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# UNIVERSITI SAINS MALAYSIA

First Semester Examination  
2015/2016 Academic Session

December 2015 / January 2016

## EBB 113/3 – Engineering Materials [Bahan Kejuruteraan]

Duration : 3 hours  
[Masa : 3 jam]

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Please ensure that this examination paper contains FOURTEEN printed pages and ONE page APPENDIX before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi EMPAT BELAS muka surat dan SATU muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.]*

This paper consists of SEVEN questions. ONE question from PART A, THREE questions from PART B and THREE questions from PART C.

*[Kertas soalan ini mengandungi TUJUH soalan. SATU soalan dari BAHAGIAN A, TIGA soalan dari BAHAGIAN B dan TIGA soalan dari BAHAGIAN C.]*

**Instruction:** Answer FIVE questions. Answer ALL questions from PART A, TWO questions from PART B and TWO questions from PART C. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.

**Arahan:** Jawab LIMA soalan. Jawab SEMUA soalan dari BAHAGIAN A, DUA soalan dari BAHAGIAN B dan DUA soalan dari BAHAGIAN C. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]

The answers to all questions must start on a new page.

*[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]*

You may answer a question either in Bahasa Malaysia or in English.

*[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

In the event of any discrepancies in the examination questions, the English version shall be used.

*[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunakan.]*

PART A / BAHAGIAN A

1. [a] (i) List the main classes of engineering materials.  
*Senaraikan pengkelasan utama bahan kejuruteraan.*
- (10 marks/markah)
- (ii) Give ONE example for each class of materials engineering.  
*Berikan SATU contoh bagi setiap pengkelasan bahan kejuruteraan.*
- (10 marks/markah)
- [b] State any FOUR properties of engineering materials.  
*Nyatakan sebarang EMPAT sifat-sifat bahan kejuruteraan.*
- (20 marks/markah)
- [c] State TWO methods to change the properties of materials.  
*Nyatakan DUA kaedah bagi mengubah sifat-sifat bahan.*
- (10 marks/markah)
- [d] An aluminum specimen having a rectangular cross section 12 mm x 12.9 mm is pulled in tension with 38 200 N force, producing only elastic deformation. Calculate the resulting strain. Given the modulus of elasticity for aluminum 69 GPa.
- Suatu spesimen aluminium mempunyai keratan rentas segi empat tepat berukuran 12 mm x 12.9 mm ditarik secara tegangan dengan daya 38 200 N, menghasilkan hanya ubah bentuk kenyal. Hitung terikan yang terhasil. Di beri modulus kekenyalan untuk aluminium adalah 69 GPa.*
- (15 marks/markah)

[e] Describe TWO properties of each of the material listed below:

- (i) Diamond
- (ii)  $ZrO_2$
- (iii) Graphite
- (iv) Silicon
- (v) Silica glass

*Terangkan DUA sifat untuk setiap bahan yang disenaraikan di bawah:*

- (i) *Intan*
- (ii)  *$ZrO_2$*
- (iii) *Grafit*
- (iv) *Silikon*
- (v) *Kaca silika*

(20 marks/markah)

[f] Sketch portions of a linear poly (vinyl chloride) molecule that are

- (i) syndiotactic
- (ii) atactic
- (iii) isotactic

*Lakarkan bahagian molekul poli (vinil klorida) linear yang*

- (i) *Sindiotaktik*
- (ii) *Ataktik*
- (iii) *Isotaktik*

(15 marks/markah)

**PART B / BAHAGIAN B**

2. [a] Sketch and label Schottky and Frenkel defects.

*Lakar dan label kecacatan-kecacatan Schottky dan Frenkel.*

(30 marks/markah)

- [b] The diffusivity of copper atoms in solid copper metal is  $1.0 \times 10^{-17} \text{ m}^2/\text{s}$  at  $500^\circ\text{C}$  and  $7.0 \times 10^{-13} \text{ m}^2/\text{s}$  at  $800^\circ\text{C}$ . Calculate:

(i) The activation energy (joules per mole) for the diffusion of copper atoms in the temperature range  $500$  to  $800^\circ\text{C}$  and

(ii) Proportionality constant ( $D_0$ )

Use gas constant,  $R = 8.314 \text{ J/mol.k}$

*Resapan atom kuprum di dalam pepejal logam kuprum adalah  $1.0 \times 10^{-17} \text{ m}^2/\text{s}$  pada  $500^\circ\text{C}$  dan  $7.0 \times 10^{-13} \text{ m}^2/\text{s}$  pada  $800^\circ\text{C}$ . Kirakan:*

(i) *Tenaga pengaktifan (joule per mol) bagi resapan atom kuprum pada julat suhu  $500$  ke  $800^\circ\text{C}$  dan*

(ii) *Pekali perkadaran ( $D_0$ )*

*Gunakan pemalar gas,  $R = 8.314 \text{ J/mol.k}$*

(50 marks/markah)

- [c] State 2 (two) reasons why interstitial diffusion is normally more rapid than vacancy diffusion.

*Nyatakan 2 (dua) alasan mengapa resapan antara kekisi pada kebiasaannya lebih pantas berbanding resapan kekosongan.*

(20 marks/markah)

3. In Table 1 solidus and liquidus temperature for the silicon-germanium system are given.

[a] Based on these data, construct the Binary phase diagram for this system and label each region (use the graph paper provided).

*Di dalam Jadual 1, diberikan suhu pepejal dan suhu cecair bagi sistem silikon-germanium.*

*[a] Berdasarkan data-data tersebut, binakan gambarajah fasa bagi sistem Binari ini dan labelkan setiap kawasan (gunakan kertas graf yang disediakan).*

Table 1: The solidus temperature and liquidus temperature for the Si-Ge system

*Jadual 1: Suhu pepejal dan suhu cecair bagi sistem Si-Ge*

Composition ( wt % Si )	Solidus Temperature, °C	Liquidus Temperature, °C
0	938	938
10	1005	1147
20	1065	1226
30	1123	1278
40	1178	1315
50	1232	1346
60	1282	1367
70	1326	1385
80	1359	1397
90	1390	1408
100	1414	1414

(30 marks/markah)

- [b] At 1200°C make a phase analysis for 30 wt % Si - 70 wt % Ge, assuming equilibrium condition. In the phase analysis include the following:

*Pada suhu 1200°C, buat analisis bagi 30 % berat Si - 70 % berat Ge, anggapkan pada keadaan keseimbangan. Dalam analisis fasa tersebut masukkan mengenai berikut:*

- (i) What phases are present?  
*Apakah fasa yang hadir?*  
(10 marks/markah)
- (ii) What is (are) the chemical composition(s) of each phase?  
*Apakah komposisi kimia setiap fasa?*  
(20 marks/markah)
- (iii) What is (are) the weight fraction(s)?  
*Apakah pecahan berat?*  
(20 marks/markah)

- [c] Explain, why below temperature 938°C, Si and Ge are soluble in each other (complete solubility)? (Refer to Appendix 1).

*Jelaskan, kenapa di bawah suhu 938°C, Si dan Ge terlarut antara satu sama lain (keterlarutan lengkap)? (Rujuk Lampiran 1).*

(20 marks/markah)

4. [a] State the groups in the periodic table of these elements by considering their atomic number ( $Z$ ).

- (i) Aluminium ( $Z = 13$ )
- (ii) Calcium ( $Z = 20$ )
- (iii) Germanium ( $Z = 32$ )
- (iv) Krypton ( $Z = 36$ )

*Nyatakan kumpulan dalam jadual berkala unsur-unsur ini dengan mempertimbangkan nombor atom mereka ( $Z$ ).*

- (i) *Aluminium ( $Z = 13$ )*
- (ii) *Kalsium ( $Z = 20$ )*
- (iii) *Germanium ( $Z = 32$ )*
- (iv) *Kripton ( $Z = 36$ )*

(20 marks/markah)

- [b] Derive planar density expressions for BCC (100) and (110) planes in terms of the atomic radius,  $R$ . Calculate the planar density values for these two planes for vanadium (the atomic radius for vanadium is 0.132 nm).

*Terbitkan ungkapan ketumpatan satah untuk satah BCC (100) dan (110) dalam sebutan jejari atom,  $R$ . Kirakan nilai ketumpatan satah untuk kedua-dua satah bagi vanadium (jejari atom untuk vanadium adalah 0.132 nm).*

(30 marks/markah)

- [c] Figure 1 shows the first four peaks of the x-ray diffraction pattern for copper, with the following  $2\theta$  angles: 43.8, 50.8, 74.4 and 90.4. Monochromatic x-ray radiation having a wavelength of 0.154 nm was used.
- (i) Determine the cubic structure of copper.
  - (ii) Provide Index (*i.e.* give  $h$ ,  $k$  and  $l$  indices) for the first TWO peaks of this pattern.
  - (iii) Determine the interplanar spacing for the first TWO peaks of this pattern.
  - (iv) Determine the atomic radius for copper by only considering the first peak of this pattern.

*Rajah 1 menunjukkan empat puncak pertama corak pembelauan sinar-x untuk kuprum, dengan sudut  $2\theta$  berikut: 43.8, 50.8, 74.4 dan 90.4. Radian sinar-x monokromatik yang mempunyai panjang gelombang 0.154 nm telah digunakan.*

- (i) Tentukan struktur kubik bagi kuprum.*
- (ii) Indeks (beri  $h$ ,  $k$  dan  $l$  indeks) bagi DUA puncak pertama corak ini.*
- (iii) Tentukan jarak antara satah bagi DUA puncak pertama corak ini.*
- (iv) Tentukan jejari atom kuprum dengan hanya mempertimbangkan puncak pertama corak ini.*

(50 marks/markah)



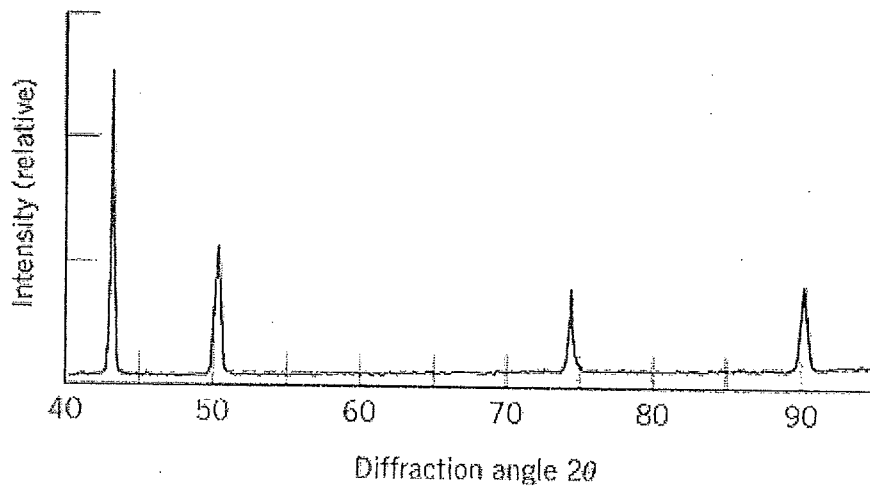


Figure 1- Diffraction pattern for polycrystalline copper

*Rajah 1 - Corak pembelaan bagi kuprum polihablur*

PART C / BAHAGIAN C

5. [a] A large tower is to be supported by a series of steel wires. It is estimated that the load on each wire will be 11 100 N. Determine the minimum required wire diameter, assuming a factor of safety 2 and a yield strength of 1030 MPa.

*Sebuah menara yang besar akan disokong oleh satu siri wayar keluli. Dianggarkan bahawa beban pada setiap wayar adalah sebanyak 11 100 N. Tentukan diameter minimum dawai yang diperlukan, dengan mengandaikan faktor keselamatan 2 dan kekuatan alah 1030 MPa.*

(30 marks/markah)

- [b] (i) Sketch the energy band diagram for aluminum, aluminum oxide and aluminum arsenite. Provide label: metal, ceramic and semiconductor.

*Lakarkan gambarajah jalur tenaga untuk aluminium, aluminium oksida dan aluminium arsenit. Labelkan: logam, seramik dan semikonduktor.*

(15 marks/markah)

- (ii) Cite two characteristics of each of the following materials:
- (a) Glasses
  - (b) Glass-ceramics
  - (c) Refractory ceramics
  - (d) Abrasive ceramics

*Nyatakan dua ciri-ciri setiap bahan berikut:*

- (a) *Kaca*
- (b) *Kaca-seramik*
- (c) *Seramik refraktori*
- (d) *Seramik abrasif*

(15 marks/markah)

...11/-

- [c] Table 2 lists molecular weight data for a polypropylene material. Compute

*Jadual 2 berikut menyenaraikan data berat molekul untuk bahan polipropilena. Kirakan*

- (i) the number-average molecular weight  
*nombor-purata berat molekul*  
(15 marks/markah)
- (ii) the weight-average molecular weight  
*berat-purata berat molekul*  
(15 marks/markah)
- (iii) the degree of polymerization  
*darjah pempolimeran*  
(10 marks/markah)

Table 2

*Jadual 2*

Molecular Weight Range (g/mol)	$x_i$	$w_i$
<i>Julat berat molekul (g/mol)</i>		
8000 - 16000	0.05	0.02
16000 - 24000	0.16	0.10
24000 - 32000	0.24	0.20
32000 - 40000	0.28	0.30
40000 - 48000	0.20	0.27
48000 - 56000	0.07	0.11

6. [a] List four classifications of steels and briefly describe the properties and typical applications for each classification.

*Senaraikan empat klasifikasi keluli dan terangkan secara ringkas sifat-sifat dan aplikasi biasa bagi setiap klasifikasi.*

(30 marks/markah)

- [b] (i) Explain how free electrons can be generated in a doped semiconductor by drawing the energy band diagram.

*Terangkan bagaimana elektron bebas boleh dihasilkan di dalam semikonduktor terdop dengan melakar gambarajah jalur tenaga.*

(15 marks/markah)

- (ii) Cite why heat treatment process in glass: (i) tempering and (ii) annealing are required.

*Nyatakan kenapa proses rawatan haba pada kaca: (i) tampering dan (ii) peyepuhlindungan diperlukan.*

(15 marks/markah)

(iii) Write a short note on ONE of the following topics:

- (a) Stress-strain behavior of ceramics
- (b) Mechanism of plastic deformation in ceramics
- (c) Hardness of ceramic materials

*Tuliskan nota ringkas pada salah SATU daripada topik-topik berikut:*

- (a) *Kelakuan tekanan-tarikan seramik*
- (b) *Mekanisma ubahbentuk plastik seramik*
- (c) *Kekerasan bahan seramik*

(10 marks/markah)

[c] (i) Sketch and label the key components of an extruder for processing of thermoplastic material.

*Lakarkan dan label komponen-komponen utama bagi penyemperit dalam pemprosesan bahan termoplastik.*

(10 marks/markah)

(ii) Discuss briefly the process involved during extrusion.

*Bincangkan secara ringkas proses yang terlibat semasa penyemperitan.*

(20 marks/markah)

7. [a] Briefly describe the 8 forms of corrosion.

*Perihalkan secara ringkas 8 bentuk kakisan.*

(35 marks/markah)

- [b] (i) Silicon is an example of a semiconductor material. Write on the material by stating its important characteristic and applications.

*Silikon adalah contoh bahan semikonduktor. Tuliskan berkenaan bahan dengan menyatakan semua ciri-ciri penting dan aplikasinya.*

(15 marks/markah)

- (ii) Describe the terms firing and glazing in ceramic process.  
*Huraikan istilah pembakaran dan pelicauan di dalam proses seramik.*

(15 marks/markah)

- [c] For a polymer matrix fiber-reinforced composite,  
*Untuk komposit matriks polimer yang diperkukuhkan dengan gentian,*

- (i) List three functions of a matrix phase.  
*Senaraikan tiga fungsi fasa matriks.*

(15 marks/markah)

- (ii) Give two reasons why there must be a strong bond between fiber and matrix at their interface.

*Berikan dua sebab mengapa perlu ada satu ikatan yang kuat di antara gentian dan matriks pada antara mukanya.*

(10 marks/markah)

- (iii) Briefly describe sandwich panels. What is the prime reason for fabricating these structural composites.

*Huraikan secara ringkas panel-panel sandwic. Apakah tujuan utama bagi penghasilan komposit struktur ini?*

(10 marks/markah)

LAMPIRAN 1

## Characteristic of Selected Elements

element	symbol	Z	at. wt.	$\rho$ (g/cm <sup>3</sup> )	structure	$r_{\text{atomic}}$	valence	electronegativity
Aluminum	Al	13	26.98	2.71	FCC	0.143	3+	1.5
Argon	Ar	18	39.95	—	—	—	—	—
Barium	Ba	56	137.33	3.5	BCC	0.217	2+	0.9
Beryllium	Be	4	9.012	1.85	HCP	0.149	3+	1.5
Boron	B	5	10.81	2.34	rhomb.	—	3+	2.0
Bromine	Br	35	79.90	—	—	—	1-	2.8
Cadmium	Cd	48	112.41	8.65	HCP	0.149	2+	1.7
Calcium	Ca	20	40.08	1.55	FCC	0.197	2+	1.0
Carbon	C	6	12.011	2.25	hexag.	0.071	4+	2.5
Cesium	Cs	55	132.91	1.87	BCC	0.265	1+	0.7
Chlorine	Cl	17	35.45	—	—	—	1-	3.0
Chromium	Cr	24	52.00	7.19	BCC	0.125	3+	1.6
Cobalt	Co	27	58.93	8.9	HCP	0.125	2+	1.8
Copper	Cu	29	63.55	8.94	FCC	0.128	1+	1.9
Fluorine	F	9	19.00	—	—	—	1-	4.0
Germanium	Ge	32	72.64	5.32	diamond	0.122	4+	1.8
Hydrogen	H	1	1.008	—	—	—	1+	2.1
Iodine	I	53	126.91	4.93	ortho.	0.136	1-	2.5
Iron	Fe	26	55.85	7.87	BCC	0.124	2+	1.8
Lead	Pb	82	207.2	11.35	FCC	0.175	2+	1.8
Lithium	Li	3	6.94	0.534	BCC	0.152	1+	1.0
Magnesium	Mg	12	24.31	1.74	HCP	0.160	2+	1.2
Manganese	Mn	25	54.94	7.44	cubic	0.112	2+	1.5
Mercury	Hg	80	200.59	—	—	—	2+	1.9
Molybdenum	Mb	42	95.94	10.22	BCC	0.136	4+	1.8
Neon	Ne	10	20.18	—	—	—	—	—
Nickel	Ni	28	58.69	8.90	FCC	0.125	2+	1.8
Nitrogen	N	7	14.007	—	—	—	5+	3.0
Oxygen	O	8	16.00	—	—	—	2-	3.5
Platinum	Pt	78	195.08	21.45	FCC	0.139	2+	2.2
Potassium	K	19	39.10	0.862	BCC	0.231	1+	0.8
Silicon	Si	14	28.09	2.33	diamond	0.118	4+	1.8
Silver	Ag	47	107.87	10.49	FCC	0.144	1+	1.9
Sodium	Na	11	22.99	0.971	BCC	0.186	1+	0.9
Sulfur	S	16	32.06	2.07	ortho.	0.106	2-	2.5
Tin	Sn	50	118.69	7.3	tetra.	0.151	4+	1.8
Titanium	Ti	22	47.88	4.51	HCP	0.145	4+	1.5
Tungsten	W	74	183.85	19.3	BCC	0.137	4+	1.7
Vanadium	V	23	50.94	6.1	BCC	0.132	5+	1.6
Zinc	Zn	30	65.39	7.13	HCP	0.133	2+	1.6
Zirconium	Zr	40	91.22	6.51	HCP	0.159	4+	1.4