



JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF ENGINEERING AND TECHNOLOGY

**UNIVERSITY EXAMINATION FOR THE DEGREE IN SCIENCE IN RENEWABLE
ENERGY TECHNOLOGY AND MANAGEMENT**

2ND YEAR 2ND SEMESTER 2024/2025 ACADEMIC YEAR

CENTRE: MAIN CAMPUS

COURSE CODE: TEB 1204

COURSE TITLE: MATERIAL SIENCE II

EXAM VENUE:

STREAM: BSc. REN ENGY TEC & MGT

DATE: 14 /04/2025

EXAM SESSION: 15-17.00 HRS

DURATION: 2 HOURS

Instructions

- 1. Answer ANY FOUR (4) questions**
- 2. Candidates are advised not to write on question paper**
- 3. Candidates must hand in their answer booklets to the invigilator while in the examination room.**

QUESTION ONE (25 MARKS)

- (a) Define the following heat treatment processes as applied to material science and engineering:
- Annealing (1 ½ Marks)
 - Tempering (1 ½ Marks)
 - Case Hardening (1 ½ Marks)
 - Austempering (1 ½ Marks)
- (b) Explain five factors that affect heat treatment in materials (10 Marks)
- (c) Describe five methods of powder compaction of metals (10 Marks)

QUESTION TWO (25 MARKS)

- (a) Discuss the phase diagram and its significance in materials science. (10 Marks)
- (b) Outline the iron-carbon phase diagram and describe the different phases present at various compositions and temperatures. (10 Marks)
- (c) What is the eutectoid composition in the iron-carbon phase diagram, and what is its significance in steel alloy production? (5 Marks)

QUESTION THREE (25 MARKS)

- (a) Define the term 'alloying' and explain its purpose in metallurgy. (5 Marks)
- (b) A steel alloy with 0.6% carbon is held at 750°C, where it is in equilibrium between austenite (γ) and ferrite (α). Using the lever rule and the iron-carbon phase diagram values given below, calculate:
- The weight fraction of ferrite. 3 marks
 - The weight fraction of austenite. 3 marks

Given:

At 750°C, the steel is in a two-phase region ($\alpha+\gamma$). From the iron-carbon phase diagram:

- The composition of ferrite (α) at 750°C is approximately 0.02% C.
- The composition of austenite (γ) at 750°C is approximately 0.76% C.

- (c) A steel component undergoes carburizing at 950°C for 5 hours. The carbon diffusion coefficient at this temperature is $1.5 \times 10^{-11} m^2/s$

- i. Calculate the depth of the carbon-enriched layer.
- ii. Estimate the surface carbon concentration assuming an initial concentration of 0.2% and a carburizing gas concentration of 1.0%.

(Use Fick's second law: $= \sqrt{2 \cdot D \cdot t}$)

(14 marks)

QUESTION FOUR (25 MARKS)

- (a) Discuss at least four types of cast iron as applied to material science
(8 Marks)
- (b) A gray cast iron has the following composition: Carbon = 4.0%, Silicon = 2.5%, Manganese = 0.6% and Phosphorus = 0.5%. Calculate the Carbon Equivalent (CE) and Comment on the type of microstructure that will form. Given:

$$CE = C + \frac{Si}{3} + \frac{P}{3}$$

(4 Marks)

- (c) A casting process uses a sand mold and a metal mold for the same gray cast iron composition.
 - i. Explain the effect of the cooling rate in each mold on the graphite structure (flake size and distribution).
(6 Marks)
 - ii. Calculate the time required for complete solidification in each case using the Chvorinov rule:

$$t = C_m \left(\frac{V}{A} \right)^n$$

Assume $C_m = 5s/cm^2$, $n = 2$, and V/A ratio are 3cm and 1.5cm, for the sand and metal molds, respectively

(7 Marks)

QUESTION FIVE (25 MARKS)

- (a) Define oxidation corrosion and explain how it differs from other forms of corrosion
(5 Marks)
- (b) Explain the role of oxidation and corrosion in the degradation of reinforced concrete structures.
(5 Marks)

- (c) Describe how oxidation corrosion affects the performance of jet engine turbine blades. What materials and coatings are used to mitigate this issue? (8 Marks)
- (d) A steel specimen is exposed to air at high temperature, and its oxide layer grows according to a parabolic rate law. The oxide thickness after 5 hours of exposure is 0.5 mm. If the parabolic rate constant k_p is $2 \times 10^{-9} \text{mm}^2/\text{h}$, calculate the oxide thickness after 20 hours of exposure. (7 Marks)

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