UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2026

Module Number: ME3304 **Module Name: Metallurgy for Engineers (C-18)**

[Three Hours]

[Answer **all questions**, each question carries **12** marks]

Q1. A phase diagram is a graphical representation that depicts the equilibrium phases of a material system as functions of temperature, pressure, and composition.

a) Briefly explain the practical applications of phase diagrams in engineering.

[2.0 Marks]

b) State the **three** principal types of phase diagrams and provide one representative example for each.

[1.5 Marks]

c) Construct the phase diagram on the provided graph sheet for an alloy system containing metal **A** and **B** between **50°C** and **800°C** using the following data.

Melting temperature of metal **A** is **700°C**.
Melting temperature of metal **B** is **550°C**.
Eutectic reaction occurs at **300°C** with a composition of **55 wt% B** and **45 wt% A**.
Maximum solubility of **B** in **A** is **20 wt% B**, occurring at **300°C**.
Maximum solubility of **A** in **B** is **15 wt% A**, occurring at **300°C**.
Solubility of **B** in **A** at **150°C** and **50 °C** is **10 wt% B** and **5 wt% B** respectively.
Solubility of **A** in **B** at **150°C** and **50 °C** is **5 wt% A** and **2.5 wt% A** respectively.

[6.5 Marks]

d) Sketch the microstructure of an alloy contains **55 wt% B** and **45 wt% A** at **50 °C** under equilibrium cooling conditions and clearly label all phases present in the diagram.

[2.0 Marks]

Q2. Refined from pig iron, steel remains the foundational material of modern engineering due to its exceptional strength, versatility, and cost-effectiveness.

a) Briefly describe the chemical and physical characteristics of hematite, magnetite, and siderite ores used in the production of pig iron.

[3.0 Marks]

Q2. Continues to the next page

b) Discuss the primary functions of coke and the properties that determine its value in pig iron production.

[3.0 Marks]

c) Compare the **open-hearth process** and the **Bessemer process** in steelmaking, addressing their operating principles, raw material requirements, resultant steel quality, and overall economic considerations.

[4.0 Marks]

d) Briefly explain the role and significance of slag in the steelmaking process.

[2.0 Marks]

Q3. The mechanical properties of steel are primarily governed by its microstructure, which can be systematically modified through heat treatment processes without altering the alloy's overall chemical composition.

a) Define **heat treatment** and explain how the hardness and ductility of steel can be modified while maintaining a constant chemical composition.

[2.0 Marks]

b) Compare and contrast **full annealing** and **normalizing**, highlighting differences in heating temperature ranges, cooling conditions, and resulting microstructures.

[2.0 Marks]

c) State the differences between **diffusion methods** (*e.g. Carburizing*) and **selective heating methods** (*e.g. Induction hardening*) in surface hardening of steel.

[2.0 Marks]

d) **Figure Q3.** presents the **Time-Temperature-Transformation** (TTT) diagram for eutectoid steel (0.76% C). Describe cooling paths **1, 2, 3,** and **4**, identifying the phase transformation that occurs at each stage.

[4.0 Marks]

e) With reference to **Figure Q3.**, sketch the expected microstructure at **Point D** and **Point E** along cooling path 4 and clearly label all phases present at each location.

[2.0 Marks]

Q4. a) The durability of a metal in high-temperature oxidizing environments is governed not solely by its chemical reactivity, but critically by the structural integrity and adherence of the oxide scale it forms.

i) Define the **Pilling-Bedworth Ratio (PBR)** and present its mathematical expression in terms of the molar mass (M) and density (ρ) of both the metal and its corresponding oxide.

[2.0 Marks]

Q4. Continues to the next page

ii) Using the PBR as a guiding criterion, briefly explain the three principal scenarios of oxide scale formation and their respective effects on the underlying metal :

1. PBR < 1
2. 1 < PBR < 2
3. PBR > 2

In your explanation, identify the range of the Pilling–Bedworth Ratio that corresponds to a passivating (*protective*) oxide scale and justify your reasoning. Where appropriate, support your answer with clearly labelled sketches.

[3.0 Marks]

b) Corrosion weakens the structural integrity of materials over time, therefor understanding its mechanisms and prevention strategies is essential for modern industrial design.

i) Briefly explain the mechanism of pitting corrosion and explain why it is considered autocatalytic (*self-stimulating*).

[3.0 Marks]

ii) A welded austenitic stainless steel (AISI 304) machine component exhibited cracking in the heat-affected zone (HAZ) after several years of service. Identify the specific type of corrosion that occurred and explain the underlying metallurgical reason for this failure.

[3.0 Marks]

iii) Propose a method to prevent the type of corrosion identified in **Q4. (b) (ii)**.

[1.0 Mark]

Q5. a) The catastrophic failures of Liberty ships during World War II highlighted the critical danger of the ductile-to-brittle transition (DBT) in structural materials.

i) Briefly explain the experimental procedure used to determine the ductile-to-brittle transition temperature (DBTT) in a laboratory setting.

[2.0 Marks]

ii) Explain the crystallographic reasons why **body-centered cubic (BCC)** metals exhibit brittle fracture at low temperatures, whereas **face-centered cubic (FCC)** metals generally remain ductile.

[2.0 Marks]

iii) Compare the differences between **edge dislocation** and **screw dislocation.**

[2.0 Marks]

Q5. Continues to the next page

b) Write short notes on followings;

i) Properties and application of Cu-Zn alloys.

ii) The role of any two alloying elements used in commercial aluminum (Al) alloys and their effect on materials properties.

iii) The unique characteristic and applications of Nitinol

[6.0 Marks]

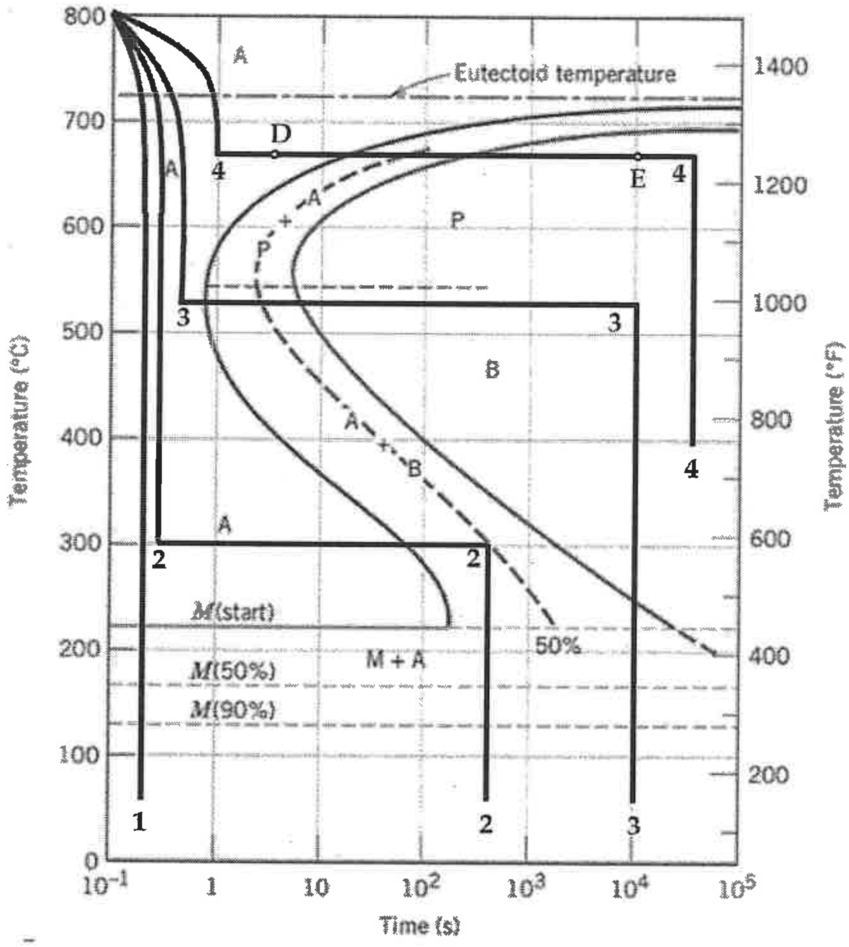

Figure Q3