NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF CIVIL AND WATER ENGINEERING
BACHELOR OF ENGINEERING (HONOURS) DEGREE
PART I SUPPLEMENTARY EXAMINATION - AUGUST 2014
TCW 1202: MATERIAL SCIENCE

INSTRUCTIONS
1. Answer all questions.
2. Each question carries 20 marks.

SPECIAL REQUIREMENTS
1. Table of Electronegativities of Elements.
2. Periodic Table of Elements.

Time: 3 Hours

Total Marks: 100

SECTION A

Question 1
(a) Explain why engineers need to have some knowledge about materials. [2]
(b) Discuss the statement that 'selection of a material is compromise of many factors'. [9]
(c) Briefly describe metallic bonding. [5]
(d) Write the electronic configuration of Fe^{2+} and Fe^{3+} ions using *spdf* convention given that for the Fe atom, Z = 26. [4]

Question 2
(a) Distinguish between atomic weight and atomic mass. [2]
(b) If the attractive force between a pair of Sr^{2+} and S^{2-} is 9.544 x 10^{-9} N and the ionic radius of the S^{2-} is 0.184nm, calculate the ionic radius of the Sr^{2+} ion in nanometers.
You are also given that e=1.602 x 10^{-19}C and ε_0 = 8.85 x 10^{-12}F/m. [4]
(c) Calculate the percentage ionic character in the semiconducting compounds ZnS and GaP. [4]
(d) Represent the following on neatly drawn sketches:
(i) [101]
(ii) [111]
(iii) $[2\underline{0}3]$
(iv) $[3\bar{1}2]$ [9]
(e) Calculate the Miller indices of a cubic plane which has the following intercepts:
a = ½, b = ⅓ and c = 1. [1]

SECTION B

Question 3

(a) Calculate the planar atomic density on the (110) plane of the α iron BCC lattice in atoms per square millimetre given that the lattice constant of α iron is 0.287nm. [5]

(b) Calculate the linear atomic density in the [110] direction in the copper crystal lattice in atoms per millimetre. Copper is FCC and has a lattice constant of 0.361nm. [3]

(c) Calculate the theoretical volume change accompanying a polymorphic transformation in a pure metal from the FCC to BCC crystal structure. Assume the hard-sphere atomic model and that there is no change in atomic volume before and after the transformation. [6]

(d) Define the following terms:
 (i) polymorphism,
 (ii) crystal,
 (iii) Pauli's exclusion principle,
 (iv)Heisenberg's uncertainty principle,
 (v) Permanent dipole bond. [6]

Question 4

(a) With the aid of a neatly drawn sketch, write brief notes on twin boundaries. [6]

(b) The fraction of vacancy sites in a metal is 1.0×10^{-10} at 5000°C. What will be the fraction of vacancy sites at 1000°C? [4]

(c) The surface energy of a single crystal depends on crystalline orientation. Does this surface energy increase or decrease in planar density? Explain. [4]

(d) Briefly describe the following imperfections found in solid materials:
 i)point imperfection, [2]
 ii)line imperfection, [2]
 iii)surface imperfection. [2]

Question 5

(a) For a bronze alloy, the stress at which plastic deformation begins is 280MPa, and the modulus of elasticity is 115GPa.
 i) What is the maximum load that may be applied to a specimen with cross-sectional area of $325 mm^2$ without plastic deformation? [2]
 ii) If the original specimen length is 120mm, what is the maximum length to which it may be stretched without causing plastic deformation? [3]

(b) Cite the primary differences between elastic, anelastic, viscoelastic and plastic deformations. [4]

(c) A cylindrical specimen of a hypothetical metal alloy is stressed in compression. If its original and final diameters are 20.000mm and 20.025mm, respectively, and its final length is 74.96mm, compute its original length if the deformation is totally elastic. The elastic and shear moduli for this alloy are 105GPa and 39.7GPa, respectively. [7]

(d) A metal wire is 2.5mm diameter and 2m long. A force of 12N is applied to it and stretches 0.3mm. Assume the material is elastic. Determine the following:
 i) the stress in the wire, [2]
 ii) the strain in the wire. [2]

Figure 1. The electronegativity values of elements

IA	IIA	IIIB	IVB	VB	VIB	VIIB		VIII		IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 2.1																	2 He –
3 Li 1.0	4 Be 1.5											5 B 2.0	6 C 2.5	7 N 3.0	8 O 3.5	9 F 4.0	10 Ne –
11 Na 0.9	12 Mg 1.2											13 Al 1.5	14 Si 1.8	15 P 2.1	16 S 2.5	17 Cl 3.0	18 Ar –
19 K 0.8	20 Ca 1.0	21 Sc 1.3	22 Ti 1.5	23 V 1.6	24 Cr 1.6	25 Mn 1.5	26 Fe 1.8	27 Co 1.8	28 Ni 1.8	29 Cu 1.9	30 Zn 1.6	31 Ga 1.6	32 Ge 1.8	33 As 2.0	34 Se 2.4	35 Br 2.8	36 Kr –
37 Rb 0.8	38 Sr 1.0	39 Y 1.2	40 Zr 1.4	41 Nb 1.6	42 Mo 1.8	43 Tc 1.9	44 Ru 2.2	45 Rh 2.2	46 Pd 2.2	47 Ag 1.9	48 Cd 1.7	49 In 1.7	50 Sn 1.8	51 Sb 1.9	52 Te 2.1	53 I 2.5	54 Xe –
55 Cs 0.7	56 Ba 0.9	57-71 La–Lu 1.1–1.2	72 Hf 1.3	73 Ta 1.5	74 W 1.7	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.2	79 Au 2.4	80 Hg 1.9	81 Tl 1.8	82 Pb 1.8	83 Bi 1.9	84 Po 2.0	85 At 2.2	86 Rn –
87 Fr 0.7	88 Ra 0.9	89–102 Ac–No 1.1–1.7															

****End of Examination Paper****