



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2026

Module Number: ME3305 Module Name: Metallurgy for Engineers (C-23)

[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, therefore 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;
- Properties and application of Cu-Zn alloys.
 - The role of any two alloying elements used in commercial aluminum (Al) alloys and their effect on materials properties.
 - The unique characteristic and applications of Nitinol

[6.0 Marks]

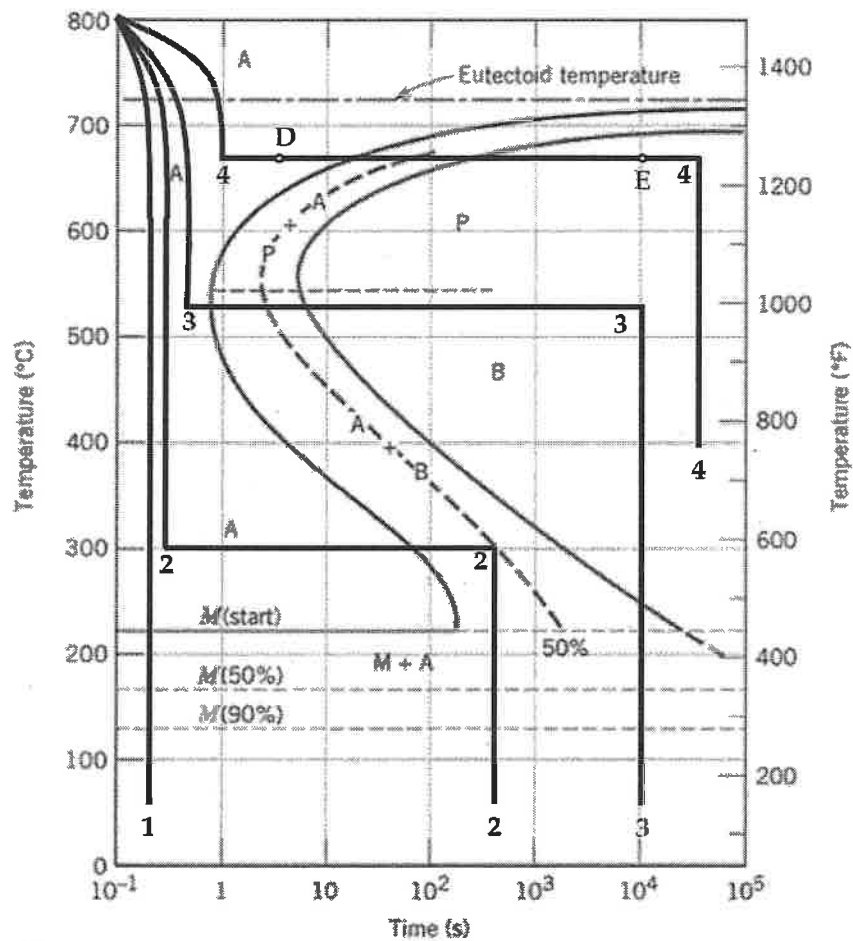


Figure Q3