

SULIT



First Semester Examination
2024/2025 Academic Session

February 2025

EBP 317 – Advanced Polymer Composites
[Komposit Polimer Termaju]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of THIRTEEN (13) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS (13) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions : Answer **FIVE (5)** questions. Answer **ALL** questions from PART A, **ONE (1)** question from PART B and **ONE (1)** question from PART C. All questions carry the same marks.

Arahan : Jawab **LIMA (5)** soalan. Jawab **SEMUA** soalan daripada BAHAGIAN A, **SATU (1)** soalan daripada BAHAGIAN B dan **SATU (1)** soalan daripada BAHAGIAN C. Semua soalan membawa jumlah markah yang sama.]

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

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

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PART A / BAHAGIAN A

- (1). (a). The following two formula provide estimates of the density of a composite material having more than two constituents. However, only one of the formulas is correct.

Kedua-dua formula berikut memberikan anggaran ketumpatan bahan komposit yang mempunyai lebih daripada dua komponen. Namun, hanya satu daripada formula tersebut yang betul.

$$(i). \rho_c = \sum_{i=1}^N v_i \rho_i \qquad (ii). \rho_c = \sum_{i=1}^N \frac{v_i}{\rho_i}$$

Identify which one is the correct formula either (i) or (ii) and show your proof.

Tentukan yang manakah adalah formula yang betul sama ada (i) atau (ii) dan tunjukkan bukti anda.

(5 marks/markah)

- (b). Use the correct formula to estimate the density of a hybrid composite made up of 20% High Strength (HS) carbon fiber by weight and 30% E-glass fiber by weight in an epoxy matrix. The densities of HS carbon fiber, E-glass fiber and epoxy are 1.79 g/cm³, 2.54 g/cm³ and 1.16 g/cm³, respectively.

Gunakan formula yang betul untuk menganggarkan ketumpatan komposit hibrid yang terdiri daripada 20% gentian karbon kekuatan tinggi (HS) mengikut berat dan 30% gentian kaca E mengikut berat dalam matrik epoksi. Ketumpatan gentian karbon HS, gentian kaca E dan epoksi masing-masing adalah 1.79 g/cm³, 2.54 g/cm³ dan 1.16 g/cm³.

(5 marks/markah)

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- (c). **Figure 1** shows the relationship between force and displacement that was obtained from a fiber pullout test.

Rajah 1 menunjukkan hubungan antara daya dan anjakan yang diperolehi daripada ujian penarikan gentian.

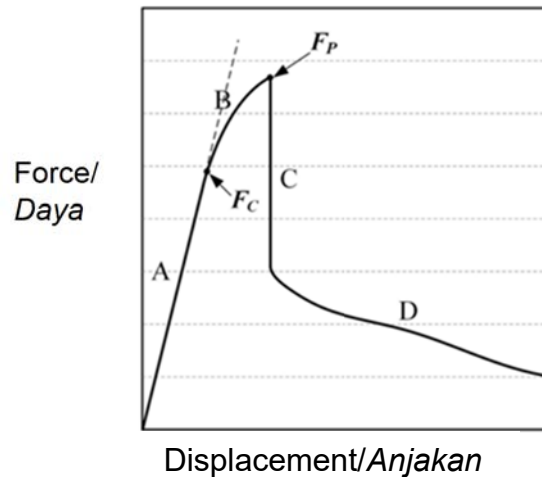


Figure 1: Force-displacement curve of a fiber pullout test.

Rajah 1: Lengkung daya-anjakan bagi suatu ujian penarikan gentian.

With the help of some sketches, describe the sequence of events (at A, B, C, and D) associated with fiber and matrix deformation during the pullout test. What does F_c refer to?

Dengan bantuan beberapa lakaran, huraikan urutan kejadian (di A, B, C, dan D) yang berkaitan dengan ubah bentuk gentian dan matrik semasa ujian tarik keluar. F_c merujuk kepada apa?

(10 marks/markah)

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- (2). (a). Considering that the polyetherimide (PEI) matrix contains 63.5% aramid fiber with the following values:

Pertimbangkan matriks polieterimida (PEI) mengandung 63.5% gentian aramid dengan nilai berikut:

Modulus of elasticity of aramid fiber = 135.7 GPa
Modulus keanjalan bagi gentian aramid

Poisson's ratio of aramid fiber = 0.5
Nisbah Poisson bagi gentian aramid

Modulus of elasticity of PEI = 3.33 GPa
Modulus keanjalan bagi PEI

Poisson's ratio of PEI = 0.35
Nisbah Poisson bagi PEI

Calculate:

Kirakan:

- (i). The stiffness of coefficient of matrix.

Pekali kekukuhan bagi matrik

(6 marks/markah)

- (ii). Mechanical anisotropy value.

Nilai mekanikal tak isotropi.

(2 marks/markah)

- (b). A hybrid polymer composite is made from two distinct types of reinforcement fibers within a polyester matrix. Given the properties of the individual components provided below, determine the following:

Satu komposit polimer hibrid yang diperbuat dari dua jenis gentian pengukuhan dalam matriks poliester. Diberikan sifat-sifat bagi komponen individu di bawah, tentukan yang berikut:

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- (a). Volume fraction of each type of reinforcement fibers.

Pecahan isipadu bagi setiap jenis gentian.

(3 marks/markah)

- (b). Tensile modulus of the composite along the longitudinal and transverse direction.

Modulus tegangan bagi komposit dari arah membujur dan melintang.

(4 marks/markah)

- (c). Verify the modulus of the composites using the Halpin-Tsai model if Kevlar 49 replaces the remaining carbon fiber portion.

Sahkan nilai modulus komposit tersebut menggunakan model Halpin-Tsai jika Kevlar 49 menggantikan jumlah bahagian gentian karbon.

(5 marks/markah)

Table 1: Type of materials with their properties

Jadual 1: Jenis-jenis bahan dan sifat-sifatnya

Material/ Bahan	Weight Percent/ Peratusan Berat (%)	Density/ Ketumpatan (g/ml)	Young's Modulus / Modulus Young (GPa)	Tensile Strength / Kekuatan Tegangan (MPa)	Diameter/ Diameter (um)	Length/ Panjang (mm)
Polyester/ Poliester	37.5	1.38	0.92	75	-	-
Kevlar 49/ Kevlar 49	30	1.44	166	3000	4	1200
Carbon Fiber/ Gentian Karbon	32.5	1.75	255	4500	5.5	1300

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- (3.) (a). **Figure 2** shows a schematic diagram showing all layers within a vacuum bag setup. Briefly describe the function of each layer.

Rajah 2 menunjukkan gambarajah skema yang menunjukkan semua lapisan dalam persediaan beg vakum. Terangkan secara ringkas fungsi setiap lapisan.

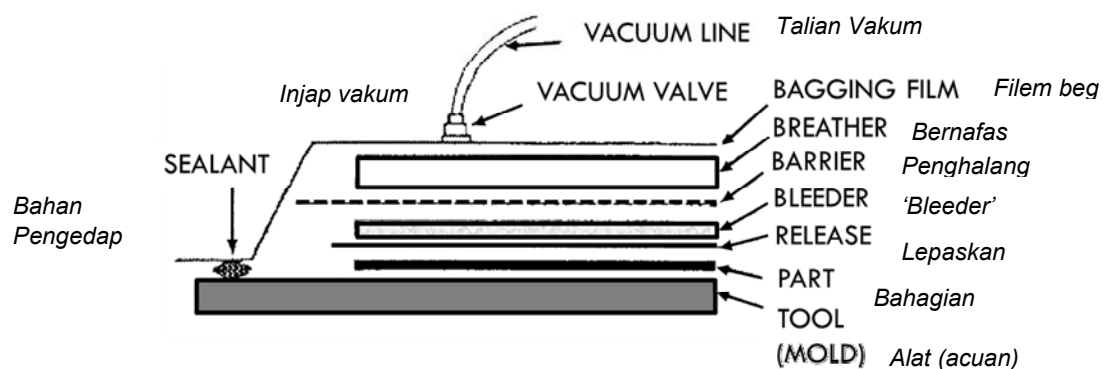


Figure 2: Vacuum bag setup.

Rajah 2: Persediaan beg vakum.

(10 marks/markah)

- (b). With the aid of a diagram discuss how resin transfer molding works, also give the advantages and disadvantages of this manufacturing process.

Dengan bantuan gambarajah bincangkan bagaimana pengacuan pemindahan resin berfungsi, juga berikan kelebihan dan kekurangan proses pembuatan ini.

(10 marks/markah)

PART B / BAHAGIAN B

- (4). (a). Describe the process to produce graphite fibers. **Figure 3** shows the production process of graphite fibers.

Jelaskan process penghasilan gentian grafit. Rajah 3 menunjukkan proses penghasilan gentian grafit.

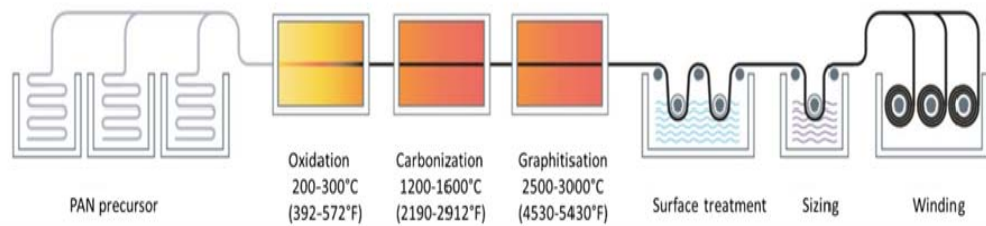


Figure 3: Production process of graphite fibers.

Rajah 3: Proses penghasilan gentian grafit.

(10 marks/markah)

- (b). A graphite/epoxy composite specimen has dimensions of 2.54 cm x 2.54 cm x 0.3 cm and a weight of 2.98 g. After 'resin digestion' in an acid solution the remaining graphite fibers weight 1.863 g. From independent tests, the densities of the graphite fibers and epoxy matrix materials are found to be 1.9 g/cm³ and 1.2 g/cm³, respectively. Determine the volume fraction of fibers, epoxy matrix, and voids in the specimen.

Suatu spesimen komposit grafit/epoksi berukuran 2.54 cm x 2.54 cm x 0.3 cm mempunyai berat bersamaan 2.98 g. Selepas penyingkiran matrik oleh larutan berasid, berat grafit yang tinggal ialah 1.863 g. Dari ujian berasingan, ketumpatan gentian grafit dan matrik epoksi masing-masing ialah 1.9 g/cm³ dan 1.2 g/cm³. Tentukan pecahan isipadu gentian, matrik epoksi dan keliangan di dalam specimen tersebut.

(10 marks/markah)

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- (5). (a). Epoxy is a cross-linked resin prepared in two steps. The first step involves the reaction between bisphenol A and epichlorohydrin (**Figure 4**) to form a low molecular weight prepolymer. In the second step, this prepolymer is cured into a cross-linked resin with the addition of a hardener such as diethylenetriamine ($\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}_2$).

*Epoksi ialah resin tersambung-silang yang disediakan dalam dua langkah. Langkah pertama melibatkan tindak balas antara bisphenol A dan epiklorohidrin (**Rajah 4**) untuk membentuk prapolimer berat molekul rendah. Dalam langkah kedua, prapolimer ini diawetkan menjadi resin tersambung-silang dengan penambahan pengeras seperti dietilenatriamina ($\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}_2$).*

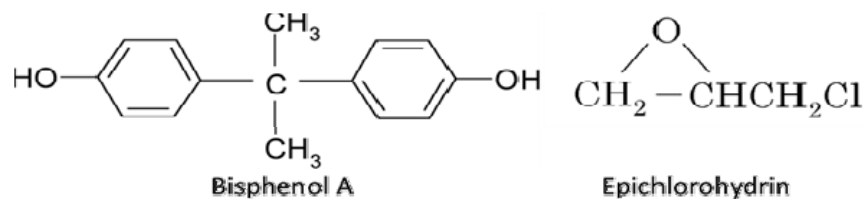


Figure 4: Chemical structures of bisphenol A and epichlorohydrin.

Rajah 4: Struktur kimia bagi bisfenol A dan epiklorohidrin.

- (i). Sketch the chemical structure of the prepolymer.
Lakarkan struktur kimia prapolimer tersebut.
 (5 marks/markah)
- (ii). Sketch the chemical structure of the cross-linked resin.
Lakarkan struktur kimia resin tersambung-silang tersebut.
 (5 marks/markah)

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- (b). The maximum fiber packing arrangement for a composite with two different fiber types and size is shown in **Figure 5**. Both fibers are arranged in equilateral triangle arrangement. Compute the maximum fiber volume fraction for i) the glass fiber and ii) the carbon fiber. The diameter of the glass fiber (r_g) is $13\ \mu\text{m}$ and the diameter of the carbon fiber (r_c) is $8\ \mu\text{m}$.

*Aturan penyusunan gentian maksimum bagi komposit yang mengandungi dua jenis gentian dan saiz berbeza ditunjukkan di **Rajah 5**. Kedua-dua gentian tersusun secara penyusunan segi tiga sama sisi. Kirakan pecahan isipadu gentian maksimum bagi i) gentian kaca dan ii) gentian karbon. Garispusat bagi gentian kaca (r_g) ialah $13\ \mu\text{m}$ dan garispusat bagi gentian karbon (r_c) ialah $8\ \mu\text{m}$.*

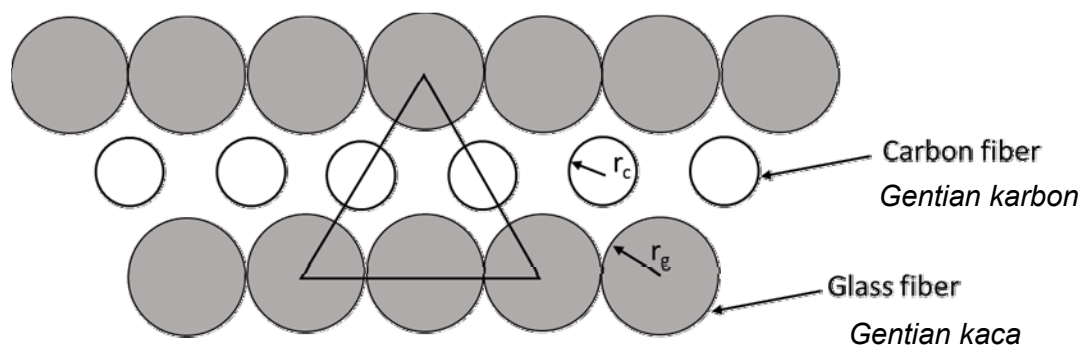


Figure 5: Fiber packing arrangement of a composite.

Rajah 5: Penyusunan gentian bagi suatu komposit.

(10 marks/marks)

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PART C / BAHAGIAN C

- (6). (a). During takeoff from Rome, a wheel tread struck the wing of a Qantas 787 Dreamliner aircraft, causing cracks in the wing paneling and a flap. Outline ONE (1) comprehensive method in order to evaluate the mechanical properties of polymer composites. Your proposed methods must include the expression of modulus in both transverse and longitudinal directions using a suitable example of matrix and fiber used to manufacture the 787 wing paneling.

Semasa berlepas dari Rome, tapak roda tayar menghentam sayap pesawat Qantas 787 Dreamliner, menyebabkan retakan pada panel sayap dan flap. Huraikan SATU (1) kaedah menyeluruh untuk menilai sifat mekanikal komposit polimer. Kaedah yang dicadangkan mesti merangkumi ungkapan modulus dalam arah melintang dan membujur menggunakan contoh matriks dan gentian yang sesuai untuk pembuatan panel sayap 787.

(10 marks/markah)

- (b). Discuss the factors that influence the toughness of polymer composites. Your discussion must includes the analysis of fiber-matrix adhesion, fiber geometry, and volume fraction of fillers in enhancing the toughness of composites. Then, examine the mechanisms of energy absorption during failure, including fiber pull-out and debonding, and how they contribute to the overall toughness.

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Bincangkan tentang faktor-faktor yang mempengaruhi keliatan komposit polimer. Perbincangan anda harus merangkumi analisis mengenai lekatan antara gentian dan matriks, geometri gentian, dan pecahan isipadu gentian dalam meningkatkan keliatan komposit ini. Kemudian, teliti mekanisme penyerapan tenaga semasa kegagalan, termasuk penarikan dan pemisahan gentian, dan terangkan bagaimana mekanisme ini menyumbang kepada keliatan keseluruhan komposit.

(10 marks/markah)

- (7). (a). Elaborate the stress-strain behaviour of a reinforcing fiber, matrix, fiber-controlled and matrix-controlled systems. Support your elaborations with sketches and examples of each components.

Huraikan sikap ketegangan-terikan bagi sistem-sistem gentian pengukuhan, matriks, dikawal gentian dan dikawal matriks. Sokongkan huraian anda dengan lakaran dan contoh-contoh yang sesuai bagi setiap komponen.

(8 marks/markah)

- (b). In a glass fiber-reinforced composite, the fibers are distributed with varying lengths and orientations, resulting in a non-uniform fiber length distribution and a random fiber orientation within the epoxy matrix. Given the following parameters:

Dalam komposit dikukuhkan dengan gentian kaca, gentian diagihkan dengan panjang dan orientasi yang berbeza-beza, menghasilkan pengagihan panjang gentian tidak seragam dan orientasi gentian rawak dalam matriks epoksi. Diberikan parameter berikut:

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Average fiber length based on normal distribution = 5 ± 1.2 mm

Purata panjang gentian berdasarkan taburan normal

Fiber volume fraction = 0.45

Pecahan isipadu gentian

Young's modulus of glass fiber = 72 GPa

Modulus Young bagi gentian kaca

Young's modulus of epoxy = 3 MPa

Modulus Young bagi epoksi

Shear modulus of epoxy = 2.15 GPa

Modulus ricih bagi epoksi

- (i). Calculate the effective modulus of the composite in the longitudinal direction, taking into account the fiber length distribution and orientation effects using Cox-shear lag model. Given that centre-to-centre fiber distance is R and fiber radius is r .

Kira modulus berkesan komposit dalam arah membujur, dengan mengambil kira taburan panjang gentian dan kesan orientasi menggunakan model lag ricih Cox. Diberi jarak gentian pusat ke pusat ialah R dan jejari gentian ialah r .

(6 marks/markah)

- (ii). Calculate the critical fiber length for effective load transfer if the interfacial shear strength is 35 MPa.

Kirakan panjang gentian kritikal bagi pengagihan beban yang efektif jika kekuatan ricih antaramuka adalah 35 MPa.

(3 marks/markah)

- (iii). Discuss the effect of fiber length on the modulus of the composites.

Bincangkan kesan panjang gentian ke atas modulus bagi komposit.

(3 marks/markah)

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