KATHMANDU UNIVERSITY
End Semester Examination
June/July, 2023

Marks Scored:

Level : B.E.
Year : II

Course : MEEG 213
Semester : I

Exam Roll No. :

Time: 30 mins.

F. M. : 10

Registration No.:

Date 04 JUL 2023

SECTION "A"
[20 Q. × 0.5 = 10 marks]

Mark [X] in the most appropriate option.

1. An iron particle weighing exactly 100 mg is required for a specific application. Calculate the number of iron atoms required to manufacture one such particles. (Given molar mass of Fe = 56 g/mole).
[ ] 1.755×10^{23} atoms [ ] 10.755×10^{20} atoms
[ ] 1.755×10^{21} atoms [ ] 10.755×10^{22} atoms

2. The number of atoms per unit cell for SC, BCC and FCC unit cells are respectively:
[ ] 1, 2, 3 [ ] 1, 2, 2 [ ] 1, 2, 4 [ ] 1, 1, 2

3. The lattice constant 'a' for BCC and FCC crystal structure are respectively given by.
[ ] $4r/\sqrt{3}$, $4r/\sqrt{2}$ [ ] $4r/\sqrt{2}$, $4r/\sqrt{3}$ [ ] $2\sqrt{2}r$, $2\sqrt{3}r$ [ ] $2\sqrt{3}r$, $2\sqrt{2}r$

4. Calculate the radius of an Iridium atom, given that Iridium has an FCC crystal structure, a density of 22.4 g/cm^3, and an atomic weight of 192.2 g/mol.
[ ] 0.136 nm [ ] 0.235 nm [ ] 0.316 nm [ ] 0.423 nm

5. A crystallographic direction and family of direction are respectively represented by.
[ ] (hkl), {hkl} [ ] (hkl), <hkl> [ ] [hkl], <hkl> [ ] [hkl], {hkl}

6. Incorporation of dopants such as P and B in silicon is an example of _____.
[ ] substitutional defect [ ] interstitial defect
[ ] Frenkel defect [ ] Schottky defect

7. The Hall-Petch equation for mild steel grade is given by, $\sigma_y = 55.49 + 18.45d^{-1/2}$. Calculate the required grain size to attend the yield strength of 275 MPa.
[ ] 5 μm [ ] 7 μm [ ] 50 μm [ ] 70 μm

8. Formation of micro-voids in the failed material indicates_____.
[ ] ductile fracture [ ] brittle fracture [ ] fatigue fracture [ ] corrosion failure

9. Brittle fracture is more dangerous than ductile fracture because _____.
[ ] Crack propagates at very high speeds
[ ] No warning sign
[ ] No need for extra stress during crack propagation
[ ] All of the above

10. A metal rod of original diameter 7.5 mm and length 100 mm is subjected to tensile load of 1 kN. Under this load the rod deformed into a diameter of 5 mm. Calculate the true stress in the rod. (Given, Young's modulus of the material is 200 GPa)
[ ] 25 MPa [ ] 50 MPa [ ] 75 MPa [ ] 100 MPa

11. In phase nucleation process, the nucleated solid is _____ if its radius is greater than the critical radius.
[ ] a nucleus [ ] an embryo [ ] a tiny particle [ ] a molecule

12. In dendritic growth, the dendrite size is characterized by measuring _____.
[ ] the length of the primary dendrite arm
[ ] the distance between the primary dendrite arm
[ ] the distance between the secondary dendrite arm
[ ] the width of the primary or secondary dendrite arm

13. A Heat treated Cu-40%Zn brass alloy is stronger than pure copper. If the solubility limit of Zn in Cu is 30%, what are the active strengthening mechanisms in brass?
[ ] Solid-Solution strengthening [ ] Dispersion strengthening
[ ] Grain size strengthening [ ] All of the above

14. In the Al – Si material system, the liquid metal mixture at the temperature of 577 °C and composition of 12.6 % Si transforms into combination of α-phase (Al reach) and β-phase (Si reach). What type of invariant transformation process is this?
[ ] Peritectic [ ] Eutectic [ ] Peritectoid [ ] Eutectoid

15. Considering the phase diagram of elements A and B presented in Figure 1, what is the phase fraction of solid phase if the whole system is maintained at temperature T and w_o % weight fraction of B?
[ ] $Solid\ Fraction = \frac{w_o - w_l}{w_s - w_l}$
[ ] $Solid\ Fraction = \frac{w_s - w_o}{w_s - w_l}$
[ ] $Solid\ Fraction = \frac{w_o - w_l}{w_s - w_o}$
[ ] $Solid\ Fraction = \frac{w_s - w_o}{w_o - w_l}$

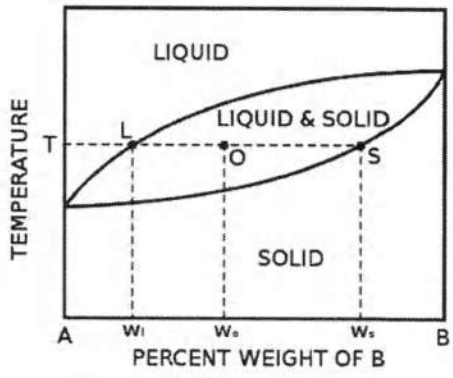

Figure 1: Phase diagram

16. Arrange the microstructure phases from lowest to highest tensile strength: Austenite (A), Bainite (B), Course Pearlite (CP), Fine Pearlite (FP), Tempered Martensite (TM)
[ ] A, B, CP, FP, TM [ ] A, CP, FP, B, TM
[ ] B, A, CP, CF, TM [ ] B, A, CF, CP, TM

17. Which of the following microstructure in the final structure of steel increases the toughness of steel?
[ ] Martensite [ ] Pearlite [ ] Bainite [ ] Austenite

18. Solvus line in phase diagram represents _____.
[ ] a solubility limit of a single phase region from a two phase region
[ ] a solubility limit of a single solid phase region from a two solid phase region
[ ] a solution temperature at which solid-solution starts to melt
[ ] a solution temperature at which solid solution starts to boil

19. Austempering process in cast iron produces a combine structure of _____.
[ ] acicular ferrite and graphite [ ] acicular ferrite and pearlite
[ ] acicular ferrite and martensite [ ] acicular ferrite only

20. Aluminum alloys with the addition of Mn alloying element is labeled as _____.
[ ] 2xxx series [ ] 3xxx series [ ] 4xxx series [ ] 5xxx series

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SECTION "B"

Attempt *ALL* questions. Assume suitable data if necessary.

1.

a. Explain the terms Composition, Structure and Synthesis in material science and engineering. [1.5]

b. Classify in which material type does following materials belong to. Give two properties of each of the material along with their applications. [3]
   i. Carbon Fiber Reinforced Polymer (CFRP)
   ii. Zirconia (ZrO_2)

c. Explain the significance of length scale from nano-scale to macro-scale in engineering components. [1.5]

2.

a. Determine the relationship between the atomic radius and the lattice parameter in BCC structures when one atom is located at each lattice point. Evaluate number of atoms per unit cell and packing factor for the BCC unit cell. [3]

b. Define Miller Indices for crystal structure. Explain the procedure to identify Miller indices of crystallographic direction. Indicate (111) crystallographic plane in the cubic unit cell. [3]

c. Explain and illustrate edge dislocation in crystal structure. Significantly high number of edge dislocations are introduced in plastic deformation process, discuss how does such dislocations renders overall material properties. [3]

3.

a. A cylindrical steel specimen of original diameter 15 mm was loaded in tension. At the load of 45 kN, the cross sectional area of the specimen was noted to be 135.5 mm^2. Given E = 200 GPa for the steel material used, determine:
   i. Ductility of the steel material used. [1]
   ii. Difference between true stress and engineering stress at the load of 45 kN. [2]
   iii. On further loading, fracture of the specimen was observed at the load of 68 kN. Calculate the fracture stress of the steel material used. [1]

b. Explain the similarities and differences between Vickers hardness and Knoop hardness scale used to characterize material hardness. [2]

c. Define creep behavior of the material with suitable examples. Explain how creep behavior is different from fatigue behavior of the material. [2]

4.

a. Explain different types of cast structure developed during solidification of molten metal in the solidification process. [2]

b. Define solid-solution strengthening. Explain Hume-Rothery conditions for unlimited solid solubility of cupper-nickel alloy system. [3]

c. The equilibrium phase diagram of Aluminum – Silicon material system is shown in Figure 1 below. Considering the Al – Si phase diagram answer the following questions.

i. Describe all the invariant phase transformation processes occurring in the phase diagram. [1]

ii. Determine the maximum solubility of Al in β phase and Si in α phase. [1]

iii. Considering 12.6 % Si in the alloy, calculate the amount of α and β phases formed after cooling to 0^{o}C. [2]

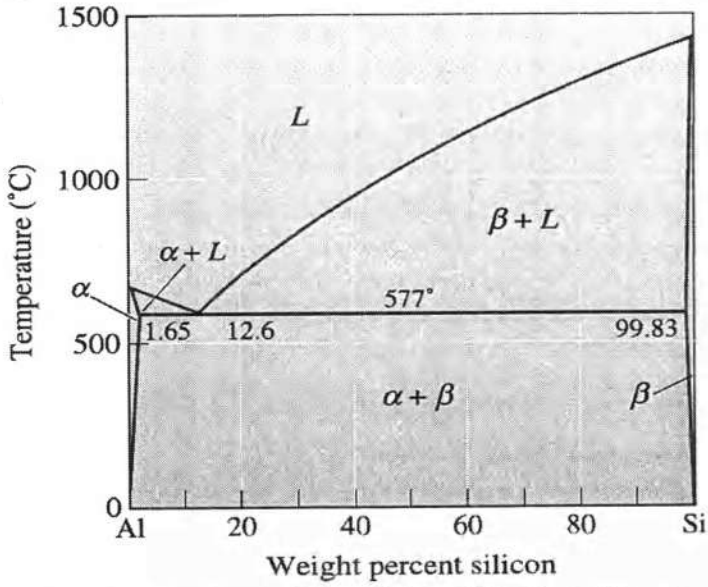

Figure 1: Aluminum (Al) – Silicon (Si) phase diagram

5.

a. The eutectoid region of the iron – iron carbide phase diagram represents steel materials with carbon content less than 2 %. Draw and explain eutectoid region of the iron – iron carbide phase diagram. Explain all the single phase regions involved in eutectoid phase transformation of steel. [3]

b. With reference to the eutectoid region of iron – iron carbide phase diagram drawn in previous question, describe full annealing, normalizing and spheroidizing heat treatment process for hyper eutectoid steels. [3]

c. Write short notes on: [2 × 1 = 2]

i. Continuous-Cooling-Transformation (CCT) diagram

ii. Dendritic growth mechanism