UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014/January 2015

ESA 323/3 – Aerocomposite Engineering
[Kejuruteraan Aerokomposit]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this paper contains **ELEVEN (11)** printed pages and **FIVE (5)** questions before you begin examination.

*Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS (11)** mukasurat bercetak dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.*

Instruction : Answer **ALL** questions.

Arahan *: Jawab **SEMUA** soalan.*

Student may answer the questions either in English or Bahasa Malaysia.
Pelajar boleh menjawab soalan dalam Bahasa Inggeris atau Bahasa Malaysia.

Each question must begin from a new page.
Setiap soalan mestilah dimulakan pada mukasurat yang baru.

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.

1. [a] Provide definition of a composite material. Name **TWO** types of advanced composite material in aircraft construction.

(5 marks)

[b] Among the principal functions of resin or matrix are to distribute the applied load between fibres and to hold the fibre in place, which at the same time protect the fibres. In aerospace industries, thermosetting resin has been used extensively in the manufacturing of the composite parts. It possesses excellent mechanical properties over other types of resin.

Based on the following **Figure 1[a],** demonstrates your understanding on the curing process with the temperature over the curing time for the thermosetting resin.

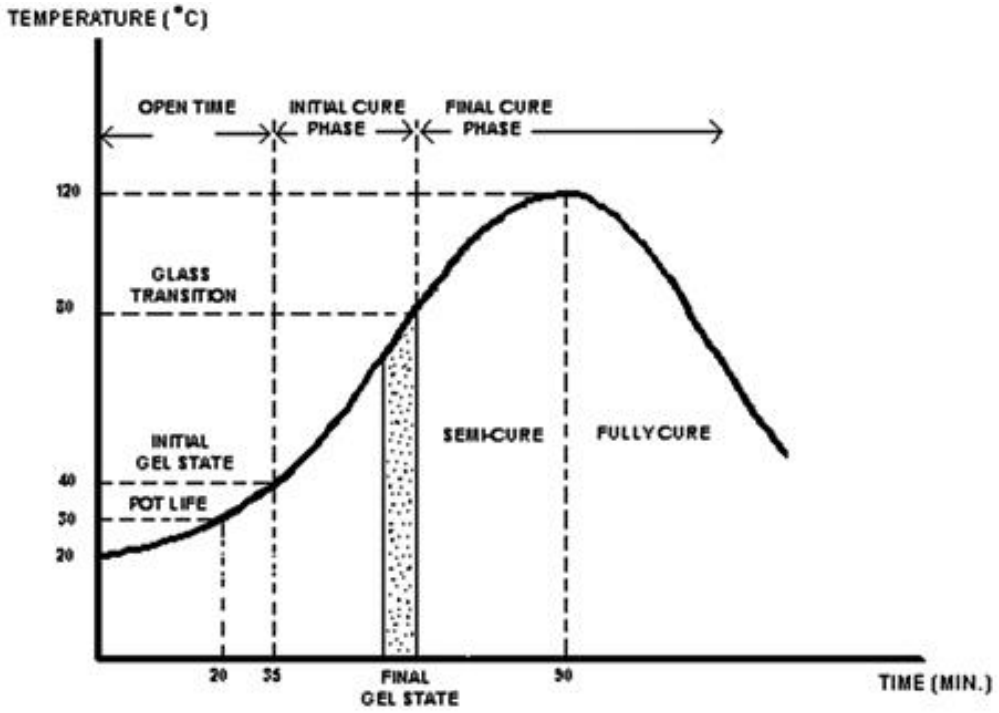


Figure 1[a]

(10 marks)

[c] In brief, fibres are responsible to sustain most of the applied load of the composite materials. Among the criteria used in the selection of fibre material is the ability of fiber to withstand crushing, shearing and buckling effects under a compressive load. For that, Euler's buckling formula has been employed to predict the buckling stress of a particular fiber.

Given a specific length mentioned in a design requirement, analyse that the Euler's buckling stress is different for Kevlar, E-glass, high-modulus carbon and high-strength carbon fibres. Use the following formula and **Table 1[a]** for your reference.

$$\sigma_{Euler\_buckling} = \frac{\pi^2 E}{16}\left(\frac{d}{L}\right)^2$$

Fibre	**Diameter, d (μm)**	**Young's modulus, E (GPa)**	**Flexibility, κ/M ($GPa^{-1}mm^{-4}$)**	**Fracture strength, σ_s (GPa)**	**Maximum curvature, κ_{max} (mm^{-1})**
SiC monofilament	150	400	1×10^2	2.4	0.08
Nicalon™	15	190	2.1×10^6	2.0	1.4
Kevlar™ 49	12	130	7.6×10^6	3.0	3.8
E-glass	11	76	1.8×10^7	2.0	4.8
HM carbon	8	390	1.3×10^7	2.2	1.4
HS carbon	8	250	2.0×10^7	2.7	2.7
Saffil™	3	300	8.4×10^8	2.5	5.5
SiC whisker	1	450	4.5×10^{10}	5.0	22.2

Table 1[a]

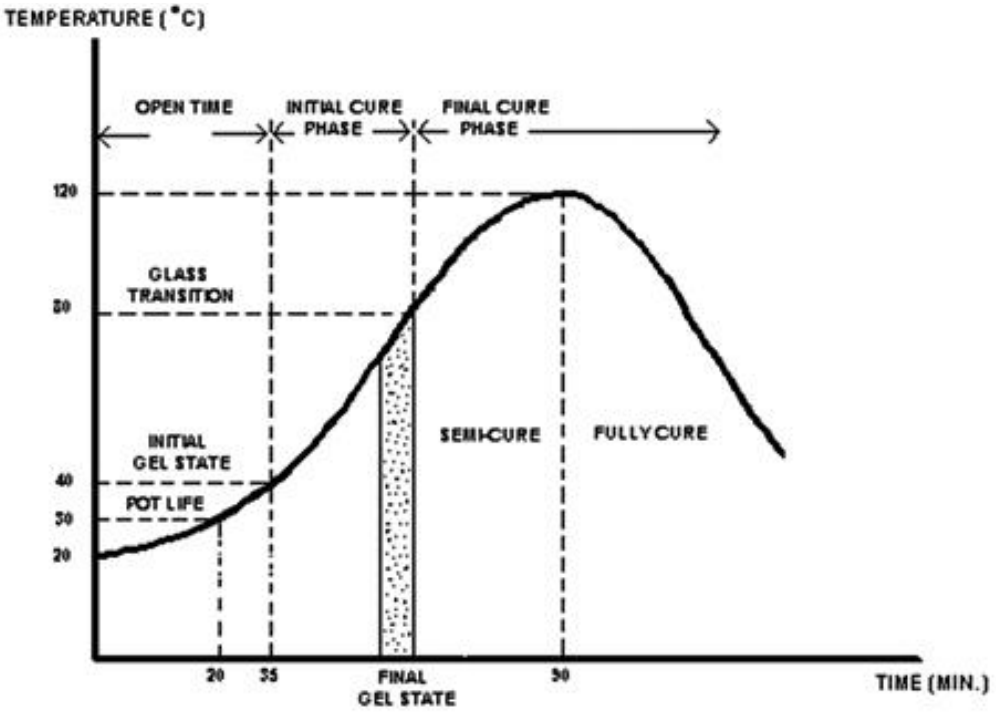
(25 marks)

[a] *Berikan definisi bahan komposit. Namakan **DUA** jenis bahan komposit termaju dalam pembuatan kapal terbang.*

(5 markah)

[b] *Antara fungsi utama resin atau matriks adalah untuk mengagihkan beban kenaan di antara gentian dan untuk memegang gentian pada tempatnya, pada waktu yang sama melindungi gentian tersebut.Di dalam industri Aeroangkasa, 'thermosetting resin' digunakan secara meluas dalam pembuatan bahan-bahan komposit. Ia memiliki sifat-sifat mekanikal yang terbaik berbanding jenis resin yang lain.*

*Berdasarkan **Rajah 1[a]** berikut, huraikan apa yang anda fahami tentang proses pengawetan dengan suhu terhadap masa pengawetan untuk 'thermosetting resin'.*



Rajah 1[a]

(10 markah)

[c] *Secara ringkasnya, gentian bertanggungjawab untuk menahan kebanyakkan beban kenaan daripada bahan komposit. Di antara kriteria yang digunakan dalam pemilihan bahan gentian adalah keupayaan bahan tersebut untuk menahan kesan penghancuran, ricihan, dan lengkokan di bawah beban mampat. Untuk itu, formula lengkokan Euler digunakan untuk meramal tegasan lengkokan untuk gentian tertentu.*

Dengan diberikan panjang tentu yang dinyatakan di dalam keperluan rekabentuk, buktikan bahawa tegasan lengkokan Euler adalah berbeza untuk Kevlar, E-glass, karbon-modulus tinggi dan gentian karbon kekuatan-tinggi. Gunakan formula dan ***Jadual 1[a]*** *untuk rujukan anda.*

$$\sigma_{Euler\_buckling} = \frac{\pi^2 E}{16}\left(\frac{d}{L}\right)^2$$

Fibre	**Diameter, d (μm)**	**Young's modulus, E (GPa)**	**Flexibility, κ/M ($GPa^{-1}mm^{-4}$)**	**Fracture strength, σ_s (GPa)**	**Maximum curvature, κ_{max} (mm^{-1})**
SiC monofilament	150	400	1×10^2	2.4	0.08
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HS carbon	8	250	2.0×10^7	2.7	2.7
Saffil™	3	300	8.4×10^8	2.5	5.5
SiC whisker	1	450	4.5×10^{10}	5.0	22.2

Jadual 1[a]

(*25 markah)*

2. [a] The following tensile stress-strain values were obtained in uniaxial tensile testing of a $[\pm 45]_s$ laminate:

σ_{xx} (MPa)	ε_{xx} (mm/mm)	ε_{yy} (mm/mm)
27.5	0.001	–0.00083
54.4	0.002	–0.00170
82.7	0.003	–0.00250
96.5	0.004	–0.00340
115.7	0.005	–0.00700
132.5	0.006	–0.00811
161.0	0.007	–0.00905
214.0	0.014	–0.01242

Generate the curve with the given data, and determine E_{xx} of the laminate. Also, reduce the data to assess τ_{12} versus γ_{12} for the material in order to determine G_{12}.

(20 marks)

[b] The followings highlight several design cases of composite structures, which may indicate good or poor designs. Critically, evaluate those designs and justify your assessment accordingly.

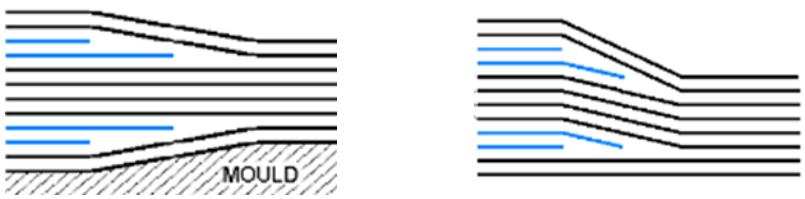
[i] [45/90/135/0_3/135/90/45]
[45/135/90/45/0/45_2/0/135/90/135/45]

[ii] [45/135/0/135/45/90]s
[0/45/135/90/135/45]s

[iii] [45/135/90/135/45/0/45/135/90/45/135/0/135/45/90]s
[45/135/90_3/135/45/0/45/135_2/45/0/135/45]s

[iv] [45/0/135/90/45/0/135]s
[45/0/90/135/45/0/135]s

[v]



(20 marks)

[a] *Nilai tegangan tegasan-terikan berikut diperolehi dalam ujian tegangan eka-paksi $[\pm 45]_s$ lamina:*

σ_{xx} (MPa)	ε_{xx} (mm/mm)	ε_{yy} (mm/mm)
27.5	0.001	–0.00083
54.4	0.002	–0.00170
82.7	0.003	–0.00250
96.5	0.004	–0.00340
115.7	0.005	–0.00700
132.5	0.006	–0.00811
161.0	0.007	–0.00905
214.0	0.014	–0.01242

Hasilkan lengkuk berdasarkan data yang diberi dan tentukan E_{xx} pada lamina. Juga, kurangkan data bagi menilaikan τ_{12} melawan γ_{12} bagi bahan tersebut dan tentukan G_{12}.

(*20 markah*)

[b] *Berikut adalah merupakan kes-kes reka bentuk beberapa struktur komposit, yang mungkin menunjukkan reka bentuk yang baik atau buruk. Nilaikan rekabentuk-rekabentuk tersebut dan bincangkan penilaian anda dengan sewajarnya.*

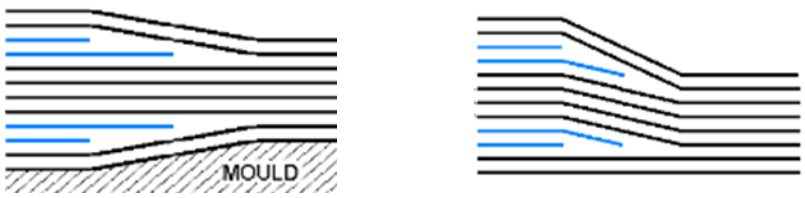
[i] [45/90/135/0_3/135/90/45]
[45/135/90/45/0/45_2/0/135/90/135/45]

[ii] [45/135/0/135/45/90]s
[0/45/135/90/135/45]s

[iii] [45/135/90/135/45/0/45/135/90/45/135/0/135/45/90]s
[45/135/90_3/135/45/0/45/135_2/45/0/135/45]s

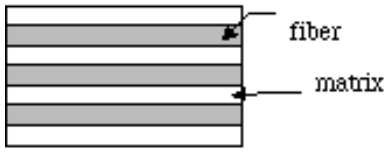
[iv] [45/0/135/90/45/0/135]s
[45/0/90/135/45/0/135]s

[v]



(20 markah)

3. A unidirectional fibre reinforced composite is made from materials with the following properties: $E_f = 100$ GPa, $\sigma_f = 300$ MPa; $E_m = 5$ GPa, $\sigma_m = 30$ MPa.



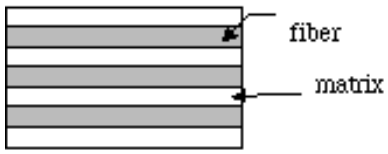
[a] The composite modulus normal to the fibre axis is found to be $E_c = 7$ GPa. Compute the volume fraction of fibres in the composite?

(8 marks)

[b] If a second composite is designed to elastically carry 70 MPa along the fibre-axis at failure, what should the fibre fraction be? (Assume the fibre is brittle, and fails at its yield point. Also assume composite failure when the fibre fails, and that both matrix and fibre are still in the elastic region.)

(12 marks)

. *Gentian karbon komposit eka-arah telah dibuat dengan properti berikut: E_f=100GPa, $\sigma_f = 300$ MPa; $E_m = 5$ GPa, $\sigma_m = 30$ MPa.*



[a] Modulus komposit normal kepada fiber adalah $E_c = 7$ GPa. Apakah pecah isipadu gentian fiber komposit?

(*8 markah*)

[b] Sekiranya komposit seterusnya dibina kenyal untuk membawa 70 MPa arah paksi-gentian pada kegagalan, berapakah nilai pecahan gentian? (Anggapkan gentian adalah rapuh dan gagal pada titik alah. Juga, anggapkan, apabila komposit tersebut gagal apabila gentian gagal, dan kedua-dua matrik dan gentian masih dalam lingkungan had kenyal).

(12 markah)

4. Tensile stress-strain diagram of a $[0/90_4]_S$ AS-4 carbon fibre/epoxy laminate is shown in **Figure 4[a].** It was shown that the longitudinal and transverse moduli of 0^0 unidirectional laminate of the same material are 142 and 10.3 GPa, respectively.

[a] Determine the initial axial modulus of the $[0/90_4]_S$ laminate and compare it with the theoretical value. How would this value change if the 90^0 layers are at the outside or the laminate construction is changed to $[0_2/90_3]_S$?

(22 marks)

[b] Point out the reason for the non-linear portion of the stress-strain diagram.

(8 marks)

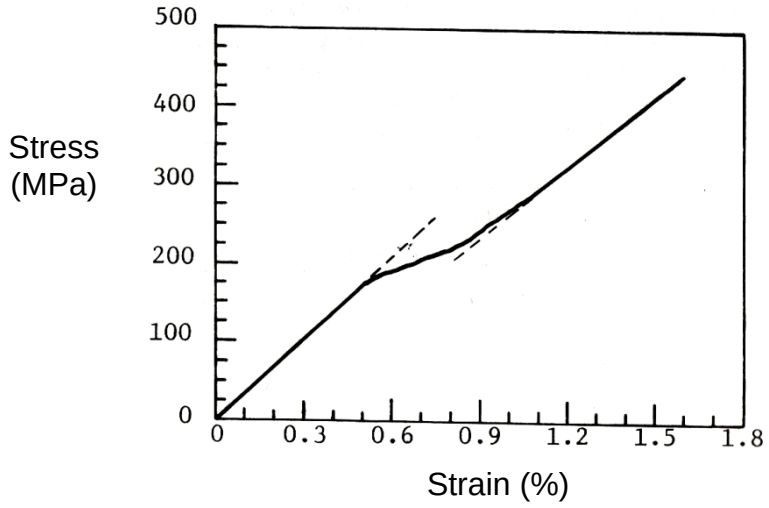


Figure 4[a]

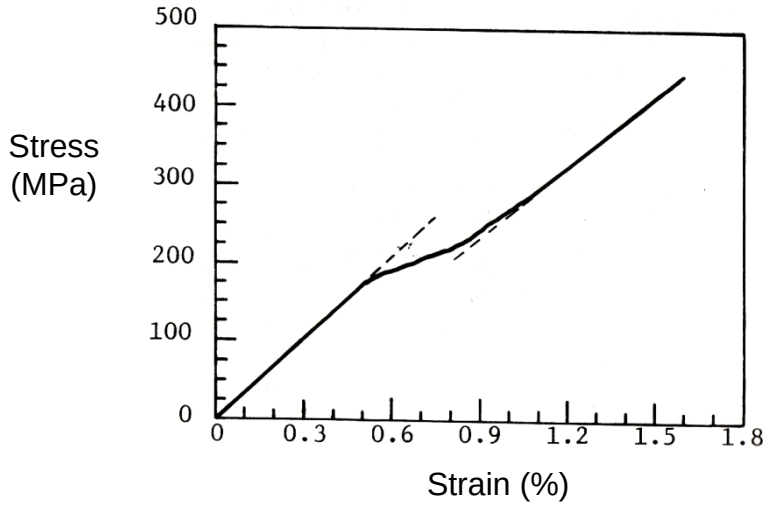
Gambarajah tegasan-terikan tegangan untuk $[0/90_4]_S$ AS-4 gentian fiber/epoksi lamina ditunjukkan di dalam ***Rajah 4[a].*** *Ia menunjukkan modulus membujur dan melintang untuk 0^0 lamina eka arah untuk bahan yang sama masing-masing adalah 142 dan 10.3 GPa.*

[a] *Tentukan modulus paksi mula untuk $[0/90_4]_S$ lamina dan bandingkannya dengan nilai teori. Bagaimanakah nilai ini berubah sekiranya lapisan 90^0 berada di luar atau pembinaan lamina ditukar kepada* $[0_2/90_3]_S$?

(22 markah)

[b] *Berikan sebab kepada bahagian tak linear pada gambarajah tegasan terikan.*

(*8 markah*)



Rajah 4[a]

5. Automated tape lay-up is a manufacturing process used by the aerospace industry to manufacture carbon-epoxy aircraft structures.

[a] Describe the tape laying process.

(8 marks)

[b] Describe the benefits of using this process in aircraft manufacturing.

(8 marks)

[c] Identify two types of aircraft component made using the automated tape lay-up process.

(4 marks)

Hamparan pita adalah proses pembuatan oleh industri aeroangkasa untuk menghasilkan struktur kapal terbang karbon-epoksi.

[a] Huraikan proses hamparan pita.

(8 markah)

[b] Huraikan faedah-faedah apabila kaedah ini digunakan bagi tujuan pembuatan kapal terbang.

(8 markah)

[c] Kenalpasti dua jenis komponen kapal terbang yang meggunakan proses hamparan pita automatik.

(*4 markah*)

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