



**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF CHEMICAL ENGINEERING**

**ENGINEERING MATERIALS**

**ECE1102**

**Final Examination Paper**

**December 2024**

This examination paper consists of 5 pages

**Time Allowed: 3 hours**

**Total Marks: 100**

**Examiner's Name: Dr Liberty Lungisani Mguni**

**INSTRUCTIONS**

1. Answer **Section A** and any other **three (3)** questions
2. Each question carries 25 marks
3. The use of calculators is permissible

**MARK ALLOCATION**

<b>QUESTION</b>	<b>MARKS</b>
1.A	25
1.B	25
2.B	25
3.B	25
4.B	25
<b>TOTAL ATTAINABLE</b>	<b>100</b>

## **SECTION A**

*Answer all questions*

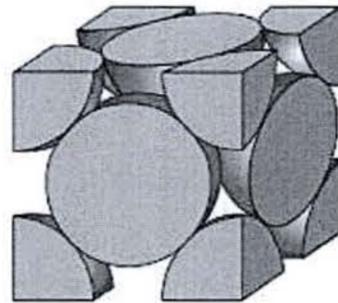
- a) Distinguish between an amorphous and crystalline material and use examples. [6]
- b) State six types of defects or dislocations. [6]
- c) Assisted by a stress-strain diagram, differentiate between a brittle and ductile material. [6]
- d) Compare and contrast these systems: Binary Isomorphous And Binary Eutectic. [7]

## **SECTION B**

*Answer any 3 questions*

### **QUESTION B1**

- a) Why do atoms assemble into ordered structures (crystals)? [5]
- b) State the atomic arrangement given below. Show how the unit cell edge length  $a$  and the atomic radius  $R$  are related to the arrangement. [8]



- b) Determine the atomic packing factor for the arrangement. [5]
- c) Iron has a BCC crystal structure, an atomic radius of 0.124 nm, and an atomic weight of 55.85 g/mol. Compute the theoretical density. [7]

### **QUESTION B2**

- a) Discuss the following terms: yield strength, tensile strength, and hardness of materials. [8]
- b) The following data (Table 1) were collected from a 20-mm diameter ductile cast iron test specimen ( $l_0 = 40.00$  mm). After fracture, the total length was 47.42 mm, and the diameter was 18.35 mm. Plot the data and calculate:
  - i) The modulus of elasticity. [5]
  - ii) The yield strength at a strain offset of 0.2%. [4]

iii) Determine the tensile strength of the material. [3]

iv) The true stress at fracture. [5]

Table 1: The load behavior of cast iron (William Callister and David G Rethwisch, 2010)

Load	$\Delta l$	
(N)	(mm)	
0	0	
25,000	0.0185	
50,000	0.0370	
75,000	0.0555	
90,000	0.20	
105,000	0.60	
120,000	1.56	
131,000	4.00	(maximum
125,000	7.52	(fracture)

### QUESTION B3

a) State three variables that determine the microstructure of an alloy? [6]

b) For a 99.6 wt% Fe-0.40 wt% C steel at a temperature just below the eutectoid, determine the following:

i) The compositions of  $Fe_3C$  and ferrite ( $\alpha$ ). [2]

ii) The amount of cementite (in grams) that forms in 100 g of steel. [4]

iii) The amounts of pearlite and proeutectoid ferrite ( $\alpha$ ) in the 100 g. [5]

iv) Describe what happens as we cool along the 98.5 Fe-1.5 wt% C (along green line 3 points given) and how you would calculate composition at each point. [8]

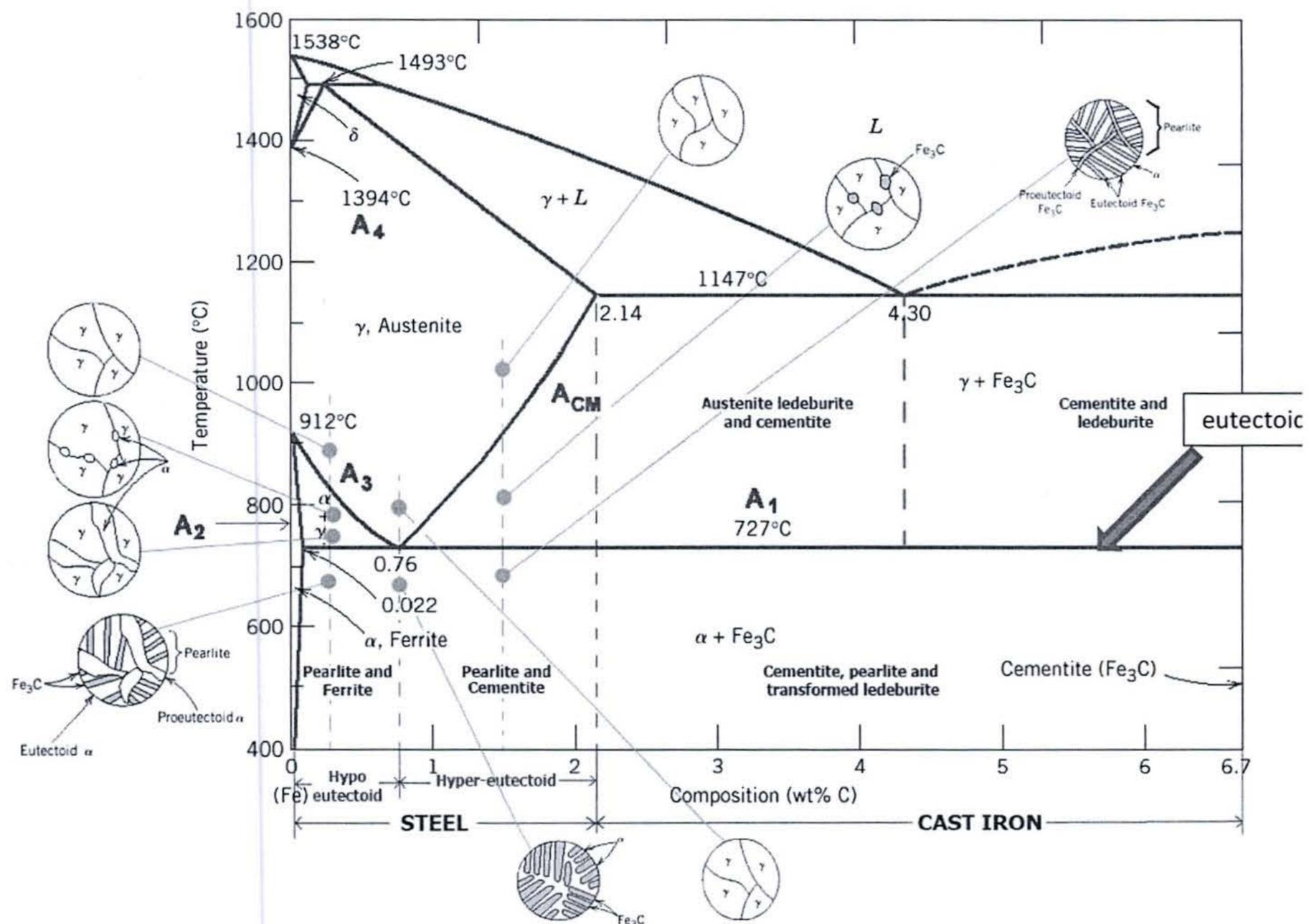
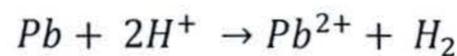


Figure 2: The lead-tin phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 3, T. B. Massalski (Editor-in-Chief), 1990]

**QUESTION B4**

- a) What are the limitations of Pourbaix diagrams [4]
- b) An electrochemical cell is composed of pure copper and pure lead electrodes immersed in solutions of their respective divalent ions. For a 0.6 M concentration of  $Cu^{2+}$  the lead electrode is oxidized yielding a cell potential of 0.507 V. Calculate the concentration of  $Pb^{2+}$  ions if the temperature is 25°C. [8]

c) Lead experiences corrosion in an acid solution according to the reaction



The rates of both oxidation and reduction half-reactions are controlled by activation polarization.

i) Compute the rate of oxidation of Pb (in mol/cm<sup>2</sup>.s) given the following activation polarization data. [8]

For Lead	For Hydrogen
$V_{(Pb/Pb^{2+})} = -0.126 \text{ V}$	$V_{(H^+/H_2)} = 0 \text{ V}$
$i_0 = 2 \times 10^{-8} \text{ A/cm}^2$	$i_0 = 1.0 \times 10^{-8} \text{ A/cm}^2$
$\beta = -0.12$	$\beta = -0.10$

ii) Compute the value of the corrosion potential. [5]

(END OF PAPER)

### The Standard emf Series

	Electrode Reaction	Standard Electrode Potential, $V^0$ (V)
↑ Increasingly inert (cathodic)	$Au^{3+} + 3e^- \rightarrow Au$	+1.420
	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.229
	$Pt^{2+} + 2e^- \rightarrow Pt$	~ +1.2
	$Ag^+ + e^- \rightarrow Ag$	+0.800
	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.771
	$O_2 + 2H_2O + 4e^- \rightarrow 4(OH^-)$	+0.401
	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.340
	$2H^+ + 2e^- \rightarrow H_2$	0.000
	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.136
↓ Increasingly active (anodic)	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.250
	$Co^{2+} + 2e^- \rightarrow Co$	-0.277
	$Cd^{2+} + 2e^- \rightarrow Cd$	-0.403
	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.440
	$Cr^{3+} + 3e^- \rightarrow Cr$	-0.744
	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.763
	$Al^{3+} + 3e^- \rightarrow Al$	-1.662
	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.363
	$Na^+ + e^- \rightarrow Na$	-2.714
	$K^+ + e^- \rightarrow K$	-2.924