MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FIRST YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 102: INTRODUCTON TO MATERIAL SCIENCE

DATE: 26/7/2019 **TIME: 2.00-4.00 PM**

INSTRUCTIONS:

Answer Question One and Any Other Two Questions

All symbols have usual meanings unless otherwise stated

QUESTION ONE (30 MARKS)

a) Using neat sketches, distinguish the following crystal structures stating their distinct characteristic(s).

i. Face centered cubic crystal structure (FCC)

ii. Body centered cubic crystal structure (BCC)

iii. Hexagonal closed packed structure (HCP) (9 marks)

b) State three primary classifications of solid materials based on chemical bonding, briefly explain their distinctive chemical features and cite two applications for each class. (6 marks)

c) Define the following terms as they are used in crystal structures (3 marks)

i. Unit cell

ii. Space lattice

iii. Coordination number

d) Enumerate **THREE** comparisons between Bessemer and Open Hearth processes as applied in steel manufacturing. (3 marks)

e) In order to evaluate various mechanical properties, a steel specimen of 12.5mm diameter and 62.5mm gauge length was tested in a standard tension test. The following observations were made during the test; (9 marks)

Yield load =40,000 N Fracture load =50,500 N

Strain at load of 20,000 N $=7.75 \times 10^{-4}$ Maximum load = 71,500 N

Gauge length at fracture =79.5mm

Determine;

i. Yield point stress
ii. Ultimate tensile strength
iii. Percentage elongation
iv. Modulus of elasticity
v. Fracture stress
vi. Modulus of toughness

QUESTION TWO (20 MARKS)

a) Prove that for the FCC crystal structure, the cubic edge length $a=2R\sqrt{2}$ and atomic packing factor (APF) is 0.74. Where: R is the atomic radius (6 marks)

b) Using conventional *s, p, d, f,* . . . notations, write the electronic configuration of the following atoms (3 marks)

i. sodium ion, Na^{+} Z = 11
ii. vanadium, V, Z = 23
iii. bromine, Br, Z = 35

c) Explain briefly the following types of bonds: (4 marks)

i. Ionic bond
ii. Covalent bond.
iii. Metallic bond
iv. Van der Waals bond

d) List **SIX** main classifications of Cast iron. (3 marks)

e) Enumerate **FOUR** effects of Silicon when added to Iron as an impurity (4 marks)

QUESTION THREE (20 MARKS)

a) Explain the following types of crystal defects (6 marks)

i. Point defects

ii. Line defects (dislocation)

iii. Area defects

b) Distinguish between: (4 marks)

i. Engineering stress and true stress

ii. Frenkel defect and Schottky defect

c) A steel wire 0.5mm^2 in cross-sectional area and 10m long is extended elastically 1.68mm by a force of 17.24N. Calculate the modulus of elasticity for the steel. (4 marks)

d) Discuss the THREE types of plain carbon steels and state ONE application of each. (6 marks)

QUESTION FOUR (20 MARKS)

a) Define a phase Diagram (PD) (2 marks)

b) Explain four Hume Rothery rules for formation of substitution solid solution (8 marks)

c) Write phase transformation reactions for the following binary phase systems (4 marks)

i. Eutectic

ii. Peritectic

iii. Eutectoid

iv. Monotectic

d) Draw and describe a binary thermal equilibrium diagram with complete solubility in solid state. (6 marks)

QUESTION FIVE (20 MARKS)

a) Explain the following mechanical properties of engineering materials (6 marks)

i. Ductility

ii. Toughness

iii. Hardness

b) Give a brief description of the following solid phases in iron-iron carbide phase diagram

i. α-ferrite (2 marks)

ii. Austenite (2 marks)

c) Differentiate between the following

i. interstitial impurity and substitutional impurity (2 marks)

ii. diamagnetism and ferromagnetism (2 marks)

d) Determine the fractional composition of each phase present at point E in Figure 1 using lever rule. If the initial alloy composition C_0 = 53 wt% Ni, 47 wt% Cu shown by the vertical arrow and dashed line in the Figure 1 at 1300◦C. (6 marks)

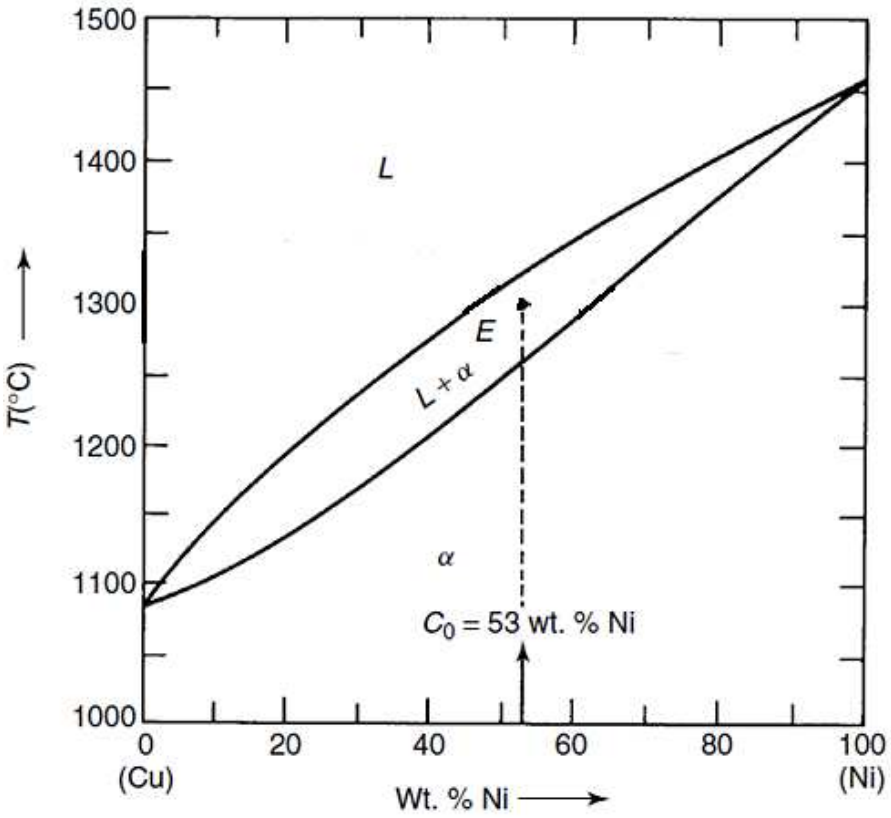

Figure 1: The Cu-Ni binary isomorphous phase diagram showing the temperature against % composition by weight adapted from (D. C. J. William and G. R. David, *Materials science*, 9th ed. United States of America, 2014).