UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2011/2012

Januari 2012

EBP 306/3 – Properties of Polymer Materials Engineering
[Sifat-sifat Kejuruteraan Bahan Polimer]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains NINE printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of THREE questions from PART A and FOUR questions from PART B.
[Kertas soalan ini mengandungi TIGA soalan dari BAHAGIAN A dan EMPAT soalan dari BAHAGIAN B.]

Instruction: Answer **ALL** questions from PART A and **TWO** questions from PART B. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **SEMUA** soalan dari BAHAGIAN A dan **DUA** soalan dari BAHAGIAN B. 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.]

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PART A:

BAHAGIAN A:

1. An amorphous polymer in a stress relaxation experiment behaves like a Maxwell element.

   Polimer amorfus bagi ujian pengenduran tegasan mempamerkan sifat seperti bahan Maxwell.

   [a] Sketch and determine the response of stress as a function of time for that polymer.

   Lakarkan dan tentukan reaksi tegasan sebagai fungsi masa bagi polimer tersebut.

   (40 marks/*markah*)

   [b] A stress relaxation test experiment was performed at room temperature on polymer using a universal tensile testing machine. The specimen was held with 50 mm between the clamps. In the test, the specimen was rapidly stretched to 60 mm, kept there and the relaxation process was recorded. Calculate the time at which the initial stress dropped by 50%. It can be assume that the relaxation time of the material is 300 days and the short-term (instantaneous) modulus of the polymer is 3 MNm^{-2}. The T_g of the polymer is below the room temperature.

   Suatu ujian pengenduran tegasan dilakukan pada suhu bilik ke atas polimer menggunakan mesin ujian tegangan universal. Sampel dipegang pada jarak 50 mm di antara pengapit. Semasa ujian sampel diregangkan serta merta ke 60 mm, dikekalkan dan proses pengenduran direkodkan. Kirakan masa di mana tegasan awal merosot sebanyak 50%. Dianggapkan masa pengenduran adalah 300 hari dan modulus jangka pendek (seketika) adalah 3 MNm^{-2}. Suhu peralihan kaca bagi polimer tersebut adalah di bawah suhu bilik.

   (50 marks/*markah*)

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[c] Calculate the relaxation modulus for the polymer.

Kirakan modulus pengenduran bagi polimer tersebut.

(10 marks/*markah*)

2. A notched rectangular bar of polyamide 6 with a thickness and width of 8 mm and 20 mm respectively, were subjected to three point bending test at 20ºC. For this geometry, with *S/W* = 4, *Y* is given by:

Satu kepingan poliamida 6 yang bertakuk dengan ketebalan dan lebar masing-masing 8 mm dan 20 mm, telah dikenakan ujian pembengkokan 3 titik pada 20^0C. Untuk geometri tersebut, dengan S/W = 4, Y diberikan oleh:

$$Y= 1.09 – 1.73(a/W) + 8.20(a/W)^2 - 14.17(a/W)^3 + 14.55(a/W)^4$$

[a] Calculate the values of fracture energy and fracture toughness under both plane strain and plane stress conditions when the notch depth is 10 mm.

Tentukan nilai tenaga rekahan dan keliatan rekahan di bawah keadaan terikan dan tegasan satah apabila panjang retak adalah 10 mm.

(40 marks/*markah*)

[b] Explain why values of fracture parameters obtained under plane strain are of more relevant in designing polymeric products against failure?

Jelaskan kenapakah parameter rekahan yang diperolehi di bawah keadaan terikan satah adalah lebih relevan dalam merekabentuk produk polimer terhadap kegagalan?

(30 marks/*markah*)

[c] If the test is repeated using a compact tension specimen with a notch depth, thickness and width of 25 mm, 10 mm and 50 mm, respectively, calculate the applied force needed to fracture the specimen under plane strain conditions.

Jika ujian tersebut diulang menggunakan spesimen tegangan padat dengan masing-masing panjang retak, ketebalan dan kelebaran 25 mm, 10 mm dan 50 mm, tentukan daya gunaan yang diperlukan untuk menggagalkan spesimen di bawah keadaan terikan satah.

(30 marks/*markah*)

Given / *Diberi*:

Shear Modulus / *Modulus ricih*	= 1.14 GPa
Compression yield stress / *Tegasan satah mampatan*	= 88 MPa
Poisson's ratio / *Nisbah Poisson*	= 0.42
Material's constant / *Pemalar bahan*	= 0.05

State clearly any assumption made in your calculation.

Nyatakan dengan jelas sebarang anggapan yang dibuat dalam pengiraan anda.

3. [a] Explain how the long chain nature of the molecules in rubber increase the characteristic elastic properties of the material.

Terangkan bagaimana rantaian panjang semulajadi molekul di dalam getah dapat meningkatkan pencirian sifat-sifat keelastikan sesuatu bahan.

(60 marks/*markah*)

[b] What is the effect of strain induced crystallization in rubber on its:

(i) stress strain curve and

(ii) tear properties

Apakan kesan penghabluran teraruh terikan dalam getah ke atas:

(i) lengkungan tegasan-terikan dan

(ii) sifat-sifat pencabikan

(20 marks/*markah*)

[c] The natural rubber band has a much higher tear resistance than a similar band made from SBR gum. Explain in molecular terms why this is so.

Gegelang getah asli mempunyai ketahanan pencabikan yang lebih tinggi daripada gegelang yang sama yang diperbuat daripada gam SBR. Jelaskan dari segi molekul bagaimana keadaan ini berlaku.

(20 marks/*markah*)

PART B:

***BAHAGIAN B*:**

4. [a] What is the Boltzmann superposition principal? Derive the expression for creep compliance for a polymer that follows the Boltzmann superposition principal.

Apakah prinsip superposisi Boltzmann? Terbitkan ungkapan bagi komplians krip bagi polimer yang mematuhi prinsip superposisi Boltzmann.

(40 marks/*markah*)

[b] The creep compliance of a thermoplastic at 25°C is described by:

Komplians krip bagi suatu termoplastik pada 25°C adalah:

$$J_{c25}(t) = 1.2 \times 10^{-3} t^{0.10} \qquad (m^2/N \text{ with } t \text{ in } s)$$

The thermoplastic is subjected to the following stress history at 25°C:

Termoplasik tersebut dikenakan sejarah tegasan seperti berikut pada 25°C:

Stress / *Tegasan* (m^2/N)	**Duration / *Masa***
1000	1000
1500	1000
Unloaded	

Calculate the total strain at 2500 s.

Kirakan jumlah terikan pada 2500 s.

(30 marks/*markah*)

[c] A viscoelastic polymer that follows the Boltzmann superposition principal had the following loading history. At t = 0, a stress of 10 MNm^{-2} was applied for 100 s. The stress then was removed immediately. Given J_o = 2 $m^2 GN^{-1}$, τ_o = 200s and $J(t) = J_o(1-\exp(-t/\tau_o))$. Calculate the total strain after 100 and 200 s.

Suatu polimer viskoelastik yang mematuhi prinsip superposisi Boltzmann mengalami sejarah tegasan yang berikut. Pada t = 0, tegasan 10 MNm^{-2} dikenakan selama 100 s. Tegasan tersebut kemudiannya dialihkan serta-merta. Diberi J_o = 2 $m^2 GN^{-1}$, τ_o = 200s dan $J(t) = J_o(1-\exp(-t/\tau_o))$. Kirakan jumlah terikan selepas 100 dan 200 s.

(30 marks/*markah*)

5. [a] A sample of natural rubber containing 8 x 10^{20} chains between cross-links is extended uniaxially at 50°C until its length is double the initial length. Calculate the heat gained or lost. Assume a Gaussion network and $\langle r^2 \rangle_i = \langle r^2 \rangle_o$.

Given; the transverse extension ratios (which must be equal) are

$$\gamma_x = \gamma_y = 1/\gamma_z^{1/2}$$

γ_z = 2 and Boltzmann's constant = 1.38 x 10^{-23} J/K

Satu sampel poliisoprena mengandungi 8 x 10^{20} rantaian di antara tersambung silang yang telah dipanjangkan secara unipaksi pada 50°C sehingga panjangnya telah berubah menjadi dua kali ganda daripada panjang asal. Kirakan haba yang terkumpul ataupun hilang. Anggarkan rangkaian Gaussion dan $\langle r^2 \rangle_i = \langle r^2 \rangle_o$.

Diberikan; ratio pemanjangan melintang (yang semestinya sama) adalah:

$$\gamma_x = \gamma_y = 1/\gamma_z^{1/2}$$

γ_z = 2 dan pemalar Boltzmann's = 1.38 x 10^{-23} J/K

(75 marks/*markah*)

[b] The specimen of Question 8(a) is of initial length L_i = 0.05m. What is the force required to double its length?

Sampel di dalam Soalan 8(a) mempunyai panjang asal L_i = 0.05m. Berapakah kekuatan yang diperlukan untuk menggandakan panjangnya?

(25 marks/*markah*)

6. [a] Write short notes on TWO of the following topics:

(i) The application of linear elastic fracture mechanic theory in characterizing the impact behaviour of polymers.

(ii) Fatigue behavior of polymers.

(iii) Crazing phenomena in polymers.

Tulis nota ringkas tentang DUA daripada topik berikut:

(i) Penggunaan teori mekanik kenyal linear dalam mencirikan sifat hentaman polimer.

(ii) Kelakuan fatig polimer.

(iii) Fenomena retak halus dalam polimer.

(60 marks/*markah*)

[b] What is the main contribution of the theory proposed by Griffith and Inglis in understanding the fracture property of materials? What is the modification needed in order for the theory to predict the fracture behaviour of polymers accurately.

Apakah sumbangan utama teori yang dikemukakan oleh Griffith dan Inglis dalam memahami sifat rekahan bahan? Apakah pengubahsuaian yang perlu dilakukan untuk membolehkan teori tersebut memberikan ramalan yang lebih tepat terhadap sifat rekahan polimer?

(40 marks/*markah*)

7. [a] A fixed length of flexible tubing was subjected to a burst test at 20°C. The tubing was pressurized to 50 psi (0.34 MNm^{-2}). The test was conducted on a large number of samples. The average burst time for the tubing was 40 h. To what common laboratory test viscoelasticity does this test most closely correspond? Estimate the average life of the same tubing in the same test at 30°C. The tubing was made of a linear, amorphous polymer with T_g=-10°C.

Suatu tiub pada panjang tertentu dikenakan ujian pecah pada 20°C. Tiub tersebut dikenakan tekanan sebanyak 50 psi (0.34 MNm^{-2}). Ujian ini dilakukan ke atas bilangan sampel yang banyak. Apakah ujian makmal viskoelastik yang mirip kepada ujian tersebut? Anggarkan purata hayat tiub tersebut apabila ujian yang sama dilakukan pada 30°C. Tiub diperbuat dari polimer amorfus yang linear dengan T_g = -10°C.

(30 marks/*markah*)

[b] By referring to suitable examples, describe the microstructure-processing-property relationships of polymers.

Dengan merujuk kepada beberapa contoh yang sesuai, jelaskan hubungkait mikrostruktur-pemprosesan-sifat bagi polimer.

(40 marks/*markah*)

[c] Knowledge regarding network imperfections are important because it can effect the elasticity of the elastomer. Critically comment on three different types of 'network defects'.

Pengetahuan berkenaan dengan ketidaksempurnaan jaringan amat penting kerana ia boleh menentukan keelastikan sesuatu elastomer. Berikan kritikal komen terhadap tiga jenis kecacatan jaringan yang berbeza.

(30 marks/*markah*)

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