MACHAKOS UNIVERSITY

University Examinations for 2022/2023

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

SECOND YEAR FIRST SEMESTER EXAMINATIONS FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 211: INTRODUCTION TO MATERIAL SCIENCE

DATE: **TIME:**

INSTRUCTIONS

- This paper contains **FIVE (5)** questions.
- You are required to answer **THREE (3)** questions only.
- Question **one** is compulsory.
- Attempt any other two questions.
- Question one carries 30 marks and the others carry 20 marks each.

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Define material science and state three types of materials used in engineering (4 marks)

b) Describe five mechanical properties of a material (5 marks)

c) Differentiate between: (6 marks)

(i) Malleability and ductility;

(ii) Toughness and hardness;

(iii) Yield strength and tensile strength.

d) An alloy steel rod of diameter 15 mm is subjected to a tensile force of 150 kN. What is the tensile stress acting in the rod? (2 marks)

e) Describe five advantages of Vickers test over Brinell test (5 marks)

f) The atomic radius of an iron atom is 1.238 x 10^{-10} m. Iron crystallises as b.c.c. Calculate the lattice parameter. Of the unit cell, *a.* How many atoms are contained within the b.c.c. unit cell? (4 marks)

g) What non-destructive testing methods would be applied to reveal the presence of: (4 marks)

i. subcutaneous slag inclusions in a thick steel plate;
ii. quench-cracks in a heat-treated carbon steel axle;
iii. surface cracks near to a welded joint in mild-steel plate
iv. Give reasons for your choice of method in each case and outline the principles of the method involved.

QUESTION TWO (20 MARKS)

a) Describe the force-extension diagram for annealed low-carbon steel using a well label diagram. (8 marks)

b) The diameter of the test piece was 16 mm and the gauge length used was 80 mm. Draw the force-extension diagram and determine: (8 marks)

(i) Young's modulus of elasticity;
(ii) the 0.1 % proof stress
(iii) the tensile strength;
(iv) The percentage elongation of the material.

c) An aluminium alloy has a modulus of elasticity of 69 kN/mm^2 and a yield strength of 275 N/$mm^{2.}$ What is the maximum force which a wire 3 mm in diameter could support without suffering permanent deformation? If a wire of this diameter and 25 m long is stressed by a force of 430 N what will be the elongation of the wire? (4 marks)

QUESTION THREE (20 MARKS)

a) What inspection techniques would be appropriate for detecting the following defects in cast products: (5 marks)

i. Internal cavities in a large steel casting;
ii. surface cracks in grey iron castings;
iii. surface cracks in aluminum alloy castings;
iv. Internal cavities in aluminum alloy casting?
v. Give reasons for your choice of method in each case.

b) Using diagrams describe three crystal structures of metals. (9 marks)

c) Copper contains two isotopes, with mass numbers of 63 and 65. The atomic mass number of copper is 63.54.

i. Estimate the relative proportions of the two isotopes. (3 marks)

ii. with the aid of a diagram differentiate between covalent and ionic bond (3 marks)

QUESTION FOUR (20 MARKS)

a) Define atomic structure (1 mark)

b) Copper atoms are 2.552 x $1O^{-lO}$ m diameter and form an f.c.c. structure. X-radiation of wavelength 1.52 x $1O^{-lO}$ m is used for the analysis of two samples of copper. For sample A the first-order Bragg reflection from (Ill) planes occurred at an angle of 21 °00', while for sample B the first-order Bragg reflection from (111) planes were at 21 °23'. Give an explanation for the difference between the samples. (5 marks)

c) Considering that metal atoms in a single plane are represented as discs of uniform diameter, show, by calculation, that the packing density in FCC (Ill) planes is greater than in BCC (110) planes. (5 marks)

d) X-radiation of wavelength of 1.71 x 10-lO m is directed at a cubic crystalline metal. The first two Bragg reflections occur at angles of 30°00' and 35°17' respectively. Determine: (9 marks)

i. Whether the crystal type is b.c.c. or f.c.c.,

ii. The lattice parameter of the unit cell, and

iii. The atomic diameter (assuming that all atoms are identical).

QUESTION FIVE (20 MARKS)

a) The phase diagram for a binary alloy system is shown in Figure 11.16. (10 marks)

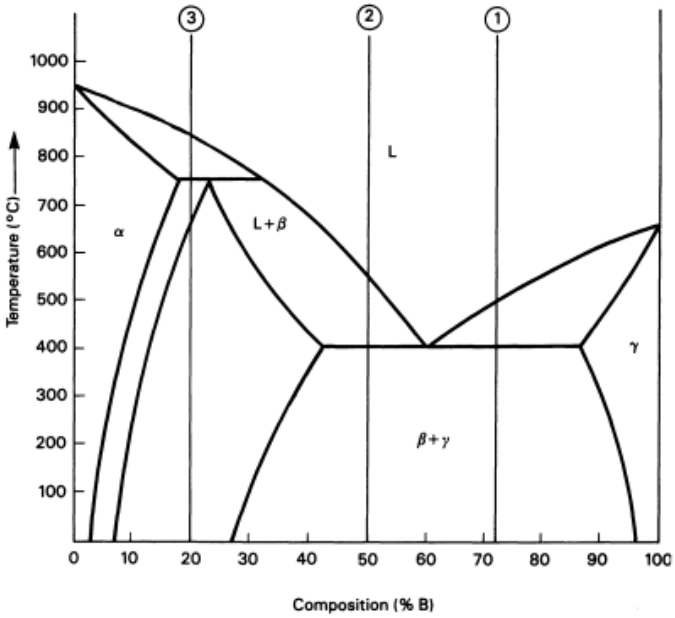

FIGURE 11.16

i. Label all the phase fields.

ii. Estimate the liquidus and solidus temperatures for the alloy containing 20 percent B.

iii. For the alloy containing 40 percent B, state what phases are present, and in what relative proportions, at (i) 600·C, (ii) 300·C, and (iii) 100·C.

iv. What percentage of the microstructure is a eutectic mixture in the alloy containing 70 percent of B at room temperature?

b) Two pure metals A and B, and a series of alloys of these two metals, were cooled from the liquid state and the information, in the Table below, was obtained. (10 marks)

Per cent A in alloy	100	95	85	60	30	10	5	0
1sr arrest point (°C)	600	575	535	425	300	400	425	450
2nd arrest point (°C)	–	500	300	300	–	300	350	–
3rd arrest point (°C)	–	40	–	–	–	–	200	–

i. From the data, plot and fully label the thermal equilibrium diagram for the alloy system of metals A and B.

ii. For the alloy containing 75 percent of A, what phases exist at the following temperatures: (a)525°C, (b) 425°C, (c) 250°C?

iii. Explain how the properties of hardness and tensile strength of slowly cooled alloys would vary with composition from pure A to pure B.