NATIONAL INSTITUTE OF TECHNOLOGY, HAMIRPUR, H.P.
Department of Materials Science and Engineering (DoMSE)

End-Term Examination
Materials Science and Engineering (MS-101)
Duration: 2 hrs (120 minutes) *Maximum Marks: 50*
Attempt all the questions.

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1. Briefly explain/define any *ten* of the following terms/concepts with suitable examples, wherever required:
   i. *Bragg's Law of X-Ray Diffraction*
   ii. *Fick's Laws of Diffusion*
   iii. *Diamond Cubic Structure*
   iv. *Schottky and Frenkel Defects*
   v. *Edge and Screw Dislocations*
   vi. *Creep and Fatigue*
   vii. *Annealing, Normalizing and Hardening*
   viii. *Carburizing and Flame Hardening*
   ix. *Homogeneous and Heterogeneous Nucleation*
   x. *Ferromagnetic and Ferrimagnetic Materials*
   xi. *Hard and Soft Magnetic Materials*
   xii. *Hall Effect*

   (15 Marks)

2. Enumerate the various common crystal structures exhibited by ceramic materials. Would you expect NiO to have the cesium chloride, sodium chloride, or zinc blende structure? Based on your answer, determine (a) lattice parameter, (b) the density and (c) the packing factor of NiO. ***Given data:*** (i) atomic radii of Ni and O ions are 0.069 nm and 0.132 nm (ii) atomic weights of Ni and O are 58.71 and 16, respectively. ***(5 Marks)***

3. Derive expressions for critical radius (r*) and activation energy (ΔG^*) for homogeneous nucleation in a liquid to solid transformation. For the solidifications of pure nickel (Ni), calculate the critical radius (r*) and the activation energy (ΔG^*) if nucleation is homogeneous. Given data: latent heat of fusion for Ni (ΔH_f) = -2.53×10^9 J/m^3, surface free energy for Ni = 0.255 J/m^2, melting temperature for Ni = 1455°C, supercooling (ΔT) = 319 K. Also calculate the number of atoms found in a nucleus of critical size. Assume a lattice parameter of 0.360 nm for solid nickel at its melting temperature.

   (5 Marks)

4. Draw a neat sketch of iron-carbon phase diagram and briefly explain the various phases, microconstituents and phase transformations relevant to this equilibrium diagram.

   (5 Marks)

5. The kinetics of the austenite-to-pearlite transformation obeys the Avrami relationship. Using the fraction transformed data given below, determine the total time required for 95% of the austenite to transform to pearlite:

Fraction Transformed	*Time (s)*
0.2	280
0.6	425

(3 Marks)

6. Draw a neat sketch of isothermal transformation diagram for an iron-carbon alloy of eutectoid composition and using this diagram, specify the nature of final microstructure of a small specimen that has been subjected to the following time-temperature treatments. In each case assume that the specimen begins at 760ºC and it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

   (a) Rapidly cool to 350ºC, hold for 10^3 s, and quench to room temperature.

   (b) Rapidly cool to 665ºC, hold for 10^3 s, and quench to room temperature.

   (c) Rapidly cool to 600ºC, hold for 4 s, rapidly cool to 450ºC, hold for 10 s, and quench to room temperature.

(5 Marks)

7. Write short notes on any ***<u>four</u>*** of the following:-
   (a) Miller Indices in Cubic Crystal Systems
   (b) Defects in Crystalline Materials
   (c) Tensile Testing of Materials
   (d) Polarization Mechanisms
   (e) Thermal Properties of Materials
   (f) Surface Hardening Heat Treatment Processes

(12 Marks)

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Attempt all the following questions

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1. Explain the Bragg's law of diffraction and extinction rules for allowed reflections in X-ray diffraction. Would you expect NiO to have cesium chloride, sodium chloride or zinc blende structrure? Based on your answer, determine (a) the lattice parameter (b) the density and (c) the packing factor. Given data: *Atomic mass of Ni = 58.71 g/mol, Atomic mass of oxygen = 16 g/mol, Ionic radius of* Ni^{2+} *= 0.069 nm, Ionic radius of* O^{2-} *= 0.132 nm*. ***4 + 3***

2. State the Fick's laws of diffusion. For a steel alloy it has been determined that a carburizing heat treatment of 10 hours duration will raise the carbon concentration to 0.45 at a point 2.5 m from the surface. Estimate the time necessary to achieve the same concentration at a 5 mm position for an identical steel and at the same carburizing temperature. ***2 + 2***

3. Draw a net sketch of iron-iron carbide phase diagram and answer any three of the following:-

   (a) Explain the various invariant reactions taking place in iron-iron carbide system.

   (b) Compute the mass fractions of ferrite and cementite in pearlite.

   (d) What is the carbon concentration of an iron–carbon alloy for which the fraction of total cementite is 0.10?

   (e) What is the proeutectoid phase for an iron–carbon alloy in which the mass fractions of total ferrite and total cementite are 0.86 and 0.14, respectively? Why?

   4 + 3

4. Draw the isothermal transformational diagram (or time-temperature transformation (TTT) diagram) for an iron-carbon alloy of eutectoid composition and label all its parts. Briefly describe the various microconstituents that occur in this diagram.

4 + 3

5. Derive the relations for the critical radius and the activation energy for the formation of a stable nucleus for homogeneous nucleation. For the solidifications of pure gold (Au), calculate the critical radius (r*) and the activation energy (ΔG^*) if nucleation is homogeneous. Given data: latent heat of fusion for Au (ΔH_f) = -1.16×10^9, surface free energy for Au = 0.132 J/m^2, melting temperature for Au = 1064°C, supercooling (ΔT) = 230 K. Also calculate the number of atoms found in a nucleus of critical size. Assume a lattice parameter of 0.413 nm for solid gold at its melting temperature.

4 + 2+ 1

6. The kinetics of the austenite-to-pearlite transformation obeys the Avrami relationship. Using the fraction transformed data given below, determine the total time required for 95% of the austenite to transform to pearlite:

Fraction Transformed	*Time (s)*
0.2	280
0.6	425

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7. Briefly explain **any *five*** of the following terms/concepts, with examples:-
   (a) Ferromagnetic, Antiferromagnetic and Ferrimagnetic Materials
   (b) Ultimate Tensile Strength, Resilience and Toughness
   (c) Continuous Cooling Diagrams
   (d) Annealing, Normalizing and Hardening
   (e) Martempering and Austempering
   (f) True Stress and True Strain
   (g) Band Theory of Solids

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