Ref. No.: Ex/ME(M2)/PC/B/T/215/2023

B.E. MECHANICAL ENGINEERING 2ND YEAR 1ST SEMESTER EXAMINATION 2023

Sub: MATERIAL SCIENCE AND ENGG. Time: THREE HOUR Full Marks: 100

(Answer any **FIVE** questions)

There are total 8 questions with numbering as 1,2,3...8. You have to answer any 5. Against each question number (e.g. 1, 2...) you should try to answer all parts together (e.g. a,b,c),For example, if you choose question no 2, try to answer all parts 2a,2b and 2c altogether. For question no. 3 and 5, you have to choose any one set.

1.a) Explain the following mechanical properties (any four): (3×4)

Hardness, Ductility, Toughness, Fatigue, Creep, Hardenability

b) Draw the stress-strain diagram of the following materials on a single graph: (8)

Diamond, Mild steel, Aluminium, Cast Iron

Or

b) What is yielding? Discuss the difference between true stress, true strain and engineering stress, engineering strain. (2+6)

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2. a) Explain the BCC crystal structure and determine its atomic packing factor. (2+4)

b) Draw the following crystallographic planes and directions:

(i) $(0\bar{1}2)$ (ii) [201] (iii) $(32\bar{1})$ (iv) $[3\bar{1}2]$ (8)

(c) Calculate 'linear density' and 'planer density' for FCC crystal structure along the direction [101] and along the plane (111).Assume, lattice constant = 2.83 Å (6)

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3. a) Define 'activation energy' for solid state diffusion. How will you estimate activation energy for solid state diffusion? State and derive Fick's second law of diffusion. (2+3+5)

b) For a carburization process, the carbon environment used has carbon content of 1.4%. The initial carbon content in steel is 0.3% and a carbon content of 0.8% is reached at a depth of 0.75 mm from the surface in 8 hours. Determine the carburization temperature. (10)

Given: $D_0 = 20\times10^{-6} \frac{m^2}{s}$; $Q = 142 \frac{KJ}{mol}$; $R = 8.314 \frac{J}{mol\,K}$

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Z	0.45	0.50	0.55	0.60
erf(Z)	0.4755	0.5205	0.5633	0.6034

Or

3. a) What is a slip system? For BCC iron, compute (i) the interplanar spacing and (ii) the diffraction angle for the (220) set of planes. The lattice parameter for Fe is 0.2866 nm. Assume that monochromatic radiation having a wavelength of 0.1790 nm is used, and the order of reflection is 1. (5+5)

b) Consider one such alloy that initially has a uniform carbon concentration of 0.25 wt% and is to be treated at 950°C. If the concentration of carbon at the surface is suddenly brought to and maintained at 1.20 wt%, how long will it take to achieve a carbon content of 0.80 wt% at a position 0.5 mm below the surface? The diffusion coefficient for carbon in iron at this temperature is $1.6 \times 10^{-11} m^2/s$; assume that the steel piece is semi-infinite. (10)
Use the following table if required.

Z	0.25	0.30	0.35	0.40
erf(Z)	0.2763	0.3286	0.3794	0.4284

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4. a) Derive the expression for composite elastic modulus under transverse loading for a fibre reinforced composite material. Also mention the assumptions made to derive the expression. (6+3)

b) For a fibre reinforced composite material, the modulus ratio is 32 and the fibre takes 28% of the cross sectional area. What percentage of the longitudinal load is taken by the fibre ? (5)
c) Explain the stress-strain behaviour of a fibre reinforced composite under longitudinal loading. (6)

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5. a) Explain with an example how 'energy band structure' is developed in solids. (5)
b) Explain the term 'Fermi energy level' and 'free electron' using Fermi-Dirac electron energy distribution function. Draw the above function for absolute temperatures 0 K, 250 K

and 750 K for pure silicon. How does this function get affected if silicon is doped by phosphorous? (4+3+3)

c) The resistivity of a semi-conductor at 350°C is $6.65 \times 10^{-4}(\Omega m)$ and the conductivity at 55°C is $275(\Omega m)^{-1}$. Calculate the energy band gap for the semi-conductor. (5)

Given, Boltzman constant = $86.2 \times 10^{-6} \frac{eV}{K}$

Or

5. a) Discuss how dislocations are related to deformation.

b) Consider a single crystal of BCC iron oriented such that a tensile stress is applied along a [010] direction. (i) Compute the resolved shear stress along a (110) plane and in a [111] direction when a tensile stress of 52 MPa is applied. (ii) If slip occurs on a (110) plane and in a [111] direction, and the critical resolved shear stress is 30 MPa, calculate the magnitude of the applied tensile stress necessary to initiate yielding.

c) Discuss mechanisms of strengthening in metals. (4+12+4)

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6. a) Explain the significance of 'critical cooling rate' with reference to TTT diagram? Draw the Fe-C phase diagram with according scale and label it mentioning salient points. (3+8)

b) A 5 kg ferrous alloy that contains 2.85 % carbon cooled from liquid phase and undergoes eutectic reaction forming γ-austenite and cementite. Determine the amount in kg of (i) Primary (pro-eutectic) γ-austenite (ii) Eutectic γ-austenite and (iii) Cementite (9)

Or

b) For a 99.65 wt% Fe–0.35 wt% C alloy at a temperature just below the eutectoid, determine the following: **(i)** The fractions of total ferrite and cementite phases **(ii)** The fractions of the pro-eutectoid ferrite and pearlite **(iii)** The fraction of eutectoid ferrite (9)

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7. a) Explain one dimensional imperfections in solids? (5)

b)The fraction of points defects of aluminium at 215 °C is 2.25×10^{-5}. Calculate the number of point defects per 10 lakh of lattice sites at 575°C. The activation energy required to create one point defect = 0.76 (eV). Boltzman constant = $86.2 \times 10^{-6} \frac{eV}{K}$ (5)

Or

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b) A cylindrical specimen of steel having an original diameter of 12.8 mm is tensile tested to fracture and found to have an engineering fracture strength σ_f of 460 MPa. If its cross-sectional diameter at fracture is 10.7 mm, determine ductility in terms of percentage reduction in area. (5)

c) Explain any two of the following heat treatment processes: (5+5)

Normalizing, Annealing, Martempering

Q8) Write short notes (any four): (4×5)

a) Diffusion mechanisms

b) Piezoelectricity and its applications

c) Lever rule

d) Failure of materials

e) Metallic corrosion

f) Burger vector

g) Critical length of fibre