The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	:	**DMX3203 Introduction to Engineering Materials**
Academic Year	:	2021/22
Date	:	02nd February 2023
Time	:	13:30 hours -16:30 hours
Duration	:	**3 hours**

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Two (02)** parts in **Six (06)** pages.
3. Answer All questions in **Part A** and **Four (04)** questions from **Part B**.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (**CBT**).
6. Answers should be in clear handwriting.
7. Do not use Red colour pen.

PART A (ANSWER ALL QUESTIONS)

1. Determine the relationship between the lattice parameter a and the atomic radius r for Simple Cubic (SC), BCC and FCC structures,
2. Answer the following questions with respect to Planes and Directions
   a. Sketch the [111] direction in a cubic unit cell
   b. Sketch the (123) plane in a cubic unit cell
   c. Draw a direction in a cubic unit cell from the point (1,1,0) to (3,1,1). Find the coordinates of this direction?
3. Name four types of imperfections in crystals and give one example for each type.
4. What is the difference between crystalline and non-crystalline solids?
5. What is an atom? Briefly describe the important constituents of an atom.
6. Write general properties and characteristics of metals, polymers, ceramics, semiconductors and composite materials. Give one example for each group.
7. List the types of primary and secondary bonds present in materials and explain one type of bond from each bond category.
8. Name the two main mechanisms of solid state diffusion and state Fick's first and second laws of diffusion.
9. What is hardness? Is there any relation between hardness and tensile strength?
10. What is the purpose of annealing and normalizing heat treatments in metals?

PART B (ANSWER FOUR (04) QUESTIONS)

Question 01

(a) Define the following terms
   i. Atomic packing factor
   ii. Unit cell
   iii. Space lattice

(b) Tensile testing is not appropriate for hard brittle materials such as ceramics. What is the test commonly used to determine the strength properties of such materials?

(c) Explain the specific properties you will consider when selecting the materials for the following:
   i. Tyers for a heavy vehicle wheel
   ii. A screwdriver
   iii. Lining materials for oil fired furnace having temperature ~1200°C.
   iv. A 100 mm diameter domestic water pipeline above the ground

Question 02

(a) Please examine the stress-strain curves in the Figure Q2(a) for a certain material as a function of temperature:

i. Determine the elastic modulus of this material at **25°C**.

ii. Determine the **0.2%** offset yield strength of this material at **200°C.**

iii. Please comment on how the elastic modulus, strength, and ductility vary with temperature.

iv. Make a rough sketch on the dependence of toughness on temperature.

v. At **300°C**, if we are to unload just before failure, estimate the permanent strain.

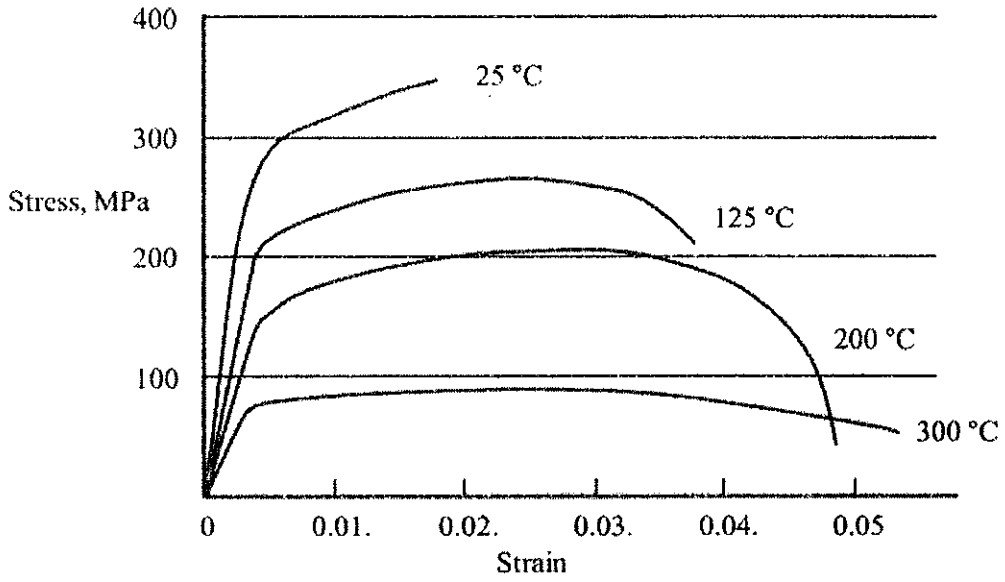

Figure. Q2(a): Stress-Strain curve

(b) For a brass alloy, the stress at which plastic deformation begins is **345 MPa** and the modulus of elasticity is **103 GPa**.

i) What is the maximum load that may be applied to a specimen with a cross sectional area of **130 mm^2** without plastic deformation?

ii) If the original specimen length is **76 mm**, what is the maximum length to which it may be stretched without causing plastic deformation?

Question 03

(a) i) State the ordinary elastic behaviour of materials?

ii) What are the methods available to increase the elastic modulus of a material?

iii) Explain the stress-strain tests which can be used to ascertain the mechanical characteristics of metals?

iv) What is plastic deformation?

(b) i) What do you understand by work hardening?

ii) State the term "fatigue" and mention the characteristic fatigue surface features.

iii) What are the different methods of heat treatments which are served for different purposes?

iv) What is a quenching process? Mention few quenching media.

Question 04

(a) Calculate the concentration of vacancies in copper at **25°C**. What temperature will be needed to heat treat copper such that the concentration of vacancies produced will be **1000 times** more than the equilibrium concentration of vacancies at room temperature? Assume that **20,000 cal/mole** are required to produce a mole of vacancies in copper.
Hint;

$$N_V = N \exp(-Q_V/RT)$$

Where N_V- Number of vacancies per cm^3
N -Number of atoms per cm^3
Q_V- Energy required to produce one mole of vacancies [J. Mol^{-1}]
R- Gas constant: 8.31[J.mol^{-1}. K^{-1}]
T - Temperature [K]

(b) i) Differentiate the carburizing and decarburizing process used in Steel industry.
ii) State the different types of metallic corrosion.
iii) Explain the methods of corrosion prevention.

Question 05

(a) From the tensile stress–strain behavior for the brass specimen shown in Figure Q05(a).

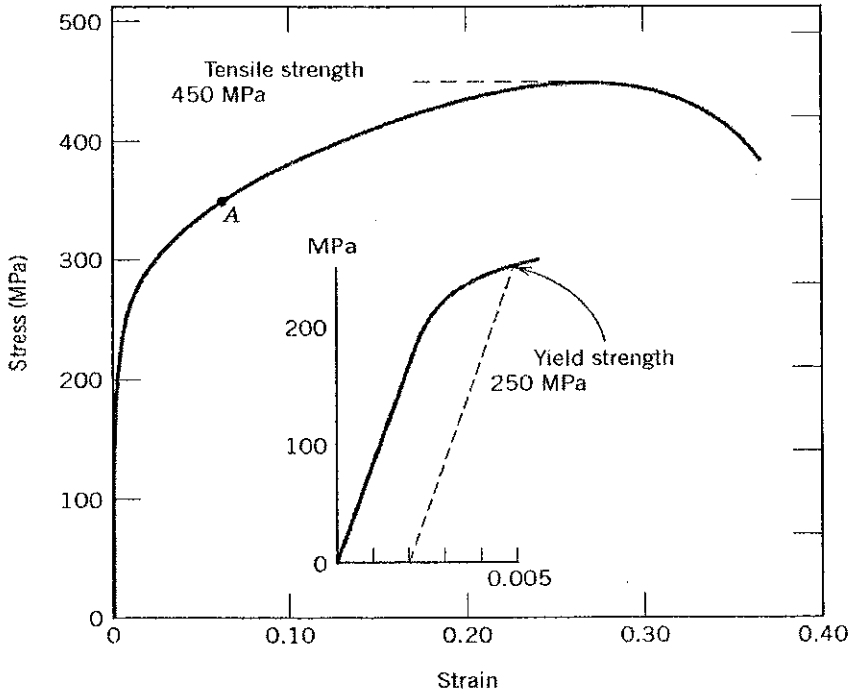

Figure Q5: The stress–strain behavior for the brass specimen

Determine the following.

i) The modulus of elasticity.
ii) The yield strength at a strain offset of 0.002.
iii) The maximum load that can be sustained by a cylindrical specimen having an original diameter of 12.8 mm.
iv) The change in length of a specimen originally 250 mm long that is subjected to a tensile stress of 345 MPa.

(b) i) Distinguish between a semiconductor and an insulator on the basis of their energy band structure.

ii) Explain the meanings of and the processes involved in

a. work hardening,
b. quench hardening,
c. precipitation hardening,

quoting instances in which each method is used in engineering practice.

iii) What are the characteristics of dielectric materials?

Question 06

(a) Refer to the Ag-Cu phase diagram given in Figure Q6.

i. What is the maximum solubility of Cu in Ag?

ii. State the composition of the eutectic alloy and the eutectic temperature.

iii. What would happen to the eutectic alloy when the temperature is raised above the eutectic temperature?

iv. Cool the eutectic alloy to slightly below the eutectic temperature to form the α- and β-phases. Calculate the weight fractions of these two phases at thermal equilibrium.

v. For a silver-copper alloy with **10 wt%** of Cu, what is the temperature at which liquid starts to appear when the temperature gradually increases from room temperature?

vi. For the alloy in above (v) at thermal equilibrium at 850°C (two-phase region), estimate the weight fraction of the liquid.

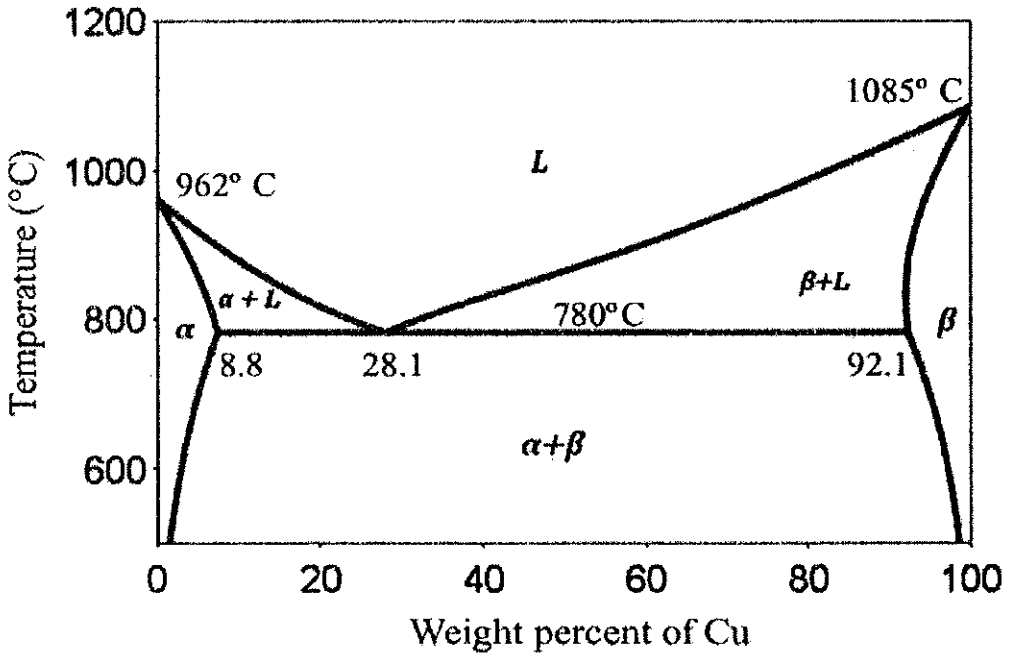

Figure Q6: Ag-Cu phase diagram

Question 07

(a) As shown in Figure Q7, start with an alloy with **50 wt%** of **B**. The temperature is increased to bring this alloy into the two-phase region. Values of wL and $w\alpha$ are **10** and **60 wt%**, respectively. How much of this alloy is in the form of a liquid?

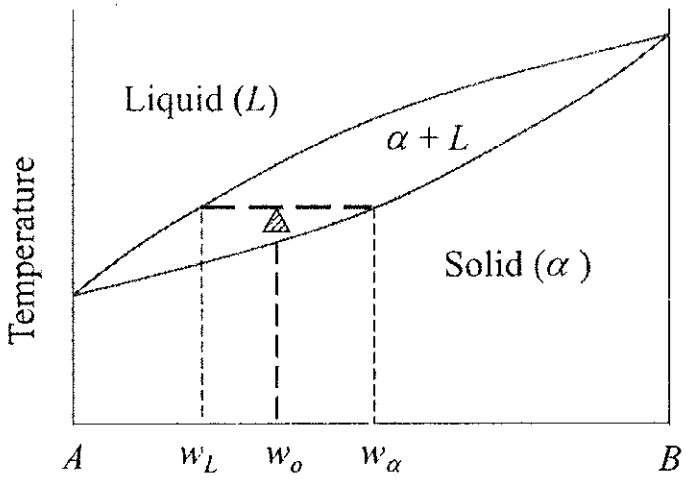

Figure Q7: Phase diagram

(b) Answer the following questions using Fe-C phase diagram.

i. When eutectoid steel is cooled to below 727°C, solid-state transformation occurs, resulting in the formation of a mixture of ferrite (α-Fe) and cementite (Fe_3C). Determine the weight fraction of cementite in eutectoid steel at slightly below 727°C.

ii. At carbon concentration of 0.5 weight percent, estimate the temperature at which the fcc-bcc transformation occurs.

iii. Can the above fcc-bcc transformation occur if the sample is cooled suddenly to low temperatures? Why or why not?

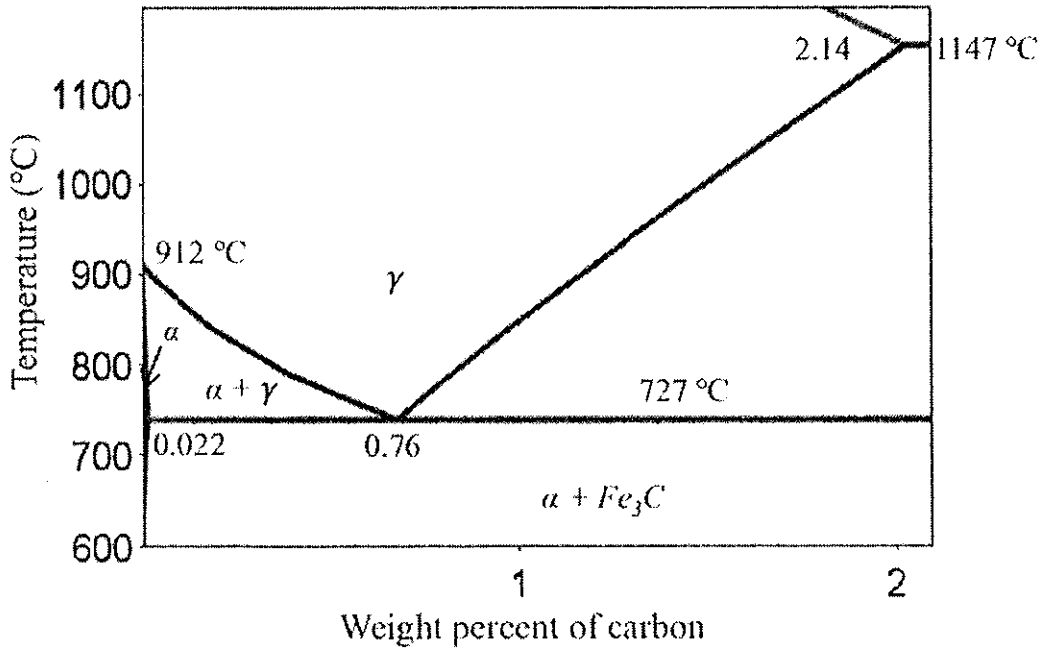

Figure Q7(b): The Fe-C phase diagram.