UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2012/2013

January 2013

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 TEN printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. THREE questions in PART A and FOUR questions in PART B.
[Kertas soalan ini mengandungi TUJUH soalan. TIGA soalan di BAHAGIAN A dan EMPAT soalan di BAHAGIAN B.]

Instruction: Answer **FIVE** questions. Answer **ALL** questions from PART A and **TWO** questions from PART B. 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 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. In your opinion which model is the best to describe the response of a viscoelastic material in a stress relaxation test, Maxwell or Voight-Kelvin model? Compare these 2 models and provide justifications for your chosen model.

Pada pendapat anda model manakah yang terbaik bagi menerangkan kelakuan suatu bahan likat-kenyal semasa ujian pengenduran tegasan, model Maxwell atau model Voight-Kelvin? Bandingkan kedua-dua model ini dan beri justifikasi bagi model pilihan anda.

(100 marks/*markah*)

2. Table 1 below shows the data obtained from an instrumented impact test conducted on acrylonitrile-butadiene-styrene (ABS) at 20^{o}C.

Jadual 1 menunjukkan data yang diperolehi daripada ujian hentaman terinstrumentasi ke atas akrilonitril-butadiena-stirena (ABS) pada 20^{o}C.

Table 1: Fracture energy of ABS obtained from impact test
Jadual 1: Tenaga rekahan ABS yang di perolehi daripada ujian hentaman

Sample	Fracture energy (mJ)	Notch length (mm)	φ
1	39.5	2.90	0.380
2	74.1	2.37	0.505
3	77.7	1.85	0.785
4	92.3	1.59	1.675
5	326.0	0.52	2.305

(i) Explain why the data obtained from an instrumented impact test is more reliable than those from the conventional impact test?

Jelaskan kenapa data yang diperolehi daripada ujian hentaman terinstrumentasi adalah lebih tepat berbanding data dari ujian hentaman konvensional?

(15 marks/*markah*)

(ii) Calculate the values of fracture toughness under both plane strain and plane stress conditions.

Tentukan nilai keliatan rekahan di bawah keadaan terikan satah dan tegasan satah.

(35 marks/*markah*)

(iii) What would you expect to happen to the mode of failures and the fracture toughness if the impact test is conducted at -60^{o}C. Explain why ABS able to retain its toughness even at sub-ambient temperature.

Apakah yang anda jangka berlaku kepada mod kegagalan dan keliatan rekahan jika ujian hentaman dijalankan pada -60^{o}C. Jelaskan kenapa ABS masih mampu mempertahankan keliatan walaupun pada suhu sub-ambien.

(20 marks/*markah*)

(iv) The fracture toughness values dropped by 20% when the experiment was repeated at -60^{o}C. Proof quantitatively that the plastic zone effect is affected by the changes in the testing temperature.

Keliatan rekahan merosot pada 20% apabila eksperimen diulangi pada suhu -60^{o}C. Buktikan secara kuantitatif bahawa kesan zon plastik dipengaruhi oleh perubahan suhu ujian.

(30 marks/*markah*)

State clearly any assumption made in your calculation.

Nyatakan dengan jelas sebarang anggapan yang dibuat dalam pengiraan anda

Given / *Diberi*:

Length of sample / *Panjang sampel*	= 90 mm
Width of sample / *Lebar sampel*	= 6 mm
Thickness of sample / *Tebal sampel*	= 6 mm
Span length / *Panjang span*	= 72 mm
Shear modulus at 20^{o}C / *Modulus ricih pada 20^{o}C*	= 1.14 GPa
Shear modulus at -60^{o}C / *Modulus ricih pada -60^{o}C*	= 2. 32 GPa
Poisson's ratio / *Nisbah poisson*	= 0. 35
Yield stress at 20^{o}C / *Tegasan alah pada 20^{o}C*	= 54 MPa
Yield stress at -60^{o}C / *Tegasan alah pada -60^{o}C*	= 76 MPa

3. [a] Why does a rubber band snap back when stretched and released? An explaination including both thermodynamic and molecular aspects are required. Equation/diagram/figures could be used to assist the explaination.

Kenapa getah gelang melantun balik apabila daya terikan/ketegangan dilepaskan? Penjelasan termasuk kedua-dua aspek termodinamik dan molekul diperlukan. Persamaan/gambarajah/angka boleh digunakan untuk membantu penjelasan.

(70 marks/*markah*)

[b] The theory of rubber elasticity and the theory of ideal gas dynamics show that the two equations, G=nRT and PV=n'RT, share certain common thermodynamic ideas. Explain what are they?

Teori keelastikan getah dan teori dinamik ideal gas menunjukkan dua persamaan, G=nRT dan PV=n'RT, berkongsi idea termodinamik biasa yang tertentu. Jelaskan apakah mereka?

(30 marks/*markah*)

PART B / *BAHAGIAN B*

4. [a] A plastic which has its creep behavior described by a Maxwell model is to be subjected to the stress history shown in Figure 1. If the spring and dashpot constants for this model are 20 GNm^{-2} and 1000 GNm^{-2} respectively then predict the strains in the material after 150, 350 and 450 seconds.

Suatu bahan plastik yang sifat kripnya diterangkan oleh model Maxwell, dikenakan sejarah tegasan seperti di Rajah 1. Jika pemalar bagi spring dan daspot masing-masing ialah 20 GNm^{-2} dan 1000 GNm^{-2}, ramalkan terikan yang dialami oleh bahan selepas 150, 350 dan 450 saat.

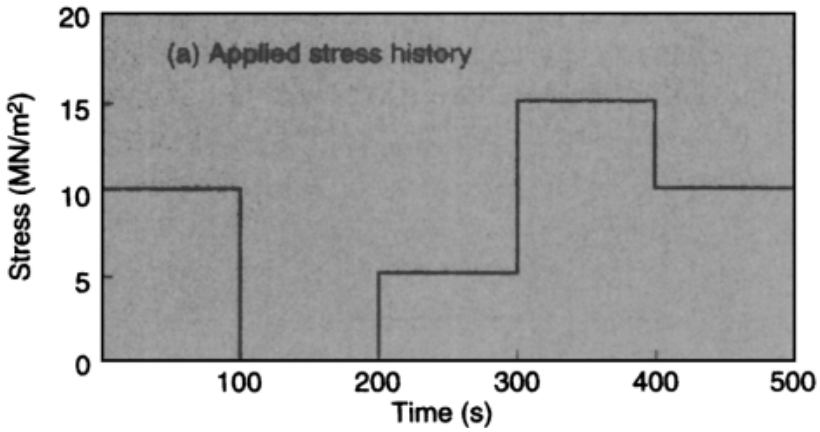

Figure 1 - Applied stress history for a plastic subjected to a creep test

Rajah 1 - Sejarah tegasan suatu bahan plastik yang dikenakan ujian krip

(30 marks/*markah*)

[b] A viscoelastic polymer that follows the Boltzmann superposition principle 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} and τ_o = 200 s

$$J(t) = J_o\left(1 - \exp\left(-\frac{t}{\tau_o}\right)\right)$$

Calculate the total strain after 100 and 200 s.

Suatu polimer likat kenyal yang mematuhi prinsip superposisi Boltzmann telah dikenakan sejarah tegasan yang berikut. Pada t = 0, tegasan sebanyak 10 MNm^{-2} telah dikenakan selama 100 s. Tegasan tersebut kemudiannya dilepaskan serta merta. Diberi J_o = 2 m^2 GN^{-1} dan τ_o = 200 s

$$J(t) = J_o\left(1 - \exp\left(-\frac{t}{\tau_o}\right)\right)$$

Kirakan jumlah terikan selepas 100 dan 200 s.

(20 marks/*markah*)

[c] A master curve for polyisobutylene indicates that stress relaxes to a modulus of 10 dyn / cm^2 in about 10 h at 25°C. Using the WLF equation,

(i) Calculate the glass transition temperature (T_g) for polyisobutylene. It is given that at T_g, the modulus is observed at 2.0 x 10^{12} h.

(ii) Estimate the time it will take to reach the same modulus at temperature of -20°C.

Keluk induk bagi poliisobutilena menunjukkan tegasan mengendur ke suatu modulus 10 dyn / cm^2 dalam tempoh 10 jam pada 25°C. Dengan menggunakan persamaan WLF,

(i) tentukan suhu peralihan kaca bagi poliisobutilena. Pada T_g, modulus tersebut diperhatikan pada 2.0 x 10^{12} jam.

(ii) Anggarkan masa yang diperlukan bagi mencapai modulus yang sama pada suhu -20°C.

(20 marks/*markah*)

[c] Stress relaxation modulus, M(t), of a polymer at 30°C is expressed as

$$M(t) = 2\ t^{-0.05}$$

where M(t) is in GPa and t is in seconds. If the glass transition temperature of the polymer is 30°C, use the WLF equation and find the 1-year relaxation modulus of the polymer at 60°C.

WLF equation: $Log\ a_t = \frac{-17.4\,(T - T_g)}{51.6 + (T - T_g)}$

Modulus pengenduran, M(t), bagi suatu polimer pada 30℃ boleh diungkapkan sebagai

$$M(t) = 2\ t^{-0.05}$$

di mana M(t) dalam unit GPa dan t dalam saat. Jika suhu peralihan kaca bagi polimer adalah 30℃, guna persamaan WLF dan tentukan modulus pengenduran pada 1-tahun bagi polimer tersebut pada suhu 60℃.

WLF equation: $Log\ a_t = \frac{-17.4\,(T - T_g)}{51.6 + (T - T_g)}$

(30 marks/*markah*)

5. Write short notes on THREE of the following topics:

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

(ii) Brittle-ductile transition

(iii) Environmental stress cracking of polymers

(iv) Factors affecting yield behaviours of polymers

Tulis nota ringkas tentang TIGA daripada topik berikut:

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

(ii) Peralihan rapuh mulur

(iii) Rekahan tegasan persekitaran polimer

(iv) Faktor yang mempengaruhi kelakuan alah polimer

(100 marks/*markah*)

6. [a] A sample of polyisoprene containing 7 x 10^{20} chains between cross-links is extended uniaxially at 45°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 polisoprena mengandungi 7 x 10^{20} rantaian di antara sambung silang telah dipanjangkan secara unipaksi pada 45°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; nisbah 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 in Question 6[a] is of initial length L_i = 0.05 m. What is the force required to double its length?

Sampel dalam Soalan 6[a] mempunyai panjang asal L_i = 0.05 m. Berapakah kekuatan yang diperlukan untuk menggandakan panjangnya?

(25 marks/*markah*)

7. [a] An elastomeric seal is interposed between a box and it's lid to provide waterproofness. Deformation of the seal is maintained constant. The behavior of this elastomer can be represented by a Maxwell model. Calculate E (modulus) and η (viscosity) considering that:

- The lid closing system causes a deformation of 5% and the initial reaction pressure is 0.1 MPa.
- After 30 days, this reaction pressure has fallen from 10%.

When the pressure reaction becomes equal to 10% of it's initial value, waterproofness will not be provided any more. Calculate the duration time after which the seal will fail.

Suatu kedap bahan elastomer diselitkan di antara kotak dan penutupnya agar kotak tersebut kalis air. Canggaan kedap tersebut dikekalkan malar. Kelakuan bahan elastomer ini boleh diwakili oleh model Maxwell. Kirakan E (kekakuan) dan η (kelikatan) dengan mempertimbangkan:

- *Sistem penutupan penutup menghasilkan canggaan sebanyak 5% dan tekanan tindak balas mula sebanyak 0.1 MPa.*
- *Selepas 30 hari, tekanan tindak balas telah berkurang 10%.*

Apabila tekanan tindak balas adalah 10% dari nilai asalnya, sifat kalis air tidak lagi wujud. Kirakan tempoh masa untuk kedap tersebut gagal.

(40 marks/*markah*)

[b] Eyering equation is given by:

Persamaan Eyering diberikan oleh:

$$(\frac{\sigma_y}{T}) = (\frac{2}{V^*})[(\frac{\Delta H}{T}) + 2.303R\log(\frac{\varepsilon_y}{\varepsilon_o})]$$

(i) Define all the terms in the equation

Takrifkan semua ungkapan yang terdapat dalam persamaan tersebut.

(ii) Describe the THREE most important information that can be derived from the equation.

Terangkan TIGA makluman terpenting yang boleh diperolehi daripada persamaan tersebut.

(30 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.

(30 marks/*markah*)

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