Registration No: | | | | | | | | | | |

Total Number of Pages: 04

B.Tech
PMT4I101

4^{th} Semester Regular / Back Examination 2017-18
Phase Transformation & Heat Treatment
BRANCH: METTA, MME
Time: 3 Hours
Max Marks: 100
Q. CODE: C782
Answer Part-A which is compulsory and any four from Part-B.
The figures in the right-hand margin indicate marks.

Part – A (Answer all the questions)

Q1 Answer the following questions: ***multiple type or dash fill up type*** **(2 x 10)**

a) The Clausius-Clapeyron equation is ______________.

b) The hardenability of steels decreases with
(A) decrease in dislocation density
(B) increase in solutionising temperature
(C) increase in strength
(D) decrease in grain size

c) Phase rule for an isomorphous system of phase diagram is _________.

d) A 0.2 wt.% plain carbon steel sheet is heated and equilibrated in the inter-critical region followed by instant water quenching. The microstructure of the quenched steel sheet consists of
(A) fully martensite (B) proeutectoid ferrite + martensite
(C) martensite + pearlite (D) martensite + austenite

e) In a slowly cooled 0.4%C plain carbon steel, the percentage of proeutectoidferrite is approximately
(A) 43.0 (B) 49.46 (C) 53.4 (D) 57.0

f) Identify the statement that precisely describes the principle of hot working of metals and alloys.
(a) It is mechanical deformation carried out above the temperature ofrecrystallisation
(b) It ismechanical deformation carried out above the room temperature
(c) It is mechanical deformation carried out above the annealing temperature
(d) It is mechanical deformation carried out just below the melting temperature

g) Mild steel can be converted into high carbon steel by using which of the following process?
a) Annealing, B, Normalizing, C. Case hardening d) None of the mentioned

h) An Fe-3wt%C-1wt%Si alloy is cooled very slowly from the liquid state to a temperature of 1023K. Thereafter, it is cooled in air. The microstructure at room temperature will consist of
(A) ferrite + graphite (B) pearlite + graphite

(C) martensite + graphite (D) ferrite + pearlite

i) ____________________ is a glissile transformation and why?

j) If the specific heat of solid copper above 300 K is given by C_p = 22.64 + 6.28 × $10^{-3}T$ J mol^{-1} K^{-1},then the increase in entropy of copperon heating from 300 to 1358 K is _____________.

Q2 Answer the following questions: ***Short answer type*** **(2 x 10)**

a) What is the difference between phase diagram & equilibrium diagram?

b) Give two reasons why interstitial diffusion is normally more rapid than vacancy diffusion?

c) Draw the Gibbs free energy (G) vs. temperature (T) for α-Fe, γ-Fe and δ-Fe at 800^{o}C and 1600^{o}C?

d) What is the need of heat treatment of steel? Briefly explain.

e) Find out the size of the critical nucleus for homogeneous nucleation if the tiny solid formed is a cube (Take *'a'* as length of the cube edge).

f) Explain with schematic microstructure the difference between upper bainite & lower bainite?

g) The diffusion coefficients for copper in aluminum at 500 and 600^{oC} are 4.8 × 10^{-14} and 5.3 × 10^{-13} m^2/s, respectively. Determine approximate time at 500^{o}C that will produce the same diffusion result (in terms of concentration of Cu at some specific point in Al) as a 10-h heat treatment at 600^{o}C?

h) What microstructural difference can be found in a plain carbon steel under annealed and normalized conditions of heat treatment?

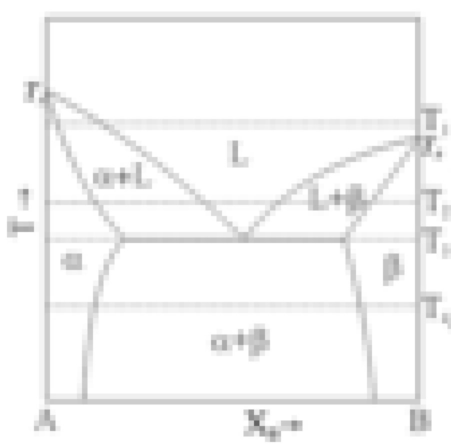
i) What is ausforming? What is its importance?

j) Differentiate between homogeneous and heterogeneous nucleation?

Part – B (Answer any four questions)

Q3 **a)** What is the physical significance of interaction parameter (Ω) on phase formation/separation in a binary alloy. Give suitable example to justify your answer. Write short notes on internal energy of mixing and configurational entropy of mixing. **(10)**

b) Draw the free energy versus composition diagram for following phase diagram for different temperatures. **(5)**



Q4 **a)** With a neat sketch, explain the process of martempering? How does it differ from austempering? What is microstructural difference between the martempered and austempered steel? Write the applications of martempering & austempering heat treatment processes. **(10)**

b) What is annealing? What are its aims? Discuss the different types of annealing processes and their respective aim? **(5)**

Q5 a) Derive the expression for Homogeneous nucleation (ΔG* and r*) and its rate, andheterogeneous nucleation (ΔG* and r*) and its rate (neglect the strain energy).Calculate the size of critical radius and number of atoms in the critical nucleus when solid copper forms by homogeneous nucleation at (i) 1083^{o}C, (ii) 849^{o}C (Given: T_{mp}= 1083^{o}C, ΔH_f = 1628×10^6 Jm^{-3}, surface energy = 177×10^{-3} Jm^{-2}, Radius of copper, a_{Cu}= 3.615×10^{-10} m) **(10)**

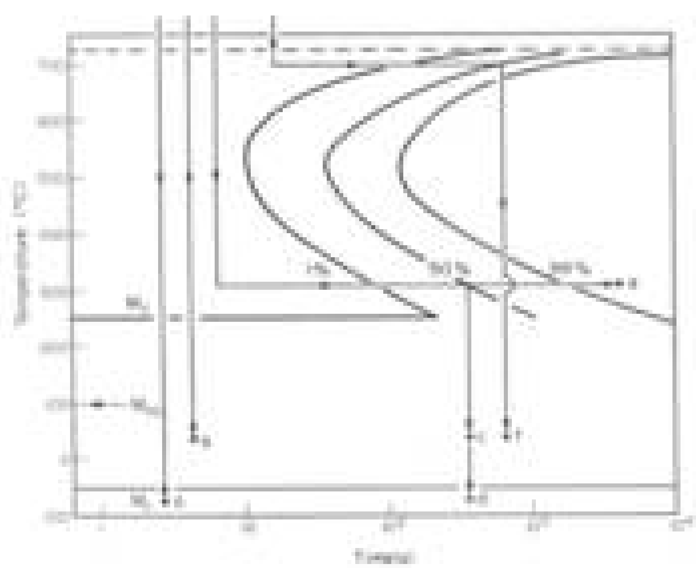
b) What is constitutional supercooling? Under what conditions it occurs? Explain dendritic growth w.r.t. constitutional undercooling? **(5)**

Q6 a) What is precipitation hardening? Explain the various stages and mechanisms of precipitation hardening by coherent particles of Al-4.5wt.%Cu alloy. Sketch Gibbs free energy (G) vs. composition (X) curve for the above transformation. **(10)**

b) Explain in details the difference between TTT diagram and CCT diagram of a eutectoid steel? **(5)**

Q7 a) Explain in details the characteristics, mechanism and driving force of martensitic transformation? **(10)**

b) Use of TTT-diagram to predict microstructures of steel. **(5)**
The figure below shows the TTT diagram of a coarse-grained, plain carbon steel of eutectoid composition. Samples of steel are austenitized at 850ºC and then subjected to quenching treatments shown on the diagram. Describe the microstructure produced by each treatment.



Q8 a) Make brief comparison between massive transformation and ordering transformation. **(10)**

b) With a neat sketch, discuss the mechanism of Spinodal decomposition and Nucleation-growth of phase separation in a binary alloy from initial to final stage. **(5)**

Q9 a) The wear resistance of a steel gear is to be improved by hardening its surface. This is to be accomplished by increasing the carbon content within an outer surface layer as a result of carbon diffusion into the steel; the carbon is to be supplied from an external carbon-rich gaseous atmosphere at an elevated and constant temperature. The initial carbon content of the steel is 0.2 wt%, whereas the surface concentration is to be maintained at 1.00 wt%. For this treatment to be effective, a carbon content of 0.60 wt% must be established at a position 0.75 mm below the surface. Determine the required heat treatment times at a temperature of 950ºC. Diffusion data: For C in α-Fe; D_0=6.2x$10^{-7}m^2s^{-1}$; Q= 80 kJ mol^{-1}; For C in γ-Fe; D_0=2.3x$10^{-5}m^2s^{-1}$; Q=148 kJ mol^{-1}. **(10)**

a) (i)Draw a sketch of composition profile and determine the boundary/initial conditions. (ii) Using the above conditions in the general error function solution of Fick's second law, determine the constants A and B.

b) (iii) Using the solution above for the desired composition and depth, find out the product D*t*. (You have to use the error function table given below. Use linear interpolation).(iv) Using the relationship describing the temperature variation of D, find Dat the required temperature. Substituting this in (iii), find the required time (t).

The Error Function

z	erf (z)	z	erf (z)
0.000	0.0000	0.85	0.7707
0.025	0.0282	0.90	0.7970
0.05	0.0564	0.95	0.8209
0.10	0.1125	1.0	0.8427
0.15	0.1680	1.1	0.8802
0.20	0.2227	1.2	0.9103
0.25	0.2763	1.3	0.9340
0.30	0.3268	1.4	0.9523
0.35	0.3794	1.5	0.9661
0.40	0.4284	1.6	0.9763
0.45	0.4755	1.7	0.9838
0.50	0.5205	1.8	0.9891
0.55	0.5633	1.9	0.9928
0.60	0.6039	2.0	0.9953
0.65	0.6420	2.2	0.9981
0.70	0.6778	2.4	0.9993
0.75	0.7112	2.6	0.9998
0.80	0.7421	2.8	0.9999

b) Elaborately explain the different factors that affect the hardenability of a plain carbon steel? Write the names of various surface hardening techniques used to improve the surface properties of a steel. **(5)**