UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2011/2012

January 2012

EBB 113/3 – Engineering Materials
[Bahan Kejuruteraan]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains FIFTEEN printed pages and ONE page APPENDIX before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi LIMA BELAS muka surat beserta SATU muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. ONE question in PART A, THREE questions in PART B and THREE questions in PART C.
[Kertas soalan ini mengandungi TUJUH soalan. SATU soalan di BAHAGIAN A, TIGA soalan di BAHAGIAN B dan TIGA soalan di BAHAGIAN C.]

Instruction: Answer **FIVE** questions. Answer **ALL** question from PART A, **TWO** questions from PART B and **TWO** questions from PART C. If 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, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

…2/-

PART A / *BAHAGIAN A*

1. [a] (i) Define a composite material. Give an example of a composite material.

Takrifkan bahan komposit. Berikan contoh bahan komposit.

(3 marks/*markah*)

(ii) Describe three characteristics of dislocations.

Terangkan tiga ciri kehelan.

(1.5 marks/*markah*)

(iii) List three factors that affect diffusion process.

Senaraikan 3 faktor yang mempengaruhi proses resapan.

(1.5 marks/*markah*)

[b] (i) Show that the minimum cation-to anion radius ratio for a coordination number of 4 is 0.225.

Tunjukkan bahawa nisbah jejari minimum kation kepada anion untuk nombor kordinasi 4 ialah 0.225.

(3 marks/*markah*)

(ii) A force of 100,000 N is applied to a 10 mm x 20 mm steel bar having yield strength of 400 MPa and a tensile strength of 480 MPa. Determine whether the bar will plastically deform and whether the bar will experience necking.

Daya seberat 100,000 N dikenakan terhadap bar keluli yang mempunyai kekuatan alah 400 MPa dan kekuatan tegangan 480 MPa. Tentukan samada bar ini mengalami ubahbentuk plastik dan peleheran.

(3 marks/*markah*)

[c] (i) Give a specific polymeric material that is used for food and drink packaging. List three properties for polymeric materials that are used in the packaging of food and drinks products.

Namakan secara khusus bahan polimer yang digunakan dalam pembungkusan makanan dan minuman. Senaraikan tiga ciri bahan polimer yang digunakan dalam pembungkusan makanan dan minuman.

(4 marks/*markah*)

(ii) Define the following terms as they pertain to semiconducting materials: intrinsic and extrinsic.

Berikan definisi terma-terma berikut yang mempunyai kaitan dengan bahan semikonduktor: intrinsik dan ekstrinsik.

(4 marks/*markah*)

PART B / *BAHAGIAN B*

2. [a] Based on Figure 1, determine the phases presence and the composition of each phase for NiO-30 mol% MgO and NiO-45 mol% MgO at 2400°C. Describe a composition that can melt at 2600°C but will not melt when is placed into service at 2300°C. Give 1 (one) industrial application from this NiO-MgO phase diagram.

Dengan menggunakan Rajah 1, tentukan fasa yang hadir serta komposisi setiap fasa untuk NiO-30 mol% MgO dan NiO-45 mol% MgO pada suhu 2400°C. Perihalkan komposisi yang akan melebur pada 2600°C tetapi tidak apabila diletakkan pada 2300°C. Berikan satu aplikasi di dalam industri daripada gambarajah fasa NiO-MgO ini.

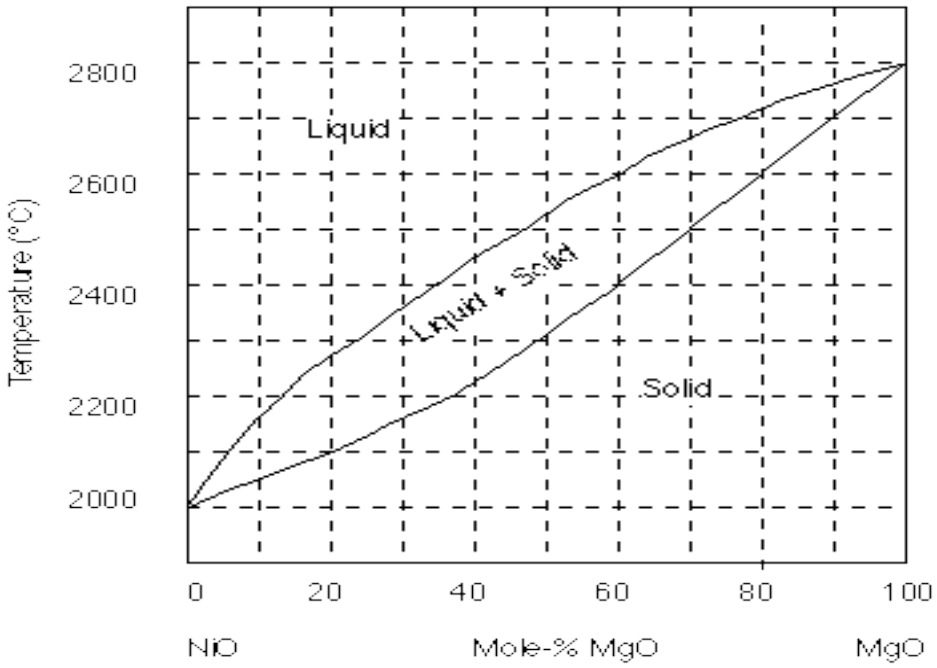


Figure 1 - Phase diagram NiO-MgO

Rajah 1 - Gambarajah fasa Nio-MgO

(7 marks/*markah*)

[b] Boron has a much lower coefficient of thermal expansion than aluminum, even though both are in the 3A column of the periodic table. Explain, based on binding energy, atomic size, and the energy well, why this difference is expected.

Boron mempunyai pekali pengembangan terma lebih rendah berbanding aluminium walaupun kedua-duanya berada di dalam kumpulan 3A pada jadual berkala. Terangkan, berdasarkan tenaga ikatan, saiz atom dan telaga tenaga, mengapa perbezaan ini wujud seperti yang dijangkakan.

	Boron	Aluminium
Atomic number *Nombor atom*	5	13
Radius (nm) *Jejari (nm)*	4.6	14.32

(6 marks/*markah*)

[c] (i) Calculate the number of kilograms of hydrogen that pass per hour through a 6-mm-thick sheet of palladium having an area of 0.25 m^2 at 600^oC. Assume a diffusion coefficient of 1.7 x 10^{-8} m^2/s, that the concentration at the high- low-pressure sides of the plate are 2.0 and 0.4 kg of hydrogen per cubic meter of palladium and that **steady-state** conditions have been attained.

Hitungkan berapa kilogram hidrogen yang meresapi kepingan palladium berketebalan 6-mm dan mempunyai luas 0.25 m^2 pada 600^oC selama sejam. Andaikan pemalar resapan 1.7 x 10^{-8} m^2/s, dan kepekatan hidrogen 2.0 dan 0.4 kg per meter padu di sebelah tekanan tinggi dan rendah masing-masing serta keadaan mantap dicapai.

(5 marks/*markah*)

(ii) Then cite 2 reasons why interstitial diffusion is normally more rapid than vacancy diffusion.

Seterusnya, namakan 2 sebab mengapa resapan celahan berlaku lebih cepat daripada resapan kekosongan.

(2 marks/*markah*)

3. [a] With an appropriate sketch, describe briefly the typical engineering stress-strain curve for metallic, polymeric and ceramic materials. From this curve, how to determine the toughness properties?

Dengan lakaran yang sesuai, perihalkan secara ringkas keluk tipikal tegasan-terikan kejuruteraan bagi bahan logam, polimer dan seramik. Daripada keluk ini, bagaimanakah sifat keliatan bahan dapat ditentukan?

(6 marks/*markah*)

[b]

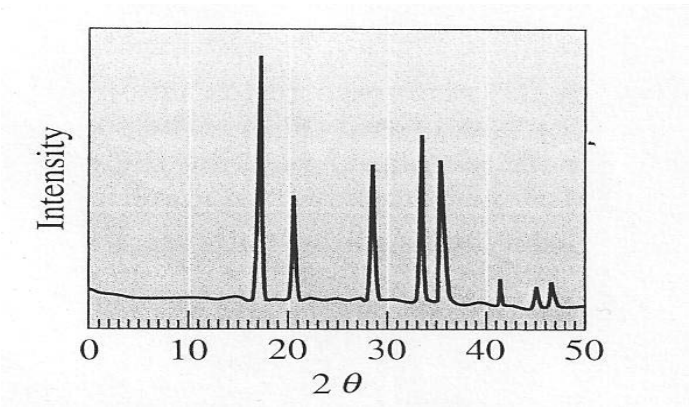


Figure 2 - X-ray pattern
Rajah 2 - Corak X-ray

Figure 2 shows the result of an X-ray diffraction experiment in the form of the intensity of the diffracted peak versus the 2θ diffraction angle. If X-ray with a wave length of 0.15418 nm is used, determine:

Rajah 2 menunjukkan keputusan eksperimen pembelauan sinar-X di dalam bentuk keamatan puncak belauan melawan sudut belauan 2θ. Jika panjang gelombang X-ray yang digunakan adalah 0.15418 nm, tentukan:

…7/-

(i) The crystal structure of the metal

Struktur hablur logam tersebut

(2 marks/*markah*)

(ii) The indices (h, k, l) of the planes of the first peak

Indisis (h, k, l) satah untuk puncak pertama

(2 marks/*markah*)

(iii) The lattice parameter of the metal

Parameter kekisi logam tersebut

(3 marks/*markah*)

[c] (i) Describe both vacancy and self-interstitial crystalline defects with two characteristics for each defect.

Terangkan kedua-dua kecacatan hablur kekosongan dan celahan sesendirian dengan dua ciri bagi setiap satunya.

(2 marks/*markah*)

(ii) Calculate the number of vacancies per cubic meter in gold at 900^{o}C. The energy for vacancy formation is 0.98 eV/atom. Furthermore, the density and atomic weight for Au are 18.63 g/cm^{3} (at 900^{o}C) and 196.9 g/mol, respectively. (Boltzman constant = 8.62 × 10^{-5} eV/atom−K)

Kirakan bilangan kekosongan per meter padu dalam emas pada 900^{o}C. Tenaga untuk pembentukan kekosongan ialah 0.98 eV/atom. Ketumpatan dan keberatan atom bagi Au adalah 18.63 g/cm^{3} (pada 900^{o}C) dan 196.9 g/mol, masing-masing. (Pemalar Boltzman = 8.62 × 10^{-5} eV/atom−K)

(5 marks/*markah*)

4. [a] With an example, briefly describe

(i) phase in material

(ii) phase diagram

Dengan memberikan contoh, perihalkan secara ringkas

(i) fasa di dalam bahan

(ii) gambarajah fasa

(6 marks/*markah*)

[b] (i) For each of the following compounds, state whether the bonding is essentially metallic, covalent or ionic. (Use Figure 3 to find electronegativities of each elements)

Bagi setiap kompaun berikut, nyatakan samada ikatan yang terbabit adalah ikatan logam, kovalen atau ionik. (Guna Rajah 3 bagi mendapatkan nilai elektronegatif bagi setiap elemen)

(a) Ni

(b) ZrO_2

(c) BN

(ii) Draw direction vector in unit cubic for the following cubic direction:

Lukiskan vektor arah dalam unit kubik bagi arahan kubik berikut:

(a) [221]

(b) $[\bar{1}12]$

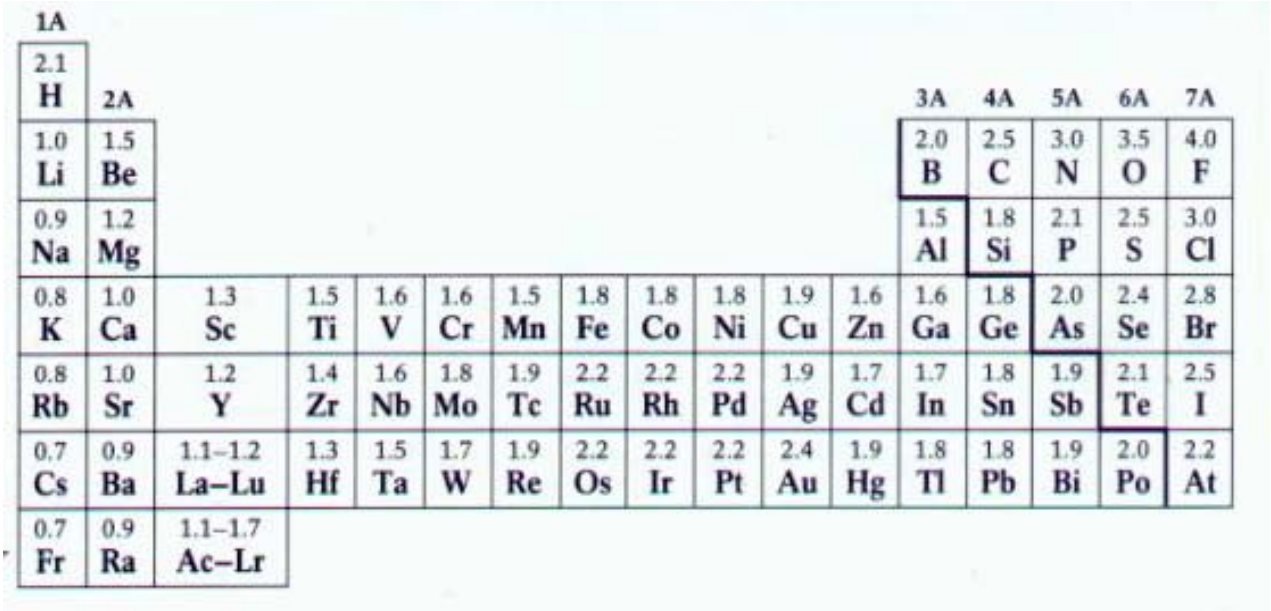
(iii) Draw in unit cubes the crystal planes which have the following Miller indices:

Lukiskan satah hablur dalam unit kubik mengikut indisis Miller:

(a) $[11\bar{1}]$

(b) $[10\bar{1}]$

(7 marks/*markah*)



1A												3A	4A	5A	6A	7A
2.1 H	2A															
1.0 Li	1.5 Be											2.0 B	2.5 C	3.0 N	3.5 O	4.0 F
0.9 Na	1.2 Mg											1.5 Al	1.8 Si	2.1 P	2.5 S	3.0 Cl
0.8 K	1.0 Ca	1.3 Sc	1.5 Ti	1.6 V	1.6 Cr	1.5 Mn	1.8 Fe	1.8 Co	1.8 Ni	1.9 Cu	1.6 Zn	1.6 Ga	1.8 Ge	2.0 As	2.4 Se	2.8 Br
0.8 Rb	1.0 Sr	1.2 Y	1.4 Zr	1.6 Nb	1.8 Mo	1.9 Tc	2.2 Ru	2.2 Rh	2.2 Pd	1.9 Ag	1.7 Cd	1.7 In	1.8 Sn	1.9 Sb	2.1 Te	2.5 I
0.7 Cs	0.9 Ba	1.1–1.2 La–Lu	1.3 Hf	1.5 Ta	1.7 W	1.9 Re	2.2 Os	2.2 Ir	2.2 Pt	2.4 Au	1.9 Hg	1.8 Tl	1.8 Pb	1.9 Bi	2.0 Po	2.2 At
0.7 Fr	0.9 Ra	1.1–1.7 Ac–Lr														

Figure 3 - Electronegativities of the Elements

Rajah 3 - Nilai elektronegatif bagi elemen dalam jadual berkala

[c] (i) Describe four characteristics of grain boundaries.

Terangkan 4 ciri sempadan butiran.

(2 marks/*markah*)

(ii) Define solid solution.

Takrifkan larutan pepejal.

(1 marks/*markah*)

(iii) For an alloy that consists of 37.7 wt% Pb and 62.3 wt% Sn, what is the composition (a) of Pb (in at%), and (b) of Sn (in at%)? The atomic weights for Pb and Sn are 207.2 and 118.7 g/mol, respectively.

Bagi sesuatu aloi yang mengandungi 37.7 wt% Pb dan 62.3 wt% Sn, apakah komposisi (a) Pb (dalam at%) dan (b) Sn (dalam at%)? Berat atom bagi Pb dan Sn diberi sebagai masing-masing 207.2 dan 118.7 g/mol.

(4 marks/*markah*)

PART C / *BAHAGIAN C*

5. [a] Choose appropriate materials for each of the following applications, and if necessary, state the corrosion prevention measures that should be taken. Explain your suggestions.

(i) Laboratory bottles to contain relatively dilute solution of nitric acid

(ii) Barrels to contain benzene

(iii) Pipe to transport hot alkaline (basic) solution

(iv) Underground tank to store large quantity of high purity water

(v) Architectural trim for high rise building

Pilih bahan yang sesuai untuk setiap aplikasi yang berikut, jika perlu berikan langkah-langkah pencegahan kakisan yang perlu diambil. Terangkan cadangan anda.

(i) Botol makmal yang mengandungi asid nitrik yang agak cair

(ii) Tong yang mengandungi benzene

(iii) Paip yang menyalurkan larutan alkali panas

(iv) Tangki bawah tanah yang menyimpan air yang amat bersih dengan kuantiti besar

(v) Trim seni bina untuk membina bangunan tinggi

(7 marks/*markah*)

[b] (i) Give five factors that affect the strength of a thermoplastic.

Senaraikan lima faktor yang mempengaruhi kekuatan termoplastik.

(5 marks/*markah*)

(ii) A high-molecular-weight polyethylene has an average molecular weight of 350,000 g/mol. What is its average degree of polymerization?

Polietilena mempunyai purata berat molekul yang tinggi iaitu 350,000 g/mol. Apakah purata darjah pempolimeran polietilena ini?

(2 marks/*markah*)

[c] Name the microstructural products of eutectoid iron–carbon alloy (0.76 wt% C) specimens that are first completely transformed to austenite, then cooled to room temperature at the following rates: (i) 1°C/s, (ii) 20°C/s, (iii) 50°C/s, and (iv) 175°C/s. (Please refer to Figure 5 [c] in the Appendix)

Namakan mikro struktur yang terhasil dari spesimen eutektoid aloi besi-karbon (0.76 wt% C) yang sepenuhnya bertukar kepada Austenite, kemudian disejukkan ke suhu bilik dengan kadar berikut: (i) 1°C/s, (ii) 20°C/s, (iii) 50°C/s, and (iv) 175°C/s. (Sila rujuk Rajah 5 [c] dalam Lampiran)

(6 marks/*markah*)

6. [a] (i) Explain how the thickness of glassware affects the magnitude of the thermal stresses that may be introduced?

Terangkan bagaimana ketebalan kaca mempengaruhi magnitud tegasan haba yang dikenakan?

(ii) Explain why a clay, once have been fired at an elevated temperature, loses its hydroplasticity.

Terangkan mengapa tanah liat, apabila telah dibakar pada suhu yang tinggi, akan kehilangan sifat hidroplastik.

(6 marks/*markah*)

[b] (i) Write the reaction for the polymerization of two phenol molecules with one of formaldehyde to produce a phenol formaldehyde molecule.

Tuliskan tindakbalas bagi pempolimeran dua molekul fenol dengan satu molekul formaldehyde untuk menghasilkan satu molekul fenol formaldehyde.

(a) (b)

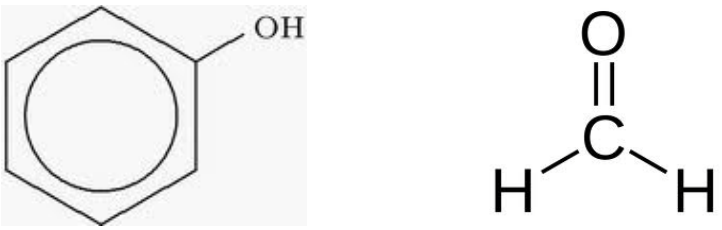


Figure 4 - (a) phenol and (b) formaldehyde

Rajah 4 - (a) Fenol dan (b) formaldehyde

(3 marks/*markah*)

(ii) What type of by-product is produced by this reaction?

Apakah hasil sampingan yang dihasilkan oleh tindakbalas ini?

(2 marks/*markah*)

(iii) What is the name of this polymerization?

Apakah nama untuk jenis pempolimeran ini?

(2 marks/*markah*)

[c] The following electrical characteristics have been determined for both intrinsic and *p*-type extrinsic gallium antimonide (GaSb) at room temperature below. Calculate electron and hole mobilities.

Ciri-ciri elektrikal yang berikut ini telah ditentukan untuk semikonduktor intrinsik dan jenis-p bagi Gallium Antimonide (GaSb) pada suhu bilik. Kirakan mobiliti elektron dan lohong.

	$\sigma\ (\Omega\text{-}m)^{-1}$	$n\ (m^{-3})$	$p\ (m^{-3})$
Intrinsic	8.9×10^{4}	8.7×10^{23}	8.7×10^{23}
Extrinsic (p-type)	2.3×10^{5}	7.6×10^{22}	1.0×10^{25}

(7 marks/*markah*)

7. [a] For a polymer matrix fiber-reinforced composite,

(i) List three function of a matrix phase.

(ii) Compare the desired mechanical characteristics of matrix and fiber phases.

(iii) Cite two reasons why there must be a strong bond between fiber and matrix at their interface.

Untuk komposit matriks polimer yang diperkukuhkan dengan gentian,

(i) Senaraikan tiga fungsi fasa matriks

(ii) Bandingkan ciri-ciri mekanik yang dikehendaki pada fasa matriks dan gentian.

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

(6 marks/*markah*)

[b] Determine the critical crack length (mm) for a through crack in a thick 2024-T6 alloy plate which has a fracture toughness K_{IC} = 24.2 MPa $m^{-1/2}$ and which is under a stress of 350 MPa. Assume Y = 1.

Tentukan panjang retakan kritikal (mm) bagi satu retakan dalaman pada kepingan alloy 2024-T6 yang mempunyai keliatan patah K_{IC} = 24.2 MPa $m^{-1/2}$ dan dikenakan tegasan 350 MPa. Anggapkan Y = 1.

(7 marks/*markah*)

[c] In your own words describe the following heat treatment procedures for steels and, for each, the intended final microstructure: full annealing, normalizing and quenching, using the figure provided below (Figure 5):

Dengan menggunakan perkataan anda sendiri, terangkan prosedur rawatan haba untuk keluli, dan strukturnya yang dikehendaki: penyepuhlindapan penuh, penormalan dan pelindapkejutan. Gunakan gambarajah yang disediakan dibawah (Rajah 5):

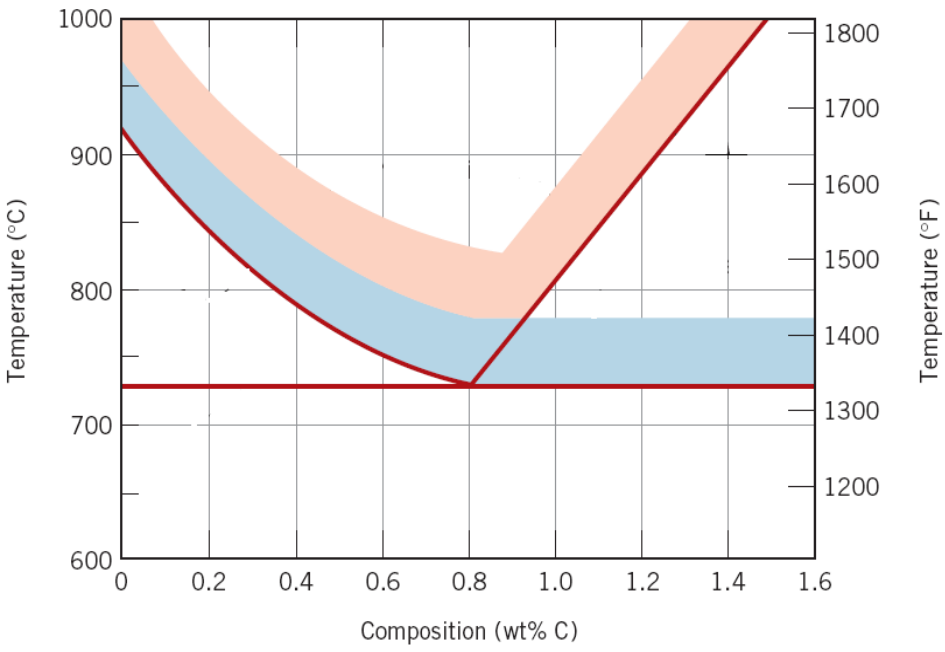


Figure 5: The iron–iron carbide phase diagram in the vicinity of the eutectoid, indicating heat-treating temperature ranges for plain carbon steels. (Adapted from G. Krauss, Steels: Heat Treatment and Processing Principles, ASM International, 1990, page 108)

(7 marks/*markah*)

- oooOooo -

APPENDIX

LAMPIRAN

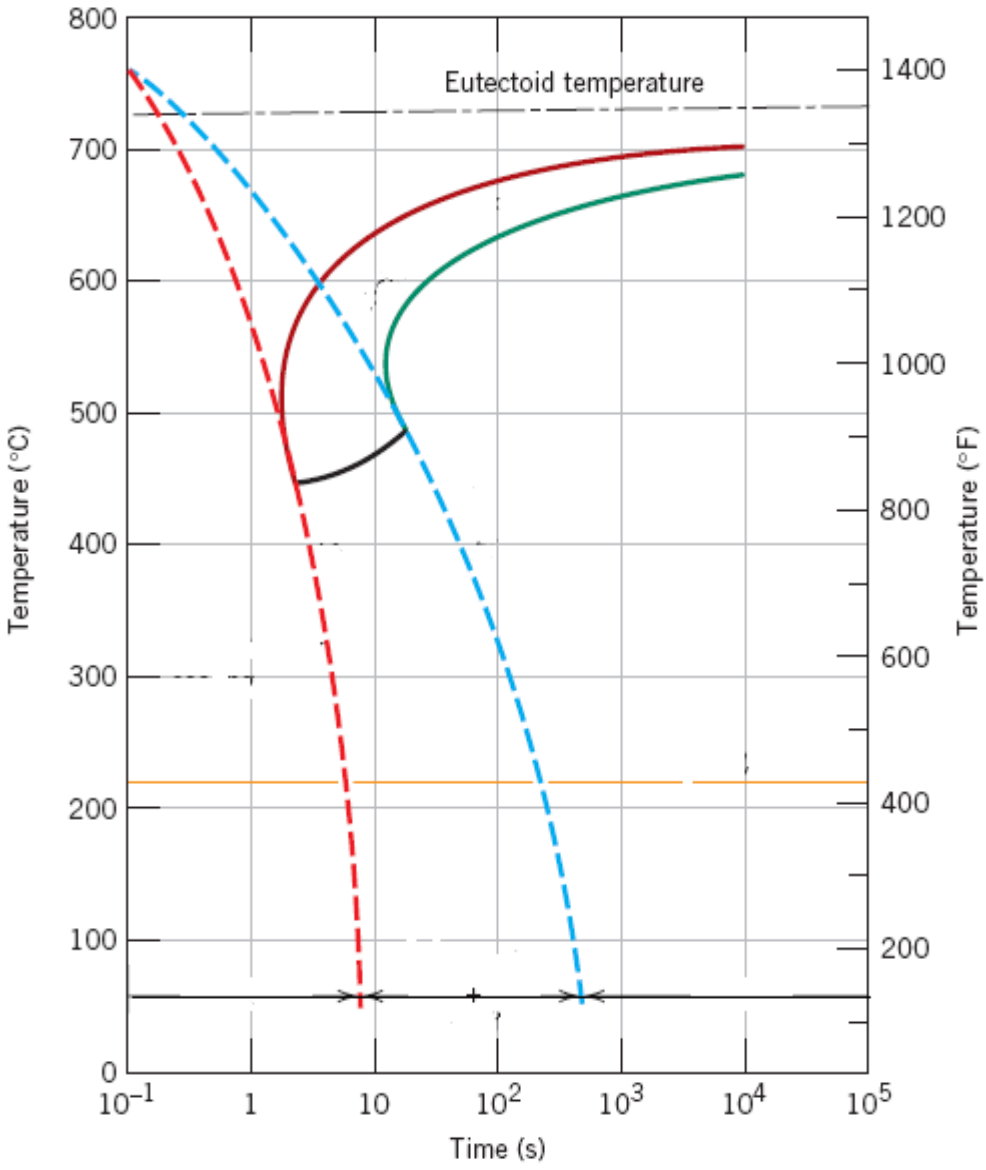


Figure 5c - Continuous cooling transformation diagram for a eutectoid iron–carbon alloy and the dependence of the final microstructure on the transformations that occur during cooling. Blue line = 35°C/s while red line= 140°C/s