

Study Programme : Bachelor of Science Honours in Engineering
Name of the Examination : Final Examination
Course Code and Title : DMX5204 Engineering Materials
Academic Year : 2023/24
Date : March 12, 2025
Time : 13.30 hrs. - 16.30 hrs.
Duration : **3 hours**

General Instructions:

1. This question paper consists of **Five (05)** questions. **Answer all the questions.**
2. Answering each question should start with a new page.
3. Any missing data can be sensibly and reasonably assumed, but such assumptions are not acceptable unless they are justified and clearly stated.

Question 01

- a. i. By means of sketches, explain most common places where fatigue failures might occur in machine components. (you are expected to provide reasonable explanations). [3 marks]
- ii. Explain the importance of giving due consideration to the stress ratio R when designing machine components to withstand fatigue failure. [3 marks]
- iii. By means of sketches explain $R = 0$ and $R = 1$. [3 marks]
- b. Determine the diameter of a shaft made of 70Cu -30Zn to withstand 10^7 cycles if it is subjected to a fully reversed load amplitude of 10,000 N. You may assume a safety factor of 2.5 and use the data given in Figure Q1. [11 marks]

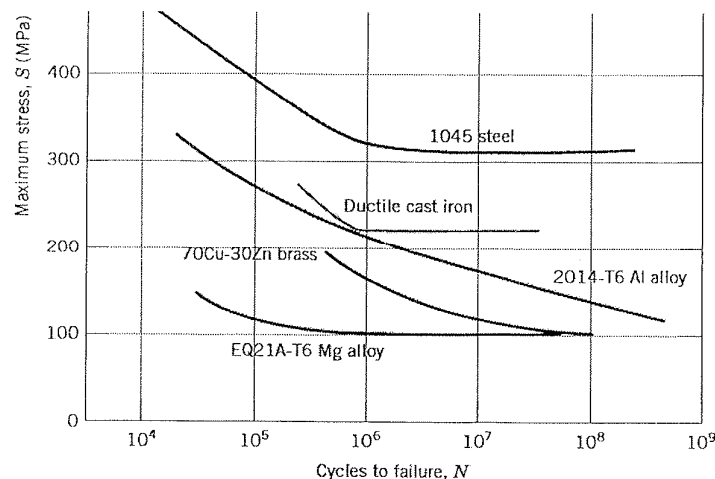


Figure Q1: Maximum stress (S) versus logarithm of the number of cycles to fatigue failure (N) for five metal alloys.

Question 2

- a. The Pb-Sn phase diagram is shown in Figure Q2-a. One kilogram (1 kg) of an alloy of 70% Pb and 30% Sn is slowly cooled from 300°C. Calculate,
- the weight percent of the liquid and proeutectic alpha at 250°C. [4 marks]
 - the weight percent of the liquid and proeutectic alpha just above the eutectic temperature (183°C) and the weight in kgs of these phases. [4 marks]
 - the weight in kg in alpha and beta formed by eutectic reaction. [3 marks]

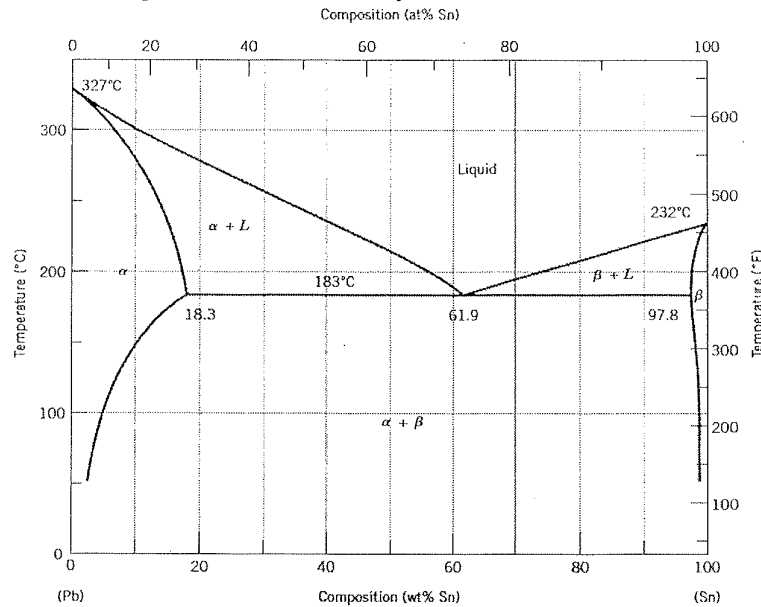


Figure Q2-a: Pb - Sn phase diagram.

- b. The Ti-Ni phase diagram is shown in Figure Q2-b. This phase diagram has six (06) points where three phases coexist. For each of these three phase points, list the coordinates of composition (weight % of Ni and temperature), write the invariant reaction during slow cooling of the Ti-Ni alloy through each point, and name the type of invariant reaction which takes place at each point. [9 marks]

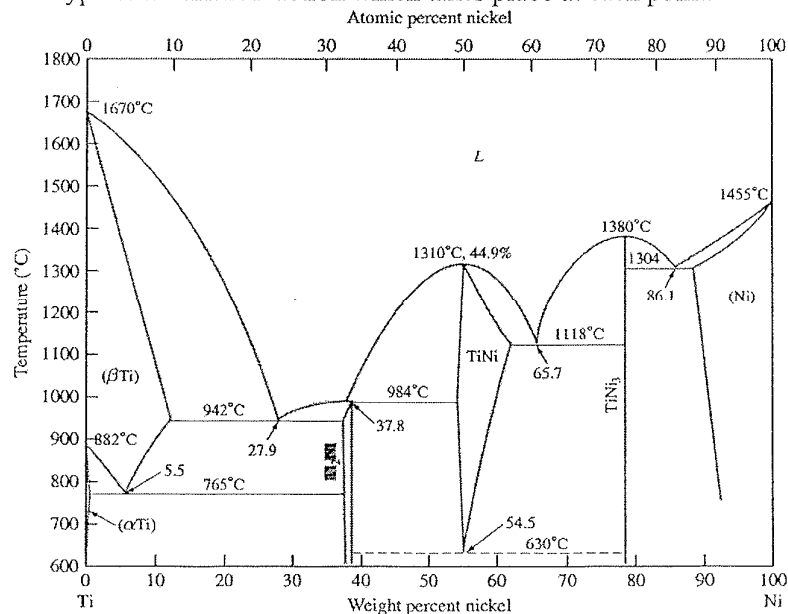


Figure Q2-b: Ti-Ni phase diagram.

- a. What would be the effect on the TTT diagram when adding of alloying elements to a steel? [5 marks]
- b. Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure Q3), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages) of a small specimen that has been subjected to the time–temperature treatments given in section i to section iii. In each case, assume that the specimen begins at 760°C (1400°F) and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.
- Rapidly cool to 350°C (660°F), hold for 104 s, and quench to room temperature. [4 marks]
 - Rapidly cool to 250°C (480°F), hold for 100 s, and quench to room temperature. [4 marks]
 - Rapidly cool to 650°C (1200°F), hold for 20 s, rapidly cool to 400°C (750°F), hold for 103 s, and quench to room temperature. [4 marks]
- c. Sketch and label time–temperature paths to produce the above three microstructures. [3 marks]
Note: you may draw the paths on Figure Q3 and attach it to the answer script.

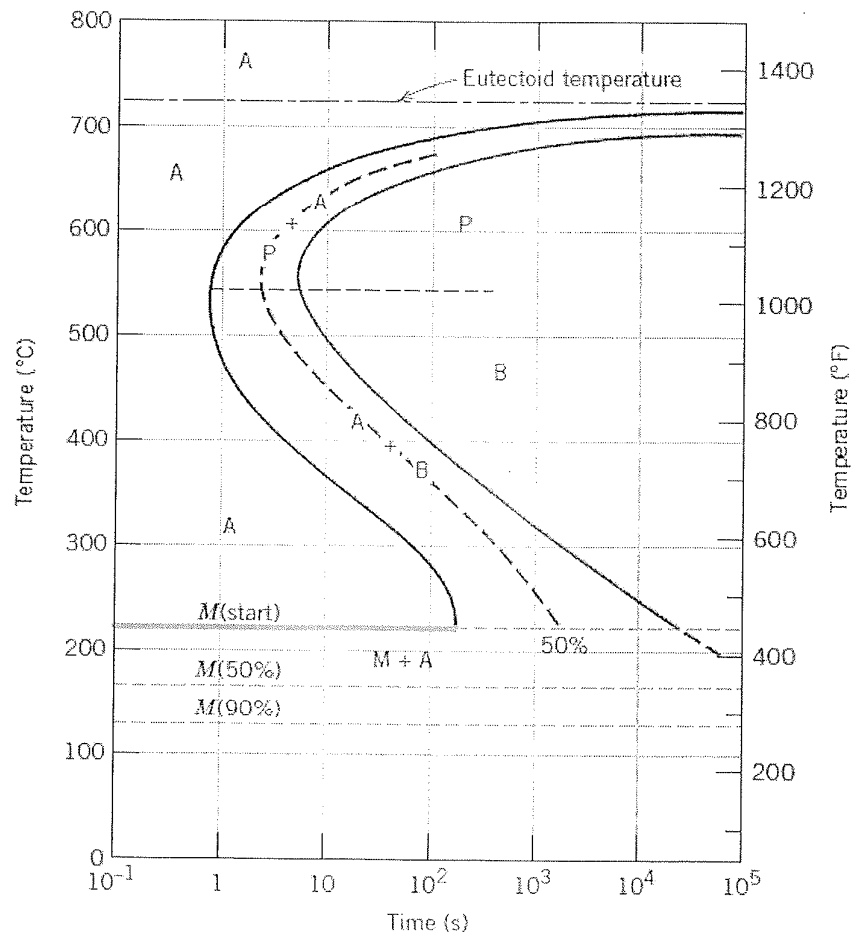


Figure Q3: Isothermal transformation diagram for an iron–carbon alloy of eutectoid composition.
 A-austenite, B-bainite, M- martensite, P- perlite

Question 4

- a. Describe the basic steps in processing of ceramic products by the agglomeration of particles. [2 marks]
- b. Discuss three (03) thermal treatments in practice in manufacturing of ceramic products. [3 marks]
- c. List the advantages of extrusion process over other ceramic forming methods. [3 marks]
- d. Discuss the effect of crystallinity in ceramics. [3 marks]
- e. The composite consists of a continuous glass fibre reinforced epoxy resin produced using 60% by volume of E-glass fibres having a modulus of elasticity (E_f) of $72.5 \times 10^9 \text{ Pa}$ and a tensile strength of $24.15 \times 10^8 \text{ Pa}$, and a hardened epoxy resin with a modulus of elasticity and a tensile strength (E_m) of $3.1 \times 10^9 \text{ Pa}$ and a tensile strength of $6.21 \times 10^7 \text{ Pa}$. Calculate,
- the modulus of elasticity of the composite parallel to the direction of fibres. [3 marks]
 - the tensile strength parallel to the direction of fibres. [3 marks]
 - the fraction of the load carried by the fibres for the above composite material stressed under isostrain (the composite is stressed parallel to the fibres) conditions. [3 marks]

Question 5

- a. Explain why stainless steels have corrosion resistant properties. [3 marks]
- b. Draw the Mer structures for following polymeric materials.
- Polypropylene (PP) [2 marks]
 - Phenol-formaldehyde (Bakelite) [2 marks]
 - Polyvinyl chloride (PVC) [2 marks]
- c. Molecular weight data for a polymer is given in Table Q5. Calculate,
- the number average molecular weight. [3 marks]
 - the weight average molecular weight. [3 marks]
 - if it known that this material's number average degree of polymerization is 477, find the type of the polymer. [3 marks]
 - what is this material's weight average degree polymerization? [2 marks]

Table Q5: Molecular weight data for a polymer (W_i weight fraction of molecules, and X_i is the fraction of the total number of chains)

Molecular weight range (g/mole)	X_i	W_i
8000-16000	0.05	0.02
16000-24000	0.16	0.10
24000-32000	0.24	0.20
32000-40000	0.28	0.30
40000-48000	0.20	0.27
48000-56000	0.07	0.11