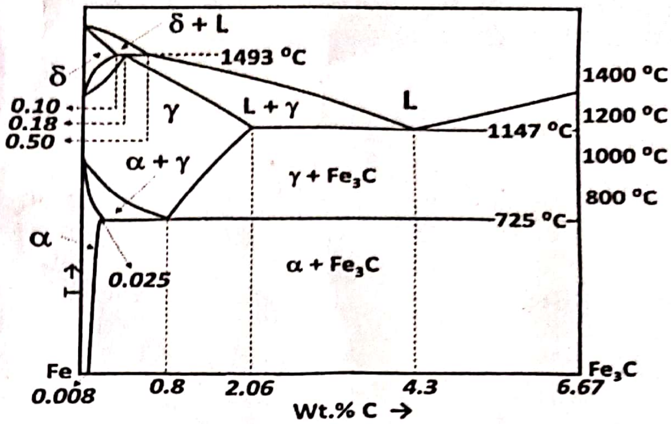
Thapar Institute of Engineering and Technology, Patiala
School of Physics and Materials Science
END SEMESTER EXAMINATION, 2nd December 2019

B. E. (Second Year): Semester-III (2019/20) | Course Code: UES012
Course Name: Engineering Materials
Time: 3 Hours, Max. Marks: 100 | Name of Faculty: OPP, KUS, PNS, CBN, BCM, LKB, JTK, CHK, SAK, RPS

***Note:** Attempt all parts of the questions together. Assume missing data, if any, suitably.*

Q. 1 The following figure shows the typical phase diagram of Fe-Fe_3C system, where α, β, γ, and δ are different solid phases. Answer the following with the help of the phase diagram.



i. Write down the different invariant reactions along with their type and corresponding composition from the phase diagram. **(6)**

ii. Calculate the weight fraction of the solid phase and liquid phase at 1200 °C for an alloy of the initial composition of 3% C. **(6)**

iii. In order to get complete lamellar structure from the liquid state, which composition will you prefer from the phase diagrams, and why? **(2)**

iv. Show the microstructural features in equilibrium cooling conditions for an alloy at 5 % of carbon. **(4)**

Q. 2 (a) The following table represents the atomic diameter (d_{atomic}) and diameter of 3d orbital (d_{3d}) of some elements. Classify these elements in the ferromagnetic and antiferromagnetic category. Also, explain the origin of their inherent magnetism. **(4)**

Elements	A	B	C	D
d_{atomic} (Å)	2.28	2.50	2.24	2.92
d_{3d} (Å)	1.40	1.37	1.89	1.99

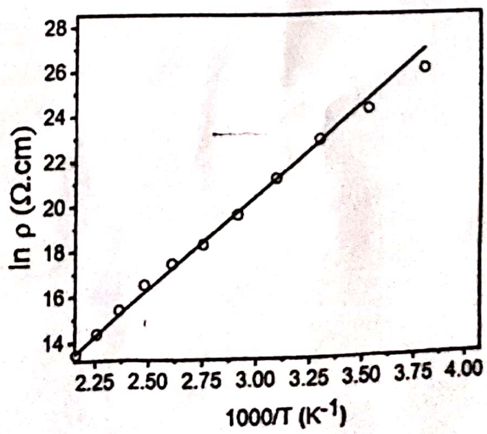
(b) List two properties, required in a material to design: (i) relay, (ii) ballast resistor. Why is Cadmium Oxide (CdO) dispersed in aluminum (Al) used for critical contacts? **(4)**

(c) Among dielectric materials, Al_2O_3 ($\varepsilon_r = 9$) and fused SiO_2 ($\varepsilon_r = 3.8$), which one will you choose to design a miniature capacitor (having identical cross-sectional area) of 1μF and why? **(4)**

(d) Draw the typical hysteresis loop for materials that are used for the following application: (i) Permanent magnets, (ii) Transformer coil, and (iii) computer memory cores. **(3)**

(e) What is the Meissner effect? Discuss it for type I and type II superconductors. Explain with a suitable diagram, why type II superconductors are used for practical applications. **(5)**

(f) The following figure shows the resistivity *vs.* temperature plot for a semiconductor sample. Estimate the bandgap of the material. **(4)**



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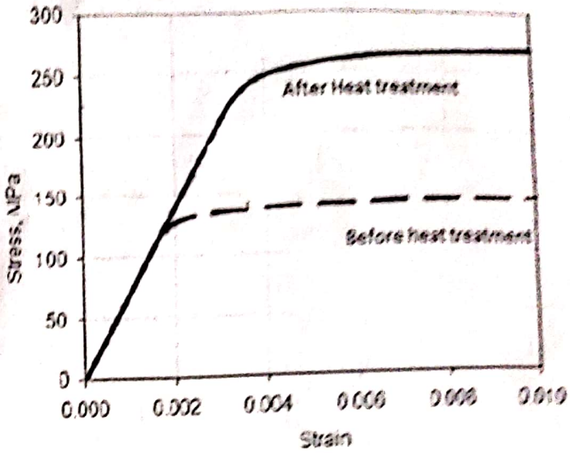
Q. 3 **(a)** Why is Cu (FCC) more ductile that Zn (HCP)? Explain based on slip systems. Calculate the resolved shear stress on the $(111)[\bar{1}10]$ slip system of a single crystal Cu if the tensile stress of 14 MPa is applied in [010] direction. **(6)**

(b) A 6283 grade Al alloy was subjected to heat treatment. The comparative engineering stress-strain curve of the alloy before and after heat treatment is shown in the following figure. **(6)**



i. Estimate the yield strength, ultimate tensile strength, and toughness.

ii. Why does the Young modulus remain unchanged after the heat treatment?

iii. In your opinion, what is the plausible reason for strengthening after heat treatment? Explain.

(c) If the width of dislocation is b and 2b for Fe (BCC; a = 2.87 Å) and Cu (FCC; a = 3.61 Å). Calculate the shear stress required to initiate dislocation motion. (Given: Shear modulus Fe = 53 GPa and Cu = 40 GPa) **(4)**

(d) Differentiate between time-dependent and time-independent recoverable deformation with suitable examples. **(4)**

Q. 4 **(a)** A melter wants to make an alloy of Cu with Zn, Pb, and Si. Which pair will show maximum, moderate and least solid solubility, and why? **(6)**

Element	Atomic radii (Å)	Crystal structure	Electronegativity	Valency
Cu	0.128	FCC	1.8	2+
Zn	0.133	HCP	1.7	2+
Pb	0.175	FCC	1.6	2+
Si	0.117	DC	1.8	4+

(b) Sketch and calculate the planar density of (110) plane and linear density of [111] direction in the diamond cubic structure. (Given a=3.67 Å) **(6)**

(c) Calculate the ideal c/a ratio for an HCP unit cell. **(4)**

(d) Differentiate between the high-angle and low-angle boundaries in a polycrystalline solid. **(4)**

Q. 5 **(a)** Explain why? (limit your answer to maximum 30 words): **(8)**

i. We cannot have four phases in equilibrium in a binary phase diagram at atmospheric pressure.

ii. For high-frequency applications (> 10^{10} Hz), we prefer ionic capacitors as compared to polar capacitors.

iii. Cu shows zero resistivity at absolute temperature, but Cu-Ni alloy does not.

iv. Temple bells are not made of grey cast iron.

(b) Determine the number of vacancies per cubic centimeter in Pb at 200 °C. Given: enthalpy of defect formation = 0.50 eV/vacancy, atomic weight = 207.2 g/mol, and density = 11.34 g/cc. **(6)**

(c) What is electrode potential? For reduction reaction, the electrode potential of Al, Cu, Fe, and Cr are −1.662 eV, +0.34 eV, +0.771 eV, and −0.744 eV, respectively. Amongst this which element is more prone to corrosion? Which pair will be least prone to corrosion? For the pair, which element will act as an anode and cathode? **(4)**

R = 8.314 J/mol.K
k_B = 8.62 $\times 10^{-5}$, eV/K

N_A = 6.023 $\times 10^{23}$ atoms/mol
ε_0 = 8.85x10^{-12} F/m