Q. No. MM - 301 / 007 **B. Tech./Odd**

2017-18/Reg

2017-18

INTRODUCTION TO METALLURGY AND MATERIALS

MM - 301

Full Marks : 70 Time : Three Hours

The figures in the margin indicate full marks.

Answer any *five* questions.

1. (a) An element 'X' has twice the atomic number of another element 'Y'. Identify the electron 'Shell' and corresponding principal quantum number for element 'X' that has energy equal to the energy of the K-Shell of element 'Y'. Thereafter, find out the magnitude of 'orbital angular momentum' for the sub-shells under that identified 'Shell' for the element 'X'.

   (b) Derive Schrodinger wave equation. Accordingly, explain the physical interpretation of 'wave function'. 7+7

2. (a) How do attractive force, repulsive force and potential energy vary with interatomic separation? How do bond strength and directionality of bonding affect mechanical properties of materials?

   (b) Explain the possible proper rotational symmetry elements in a crystalline solid. Thereafter, opine on the feasibility of five fold rotational symmetry. 7+7

P.T.O.

3. (a) What is understood by 'six fold rotational symmetry' in hexagonal crystal system? Compare the 'three indices representation' and 'four indices representation' of crystallographic direction in hexagonal crystal system.

(b) Derive an expression for equilibrium vacancy concentration in a crystal. Thereafter, comment on the stability of 'point defect' and 'Line defect'. 7+7

4. Write note on : 7+7

(a) Composite materials.

(b) Nano-crystalline materials.

5. Make a comparison between ABCABC... and ABAB... close packed stacking of atoms in terms of packing efficiency. Use neat schematic diagram for derivation. 14

6. Draw a unit cell for CsCl crystal structure. Derive the minimum cation to anion radius ratio for such types of crystal structure. What type of crystal structure does $BaTiO_3$ show above 120°C? What are the coordination numbers of Ba, Ti and O_2 ions in this structure? 4+6+1+3

7. Draw portions of a linear polypropylene molecule that are (a) syndiotactic, (b) atactic, and (c) isotactic. State the difference between thermosetting and thermoplastic polymer with example. Why linear polymers have higher density than branched polymer? 6+5+3

8. In Fe-Fe_3C binary phase diagram what are the invariant reactions? Why liquid in Fe-Fe_3C phase diagram except 4.3 wt. % C containing alloy solidified in a range of temperature? What is partially stabilized Zirconia? How is it utilized to arrest crack formation? 3+5+6

Q. No. MM - 302 / 064 **B. Tech./Odd 2017-18/Reg**

2017-18

PRINCIPLES OF EXTRACTIVE METALLURGY

MM - 302

Full Marks : 70 Time : Three Hours

The figures in the margin indicate full marks.

Question No. 5 is compulsory of 20 marks and answer any *four* (4) questions from the rest of 12.5 marks each.

1. (a) What is the standard heat of formation of CuO at 298 K from the given data :

   $c_p = 48.595 + 7.427\,T - 761304.59\,T^{-2}$ J/mol.K, (valid between temp. range of 298 to 2000 K) and

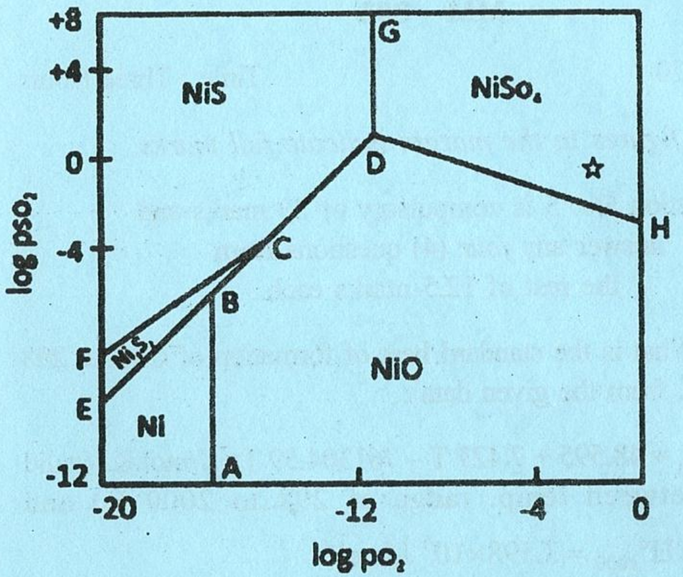
   $\Delta H^{o}_{1000} = 3.598 \times 10^{6}$ J/mol.

   (b) Determine the lowest temperature at which Cu_2O can dissociate in a vacuum of 10^{-5} mm of Hg.$Cu_2O(s) = 2Cu(s) + 1/2\ O_2$ $\Delta G^{o} = 40500 + 3.92T \log T - 29.5T$, cal.

2. Explain in details, the methodology of drawing the following predominance area diagram for Ni – S – O at 1000 K. What is it's industrial application with reference to the STAR (*) point shown in the diagram above line DH where PO_2 is that of air? Thermodynamically derive Gibbs

P.T.O.

phase rule to show the stability of different phases and calculate degrees of freedom at triple points B, C, D, lines AB, BC, CD, EB, FC, DG, DH and phase areas Ni, NiO, NiS, $NiSO_4$.



3. Explain Ellingham Diagram thermodynamically and graphically. How entropy change during phase transformation for M_S to M_L and MO_S to MO_L affect slope of the lines? Discuss it's importance in extraction of metals with reference to C-CO and C-CO_2 lines and for metallo-thermic reductions.

4. Carbothermic reduction is commonly used to produce metals from oxides. Calculate the heat required (in Kcal/kg of Zinc) to produce Zinc from reduction of ZnO with carbon. The reactants, ZnO and C, enter at 25°C,

whereas Zinc vapor and CO gas leave at 1027°C use the following data :

Zn (S) = Zn (1); Tm = 692.5K ;

ΔH_{fusion} = 1740 cal/g.mole

Zn (1) = Zn (g); Tv = 1180K ;

ΔH_{Vap} = 27565 cal/g.mole

Components	ΔH^o (Cal/g.mol)	C_p (Cal/g.mol.K)
ZnO(S)	–83800	$11.71+(1.22\times10^{-3}\ T) - (2.18\times10^{5}\ T^{-2})$
C(S)	0	$0.026+(9.307\times10^{-3}\ T) - (0.354\times10^{5}T^{-2})$
Zn(S)	0	$5.35+(2.40\times10^{-3}T)$
CO(g)	–26420	$6.79+(0.98\times10^{-3}T) - (0.11\times10^{5})$
Zn(1)	—	7.50
Zn(g)	—	5.00

Atomic Mass of Zn – 65.37; O – 16; C – 12

5. (a) Give a flow sheet for pyrometallurgical extraction of lead from its ores.

(b) What is zone refining? Explain with an example.

P.T.O.

(c) What is meant by classification? Differentiate with concentration of ore.

(d) What is the function of depressant in Froth Floatation?

(e) What is basic difference between sintering and Pelletisation?

(f) Discuss Temkin Model with reference to electrometallurgy extraction of metals.

6. Explain with a flow sheet the route of Hydrometallurgical extraction of metals. Why is this method beneficial in today's respect? What is the drawback of this process? How is cementation carried out in industries?

7. With neat sketch explain the extraction of silver and gold from its ores.

8. What is communition? How is the energy for communition calculated? Explain the different stages of communition with their equipment.

Q. No. MM 501 /

B. Tech / Odd
(17 - 18) / Reg

2017-18

FOUNDRY TECHNOLOGY

MM 501

Full Marks : 70 *Time* : 3 hours

The figures in the margin indicate full marks.

Q. No. 1 is compulsory and answer any *four* from the rest.

1. (*a*) What is the justification of shaking allowance in a pattern ?

(*b*) Why ceramic mould is used for Jet engine nozzle casting ?

(*c*) What is AFS number of sand grain ? Does it vary with type of sand ?

(*d*) Enumerate the advantages of chromite sand over silica sand.

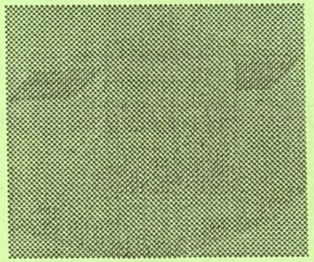
(*e*) What is slush Casting ?

(*f*) What is vacuum sealed moulding Process ?

(*g*) How do you determine the efficiency of a Cupola furnace ?

(*h*) How to form graphite in Cast iron ? 20

2. With neat sketches describe a casting process for producing surgical equipment. What are the disadvantages of it ? Give the other names of the process. 12.5

3. 

For a casting of the above figure, design the gating and risering system. 12.5

4. What are the important tests for a sand to be used for steel casting ? With the description of each state the values for the parameters. 12.5

5. Explain the solidification with all features of an impure aluminium alloy. What phenomenon leads to segregation in an alloy of Chromium, iron and carbon ? What are the grain refiners added to modify the property of Al alloys. What will be the change if Electromagnetic stirring is applied during the solidification of zinc and its alloys ? 12.5

6. (*a*) A cupola charge weighs 1000 kg and is made up of the following compositions:

Materials	Elemental Analysis (wt.%)				
	C	Si	Mn	P	S
1. Pig iron No. 1	3.5	2.5	0.70	0.17	0.016
2. Pig iron No. 2	3.5	3.0	0.65	0.11	0.018
3. New Scrap	3.4	2.3	0.50	0.20	0.030
4. Returns	3.3	2.5	0.65	0.16	0.035

Find out the cast metal analysis for cupola melting.

(Assumption: Coke/Scrap = 1:8 , Loss of Mn & Si is 15% and 10%, respectively, The different proportions are 15:20:30:35)

(*b*) Explain with neat sketch the working principle of Induction furnace. 12.5

7. Classify the various defects formed in Ferrous casting. Explain with neat sketches the following defects in casting and suggest remedies: 12.5

(*i*) Blowholes and pinholes

(*ii*) Scab

(*iii*) Hot tears

(*iv*) Cold shuts and misrun

8. Write short notes on any *four*: 12.5

(*a*) Chilled Cast Iron

(*b*) SG Iron

(*c*) Morphology of graphite flakes

(*d*) Duralumin

(*e*) Copper and its alloys

(*f*) Operation of EAF

Q. No. MM 502 / 099

B. Tech / Odd (17-18) / Reg

2017-18

TESTING OF MATERIALS

MM 502

Full Marks : 70 *Time* : 3 hours

The figures in the margin indicate full marks.

Answers should be brief and to the point.

Answer any *five* questions.

1. (*a*) Define creep. 1

(*b*) Draw the generalized creep curve for metallic materials and explain the different stages of creep. 1 + 4

(*c*) How does the stress rupture test differ from ordinary creep test ? 4

(*d*) Breifly discuss the structural changes that occur during the creep process of a material. 4

2. (*a*) Write a note on the different ways of presenting the engineering fatigue data with proper explanation. 10

(*b*) Comment on the low cycle fatigue test and the presentation of the test results. 4

3. (*a*) Describe the method of Charpy V-notch impact test. 4

(*b*) Discuss the nature of transition temperature curve for metallic materials and various criteria used to represent the transition temperature. 3 + 3 (*c*) Discuss the effect of composition on the transition temperature curve of steel. 4

4. (*a*) Comment on the geometrical factor which is standardized for a tensile test specimen. 3

(*b*) Write salient features of shear test and bend test of a material. 2 + 2

(*c*) Discuss the load dependence of Brinell hardness number in annealed metals. 3

(*d*) Derive the equation which correlates the shear stress with the torsional moment of a cylindrical bar subjected to torsional loading within the plastic range. 4

5. (*a*) Discuss the nature of flow curve (true stress - strain curve) within the uniform plastic deformation region of a ductile metal loaded in tension and the various equations used to represent this portion of the flow curve. 6

(*b*) Gve detailed mathematical analysis and graphical representation of various instability criteria in tensile testing. 8

6. (*a*) Discuss the procedure, analysis and significance of Vickers hardness measurement. 6

(*b*) Why the value of Meyer hardness number is greater than flow stress for the same meterial ? 2

(*c*) Discuss various methods for the determination of strain rate sensitivity. 3

(*d*) Discuss the experimental methods for the evaluation of activation energy for plastic flow of a material. 3

7. Write short notes on : 2 + 2 + 3 + 3 + 4

(*i*) Resilience;

(*ii*) Toughness;

(*iii*) Modulus of elasticity;

(*iv*) Measures of yielding in tension;

(*v*) Cyclic hardening and softening.

8. (*a*) Compare and contrast the engineering stress-strain curve in tension, true stress-strain curve in tension, engineering stress - strain curve in compression and cyclic stress-strain curve for a given ductile material with proper explanation. 8

(*b*) Discuss the generalized fracture analysis diagram (FAD) highlighting the design concept based on this diagram. 6

Q. No. MM 503 / 037

B.Tech / Odd
(17-18) / Reg

2017-18

HEAT TREATMENT OF METALS AND ALLOYS

MM 503

Full Marks : 70 *Time* : 3 hours

The figures in the margin indicate full marks.

Answer Q. No. 1 and any *five* from the rest.

1. (*a*) State whether the following statements are **FALSE** or **TRUE, if FALSE,** Correct the statements and **JUSTIFY** all the statements. 10

(*i*) Austenitisation is faster in fine pearlitic structure than coarse pearlitic steel. 1.5

(*ii*) Why hardening by quenching is followed by tempering treatment ? 1.5

(*iii*) Spheroidise annealing is recommended for very low carbon steel. 1

(*iv*) It is not possible to obtain 100 % martensitic structure to a very low plain carbon steel. 1

(*v*) Fully bainitic structure can be obtained in plain carbon steel by continuous cooling. 1

(*vi*) Why ferritic stainless steel is not heat treated ? 1

(*vii*) Indicate the temperature range of various heat treatment processes onto $Fe\text{-}Fe_3C$ phase diagram. State the significance of A_3 and A_{cm} lines. 1.5

(*viii*) Write the Ms temperature equation. Calculate the Ms temperature for a carbon steel with 0.2C, 0.4Si, 0.7Mn. 1.5

2. (*a*) Discuss critically austenetisation of steel. 6

(*b*) Explain how full annealing treatment refines the grains of initially coarse grain hypoeutectic cast structure. 4

(*c*) What are purposes of sub-critical annealing ? 2

3. (*a*) Highlight the important characteristics of martenstic transformation. 4

(*b*) How to developed the TTT diagram ? Draw the TTT diagram for an eutectoid steel. Label all the lines and areas and explain the various factors affecting it. 6

(*c*) Superimpose CCT curve on the TTT diagram and state the differences. 2

4. (*a*) Discuss in details the mechanism of pearlitic and bainitic transformation. 5

(*b*) Superimpose the suitable cooling paths onto the TTT diagram of a eutectoid steel to obtain the following products

(*i*) 100 % bainite,

(*ii*) 50 % medium pearlite and 50 % martensite,

(*iii*) 25 % lower bainite and 75 % martensite, and

(*iv*) 100 % uniform coarse pearlite. 5

(*c*) Explain the allotropic changes in Iron. 2

5. (*a*) Discuss how hardenability is affected by

(*i*) Austenite grain size

(*ii*) Presence of alloying elements 4

(*b*) Describe the Jominy end quench methods for determining hardenability. 4

(*c*) Describe the structural changes that take place during tempering. 4

6. (*a*) Why it is necessary to toughen the core before hardening the case ? 2

(*b*) What is vacuum carburizing process ? List the advantage and limitations of this process. 4

(*c*) Why a white layer is formed during nitriding ? How can it be prevented ? 2

(*d*) Discuss the basic difference between flame hardening and Induction hardening. 4

7. (*a*) Discuss the possible heat treatment of Ti-6Al-4V alloy. 4

(*b*) Discuss in detail precipitation hardening of an aluminium copper alloy. 6

(*c*) Explain why hardening effect is reduced during over aging. 2

8. Write note on any *three* of the following: 12

(*i*) Isoforming and cryoforming process

(*ii*) Martempering and austempering processes and

(*iii*) The mechanism of Spherodizing annealing

(*iv*) Heat treatment of Copper-Beryllium alloy

(*v*) Plasma Nitriding Process

Q. No. MM 504 / C76

B.Tech / Odd
(17-18) / Reg

2017-18

TRANSPORT PHENOMENA

MM 504

Full Marks : 70 *Time* : 3 hours

The figures in the margin indicate full marks.

Answers of a particular group to be written sequentially.

State all assumptions clearly.

GROUP A

Marks : 42

Answer Q. No. 1 and any *three* from the rest.

1. (*a*) What is the difference between force and free convection ? What is the unit of heat transfer coefficient ? 3.5

(*b*) A steel tank contains hydrogen at a constant pressure of 10 atm with a vacuum outside. The hydrogen concentration at the inner surface of the tank is equal to 10Kgm^{-3}. The diffusion coefficient of the hydrogen in steel at the room temperature is 10^{-9}m^2/Sec. Calculate the rate at which the hydrogen escapes through the wall of the tank which has a thickness of 5 mm. 3

(*c*) A plane section of a furnace wall is 8 cm thick, the inside wall furnace temperature is 700°C and outside kept at 90°C. If the thermal conductivity of the wall is 1.2 Cal/hr.cm.°C, calculate heat loss per unit area of the furnace wall. 3

(*d*) The diffusion coefficient of Ni in Cu at 1000 K is 1.93 $\times 10^{-16}$ m^2s^{-1} and it is 1.94 $\times 10^{-14}$ m^2s^{-1} at 1200 K. Calculate the activation energy (in $KJmole^{-1}$) for the diffusion of Ni in Cu. 2.5

2. An aluminium plate of dimensions $0.1\ m \times 0.005\ m \times 0.005\ m$ at an initial temperature of 400°C is cooled in air stream at 25°C. If, during cooling, $h = 400\ /m^2.K$, calculate 10

   (*a*) time required for the plate to cool to 50°C,

   (*b*) time initial rate of cooling, and

   (c) the rate of cooling after 3 min. For aluminium, in the range 25 to 400°C,

   $\rho = 2700 kg/m^3, C_p = 900 J/kg.K$ and $k = 238 W/m^2.K$

3. (*a*) Calculate the view factors for the cylindrical enclosure of radius R and length 2R shown in Figure 1. The surface 1 and surface 2 in the figure are plane and $F_{12} = 0.38$. 5

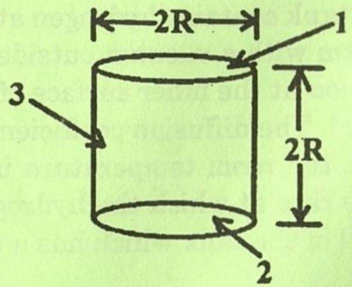


Fig. 1 Cylindrical enclosure

   (*b*) What is Biot number and Fourier number ? What is the physical significance of the Biot number ? State the Kirchhoff's law of thermal radiation. 5

4. An anodized aluminium object at 900W to be modelled as a cube with side length 0.1 m, is placed in a cold (much lower temperature), black enclosure. Its bottom is resting on insulated surface, so it cools by radiation form its other five sides.

   Aluminium data: thermal conductivity (k) = 238 W/m.K, density = 2700 Kg/m³, Heat capacity (C_p) = 917 J/kg.K, Anodized aluminium emissivity (ε) = 0.85

   (*a*) Express the net radiative heat flux from the cube surface as a function of cube surface temperature. Assume the surroundings to be at a low enough temperature that their emission back to the cube is negligible.

   (*b*) Write an expression for radiative "heat transfer coefficient", which is the heat flux divided the surface temperature, using the grey body approximation, and an "environment" temperature of zero.

   (c) Calculate the maximum Biot number for radiative cooling of this cube at between 900K and 400K. What approximation is used for the temperature profile across the cube ?

   (*d*) Calculate the time required for this object to cool from 900K to 400K by radiation only. 10

5. (*a*) Derive the Fick's second law of diffusion and explain all the term. What are the factors affecting the diffusion coefficient ? Explain it with example. 6.5

   (*b*) If Boron is diffused into a slice of pure silicon at 1100°C for 2 hours, what is the depth below the surface at which the concentration is 10^{17} *atoms/cm³*, if the surface concentration is 10^{18} *atoms/cm³*. Diffusion coefficient of boron into silicon is 4×10^{-13} cm^2/s and $erf(1.2) = 0.9$. 3.5

6. (*a*) An infinite slab of width $2L$ which is initially at a uniform temperature T_i and is cooled to an ambient temperature T_f. The heat transfer coefficient on both the surfaces is h. Determine the transient temperature distribution of the infinite slab. 6

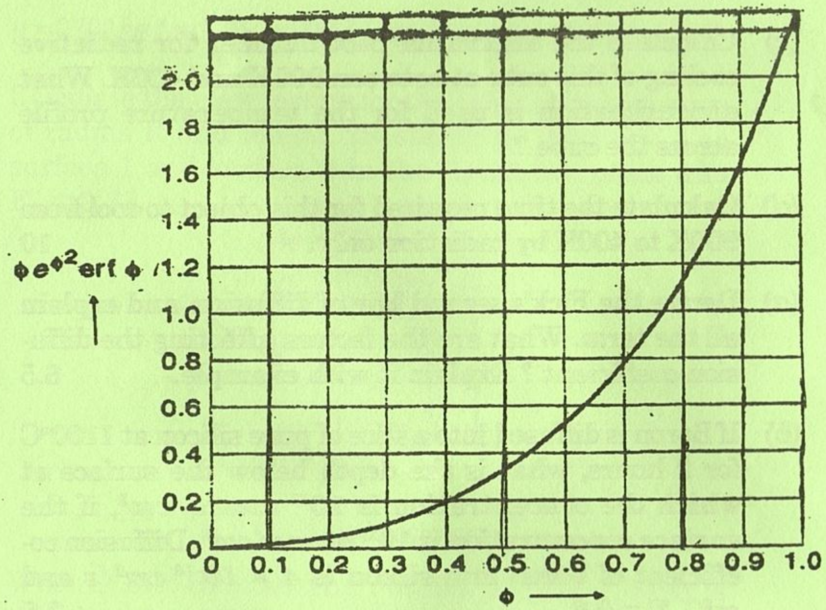
(*b*) Liquid steel at its freezing temperature of 1480°C is cast to form a slab of thickness 0.1 m. Calculate the time required for completion of the freezing process when the mold is

(a) a thick sand mold at 25°C and

(b) a water-cooled copper mold at 25°C.

For the steel $\alpha = 1.1 \times 10^{-5} m^2/sec$, $C_p = 750\ J.kg^{-1}.K^{-1}$, $\Delta H = 3 \times 10^5\ J.kg^{-1}$ and $\rho = 7100\ kg/m^3$

For the sand $\alpha = 2.5 \times 10^{-7}\ m^2/sec$ and $K = 0.3\ W.m^{-1}.K^{-1}$ 4



Variation of ϕe^{ϕ^2} erf(ϕ) with ϕ.

GROUP B

Marks : 28

Answer Q. No. 7 and any *two* from the rest.

7. (*a*) What is Hydraulic Radius wrt to fluid flow in packed bed ? 1

(*b*) Describe the characteristics for the different types of fluid flow. 2

(*c*) Explain the following terms: particulate fluidization; aggregate fluidization; elutriation velocity,; minimum fluidization velocity. 6

(*d*) Explain the term 'friction factor' ? Explain how this factor can be determined for flow through a reactor. 2

(*e*) Discuss the principles of different types of flow meters. 2

8. Stating D Arcy's law, derive the equation for pressure drop in packed bed. Find the minimum fluidization velocity in a packed bed. Which metallurgical reactor illustrates this phenomenon ? 7.5

9. Using the equation of continuity and motion explain the design of centrifugal casting. What are the assumptions for the design of it ? 7.5

10. (*a*) Discuss the importance of dimensionless numbers.

(*b*) With the help of an example describe how transport similarity between two systems leads to dimensionless numbers.

(c) How can a cold model of B.O.F designed in a laboratory ? 7.5

11. (a) Molten steel is teemed from a ladle through a 5 cm diameter nozzle at its bottom. If the volume of the molten steel in the beginning is 2 m^3 and the linear velocity of discharge is 90 cm per second, calculate the time required to empty the ladle.

(b) Derive Hagen –Poiseuille equation. State the conditions under which the equation is applicable.

(c) "The equations of continuity and momentum needs to be modified for turbulent flow"- Illustrate. 7.5

FICK'S (FIRST) LAW OF BINARY DIFFUSION[a]

B.1

$$[\mathbf{j}_A = -\rho \mathscr{D}_{AB} \nabla \omega_A]$$

Cartesian coordinates (x, y, z):

$$j_{Ax} = -\rho \mathscr{D}_{AB} \frac{\partial \omega_A}{\partial x} \quad \text{(B.3-1)}$$

$$j_{Ay} = -\rho \mathscr{D}_{AB} \frac{\partial \omega_A}{\partial y} \quad \text{(B.3-2)}$$

$$j_{Az} = -\rho \mathscr{D}_{AB} \frac{\partial \omega_A}{\partial z} \quad \text{(B.3-3)}$$

Cylindrical coordinates (r, θ, z):

$$j_{Ar} = -\rho \mathscr{D}_{AB} \frac{\partial \omega_A}{\partial r} \quad \text{(B.3-4)}$$

$$j_{A\theta} = -\rho \mathscr{D}_{AB} \frac{1}{r} \frac{\partial \omega_A}{\partial \theta} \quad \text{(B.3-5)}$$

$$j_{Az} = -\rho \mathscr{D}_{AB} \frac{\partial \omega_A}{\partial z} \quad \text{(B.3-6)}$$

Spherical coordinates (r, θ, φ):

$$j_{Ar} = -\rho \mathscr{D}_{AB} \frac{\partial \omega_A}{\partial r} \quad \text{(B.3-7)}$$

$$j_{A\theta} = -\rho \mathscr{D}_{AB} \frac{1}{r} \frac{\partial \omega_A}{\partial \theta} \quad \text{(B.3-8)}$$

$$j_{A\phi} = -\rho \mathscr{D}_{AB} \frac{1}{r \sin \theta} \frac{\partial \omega_A}{\partial \phi} \quad \text{(B.3-9)}$$

[a] To get the molar fluxes with respect to the molar average velocity, replace $\mathbf{j}_A$, ρ, and ω_A by $\mathbf{J}_A^*$, c, and x_A.

THE EQUATION OF CONTINUITY[a]

B.2

$$[\partial \rho / \partial t + (\nabla \cdot \rho \mathbf{v}) = 0]$$

Cartesian coordinates (x, y, z):

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z) = 0 \quad \text{(B.4-1)}$$

Cylindrical coordinates (r, θ, z):

$$\frac{\partial \rho}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho v_\theta) + \frac{\partial}{\partial z}(\rho v_z) = 0 \quad \text{(B.4-2)}$$

Spherical coordinates (r, θ, φ):

$$\frac{\partial \rho}{\partial t} + \frac{1}{r^2}\frac{\partial}{\partial r}(\rho r^2 v_r) + \frac{1}{r \sin \theta}\frac{\partial}{\partial \theta}(\rho v_\theta \sin \theta) + \frac{1}{r \sin \theta}\frac{\partial}{\partial \phi}(\rho v_\phi) = 0 \quad \text{(B.4-3)}$$

[a] When the fluid is assumed to have constant mass density ρ, the equation simplifies to $(\nabla \cdot \mathbf{v}) = 0$.

B.3

THE EQUATION OF MOTION IN TERMS OF τ

$$[\rho D\mathbf{v}/Dt = -\nabla p - [\nabla \cdot \boldsymbol{\tau}] + \rho \mathbf{g}]$$

Cartesian coordinates (x, y, z):[a]

$$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} - \left[\frac{\partial}{\partial x}\tau_{xx} + \frac{\partial}{\partial y}\tau_{yx} + \frac{\partial}{\partial z}\tau_{zx}\right] + \rho g_x \quad \text{(B.5-1)}$$

$$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} - \left[\frac{\partial}{\partial x}\tau_{xy} + \frac{\partial}{\partial y}\tau_{yy} + \frac{\partial}{\partial z}\tau_{zy}\right] + \rho g_y \quad \text{(B.5-2)}$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} - \left[\frac{\partial}{\partial x}\tau_{xz} + \frac{\partial}{\partial y}\tau_{yz} + \frac{\partial}{\partial z}\tau_{zz}\right] + \rho g_z \quad \text{(B.5-3)}$$

[a] These equations have been written without making the assumption that $\boldsymbol{\tau}$ is symmetric. This means, for example, that when the usual assumption is made that the stress tensor is symmetric, τ_{xy} and τ_{yx} may be interchanged.

Cylindrical coordinates (r, θ, z):[b]

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + v_z\frac{\partial v_r}{\partial z} - \frac{v_\theta^2}{r}\right) = -\frac{\partial p}{\partial r} - \left[\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rr}) + \frac{1}{r}\frac{\partial}{\partial \theta}\tau_{\theta r} + \frac{\partial}{\partial z}\tau_{zr} - \frac{\tau_{\theta\theta}}{r}\right] + \rho g_r \quad \text{(B.5-4)}$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + v_z\frac{\partial v_\theta}{\partial z} + \frac{v_r v_\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} - \left[\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\tau_{r\theta}) + \frac{1}{r}\frac{\partial}{\partial \theta}\tau_{\theta\theta} + \frac{\partial}{\partial z}\tau_{z\theta} + \frac{\tau_{\theta r} - \tau_{r\theta}}{r}\right] + \rho g_\theta \quad \text{(B.5-5)}$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} - \left[\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rz}) + \frac{1}{r}\frac{\partial}{\partial \theta}\tau_{\theta z} + \frac{\partial}{\partial z}\tau_{zz}\right] + \rho g_z \quad \text{(B.5-6)}$$

[b] These equations have been written without making the assumption that $\boldsymbol{\tau}$ is symmetric. This means, for example, that when the usual assumption is made that the stress tensor is symmetric, $\tau_{r\theta} - \tau_{\theta r} = 0$.

Spherical coordinates (r, θ, φ):[c]

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_r}{\partial \phi} - \frac{v_\theta^2 + v_\phi^2}{r}\right) = -\frac{\partial p}{\partial r}$$
$$- \left[\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\tau_{rr}) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\tau_{\theta r}\sin\theta) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \phi}\tau_{\phi r} - \frac{\tau_{\theta\theta} + \tau_{\phi\phi}}{r}\right] + \rho g_r \quad \text{(B.5-7)}$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_\theta}{\partial \phi} + \frac{v_r v_\theta - v_\phi^2\cot\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta}$$
$$- \left[\frac{1}{r^3}\frac{\partial}{\partial r}(r^3\tau_{r\theta}) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\tau_{\theta\theta}\sin\theta) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \phi}\tau_{\phi\theta} + \frac{(\tau_{\theta r} - \tau_{r\theta}) - \tau_{\phi\phi}\cot\theta}{r}\right) + \rho g_\theta \quad \text{(B.5-8)}$$

$$\rho\left(\frac{\partial v_\phi}{\partial t} + v_r\frac{\partial v_\phi}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\phi}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi} + \frac{v_\phi v_r + v_\theta v_\phi\cot\theta}{r}\right) = -\frac{1}{r\sin\theta}\frac{\partial p}{\partial \phi}$$
$$- \left[\frac{1}{r^3}\frac{\partial}{\partial r}(r^3\tau_{r\phi}) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\tau_{\theta\phi}\sin\theta) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \phi}\tau_{\phi\phi} + \frac{(\tau_{\phi r} - \tau_{r\phi}) + \tau_{\phi\theta}\cot\theta}{r}\right] + \rho g_\phi \quad \text{(B.5-9)}$$

[c] These equations have been written without making the assumption that $\boldsymbol{\tau}$ is symmetric. This means, for example, that when the usual assumption is made that the stress tensor is symmetric, $\tau_{r\theta} - \tau_{\theta r} = 0$.

B.4

EQUATION OF MOTION FOR A NEWTONIAN FLUID WITH CONSTANT ρ AND μ

$$[\rho D\mathbf{v}/Dt = -\nabla p + \mu\nabla^2\mathbf{v} + \rho\mathbf{g}]$$

Cartesian coordinates (x, y, z):

$$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} + \mu\left[\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2}\right] + \rho g_x \qquad \text{(B.6-1)}$$

$$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} + \mu\left[\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2}\right] + \rho g_y \qquad \text{(B.6-2)}$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z \qquad \text{(B.6-3)}$$

Cylindrical coordinates (r, θ, z):

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + v_z\frac{\partial v_r}{\partial z} - \frac{v_\theta^2}{r}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_r)\right) + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2} + \frac{\partial^2 v_r}{\partial z^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}\right] + \rho g_r \qquad \text{(B.6-4)}$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + v_z\frac{\partial v_\theta}{\partial z} + \frac{v_r v_\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_\theta)\right) + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2} + \frac{\partial^2 v_\theta}{\partial z^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta}\right] + \rho g_\theta \qquad \text{(B.6-5)}$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z \qquad \text{(B.6-6)}$$

Spherical coordinates (r, θ, ϕ):

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_r}{\partial \phi} - \frac{v_\theta^2 + v_\phi^2}{r}\right) = -\frac{\partial p}{\partial r}$$
$$+ \mu\left[\frac{1}{r^2}\frac{\partial^2}{\partial r^2}(r^2 v_r) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial v_r}{\partial \theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_r}{\partial \phi^2}\right] + \rho g_r \qquad \text{(B.6-7)}^a$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_\theta}{\partial \phi} + \frac{v_r v_\theta - v_\phi^2\cot\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta}$$
$$+ \mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_\theta}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial \theta}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial \theta}(v_\theta\sin\theta)\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_\theta}{\partial \phi^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta} - \frac{2\cot\theta}{r^2\sin\theta}\frac{\partial v_\phi}{\partial \phi}\right] + \rho g_\theta \qquad \text{(B.6-8)}$$

$$\rho\left(\frac{\partial v_\phi}{\partial t} + v_r\frac{\partial v_\phi}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\phi}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi} + \frac{v_\phi v_r + v_\theta v_\phi\cot\theta}{r}\right) = -\frac{1}{r\sin\theta}\frac{\partial p}{\partial \phi}$$
$$+ \mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_\phi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial \theta}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial \theta}(v_\phi\sin\theta)\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_\phi}{\partial \phi^2} + \frac{2}{r^2\sin\theta}\frac{\partial v_r}{\partial \phi} + \frac{2\cot\theta}{r^2\sin\theta}\frac{\partial v_\theta}{\partial \phi}\right] + \rho g_\phi \qquad \text{(B.6-9)}$$

[a] The quantity in the brackets in Eq. B.6-7 is *not* what one would expect from Eq. (M) for $[\nabla \cdot \nabla\mathbf{v}]$ in Table A.7-3, because we have added to Eq. (M) the expression for $(2/r)(\nabla \cdot \mathbf{v})$, which is zero for fluids with constant ρ. This gives a much simpler equation.

9/85-150

Q. No. MM 541 / 071

B. Tech / Odd
(17-18) / Reg

2017-18

BASIC MANUFACTURING PROCESS

MM 541

Full Marks : 70

Time : 3 hours

The figures in the margin indicate full marks.

Answer any *five* questions.

1. (*a*) In a three component system, what is the maximum number of phases can coexist in equilibrium. 2

(*b*) What information do we get from the study of phase diagram ? 2

(*c*) Copper can dissolve any amount of Ni in solid state and vice versa.

Justify the above statement with the help of Hume-Rothery Rules for the formation of solid solutions. 4

(*d*) Draw Fe-Fe_3C phase diagram and label the phase fields. Discuss in brief the different invariant reactions in this system. 6

2. (*a*) Briefly discuss with example the primary, secondary, joining and surface finishing operations in manufacturing process. 6

(*b*) Discuss the role and importance of alloying elements in steels 4

(*c*) Tree structure classification of Engineering Materials. 4

3. (*a*) Explain the composition, properties and applications of

(*i*) Stainless steel

(*ii*) Plain Carbon Steel and

(*iii*) Tool steels 6

(*b*) Explain the following properties

(*i*) Creep

(*ii*) Fatigue 4

(*c*) Explain with neat sketch and suitable example, the stress-strain diagram of

(*i*) ductile material and

(*ii*) brittle material. 4

4. (*a*) A tensile specimen with 12 mm initial diameter and 50 mm gauge length reaches maximum load at 90 KN and fracture at 70 KN. The minimum diameter at fracture is 10 mm. Determine the engineering stress at maximum load (the Ultimate Tensile Strength) and the true fracture stress. Also determine the true strain at fracture. What is the engineering strain at the fracture. 6

(*b*) Explain the effect of temperature and strain rate on plastic deformation. 4

(*c*) Discuss the recovery, recrystallization and grain growth in metal working process. 4

5. (*a*) Differentiate between hot working and cold working processes, 4

(*b*) Using neat sketches discuss the vaious rolling operations. 6

(*c*) Differentiate the open die forging and closed die forging with proper sketching. 4

6. (*a*) Explain the heat treatment of spheroidizing annealing and normalizing of carbon steels. 6

(*b*) Describe the Shell casting process using neat sketches. 4

(*c*) Comparison between Permanent Mould Casting and Die Casting. 4

7. (*a*) Explain the various steps involved in Lost-Wax process and its applications. 6

(*b*) Explain with neat sketches the following defects in casting and suggest remedial measures: 8

(*i*) Shift

(*ii*) Scab

(*iii*) Hot tear

(*iv*) Cold Shut

8. Write short notes on any *four*: 4 × 3.5

(*a*) Morphology of graphite flakes

(*b*) Malleable cast iron

(*c*) Bronze

(*d*) Nickel and its alloys

(*e*) Duralumin

(*f*) Ductile cast iron.

Q. No. MM 701/084

B.Tech / Odd (17-18) / Reg

2017-18

MATHEMATICAL MODELING AND SIMULATION

MM 701

Full Marks : 70

Time : 3 hours

The figures in the margin indicate full marks and state all assumptions clearly.

Q. No. 1 is compulsory and answer any *four* from the rest.

1. (*a*) Calculate the numerical value of $\frac{d}{dx}(7x^3)$ at $x = 1$, using a central difference approximation of second order accuracy, taking $\Delta x = 0.5$. Calculate the accuracy of the solution. 3

(*b*) Prove that $y_i'' = \frac{y_i - 2y_{i-1} + y_{i-2}}{h^2} + 0(h)$ for a uniform grid spacing of h. 4

(*c*) Why water is used as a working fluid in physical modeling of steel making problem ? What is the difference between an initial value problem and a boundary value problem ? What is the difference between the structured meshes and unstructured meshes ? 2 + 2 + 2

(*d*) What is a model ? Illustrate modelling with the example of any secondary steel making process. 3.5

(*e*) What is the difference between interpolating polynomial, and least square polynomial ? What is an extrapolation ? Which method is suitable for extrapolation ? 3.5

2. An infinite long cylinder of radius r_0 is initially at a uniform temperature T_i. It is suddenly immersed in a bath of hot fluid maintained at T_∞. The heat transfer coefficient between the bath and the cylindrical surface is h. Assuming constant k, ρ and C_p of the cylinder. Formulate the problem to find the temperature history $T(r, t)$. Use the pure implicit finite-difference technique. 7.5 + 3 + 2

3. A slab of thickness L = 2 cm with constant thermal conductivity k = 0.5 W/m.K and uniform heat generation q = 1000 KW/m³. The faces are at temperature 100°C and 200°C. Assuming that the dimensions in *y*- and *z*-directions are so large that the temperature gradients are significant in x-direction only. Using only five grid points, calculate the steady state temperature distribution of the slab using the finite - difference method and compare with the analytical solution. 12.5

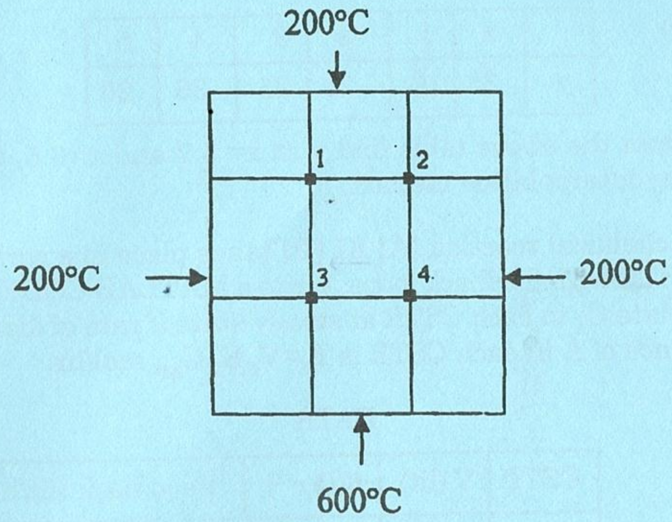
4. (*a*) Fit a curve of the type $a.exp(-bx)$ for the data given in the following table: 5

x	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.00	2.25	2.5
y	3.1	1.7	1.0	0.68	0.42	0.26	0.14	0.09	0.04	0.03

(*b*) Write an algorithm to fit a quadratic curve through n points by least squares. (Show all calculations) 5

(*c*) What is meant by 'best fit curve' ? 2.5

5. Consider the square in the figure below. The left and right faces are maintained at 200°C and the top face at 200°C, while the other face is maintained at 600°C.



The block is 1 m square and k = 10 W/m. °C. Under steady state condition compute the temperature of the various nodes as indicated in the above maintained figure using finite difference method. 12.5

6. (*a*) Write an algorithm to find the roots of the equation $f(x) = 0$ by iteration method. 3

(*b*) The yield strength of a dual phase steel is dependent on its martensite content. The following observations were made in an investigation:

Yield strength(Mpa)	Martensite Content%
400	30
630	50
950	80

Calculate the expected strength of a material having 42% martensite using any standard interpolation method. 5

(c)

	x	1	2	3	4	5
y	33	16	35	25	35	26

6

From the above table find y at x= 3.7 and x=6.5. Choose any interpolation method. 4.5

7. A chemical reaction [A] $\xrightarrow{Ki}$ [B] takes place in a series of 4 CSTR with feedback loops. Write a MATLAB CODE to calculate C_A in each CSTR at steady state if rate of disappearance of A in each CSTR is $R_i=V_i.K_i.C_{Ai}$, mol/hr. 12.5

DATA

CSTR	V_i(lit)	K_i(hr^{-1})	Feed back (lit/hr)
1	1000	0.1	No feed back
2	1500	0.2	No feed back
3	100	0.4	100 to CSTR 2
4	500	0.3	100 to CSTR 3

8. Write an Explicit Finite Difference MATLAB CODE to model the C-concentration profile with distance from surface under unsteady state carburization of 0.2 % C steel with the following data;

Surface concentration = 1.5 % C ; Diffusivity = 3×10^{-7} cm^2sec^{-1} ; Temp. & Time of carburization - 1273K and 1hour respectively. 12.5

Q. No. MM 702 / 080

B. Tech / Odd
(17 - 18) / Reg

2017-18

CORROSION AND DEGRADATION OF MATERIALS

MM 702

Full Marks : 70

Time : 3 hours

Q. No. 5 is compulsory of 20 marks and answer any *four* from the rest of 12.5 marks each.

1. In the table, mass gain-time data for the oxidation of nickel at an elevated temperature are tabulated. Determine whether the oxidation kinetics obey linear, parabolic, or logarithmic rate expression. Also calculate W after 600 minutes using the rate law that it follows.

W (mg/cm^2)	*Time* (*min*)
0.527	10
0.857	30
1.526	100

2. Construct the Eh – pH diagram for the $Zn - H_2O - O_2$ system and comment on its electrochemical behavior with respect to corrosion

$Zn^{++} + 2e = Zn$

$Zn(OH)_2 + 2H^+ + 2e = Zn + 2H_2O$

$HZnO_2^- + 3H^+ + 2e = Zn + 2H_2O$

$ZnO_2^{--} + 4H^+ + 2e = Zn + 2H_2O$

ΔF^o_f in KJ / mol	
Zn	0.00
$Zn(OH)_2$	–554.5
$HZnO_2^-$	–463.2
Zn^{++}	–147.3
ZnO_2^{--}	–390.3
H^+	0.00
OH^-	–157.3
H_2O	–236.9

Make the diagram on a graph paper keeping only that part of each line that is thermodynamically stable to show corrosion, passive and immunity areas.

3. Nickel experiences corrosion in an acid solution according to the reaction.

$$Ni + 2H^+ \rightarrow Ni^{2+} + H_2$$

The rates of both oxidation and reduction half-reactions are controlled by activation polarization.

(*i*) Calculate the rate of oxidation of Ni in mol $cm^{-2}s^{-1}$ given the following activation polarization data:

(*ii*) Calculate corrosion potential by making a graph between Voltage with $\log_{10}$ (Current density). Show, by thermodynamic calculation, that the graphical result is in agreement at the intersection of anodic and cathodic reactions with respective β values.

For Nickel	For Hydrogen
$V_{(Ni/Ni^{2+})} = -0.25V$	$V_{(H^+/H_2)} = 0V$
$i_0 = 10^{-8}$ A/cm²	$i_0 = 6 \times 10^{-7}$ A/cm²
$\beta = +0.12$	$\beta = -0.10$

4. A steel plate has corroded on both sides in seawater. After 10 years, a thickness reduction of 3 mm is measured. Calculate the average corrosion current density. Take the dissolution reaction as $Fe = Fe^{2+} + 2e^-$, and the density & atomic mass of Fe are 7.8 g/cm³ and 55.85, respectively.

5. (*a*) Which one will corrode and why : brass bolt in steel structure or stainless bolt in brass structure ?

(*b*) How galvanic corrosion can be helpful ?

(*c*) In two metals welded system which one is to be coated (w.r.t to electrochemical series) ?

(*d*) What is filiform corrosion ?

(*e*) What is weld decay ?

(*f*) What is marine corrosion ?

6. What is galvanic series ? Do the galvanic series change with environment ? How does it help in studying corrosion ? What is the difference between galvanic series and EMF series ? What is the use of EMF Series ? Explain any two standard half cells.

7. How is corrosion of a metal determined in case of zinc electrode and hydrogen electrode ? Compare the E_{corr} generated in case of iron electrode and zinc electrode wrt hydrogen electrode. Explain graphically the corrosion of metal in complex environment. How does the effect of oxidizers

play in the corrosion of an Acrive-passive metal ?

8. What is the protective coating principle ? What is an ideal coating ? What is the mechanism of protection by paints ? What are the different types of coats possible to protect from corrosion ? Explain with a neat sketch - cathodic protection and anodic protection.

Q. No. MM 711 / 078

B. Tech / Odd
(17-18) / Reg

2017-18

FATIGUE, CREEP AND FRACTURE

MM 711

Full Marks : 70 *Time* : 3 hours

The figures in the margin indicate full marks.

Answer any *five* questions.

1. (*a*) Derive an expression for theoretical cohesive strength of a metal. 4

   (*b*) Show that (by graphically also) the value of strain energy release rate (G) for linear elastic material is same for fixed load and fixed grip conditions. 6

   (*c*) How crack growth occurs when R curve is flat and when it is a rising one. 4

2. (*a*) Plot how the critical stress intensity factor Kc depends on the thickness and explain this. 2

   (*b*) If Airy's stress function $\Psi = \mathrm{Re}\,\overline{\overline{Z}} + y\,\mathrm{Im}\,\overline{Z}$ show that' $\sigma_x = \mathrm{Re}\,Z - y\,\mathrm{Im}\,Z'$, $\sigma_y = \mathrm{Re}\,Z + y\,\mathrm{Im}\,Z'$ and $\tau_{xy} = -y\,\mathrm{Re}\,Z'$ where Z is a complex analytical function of a complex variable z = x + iy.

$d\overline{\overline{Z}} / dz = \overline{Z}$, $d\overline{Z} / dz = Z$ and $Z' = dZ / dz$ 5

(c) Write down equilibrium equations, Hooke's relationships in 3-D and compatibility equations of strain for plane stress condition.

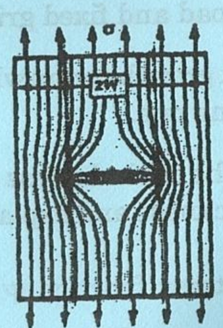
Then, prove $\Delta^2(\sigma_x + \sigma_y) = 0$, using above equations. The symbols carry their usual meaning. 7

3. (a) Derive an expression for determination of plastic zone size by Dugdale's Strip Yield model in LEFM. State all your assumptions clearly. 7

(b) Calculate K_{eff} (Irwin correction) for a through crack in a plate of width 2W (Fig. shown). Assume plane stress conditions and the following stress intensity relationship: 7

$$K_{eff} = \sigma\sqrt{\pi a_{eff}\left[\sec\left(\frac{\pi a_{eff}}{2W}\right)\right]}$$

$\sigma = 250$MPa; $\sigma_{YS} = 350$MPa; 2W=203 mm; 2a=50.8 mm.



4. (a) Describe J-integral and write the significance of J-integral in fracture mechanics. 3

(b) Explain the detailed procedure for experimental determination of J_{IC}. 7

(c) The critical crack-tip opening displacement of a particular cracked configuration was found to be 0.2 mm. The yield strength of the material is 450 MPa. The critical value for the J-integral was computed to be 85000 J/m. The elastic modulus of the material is 70GPa and its Poisson ratio is 0.3. What are the minimum specimen size requirements for a valid plane strain fracture thoughness test for K_{IC} and for J_{IC} ? 4

5. (a) Draw S-N curves with and without fatigue limit with example ? 2

(b) Explain the different stages of fatigue crack initiation and propagation. Draw and explain da/dN Vs. stress intensity range(ΔK) plot. 6

(c) A heat exchanger system is subjected to temperature variations from 27°C to 350 °C and is constrained so that it cannot expand or contract. How long will it take an internal flaw, 2mm long, to propagate to failure. The heat exchanger is made from a titanium alloy for which the fatigue crack growth rate can be expressed as

$$da/dN = C(\Delta K)^m$$

Where da/dN is in mm/cycle, $C=0.69 \times 10^{-11}$ ΔK is in $KPam^{1/2}$, m=4.4. The titanium alloy has a modulus of 116 GPa, a thermal expansion co-efficient $= 8.4 \times 10^{-6}$/°C and a fracture toughness of 73 $MPam^{1/2}$ 6

6. (a) Explain Miner's rule with its assumptions and limitations. 2

(b) The S-N curve for an elastic material is characterized by the Basquin relationship, $\sigma_a = C.N^b{}_f$, where C is a material constant, σ_a is the stress amplitude, N_f is the number of fully reversed stress cycles to failure, and b is the Basquin exponent approximately equal to –0.09. When the stress amplitude is equal to the ultimate tensile strength of the material in this alloy, the fatigue life is 1/4 cycle. If a specimen spends 70% of its life subject to alternating stress levels equal to its fatigue endurance limit σ_e, 20% at $1.1\sigma_e$, and 10% at $1.2\sigma_e$, estimate its fatigue life using the Palmgren-Miner linear damage rule. 5

(*c*) Write notes on the effect of following parameters on fatigue. (any *two*)

(*i*) Surface residual stress

(*ii*) Specimen Size

(*iii*) Stress concentration factor. 7

7. Answer the following questions in brief (and *four*) $3.5 \times 4 = 14$

(*a*) Discuss a set of conditions under which the application of a tensile overload to a component can result in

(*i*) an improvement,

(*ii*) a reduction, or

(*iii*) no change in fatigue life.

(*b*) With sketch explain the three modes of loading.

(*c*) Draw and explain Goodman diagram.

(*d*) Discuss with the help of S-N diagram, the effect of

(*i*) substitutional solute addition

(*ii*) interstitial solute addition and

(*iii*) increasing the temperature on its fatigue behaviour.

Assuming the given material shows strain aging.

(*e*) Discuss the effect of metallurgical variables on fatigue.

8. (*a*) Draw and explain the different regions in a creep curve. 4

(*b*) Explain creep mechanisms in detail (include deformation mechanism map). 10

Q. No. MM 720 / 08

B. Tech / Odd (17 - 18) / Reg

2017-18

ALTERNATIVE ROUTES OF IRONMAKING

MM 720

Full Marks : 70 *Time* : 3 hours

All questions are of equal value.

Answer any *five* questions.

1. Pyrophoricity of DRI is typical issue, endangering its storage & transportation as a *hazardous cargo*. How did the process metallurgists deal with this issue ?

2. Shockwave plasma using iron ore fines is a challenging development today. How does the orbiting system help producing hot metal ?

3. Application of chemical engineering principles to process metallurgy is best exemplified by fluid bed reduction of iron ore fines in generating iron carbide. Highlight the reactions and benefits.

4. The Australian development of Hismelt process entails certain exciting innovative measures. Can you illustrate a few ?

5. The Mexican development of a retort based DRI process, called HYL, lost in competition to the American development called Midrex. Why and how ?

6. The air-lift mechanism of a circulating hot metal, as per Minnesota concept for high-speed reduction purpose, has been an encouraging direct smelting development. How does it work ?

7. In the absence of natural gas, how can India utilise the shaft furnace concept successfully ? Is there any commercial development along these lines for gas-based DRI production ?

8. Szekely's mechanism of shrinking-core-model elucidates the basics of stagewise iron ore reduction. What parameters are playing their roles here in supporting the reaction kinetics ?

Q. No. MM 721 / 41

B.Tech / Odd (17-18) / Reg

2017-18

POWDER METALLURGY

MM 721

Full Marks : 70 *Time* : 3 hours

The figures in the margin indicate full marks.

Answer should be brief and to the point.

Answer any *five* questions.

1. Justify the following $7 \times 2 = 14$

   (*a*) Factors that improve compressibility will usually increase green strength.

   (*b*) Apparent density decreases with increasing concentration of lubricant.

   (*c*) Ceramic particles are easy to mill than metallic particles.

   (*d*) Metal powders exhibit fluid like behavior.

   (*e*) Inert gas atomization is an ideal process to produce spherical powdered particles.

   (*f*) Green strength increases as the particle coordination increases.

   (*g*) Smaller particles promote faster densification

2. Write short notes on: $3.5 \times 4 = 14$

(a) Activated sintering,

(b) Transient liquid phase sintering,

(c) Apparent density and tap density,

(d) Green density and green strength.

3. (a) More complex shaped parts can be produced by PIM process than by conventional PM. Justify this statement giving examples.

(b) Discuss advantages and disadvantages of MIM process.

(c) Draw the flow diagram of MIM process and describe steps involved in MIM.

(d) External and internal threads can be molded into MIM parts. Which ones are more problematic ?

$4 + 4 + 4 + 2 = 14$

4. (a) Three powders are die pressed using a pressure of 440 MPa. One of the three is -325 mesh Ti, one is -325 stainless steel and one is -100 mesh Cu. Which powder gives the highest green strength ? Why ?

(b) What merit would there be in forming steel compacts by pressing mixed iron and graphite powders versus using prealloyed steel powders ?

(c) For a given powder, the density achieved at any pressure is higher for isostatic compaction than for uniaxial die compaction. Explain the difference.

(d) A solid loading of 65 vol.% is sought from a powder mixture composed of 98% iron powder and 2% Ni. The binder has a density of 0.95 g/cm^3. What weight percent

[*Continued*]

is required for Fe, Ni and binder for the feedstock? The density of Fe and Ni are 7.87 g/cm^3 and 8.91 g/cm^3, respectively.

$4 + 2 + 4 + 4 = 14$

5. (a) What is the compression ratio and what is the required powder fill for final compact height of 5 cm, if the green density for a stainless steel powder is to be 6.48 g/cm^3 and the apparent density is 2.67 g/cm^3 ?

(b) What is densification parameter ?

(c) A liquid phase sintered SiC-Ni composite has a solid - solid grain boundary energy (γ SiC-SiC) of 0.80 J m^{-2} and solid-liquid ((γ SiC-Ni) interfacial energy of 0.45 J m^{-2}. For a SiC grain size of 20 μm, what is the average interparticle (SiC-SiC) neck size ?

(d) Give some examples of liquid phase sintering and its applications.

$4 + 2 + 4 + 4 = 14$

6. (a) A highly oxidized steel powder is sintered in pure hydrogen at 1000 °C. A post sintering characterization (chemical analysis) show that decarburization has occurred. Use precise chemical reaction equations to explain how that happened.

(b) Why are sintering atmospheres important ? Explain with examples.

(c) Describe the specific surface area measurement by BET method.

$4 + 4 + 6 = 14$

7. (a) Describe particle size analysis by sedimentation technique.

(b) The Reynolds number must be approximately 0.2 for Stokes law to be valid performing a sedimentation analysis for particle size. For tungsten spheres settling

[*Turn Over*]

in a fluid, what is the maximum particle diameter for which sedimentation is valid ? (Density of W = 19.3×10^3 kg/m^3, density of fluid = 1.2 kg/m^3 and viscosity of fluid= 1.8×10^{-5} kg/m/s)

(c) Describe mechanisms involved during mechanical alloying. 4 + 4 + 6 = 14

8. (a) Describe powder production by gas atomization techniques.

(b) Describe conventional die compaction technique.

(c) Define the following terms.

(i) Attrition,

(ii) Binder,

(iii) Cermet and

(iv) Double action pressing. 6 + 4 + 4 = 14
