeup and atomic Structure. Classification of material based on appearance, Structure & Physical Properties Hard, Soft, Transparent, Opaque Classification based on usage of material. of. Construction material Aerospace material Nuclear material Metal- This material has characters like high electrical, Thermal Conductivity. Ability to be deformed or cut in to shapes without breaking and high mechanical Strength. These are reduced from Compounds.	

Q.No.	Solution and Scheme	Marks
	Ceramics are generally compounds between metallic & nonmetallic compounds of oxides, Nitrides and Carbides. Polymers are generally organic compounds based upon carbon and hydrogen. These are large molecular structures.	

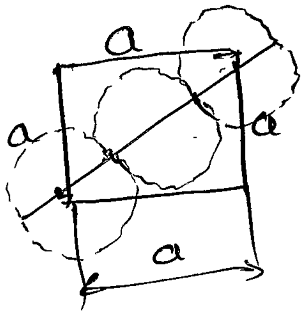
Q.No.	Solution and Scheme	Marks
1(b)	There are mainly 3 primary atomic bonds, Ionic bond, Covalent, and Metallic bond. Ionic bond It can form between two elements when one has small number of electrons when one has small number of electrons in valence shell (metal) and one has small number of electrons in the valence shell and has small number of electrons in the valency shell. Covalent bond It is an interatomic linkage that results from the sharing of an electron pair between two atoms. The binding arises from the electrostatic attraction of their nuclei for the same electrons. Metallic bond In this type of bonding the electrons surrounded to common pool & become shaped by all atoms in the solid metal	

Q.No.	Solution and Scheme	Marks
1(c)	Unit cell is the smallest structure unit that describes the crystal structure. It is simply assumed as single brick in a building. Following are the different types of unit cell  SC  BCC HCP   Tetragonal  Orthorhombic  Monoclinic	

Q.No.	Solution and Scheme	Marks
2(a)	i) Size of Unit Cell It determine the geometrical dimension of unit cell, the corner atoms are in physical contact along the edge of the unit cell. Each side length is made up of two radii. The length of the side is given as $l = 2r$. vol of unit cell $= 8r^3$ ii) Co-ordination No. (CN) It refers to the number of atoms touching a particular atom. It indicates how tightly & efficiently atoms are packed together. CN for SC = 6 CN for BCC = 8 iii) Atomic packing factor (APF) When molten metal is allowed to solidify to room temperature the atoms within the solid pack together as tightly as possible. It determine density of crystalline solid.	

91

Q.No.	Solution and Scheme	Marks
2(b)	APF for FCC unit Cell	



Let r be the radius of atom and a be the side length of the Cube

$$APF = \frac{\text{vol of atoms/unit cell}}{\text{vol of unit Cell}}$$

$$'' = \frac{\text{vol of each atom} \times \text{No. of atoms per unit Cell}}{\text{vol of unit Cell}}$$

Effective no. of atoms in above unit cell $= \left(8 \times \frac{1}{8}\right) + \left(\frac{1}{2} \times 6\right)$

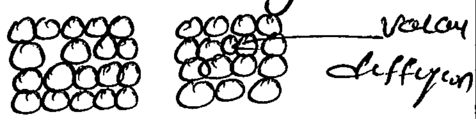
'' '' $= 1 + 3 = 4$

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

$$APF = \frac{\left(\frac{16}{3}\pi r^3\right)\left(2\sqrt{2}\right)}{64 r^3} = 0.74$$

$$= 74\%$$

Q.No.	Solution and Scheme	Marks
2(C)	Crystal imperfection denotes a deviation from the perfect arrangement of atoms/molecules in a crystal structure. Imperfection mainly classify as a) Zero dimension or point defects valancy defect, Interstical defect Substitial defect b) One dimensional or line defects Edge disslocation Screw disslocation c) Two dimension or surface defects Grain boundry defect Tilt boundry defect Twin boundry defect d) Three dimensional or volume defects	

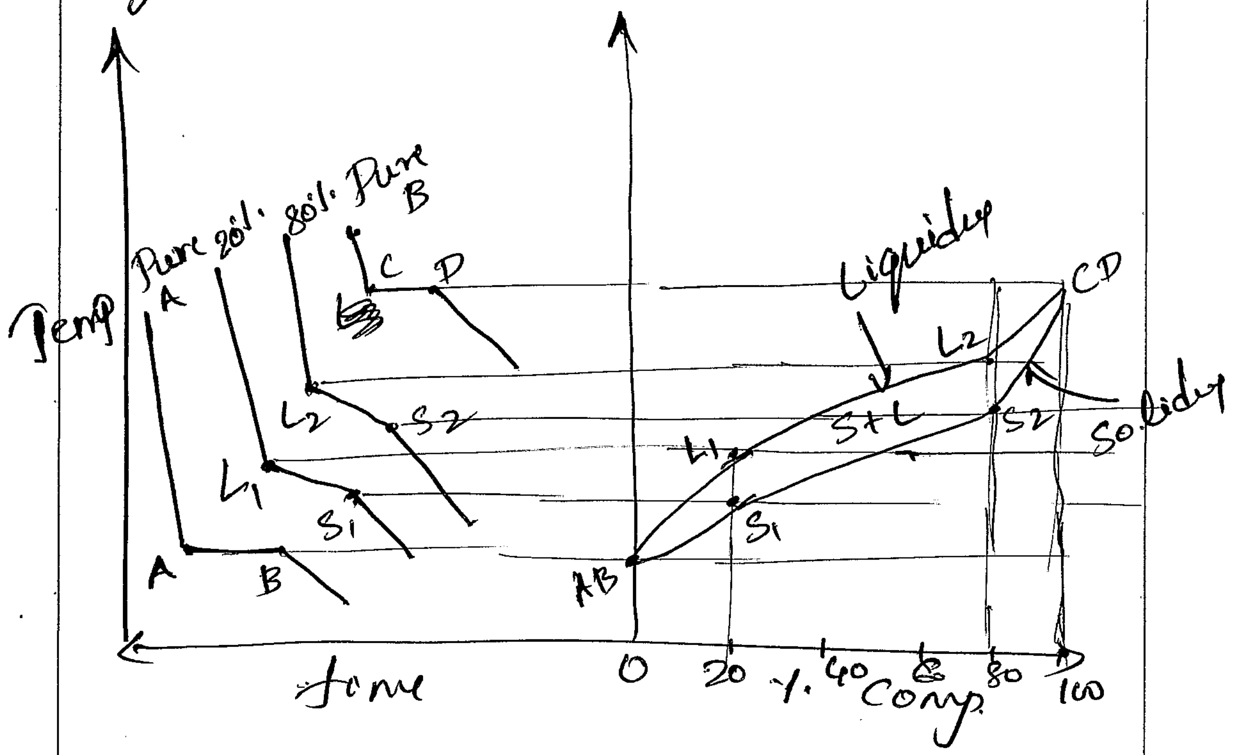
Q.No.	Solution and Scheme	Marks
3a)	<u>Atomic diffusion</u> It refers to the movement of atoms or molecules in a solid. An atom in its normal position in the crystal structure will not be stable, instead will be vibrating rapidly about its lattice position within the crystal. At higher temp atoms jump to neighbouring sites. <u>Diffusion Mechanism</u> There are mainly two diffusion mechanism vacancy diffusion and Interstical diffusion <u>Vacancy diffusion</u> involves movement of atoms from origonal lattice position to an adjacent vacant lattice  <u>Interstical diffusion</u> It involves movement of interstical atoms from one interstical site to its neighbouring site, without permanently displacing any of the parent atoms in the crystall lattice	

Q.No.	Solution and Scheme	Marks
3(b)	Fick's I law of diffusion It states that, the flux of atoms 'J' moving across a plane of unit area in unit time is propotional to the Concentration gradient $\frac{dc}{dx}$ $J \propto \frac{dc}{dx}$ or $J = -D\frac{dc}{dx}$ J = flux C = vol Concentration x = distance betn plane of direction D = diffusivity $\frac{dc}{dx}$ = Concentration gradient Fick's II law diffusion It determines diffusion under Unstedy s condition The diffusion flux and Concentration gradient at some particular point in a solid vary with time $J = f(x,t)$ It states that, the rate of Compositional change of the diffusing material at a point is equal to the diffusivity times the rate of Concentration gradient $\frac{dc}{dt} = D\frac{d^2c}{dx^2}$	

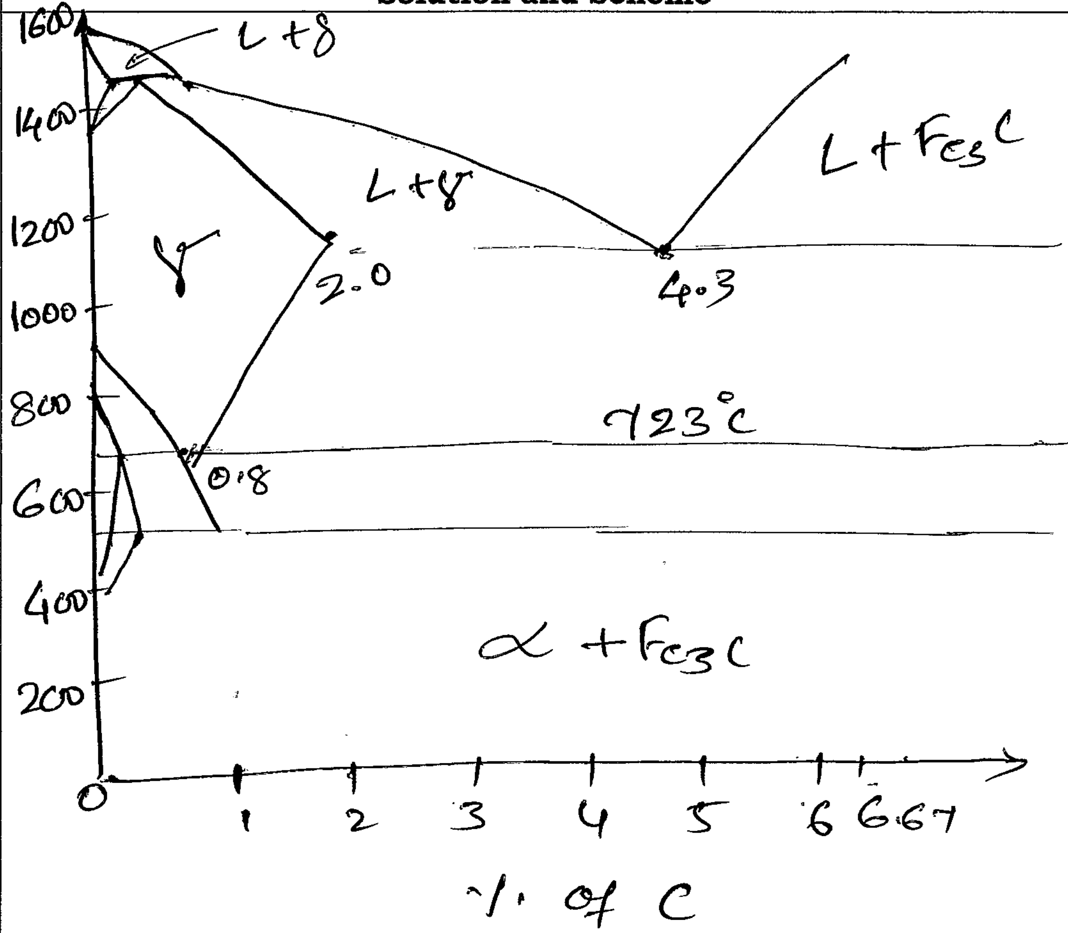
Q.No.	Solution and Scheme	Marks
3c)	Factors affecting ~~ed~~ diffusion (i) Crystal Structure with more imperfection allow diffusion to take place at a faster rate than those with lesser imperfection. Diffusion proceeds more rapidly along the grain boundary because this is a zone of crystal imperfection. (ii) Atomic packing factor Highly packed crystal have low diffusivity. For ex. FCC structure has atomic packing factor of 0.74 greater than that of BCC structure having factor of 0.68	

Q.No.	Solution and Scheme	Marks
4(a)	(i) Phase It is defined as a homogeneous, physical distinct, mechanically seperable portion of a material with given chemical composition ii) phase diagram It is graphical presentation showing change of phase with respect to temperature and composition iii) phase equilibrium It is state of system where the phase characterstics remain constant over indefinite time period iv) Solubility limit It determine max and min solubility of component in given type of alloy at particular temperature	

Q.No.	Solution and Scheme	Marks
4(b)	Lever rule. In metallurgy, the relative amount of the two phases present are determined in a similar way to that of the weights needed to balance the lever. For ex. By using the lever rule the weight percent liquid and weight percent solid for any particular temperature can be calculated for any average alloy composition in the two phase liquid plus solid region	



Q.No.	Solution and Scheme	Marks
4c		



Peritectic Reaction

$$L\ (0.53\%\ C) + \delta\ (0.09\%) \xrightleftharpoons{1495°C} \gamma\ (0.17\%\ C)$$

Eutectic Reaction

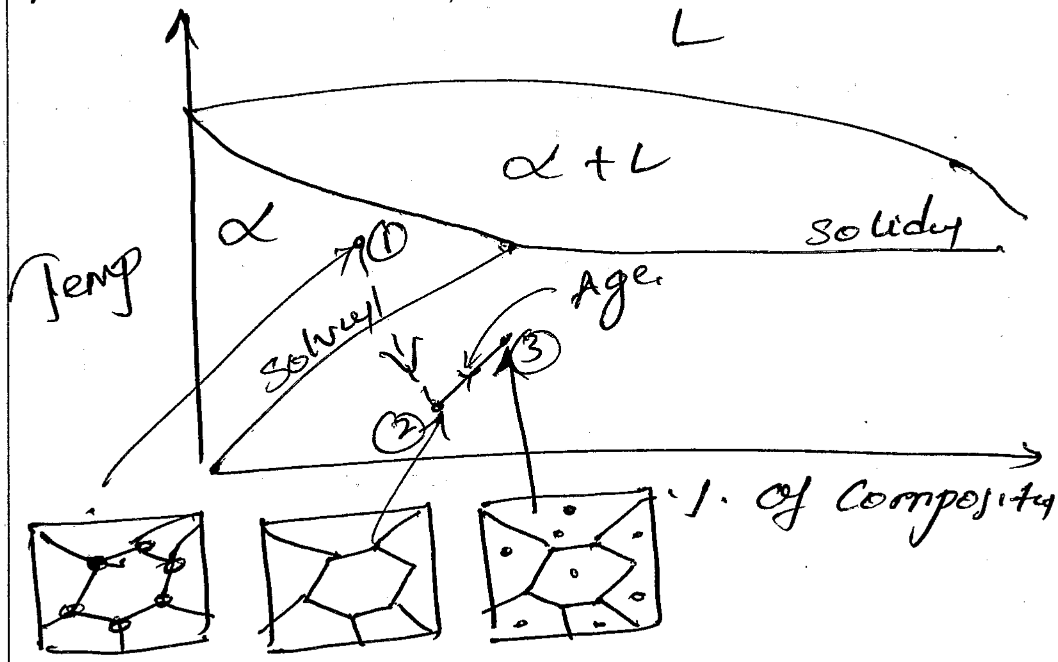
$$L\ (4.3\%\ C) \xrightleftharpoons{1148°C} \gamma\ (2.08\%\ C) + Fe_3C\ (6.67\%\ C)$$

Eutectoid Reaction

$$\gamma\ (0.8\%\ C) \xrightarrow{723°C} \alpha\ (0.02\%\ C) + Fe_3C\ (6.67\%\ C)$$

Q.No.	Solution and Scheme	Marks
5a)	There are two main mechanism by which the nucleation of solid particle in liquid metal occurs are homogeneous and heterogeneous nucleation. Homogeneous nucleation considered first since it is the simplest case of nucleation. Homogeneous nucleation in a liquid melt occurs when the metal itself provides the atoms needed to form a nuclei Heterogeneous nucleation - It is the nucleation that occurs in a liquid on the surfaces of its container, insoluble impurities, and other structural material that lower the critical free energy required to form the stable nucleus.	

Q.No.	Solution and Scheme	Marks
5(b)	Precipitation/Age hardening Certain metals and alloys show increase in their hardness after allowing sufficient time at room temperature, or after heating to a slightly higher temperature. For ex. Age ~~a~~ hardening of Al-Cu alloy	



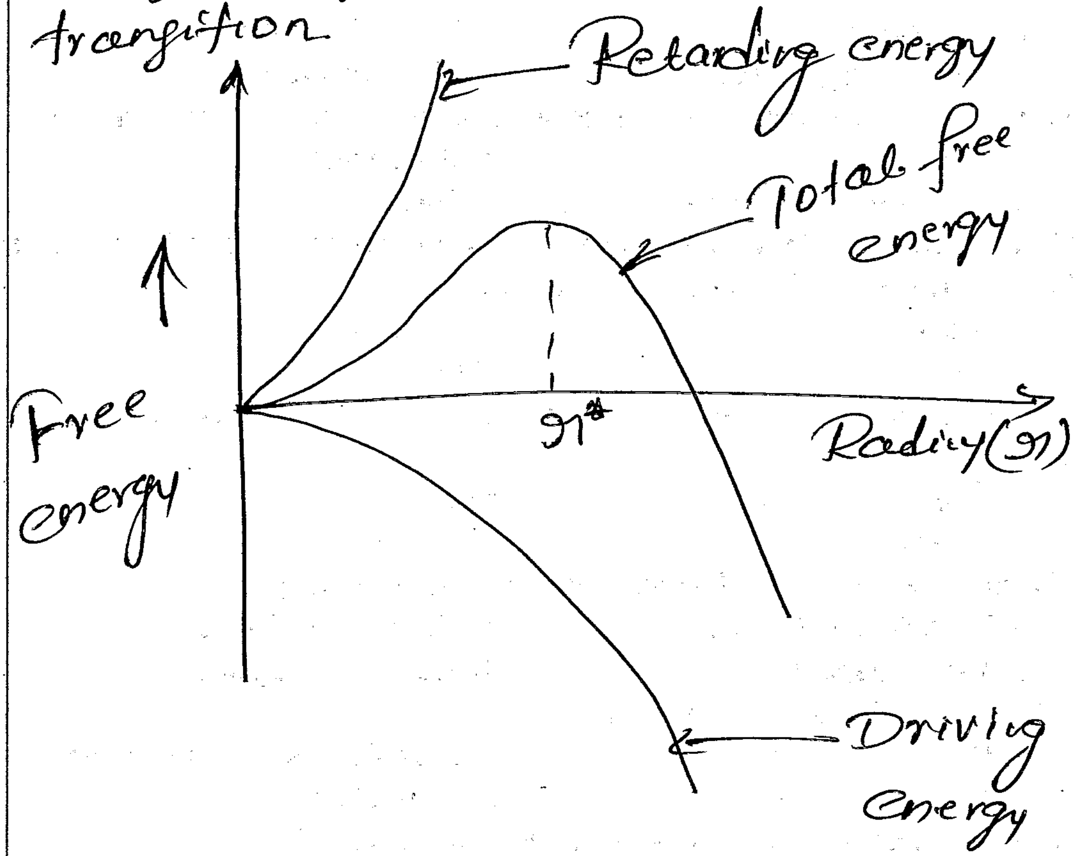
Precipitation hardening performed by → Solution treatment

Quenching &

Aging.

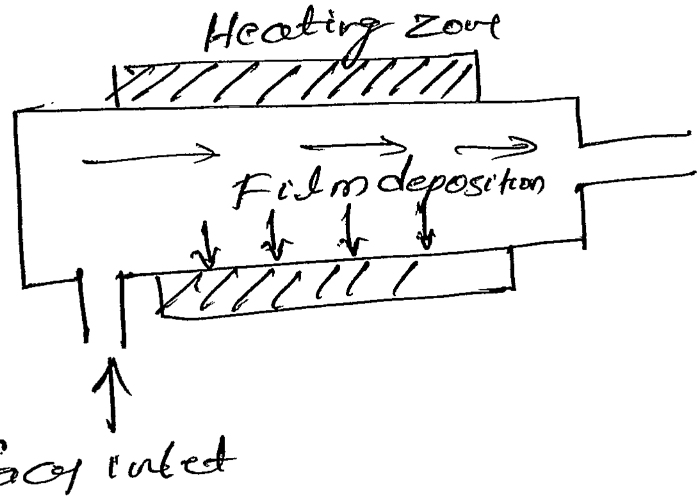
Q.No.	Solution and Scheme	Marks
6 (a)	Annealing: It is a heat treatment process, in which the metal is heated to high temp, holding it there for considerable time, and then allowing to cool at room temperature at predetermined rate. It relieve internal stresses induced by some primary process. And also some coarseness of grains. Soften the metal. Normalizing / Air quenching It involve heating material to an elevated temperature and then allowing it to cool back to room temp by exposing it to room temp air after it is heated. It refine the grain structure & improve machinability Tempering: Steels subjected to hardening heat treatment process martensitic microstructure which is brittle in nature. Even slight impacts may cause fracture of the hardened metal. Also sever	

Q.No.	Solution and Scheme	Marks
	internal stress which ~~set~~ are set up in the material. <u>Nitriding</u> It is one of the case hardening process, It involves diffusion of Nitrogen (N_2) in to the surface of certain types of steels containing Aluminium, Chromium, Molybdenum tungsten and vanadium	

Q.No.	Solution and Scheme	Marks
6(b)	Critical radius (r^*) It is radius of small nuclei that is necessary for a phase transition to occur. Such as formation of a solid from a liquid or a gas. It is an important concept in understanding the kinetics of phase transition 	

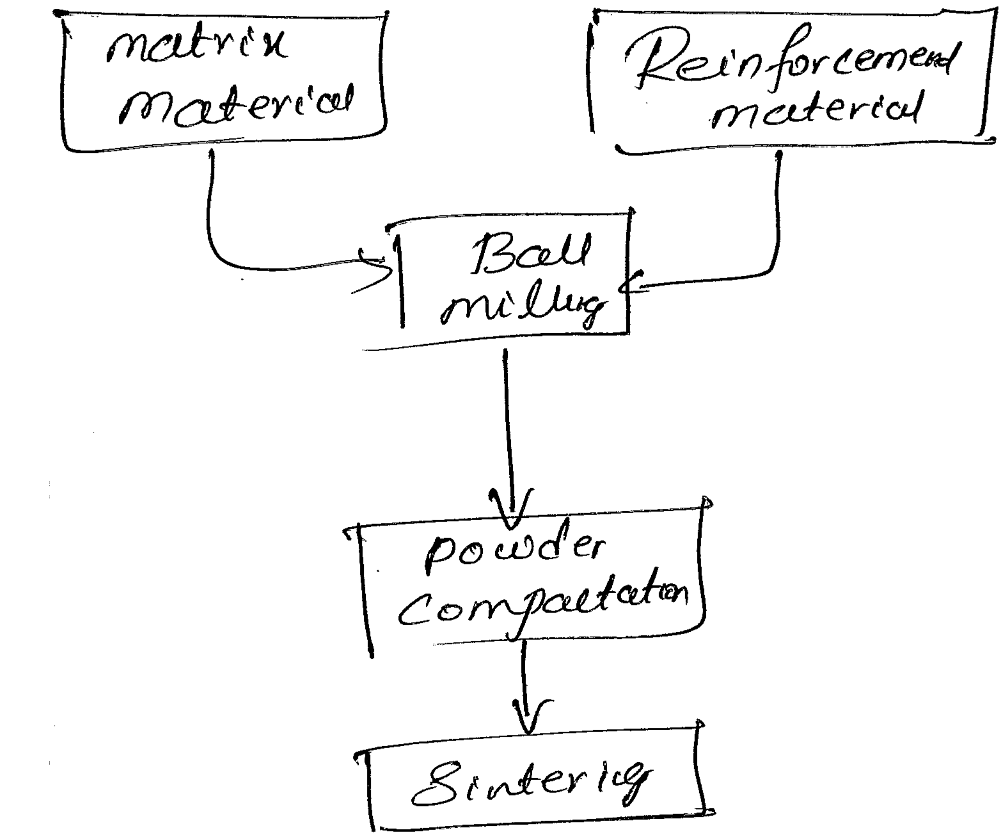
Q.No.	Solution and Scheme	Marks
7(a)	Various materials such as mild steel aluminium, & their alloys there is possibility of bacterial invasion, to overcome these surface coating technology a layer of material are implanted over the main contacting surface in order to enhance the durability of the material. Generally surface coating classify as Gaseous state process Solution state process Molten or semi molten state process Further Gaseous state process classifying as CVD, PVD, IBAD Solution state process as Chemical solution deposition Electrochemical deposition. Sol gel Molten state as Laser, Thermal spraying, & welding.	

Q.No.	Solution and Scheme	Marks
7(b)	CVD process	

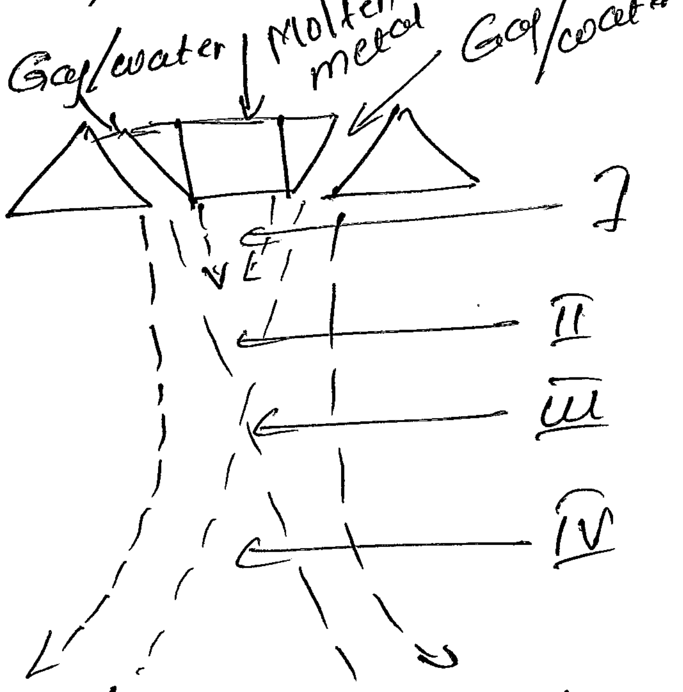


In this process, the gaseous phase of required material is condensed on to the surface target, During the CVD process high temperature heating of substrate is done due. to which the selection of material is limited since it only works with material that have high melting point. The reaction chamber consisting of target material is now introduced with the precursor materials, As they vapourize, the precursors are absorbed on to the target surface,

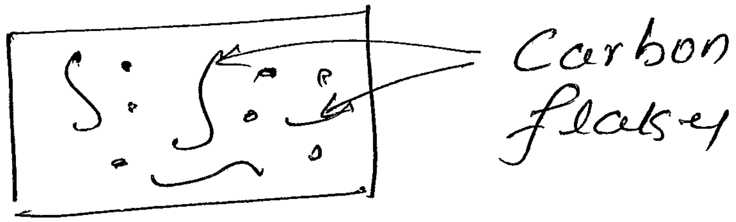
Q.No.	Solution and Scheme	Marks
7(c)	**Lubrication** It is generaly accomplished by either blending a solid lubricant powder with the iron-based powder or by spraying a liquid dispersion or solution of lubricant onto the die cavity surface. Dry lubricants or solid lubricants are materials that, despite being in the solid phase, are able to reduce friction between two surfaces sliding against each other. **Binder** A binder for metallurgical powder composition for powder metallurgy applications, include styrene and their derivatives.	

Q.No.	Solution and Scheme	Marks
8(a)		
	Powder of of matrix material and reinforcing material mixed together and processed to next steps of of ball milling. In this process grinding of large lumps of materials in to smaller process. further Compacting is performed by mechanical process to get required shape. After Compacting the product is undergoing Sintering process under different temperature.	

Q.No.	Solution and Scheme	Marks
8(b)	Atomization process ~~using~~ used in preparing metallic powder ~~A~~ This process involves formation of powder from molten metal using a spray of either gas or liquid. This is the most significant method of producing metal particles In gas atomization gases like N_2, He, Ag are used for breaking up of ~~Stre~~ molten metal when high pr. gas flow is adapted the with high force strikes metal ~~pound~~ grains and breaks in to number of pieces	



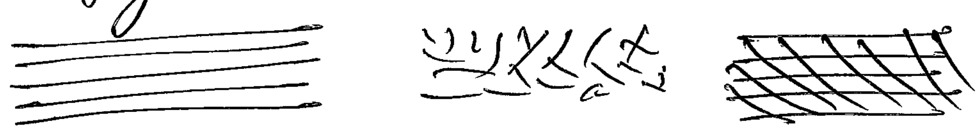
Gas automization in powder metallurgy

Q.No.	Solution and Scheme	Marks
9(a)	Chemical Composition of grey CI C → 2.5 to 4% Si → 1% to 3%  Micro Structure <u>Properties</u> Tensile Strength — 100 — 850 Mpa Compressive Strength — 300 — 1200 MPa Higher hardness Low impact Strength <u>Application</u> Base Structure for machines & heavy equipment that are exposed to vibration are frequently Constructed of this material	

Q.No.	Solution and Scheme	Marks
9(b)	Effect of alloying elements on Steel alloys Carbon → Increases mechanic properties like strength, hardness Chromium → Increses hardness, tensile strength Nickel Increases hardness & strength properties without decreasing ductility Mangeness Increases strength and decreases ductility Sulfur → It increases brittleness Silicium → Degassing agent Molybdenum → Preventing temper brittleness Vanadium → Increases strength and hardness.	

Q.No.	Solution and Scheme	Marks
9(c)	Classification of Copper alloys Copper alloys classified as Copper Zinc alloy Copper - Zinc - Lead alloys Copper - Zinc - Tin alloys Copper alloy designated by the unified number System (UNS) developed by ASTM. The designation have 5 digit preceded by the prefix letter C. For ex Cu-Zn alloy C21000 ... C28999 C70600 - Indicates Cu with Fe 1.0 - 1.8 Ni - 9 to 11 + relative impurity Properties - Corrosive resistance Good Malleability & Ductility Non magnetic, tough material Appln Bearing, gears, and valve guides. Radiators hydraulic tubing etc.	

Q.No.	Solution and Scheme	Marks
10 (a)	Composite materical are commonly classified at two distinct levels 1) with respect to matrix Constituent * polymer matrix Composite * Metal matrix Composite * Ceramic matrix Composite 2) with respect to reinforced Constituent * Fiber reinforced Composite * partical reinforced Composite * Laminated Composite Constituents of Composite material Matrix → polymer, Metal Ceramic Reinforcement materical – Fiber particle Lamination	

Q.No.	Solution and Scheme	Marks
10(b)	<u>Fiber material</u> used for FRP whiskers, graphite, SiN, SiC ~~P~~ Al_2O_3, Aramid, E-glass Boron. ~~w~~ Metal wires Steel, Mo. W <u>Matrix material</u> polymer, Epoxy, Polyester, Metallic, & Ceramic Fiber - must bear most of the load applied <u>Matrix</u> Transfer external load among fibers, Prevent Chemical & Abrasive degradation of the fibers, ~~Prep~~ Prevent Cracks Propogation. Keep fiber orientation. Following are the 3 possible Configuration of FRP  Continous Discontinous Woven	

Q.No.	Solution and Scheme	Marks
10c	Process of obtaining metal data In general identifying, evaluating and selecting material is an open ended problem solving process with more than one solution. As a consequence, selecting the optimum material for product design is not easy. Also the choice for product design is not so easy. Also the choice of material will vary depending on the stage of the design process, from a large range of posibility at the concept stage when design information is more specific and stable. In effect, material selection can be considered to be a process reflecting the design process itself. It begins with initial screening of all possible material through comparing and ranking of alternative material to selecting optimum material.	