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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	**: DMX5204 - Materials Engineering**
Academic Year	: 2021/ 22
Date	: 8th February 2023
Time	: 1330-1630hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts/ codes are provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red colour pen.

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1. (a) Explain the congruent melting and the incongruent melting with sketches.

(3 marks)

(b) Construct the phase diagram for Mg-Pb alloys between room temperature 30°C and 700°C, given the following information.

(i) The melting temperature of Mg is 640°C.

(ii) The maximum solubility of Pb in Mg is 4 wt%Pb, which occurs at 420^0C.

(iii) The solubility of Pb in Mg at room temperature is 0 wt% Pb.

(iv) One eutectic occurs at 420^0C and 18 wt% Pb-82 wt% Mg.

(v) A second eutectic occurs at 475^0C and 42 wt% Pb -58wt%Mg.

(vi) The inter metallic compound Mg-Pb exists at a composition of 30wt%Pb 70wt% Mg and melts congruently at 525^0C.

(vii) The melting temperature of Pb is 620^0C.

(viii)The maximum solubility of Mg in Pb is 13wt%Mg, which occurs at 475^0C.

(ix) The solubility of Mg in Pb at room temperature is 3wt% Mg.

(Draw all boundaries using straight lines.) **(6 marks)**

(c) Using the above phase diagram answer the following.

(i) Mark all phase fields. **(5 marks)**

(ii) For an alloy containing 25wt% Pb describe the process of solidification from 600^0C. **(3 marks)**

(iii) Calculate the amount of liquid and solid present at 550^0C and at 20 wt% Mg. **(3 marks)**

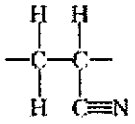
2. (a) Differentiate Thermoplastic from Thermosetting plastics. **(6 marks)**

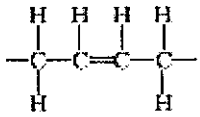
(b) Write the general reaction for the chain polymerization of ethylene monomer into polyethylene. **(6 marks)**

(c) Calculate the number-average molecular weight of a random nitrile rubber [poly (acrylonitrile-butadiene) polymer] in which the fraction of butadiene mers is 0.30. Assume that this concentration corresponds to a number-average degree of polymerization of 2000.

(Molecular weight of C, H & N are 12.01, 1.008 & 14.0 g/mole respectively.) **(8 marks)**

Repeat unit structure of Acrylonitrile and Butadiene are given below.

Acrylonitrile 

Butadiene 

3. (a) Derive an equation for Elastic modulus of a lamellar continuous fiber and matrix composite for isostrain condition. Use the usual notations. **(8 marks)**

(b) A continuous and aligned fiber-reinforced composite is to be produced consisting of 30 vol% aramid fibers and 70 vol% of a polycarbonate matrix. Mechanical characteristics of these two materials are as follows.

	Modulus of elasticity (GPa)	Tensile strength (MPa)
Aramid fiber	131	3600
Polycarbonate	2.4	65

The stress on the polycarbonate matrix when the aramid fibers fail is 45 MPa. For this composite, compute the following.

(i) The longitudinal tensile strength **(6 marks)**

(ii) The longitudinal modulus of elasticity **(6 marks)**

4. (a) List the types of strengthening mechanisms available for strengthening of materials. Explain how dislocations are involved in each of the strengthening techniques.

(8 marks)

(b) Using Hall-Petch equation, explain how the grain size affects the strength of a material.

(6 marks)

(c) With reference to TTT curves, briefly explain the effects of carbon content and alloying elements on the curves.

(6 marks)

5. (a) Briefly explain the secondary stage creep in metals and how it is affected by the temperature.

(8 marks)

(b) The data below refer to the dependence of secondary stage creep rate $\dot{\varepsilon}$ on tensile stress σ for a steel specimen tested in tension at 200^0C.

$\dot{\varepsilon}$ (h^{-1})	σ (MPa)
$2.5x10^{-3}$	55
$2.4x10^{-2}$	69

Calculate the following.

(i) The values of the constantans A and n if the relationship $\dot{\varepsilon} = A\sigma^n$ is consistent with the data.

(6 marks)

(ii) If the activation energy for creep is 140,000 J/mole, the steady state creep rate at a temperature of 200^0C and a stress level of 48 MPa. (Gas constant R=8.3 J/mol-K)

(6 marks)

6. (a) What are ceramics?

(5 marks)

(b) Ceramics offer many advantages compared to other materials. Explain why?

(5 marks)

(c) Explain briefly the basic steps in the processing of ceramic products by the agglomeration of particles?

(5 marks)

(d) Briefly describe the main three types of Glasses giving one application for each type.

(5 marks)

7. (a) What are the factors that affect the Hardenability of steel?

(4 marks)

(b) A cylindrical piece of steel 50.0 mm in diameter is to be austenitized and quenched such that a minimum hardness of 45 HRC is to be produced throughout the entire piece. Of the alloys 1040, 5140, 8640,4140 and 4340, which alloy/s will satisfy the requirement if the quenching medium is,

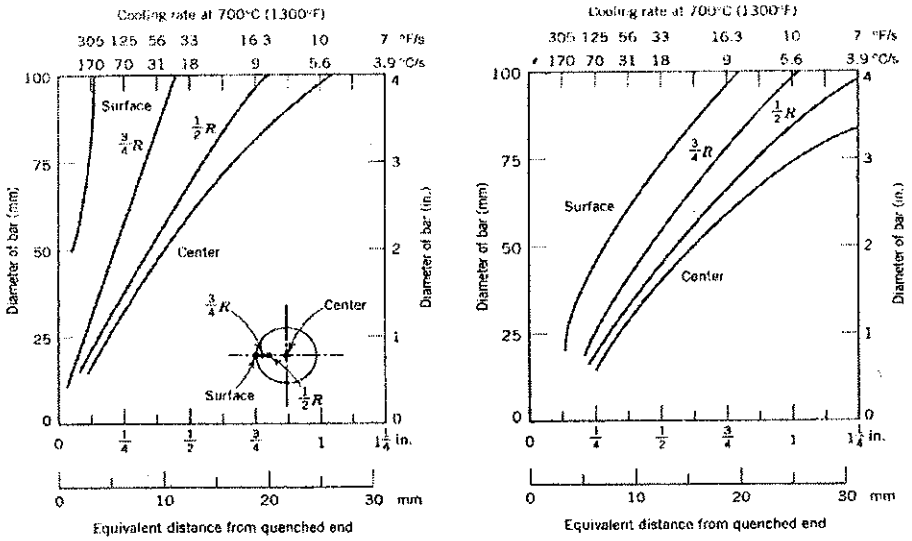
(i) moderately agitated water, and

(8 marks)

(ii) moderately agitated oil

(8 marks)

Justify your choice(s). Refer the relevant diagrams given below.



(i) Water quenching (ii) Oil quenching

Fig.7 (b) – Cooling rate as a function of diameter at surface, three-quarter radius (3/4R), mid radius (1/2R) and center positions for cylindrical bars quenched in moderately agitated (i) water and (ii) oil. Equivalent jominy positions are included in bottom axis.

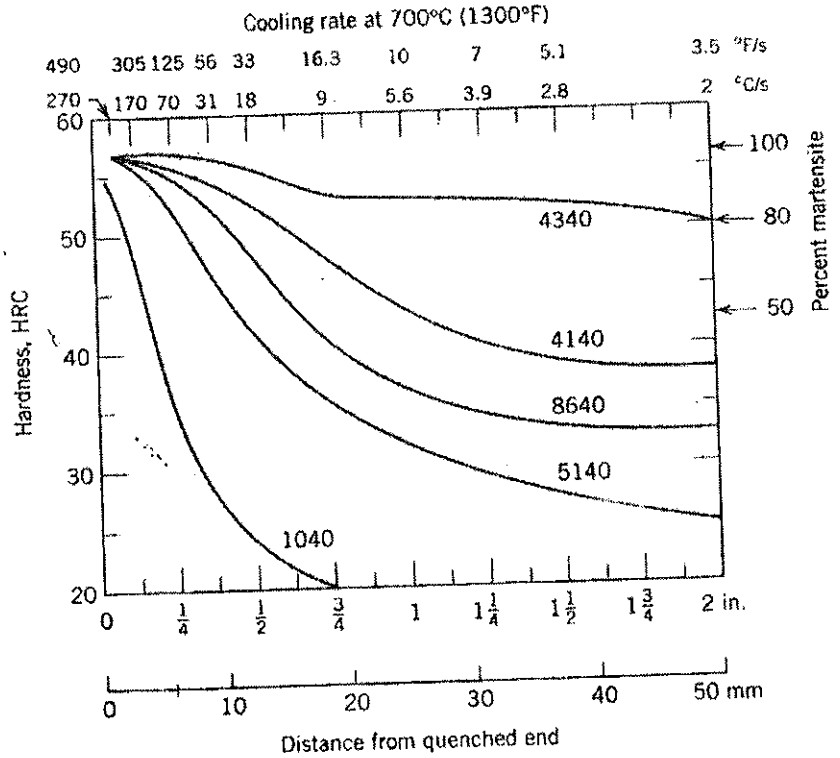


Fig.7(b) –Hardenability curves for five different alloys

8. Discuss and analyze the significance of any **three** of the following from an Engineering point of view.

(i) Invariant reactions that occur in Iron-Carbon phase diagram

(ii) Fatigue limit or the endurance limit

(iii) Types of Cast iron

(iv) Ductile failure of materials

(v) Types of fibers and matrix materials used in composites

(20 marks)