4

Program: B.Sc. Engg. (IPE)/2nd Sem 10:00 am – 12:00 pm, (Tuesday), 01 July 2025

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Mid Semester Examination | Summer Semester, A. Y. 2023-2024
Course No.: **ME 4225** | Time: 2 Hours
Course Title: **Material Engineering** | Full Marks: **120**

There are 4 (Four) questions. Answer all the questions.
Marks for each question and the corresponding CO, PO, and K/P/A are written in brackets.
Do not write on this question paper.

Q1. a) Iron (Fe) undergoes a polymorphic transformation from a Body-Centered Cubic (BCC) to a Face-Centered Cubic (FCC) crystal structure at 912°C. Assume the atomic radius of an iron atom is 0.124 nm. [14+6+10] CO1, PO1 K1, P1

i. Calculate the **Atomic Packing Factor (APF)** for the Body-Centered Cubic (BCC) structure. Derive all steps, starting with the relationship between the unit cell edge length (a) and the atomic radius (R).

ii. Calculate the theoretical **density** (ρ) of iron when it is in the BCC phase. (Given: Atomic weight of Iron = 55.85 g/mol; Avogadro's number = 6.022×10^{23} atoms/mol).

b) In the cubic unit cell, draw and clearly label the following:
 i. The crystallographic direction **[1 10]**
 ii. The crystallographic plane **(111)**

c) Classify engineering materials based on **chemical composition**, **properties**, and **crystallinity**. For each category, briefly describe the basic characteristics and provide relevant examples.

Q2. a) Differentiate between **ductility**, **toughness**, and **hardness** in terms of material behavior and testing methods. Provide one relevant engineering application for each. [8+10+12] CO3, PO4 K4, P1

b) Based on typical stress–strain behavior of different materials distinguish between the following three material responses using stress-strain diagram

- High strength, low ductility
- High strength, high ductility
- Low strength, high ductility

Briefly comment on their relative toughness and provide one engineering application where each type of material is preferred.

c) A brittle ceramic plate has an internal elliptical crack. Assume the radius of curvature at the crack tip is **0.15 nm**. If the crack length is **2 μm** and the theoretical cohesive strength of the ceramic is **6.0 GPa**, estimate the **applied stress at which fracture will occur** using Griffith's criterion.

Q3. a) Define a composite material and explain its key characteristics. Why are composite materials often preferred over conventional monolithic materials in modern engineering applications, particularly in industries like aerospace? Provide examples relevant to industrial applications. [10+12+8] CO3, PO4 K4, P1

b) Explain what makes fibers effective as reinforcement in composite materials. Discuss at least three key characteristics that contribute to their effectiveness, such as small diameter, high aspect ratio, and flexibility and explain the significance of each in enhancing mechanical performance.

c) Explain the difference between Glass Transition Temperature (Tg) and Melting Temperature (Tm) in polymers. Illustrate your answer by describing the thermal behavior of both amorphous and semicrystalline polymers with respect to these temperatures, referencing the typical **specific volume vs. temperature curve.**

Q4. a) What is an invariant point in a binary phase diagram? Why is it important in alloy design? Name and briefly explain any two invariant reactions with phase diagram. [8+10+12] CO2, PO2 K4, P1

b) At 300°C, a binary alloy of copper and nickel exists in a two-phase region consisting of solid solution (α phase) and liquid.
i) Calculate the degrees of freedom for this Cu–Ni alloy system at constant pressure (1 atm).
ii) Explain the practical implications of this result in terms of composition and temperature control during solidification.
iii) Now consider pure nickel:
- Below its melting point
- At its melting point

For each case, calculate the degrees of freedom.

c) A binary alloy of mass **2 kg** contains **42 wt% B**. At a certain temperature, the alloy is located in a two-phase region consisting of **liquid + solid solution (L + SS)**. The composition of the liquid is **60 wt% B**, and the composition of the solid solution is **25 wt% B.**
i) Using the lever rule, calculate the mass of each phase (liquid and solid solution) present in the alloy at this temperature.
ii) If the same alloy were cooled further and the composition of the liquid phase decreases to **48 wt% B** while the solid solution composition remained at **25 wt% B**, determine the new mass (kg) of solid solution formed.