Faculty of Eng. Sc. lib

UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

BSc. (ENG) MATERIALS SCIENCE AND ENGINEERING

END OF FIRST SEMESTER EXAMINATIONS: 2013/2014

MTEN 307: PHASE EQUILIBRIA OF MATERIALS (2 CREDITS)

TIME ALLOWED : 2 HRS 30 MINS

ANSWER ALL QUESTIONS

Question 1

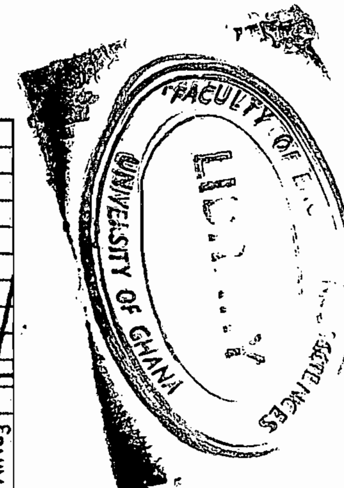
a) What is the difference between a phase and a microconstituent?

b) Briefly explain why, upon solidification, an alloy of eutectic composition forms a microstructure consisting of alternating layers of the two solid phases.

c) Cite the principal difference between congruent and incongruent phase transformations?

d) For a ternary system, three components are present; temperature is also a variable. What is the maximum number of phases that may be present for a ternary system, assuming that pressure is held constant?

e) In **Figure** 1, the aluminum–neodymium phase diagram is shown for which only single-phase regions are labeled. Specify temperature-composition points at which all eutectics, eutectoids, peritectics, and congruent phase transformations occur. Also, for each, write the reaction upon cooling.



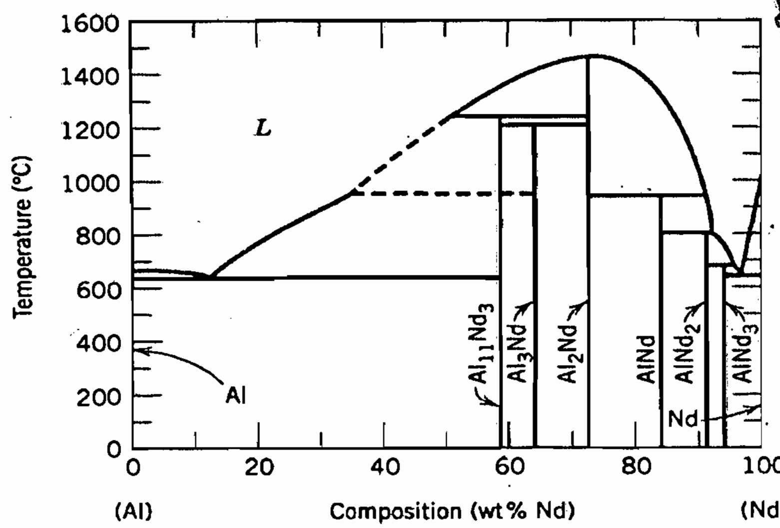


Figure 1. Aluminum–neodymium phase diagram

[25 Marks]

Question 2

A 50 wt% Pb–50 wt% Mg alloy (Phase Diagram in Fig. 2) is slowly cooled from 700°C (1290°F) to 400°C (750°F).

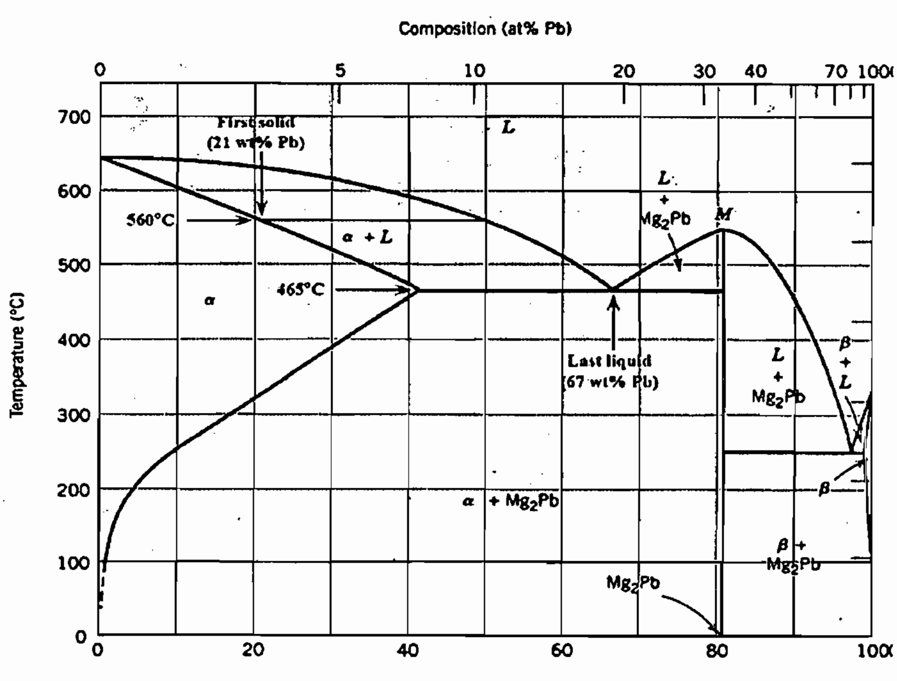


Figure 2. Phase diagram for Pb-Mg alloy.

a) At what temperature does the first solid phase form?

b) What is the composition of this solid phase?

c) At what temperature does the liquid solidify?

d) What is the composition of this last remaining liquid phase?

e) For an 85 wt% Pb–15 wt% Mg alloy, make schematic sketches of the microstructure that would be observed for conditions of very slow cooling at the following temperatures: 600°C , 500°C, 270°C, and 200°C. Label all phases and indicate their approximate compositions.

[25 Marks]

Question 3

(a) Differentiate between hypoeutectoid and hypereutectoid steels?

(b) Describe briefly, the differences between pearlite, bainite, and spheroidite relative to microstructure and mechanical properties.

(c) In terms of heat treatment and the development of microstructure, what are two major limitations of the iron–iron carbide phase diagram?

(d) Suppose that a steel of eutectoid composition (see **Figure 3**) is cooled to 550°C from 760°C in less than 0.5 seconds and held at this temperature

(i) How long will it take for the austenite to pearlite reaction to go to 50% completion? To 100% completion?

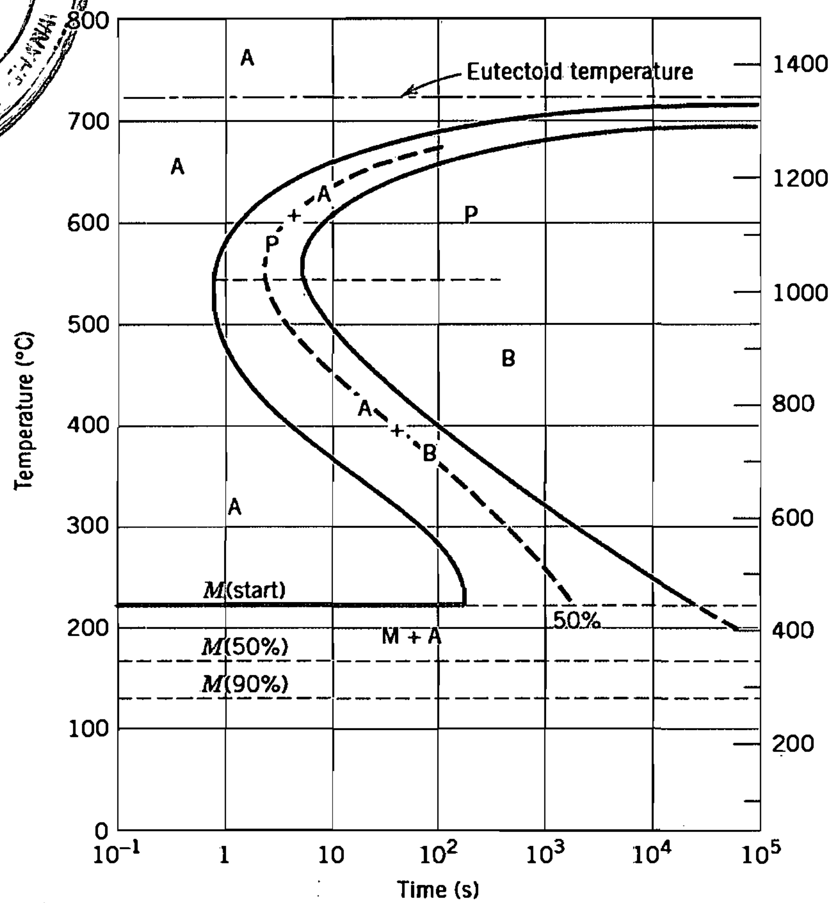


Figure 3. Isothermal transformation diagram of Iron-Carbon alloy of eutectoid composition.

[25 Marks]

Question 4

a) Name the two stages involved in the formation of particles of a new phase. Briefly describe each.

b) If copper (which has a melting point of 1085 °C) homogeneously nucleates at 849 °C, calculate the critical radius given values of -1.77 x 109 J/m^3 and 0.200 J/m^2, respectively, for the latent heat of fusion and the surface free energy.

For the solidification of iron, calculate;

(i) the critical radius r* and the activation free energy ΔG^* if nucleation is homogeneous. Values for the latent heat of fusion and surface free energy are

-1.85×10^9 J/m^3 and 0.204 J/m^2, respectively.

(ii) the number of atoms found in a nucleus of critical size. Assume a lattice parameter of 0.292 nm for solid iron at its melting temperature.

[The supercooling value for iron is 295 °C and its melting temperature is 1538°C]

c) The kinetics of the austenite-to-pearlite transformation obey the Avrami relationship. Using the fraction transformed–time data given in **table 1**, determine the total time required for 95% of the austenite to transform to pearlite.

Table 1. Fraction transformed-time data

Fraction Transformed	Time (s)
0.2	12.6
0.8	28.2

[25 Marks]