NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4204 - MATERIALS SCIENCE II

BSc HONOURS PART IV: JUNE 2004 DURATION: 3 HOURS

ANSWER **ALL** PARTS OF SECTION A AND ANY **THREE** IN SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

SECTION A

1. (a) (i) Sketch the ion arrangement on the (110) plane of ZnS (with Zinc - blend structure) and
(ii) Compare this arrangement with that on the (110) plane of CaF_2 (fluorite structure)
(iii) What are their planar packing factors? [10]

(b) Five kg of continuous boron fibres are introduced in a unidirectional orientation into 8kg of an aluminium matrix. Calculate:
(i) the density of the composite
(ii) the modulus of elasticity parallel and perpendicular to the fibres.
$\rho_{Al} = 2.699 g/cm^3$ [6]

(c) A ceramic component has a flextural strength of 825MNm^{-2}. In a three-point bend test, the bar 12mm thick and 25mm wide is supported at two points 230mm apart. The component contains flows 0.025 mm long with the tip radius of 50nm. Determine the load at which the bar is expected to fail. [6]

(d) Calculate the density of a cemented carbide or cement based on a Titanium matrix if the composite contains 50Wt%WC, 22Wt%TaC, and 14Wt% TiC. The densities of the carbides are P_{wc} = 15.77 g/cm^3, P_{TaC} = 14.5 g/cm^3, P_{TiC} = 4.94 g/cm^3,
P_{Ti} = 4.51 g/cm^3. [6]

(e) A stress of 17 MNm^{-2} is applied to a polymer serving as a fastener in a complex assembly. At a constant strain, the stress drops to 16.5 MNm^{-2} after 100 hours. If the stress on the component must remain above 14.5 MNm^{-2} for the component to function properly, determine the life of the assembly. [6]

(f) There are 10^{20} molecules per gram of Polyvinyl chloride,
(i) what is the average molecular size and
(ii) the degree of polymerization of PVC. [6]

SECTION B

2. (a) What are liquid crystal polymers? Give at least two examples. [4]

(b) Using the visco elastic models, explain the mechanical properties of polymers. [10]

(c) Distinguish thermoplastics from thermosets. [6]

3. (a) Write brief notes on the following Engineering ceramics
(i) alumina, (Al_2O_3)
(ii) Barium Titanate, and
(iii) Silicon Carbide (S_iC) or Silicone Nitride ($S_{i3}N_4$). [12]

(b) During service, a ceramic valve operating at 250°C is likely to be quenched to room temperature, (20°C), by a flowing aqueous solution. The valve could be manufactured from one of the two ceramics designated A and B, whose properties are given below. Discuss which ceramic you would select for this application.

	A	B
Young's Modulus E, (GN/m^2)	120	350
Coefficient of thermal expansion $\alpha(K^{-1})$	2×10^{-6}	9×10^{-6}
Fracture stress of δ_f	230	270
Poisson's ratio (MN/m^2)	0.25	0.27
Thermal conductivity at 50°C $K(w/mk)$	14	8

[8]

4. (a) (i) What are closed and interconnected pores? Explain the use of pores in ceramic refractory materials. [5]

(b) Silicon carbide particles are compacted and fired at a high temperature to produce a strong ceramic shape. The specific gravity of Silicon Carbide is 3.2 g/cm^3, the dry weight of the component is 360g, 385g after soaking in water and 224g while suspended in water.
Calculate
(i) the apparent porosity
(ii) the true porosity and
(iii) the fraction of the pore volume that is closed. [6]

(c) (i) What are refractory materials? [3]
(ii) Classify refractory materials giving at least two examples of each. [6]

5. (a) Define the following terms with respect to composite materials.
   (i) aspect ratio
   (ii) specific modulus and
   (iii) matrix. [6]

   (b) Select the constituents of an electrical contact material and describe a method that will produce a contact material with a density not more than 6g/cm^3 with at least 50 volume % of the material being conductive. (Use the given periodic table) [6]

   (c) Consider a stylofoam composite material of a gas and a thin walled polystyrene having an overall density of about 0.016 g/cm^3. The density of polystyrene is 1.06g/cm^3 Calculate:
   (i) The volume fraction of each material in the composite. [2]
   (ii) Assuming for simplicity that the stylo foam beads are cubes of 0.1 cm on each side, estimate the wall thickness of the beads. [3]
   (iii) If the thermal conductivity of air is about 0.63 x 10^{-4} W/mK and for polystyrene about 3 x 10^{-4} W/mK at 25^{0}C. What is the thermal conductivity of stylo foam? [3]

6. (a) (i) Define the Pilling - Bedworth ratio and discuss its significance in relation to the degree of protection offered to a metal surface by an oxide layer. [6]

   (ii) Write short notes on the degradation of polymers and oxidation of ceramic materials. [8]

   (iii) Describe the three-point bend test for ceramic materials. [6]

- END OF PAPER -

PERIODIC TABLE OF THE ELEMENTS

Table of Radioactive Isotopes

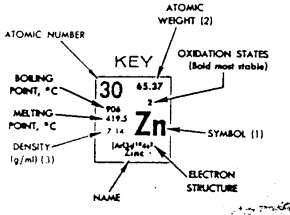
Naturally occurring radioactive isotopes are indicated by a blue mass number. Half lives are in parentheses where s, m, h, d and y stand for seconds, minutes, hours, days and years respectively. The symbols describing the mode of decay and resulting radiation are defined as follows:

α	alpha particle	L	L-electron capture
β⁻	beta particle	SF	spontaneous fission
β⁺	positron	γ	gamma ray
K	K-electron capture	e⁻	internal electron conversion

Ac 227(22y)β⁻,α
Ag 108(24d)β⁻,γ
Am 241(458y)α,γ,β⁻
242(16.0h)β⁻,K,α,γ
243(8000y)α,γ
As 76(26.7h)β⁻,γ
77(39h)β⁻,γ
At 210(8.3h)K,α,γ
211(7.2h)K,α,γ
Au 198(2.69d)β⁻,γ
Bi 131(12d)K,γ
133(7.2y)K,γ,β⁻
Bk 245(4.9d)K,α,γ
249(314d)β⁻,α,SF
Br 82(36h)β⁻,γ
C 14(5700y)β⁻
Ca 41(8x10⁴y)K
45(165d)β⁻
47(4.5d)β⁻,γ
Cd 115(43d)β⁻,γ
Ce 141(32d)β⁻,γ
143(33h)β⁻,γ
144(285d)β⁻,γ
Cf 246(35h)α,γ,SF
249(360y)α,γ,SF
251(800y)α
Cl 36(3x10⁵y)β⁻
Cm 243(35y)α,γ
245(9300y)α,γ
247(10⁷y)
Co 58(71d)K,β⁺,γ
60(5.27y)β⁻,γ
Cr 51(27d)K,γ
Cs 134(2.0y)β⁻,γ
135(3x10⁶y)β⁻
137(30y)β⁻,γ
Cu 64(12.8h)K,β⁻,β⁺,γ
Es 253(20d)α,γ,SF
254(1y)α,SF
Eu 154(16y)β⁻,γ
155(1.8y)β⁻,γ
Fe 55(2.6y)K
59(45d)β⁻,γ
Fm 255(20h)α
Fr 223(22m)β⁻,γ,α
Ga 72(14.1h)β⁻,γ
Gd 153(236d)K,γ,α
159(18h)β⁻,γ
Ge 71(11d)K
H 3(12.3y)β⁻
Hf 181(45d)β⁻,γ,α
Hg 197(65h)K,γ,α
203(47d)β⁻,γ,α
Ho 166(27.3h)β⁻,γ
I 129(10⁷y)β⁻,γ,α
131(8.05d)β⁻,γ
In 114(50d)β
Ir 192(74.4d)β⁻,γ
K 40(10⁹y)β⁻,K,γ
42(12.4h)β⁻,γ
La 140(40.2h)β⁻,γ
Lu 176(10¹⁰y)β⁻,K,γ
177(6.8d)β⁻,γ
Md 256(90m)K,SF
Mo 99(67h)β⁻,γ
Na 22(2.6y)β⁺,K,γ
24(15h)β⁻,γ
Nd 147(11.1d)β⁻,γ
Ni 63(125y)β⁻
59(8x10⁴y)K
Np 237(2.2x10⁶y)α,γ
239(2.33d)β⁻,γ
Os 191(15d)β⁻,γ,α
P 32(14.2d)β⁻
Pa 231(34000y)α,γ
Pb 210(19.4y)β⁻,γ,α
202(10⁵y)K
Pd 103(17d)K,γ
Pm 147(2.6y)β⁻
Po 210(138.4d)α,γ
209(103y)α,K,γ
Pr 143(13.6d)β⁻
Pt 197(18h)β⁻,γ
Pu 242(3.8 x 10⁵y)α,SF
241(13y)β⁻,α,γ
239(24300y)α,γ,SF
Ra 226(1620y)α,γ
Rb 86(18.6d)β⁻,γ
Re 188(16.7h)β⁻,γ
186(3.7d)β⁻,γ
Rn 222(3.82d)α
Ru 103(40d)β⁻,γ
97(2.9d)K,γ,α
S 35(88d)β⁻
Sb 122(2.8d)β⁻,K,β⁺,γ
124(60d)β⁻,γ
Sc 46(84d)β⁻,γ
Se 75(120d)K,γ
Sm 153(47h)β⁻,γ
145(340d)K,γ
Sn 113(119d)K,L,γ,e⁻
Sr 90(28y)β⁻
89(51d)β⁻,γ
85(64d)K,γ
Te 182(115d)β⁻,γ
Tb 160(73d)β⁻,γ
Tc 99(2x10⁵y)β⁻
97(10⁶y)K
Te 127(9.3h)β⁻
Th 232(1.4x10¹⁰y)α,γ,SF
228(1.91y)α
Tl 204(3.81y)β⁻,K
Tm 170(134d)β⁻,γ,e⁻
U 238(4.5x10⁹y)α,γ,SF
234(2.5x10⁵y)α,γ,SF
235(7.1x10⁸y)α,γ,SF
233(1.6x10⁵y)α,γ
W 185(75d)β⁻
Y 90(64h)β⁻,γ,e⁻
Yb 175(4.2d)β⁻,γ
169(31d)K,γ,e⁻
Zn 65(245d)K,β⁺,γ
Zr 95(65d)β⁻,γ,e⁻
93(9x10⁵y)β⁻,γ

GROUP IA											IIIA	IVA	VA	VIA	VIIA	VIIIA
1 1.00797 −252.7 −259.2 0.09 1 H Hydrogen	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	5 10.811 — (2030) 2.34 B	6 12.01115 4830 3727 9 2.26 C	7 14.0067 −195.8 −210 0.81 N	8 15.9994 −183 −218.8 1.14 O	9 18.9984 −188.2 −219.6 1.505 F	10 20.183 −246 −248.6 1.70 Ne
												Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
3 6.939 1330 180.5 0.53 1 Li	4 9.0122 2770 1277 1.85 2 Be																
Lithium	Beryllium																
11 22.9898 892 97.8 0.97 1 Na	12 24.312 1107 650 1.74 2 Mg											13 26.9815 2450 660 2.70 3 Al	14 28.086 2680 1410 2.33 4 Si	15 30.9738 280∞ 44.2∞ 1.82∞ ±3,5,4 P	16 32.064 444.6 119.0 2.07 ±2,4,6 S	17 35.453 −34.7 −101.0 1.56 ±1,3,5,7 Cl	18 39.948 −185.8 −189.4 1.40 Ar
Sodium	Magnesium											Aluminum	Silicon	Phosphorus	Sulfur	Chlorine	Argon
19 39.102 63.7 63.7 0.86 1 K	20 40.08 1440 838 1.55 2 Ca	21 44.956 2730 1539 3.0 3 Sc	22 47.90 3260 1668 4.51 4,3 Ti	23 50.942 3450 1900 6.1 5,4,3,2 V	24 51.996 2665 1875 7.19 6,3,2 Cr	25 54.938 2150 1245 7.43 7,6,4,3,2 Mn	26 55.847 3000 1536 7.86 2,3 Fe	27 58.933 2900 1495 8.9 2,3 Co	28 58.71 2730 1453 8.9 2,3 Ni	29 63.54 2595 1083 8.96 2,1 Cu	30 65.37 906 419.5 7.14 2 Zn	31 69.72 2237 29.8 5.91 3 Ga	32 72.59 2830 937.4 5.32 4 Ge	33 74.922 613* 817 5.72 ±3,5 As	34 78.96 685 217 4.79 −2,4,6 Se	35 79.909 58 −7.2 3.12 ±1,5 Br	36 83.80 −152 −157.3 2.6 Kr
Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton
37 85.47 38.8 38.8 1.53 1 Rb	38 87.62 1380 768 2.6 2 Sr	39 88.905 2927 1509 4.47 3 Y	40 91.22 3580 1852 6.49 4 Zr	41 92.906 3300 2468 8.4 5,3 Nb	42 95.94 5560 2610 10.2 6,4,3,2 Mo	43 (98) — 2140 11.5 7 Tc	44 101.07 4900 2500 12.2 2,3,4,6,8 Ru	45 102.905 4500 1966 12.4 2,3,4 Rh	46 106.4 3980 1552 12.0 2,4 Pd	47 107.870 2210 960.8 10.5 1 Ag	48 112.40 765 320.9 8.65 2 Cd	49 114.82 2000 156.2 7.31 3 In	50 118.69 2270 231.9 7.30 4,2 Sn	51 121.75 1380 630.5 6.62 ±3,5 Sb	52 127.60 989.8 449.5 6.24 −2,4,6 Te	53 126.904 183 113.7 4.94 ±1,5,7 I	54 131.30 −108.0 −111.9 3.06 Xe
Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon
55 132.905 28.4 28.4 0.86 1 Cs	56 137.34 1640 714 3.5 2 Ba	57 138.91 3470 920 6.17 3 ★ La	72 178.49 5400 2222 13.1 4 Hf	73 180.948 5425 2996 16.6 5 Ta	74 183.85 5930 3410 19.3 6,4,3,2,1 W	75 186.2 5900 3180 21.0 7,6,4,2,−1 Re	76 190.2 5500 3000 22.6 2,3,4,6,8 Os	77 192.2 5300 2454 22.5 2,3,4,6 Ir	78 195.09 4530 1769 21.4 2,4 Pt	79 196.967 2970 1063 19.3 3,1 Au	80 200.59 357 −38.4 13.6 2,1 Hg	81 204.37 1457 303 11.85 3,1 Tl	82 207.19 1725 327.4 11.4 4,2 Pb	83 208.980 1560 271.3 9.8 3,5 Bi	84 (210) 254 254 (9.2) 2,4 Po	85 (210) — (302) — ±1,3,5,7 At	86 (222) (−61.8) (−71) — Rn
Cesium	Barium	Lanthanum	Hafnium	Tantalum	Wolfram	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
87 (223) — — — 1 Fr	88 (226) 700 5.0 2 Ra	89 (227) 1050 — 2 ★★ Ac	104														
Francium	Radium	Actinium															

★	58 140.12 3468 795 6.67 3,4 Ce	59 140.907 3127 935 6.77 3,4 Pr	60 144.24 3027 1024 7.00 3 Nd	61 (147) (1027) — 3 Pm	62 150.35 1900 1072 7.54 3,2 Sm	63 151.96 1429 826 5.26 3,2 Eu	64 157.25 3000 1312 7.89 3 Gd	65 158.924 2900 1356 8.27 3,4 Tb	66 162.50 2600 1407 8.54 3 Dy	67 164.930 2600 1461 8.80 3 Ho	68 167.26 2900 1497 9.05 3 Er	69 168.934 1727 1545 9.33 3,2 Tm	70 173.04 1427 824 6.98 3,2 Yb	71 174.97 3327 1652 9.84 3 Lu
	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
★★	90 232.038 3850 1750 11.7 4 Th	91 (231) — (1230) 15.4 5,4 Pa	92 238.03 3818 1132 19.07 6,5,4,3 U	93 (237) 637 19.5 6,5,4,3 Np	94 (242) 3235 640 — 6,5,4,3 Pu	95 (243) — — 11.7 6,5,4,3 Am	96 (247) — — — 3 Cm	97 (247) — — — 4,3 Bk	98 (249) — — — 3 Cf	99 (254) — — — — Es	100 (253) — — — — Fm	101 (256) — — — — Md	102 (254) — — — — No	103 (257) — — — — Lw
	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium



NOTES:

(1) Black — solid.
Red — gas.
Blue — liquid.
Outline — synthetically prepared.

(2) Based upon carbon = 12. ( ) indicates most stable or best known isotope.

(3) Values for gaseous elements are for liquids at the boiling point.

With acknowledgement to
[illegible]t-Welch Scientific Co.,