MATERIAL SCIENCE AND ENGINEERING

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) What is the difference between a space lattice and Bravais lattice ? Determine the radius of an iridium atom, given that Ir has a FCC structure, a density of 22.4 g/cm^3 and an atomic weight of 192.2 g/mol. 4 + 4

   (*b*) Find the equilibrium concentration of vacancies in aluminium at –273 °C and 27 °C. Given : E_f = 68×10^3 J/mol. 5

   (*c*) Compare interstitial and vacancy atomic mechanism for diffusion. Cite *two* reasons why interstitial diffusion is normally more rapid than vacancy diffusion. 7

2. (*a*) Explain the rules that led to the formulation of conditions which favour extensive substitutional solid solubility. What is the difference between random and ordered solid solution ? 7

(b) What is the difference between equilibrium diagram and phase diagram ? State the Gibb's phase rule. 6

(a) What is the relation between energy of a dislocation and Burgers vector ? Why can cross-slip occur in BCC and FCC metals, but cannot occur in HCP metals ? Explain why dislocations have Burgers vector as small as possible. 7

3. (a) Explain why creep is considered to be a high temperature property. Mention the metallurgical variables affecting creep behaviour of a material. Describe the effect of grain size on the creep strength of a material. 7

(b) What are the essential differences between ductile and brittle fracture ? 5

(c) Explain the Griffith theory of fracture. A glass contains a surface crack 1 μm deep and inner crack of 1.6 μm length. Determine which crack will propagate first and at what stress, if both the cracks are normal to the tensile axis ? Given : $E = 65$ GPa and $\gamma = 0.5\ Jm^{-2}$. 8

4. (a) Distinguish between (*i*) recrystallisation and secondary recrystallisation based on driving force and (*ii*) recovery and dynamic recovery. 4 + 4

(b) Discuss the changes in internal structures of crystals by cold working. 5

(c) Explain the difference between resolved shear stress and critical resolved shear stress. What are the factors which affect the critical resolved shear stress ? 7

Group B

5. (a) What are the aims of stress-relieving annealing ? 4

(*b*) Compare the following : 5 + 5

(*i*) Age hardening and tempering

(*ii*) Martempering and austempering

(*c*) Define cyaniding. What are the aims of cyaniding ? 6

6. (*a*) For refractory ceramic materials, cite *three* characteristics that improve with and two characteristics that are adversely affected by increasing porosity. 5

(*b*) Why are borosilicate glasses and fused silica resistant to thermal shock ? 5

(*c*) Briefly explain why the thermal conductivity is higher for crystalline than non-crystalline ceramics. 5

(*d*) Briefly explain how the degree of crystallinity affects the thermal conductivity of polymeric materials and why ? 5

7. (*a*) Cite the primary differences between chain reaction polymerization and step reaction polymerization. 4

(*b*) Briefly explain how molecular weight and degree of crystallinity influences the tensile strength and tensile modulus of a semi-crystalline polymer. 6

(*c*) For a fiber-reinforced composite, (*i*) compare the desired mechanical characteristics of matrix and fiber phases and (*ii*) cite *two* reasons why there must be a strong bond between fiber and matrix at their interface. 6

(*d*) What are dispersion-strengthened composites ? 4

8. (*a*) Briefly describe the phenomenon of magnetic hysteresis and why it occurs for ferromagnetic and ferrimagnetic materials ? 6

(b) Why the magnitude of the saturation magnetization decreases with increasing temperature for ferromagnetic materials? 4

(c) In terms of electron energy band structure, discuss reasons for the difference in electrical conductivity between metals and semiconductors. 5

(d) For intrinsic In Sb, the room-temperature electrical conductivity is $2\times10^4\,(\Omega\text{-m})^{-1}$; the electron and hole mobilities are respectively 7.7 and 0.07 $m^2/V\text{-s}$. Compute the intrinsic carrier concentration at room temperature. 5

Group C

9. Answer the following in brief: 10×2

(i) The distance between (111) planes in FCC crystal structure is 2 Å. Find the lattice parameter and atomic diameter.

(ii) A 45 kN force was applied on a Cu-Ni alloy tensile specimen having 12.5 mm diameter and 50 mm gauge length. Determine whether the specimen will undergo necking. Given : $\sigma_{UTS} = 420$ MPa and $\sigma_y = 250$ MPa.

(iii) What is S-N curve?

(iv) State Fick's first law of diffusion.

(v) What is a peritectoid and monotectic reaction?

(vi) What is Jominy end-quench test?

(vii) Define (a) Tg and (b) degree of polymerization.

(viii) Define (a) Curie temperature (T_c) and (b) remanence of a magnetic material.

(ix) What is stress corrosion cracking?

(x) A steel has tensile strength of 1.6 GPa. A large tensile piece of such a steel has crack of length 7 mm in the interior and fractures at 0.6 GPa. Calculate its fracture toughness.