UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

December 2015/January 2016

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.

Kertas soalan ini tidak dibenarkan dibawa keluar dari Dewan Peperiksaan.
You are not allowed to take the question paper from Examination Hall.

Answer **ALL** questions.

1. [a] In general, composite material is a mixture of two or more different materials. In your own words give a complete definition of composite materials.

(50 marks)

[b] Composite materials are becoming more important in the construction of aerospace structures. Explain why advanced composite material is a favorable option for the aerospace industry, with assistance from **Table 1** and your own sources.

(50 marks)

Table 1: Mechanical properties of metallic and composite materials.

Material	Density	Tensile Modulus	Tensile Strength	Specific Modulus	Specific Strength
	ρ (g/mm^3)	E (GPa)	σ (MPa)	(E/ρ)	(σ/ρ)
Aluminium 7075 T6	0.0028	72	570	25.7	203.6
Steel Maraging 300	0.008	207	2000	25.9	250
Carbon/Epoxy M46J UD	0.0018	250	1415	138.9	786.1

2. [a] Several mechanical and physical properties of a unidirectional carbon fibre reinforced polymer composite were listed as follows. Categorise the properties to be either fibre or matrix dominated and justify your selection.

(i) Tensile modulus

(ii) Compression strength

(iii) Impact resistance

(iv) Chemical resistance

(v) Tensile strength

(vi) Through-thickness thermal conductivity

(vii) Fracture toughness

(viii) In-plane electrical conductivity

(ix) Flexural modulus

(x) Compression after impact strength

(40 marks)

[b] Three polymer matrices were shortlisted as possible candidate for an aircraft component. As the design engineer, evaluate the materials in term of properties, advantages and disadvantages.

(i) Polyester

(ii) Polycarbonate

(iii) Nitrile rubber (NBR)

(60 marks)

3. [a] The Rule of Mixtures (RoM) can be used to estimate the in-plane properties of fibre reinforced composites. Lists the assumptions of RoM and then show that the RoM for the in-plane stiffness of a unidirectional composite can be expressed as:

$$E_1 = E_{1f}V_f + E_mV_m$$

(20 marks)

[b] Two choices of prepreg material were presented for an aircraft wing section. Evaluate both prepreg and determine which prepreg will provide the best in-plane mechanical properties.

	Prepreg A	**Prepreg B**
Fibre type	AS4 Carbon	IM7 Carbon
Fibre diameter	7.1 µm	5.2 µm
Maximum fibre load, F_{max}	0.6585 N	0.4455 N
Strain to failure of fibre, ε_f	1.8%	1.9%
Matrix type	8552 Epoxy	3501 Epoxy
Matrix's modulus, E_m	4.67 GPa	4.24 GPa
Fibre volume fraction	65%	60%

(40 marks)

[c] A similar wing section was manufactured with a different type of unidirectional carbon fibre reinforced composite. The elastic constants for the lamina were given as follows:

E_1	130 GPa
E_2	8.6 GPa
G_{12}	4.8 GPa
v_{12}	0.335

In order to accommodate production, the lamina will be rotated at 45° to the x-axis. Determine the transformed stiffness matrix of the rotated lamina. Given:

$$Q_{11} = \frac{E_1}{1 - v_{12}v_{21}}$$

$$Q_{22} = \frac{E_2}{1 - v_{12}v_{21}}$$

$$Q_{12} = \frac{v_{12}E_2}{1 - v_{12}v_{21}} = \frac{v_{21}E_1}{1 - v_{12}v_{21}}$$

$$Q_{66} = G_{12}$$

$$\bar{Q}_{11} = Q_{11}\,cos^4\theta + 2(Q_{12} + 2Q_{66})\,sin^2\theta\,cos^2\theta + Q_{22}\,sin^4\theta$$

$$\bar{Q}_{12} = (Q_{11} + Q_{22} - 4Q_{66})\,sin^2\theta\,cos^2\theta + Q_{12}\,(sin^4\theta + cos^4\theta)$$

$$\bar{Q}_{22} = Q_{11}\,sin^4\theta + 2(Q_{12} + 2Q_{66})sin^2\theta\,cos^2\theta + Q_{22}\,cos^4\theta$$

$$\bar{Q}_{16} = (Q_{11} - Q_{12} - 2Q_{66})\sin\theta\;cos^3\theta + (Q_{12} - Q_{22} + 2Q_{66})sin^3\theta\cos\theta$$

$$\bar{Q}_{26} = (Q_{11} - Q_{12} - 2Q_{66})\,sin^3\theta\cos\theta + (Q_{12} - Q_{22} + 2Q_{66})\sin\theta\;cos^3\theta$$

$$\bar{Q}_{66} = (Q_{11} + Q_{22} - 2Q_{12} - 2Q_{66})\,sin^2\theta\,cos^2\theta + Q_{66}(sin^4\theta + cos^4\theta)$$

(40 marks)

4. [a] Sandwich composite is a group of laminated composites used extensively in aerospace industry. Give the definition of sandwich composite.

(20 marks)

[b] The components of sandwich construction are facings (skins), core and core-to-facing bonding materials. With the help from **Figure 1 and 2**, explain briefly how a sandwich construction is an analogous to an I-beam. Compare the structural efficiency of sandwich panels with respect to solid panels.

(20 marks)

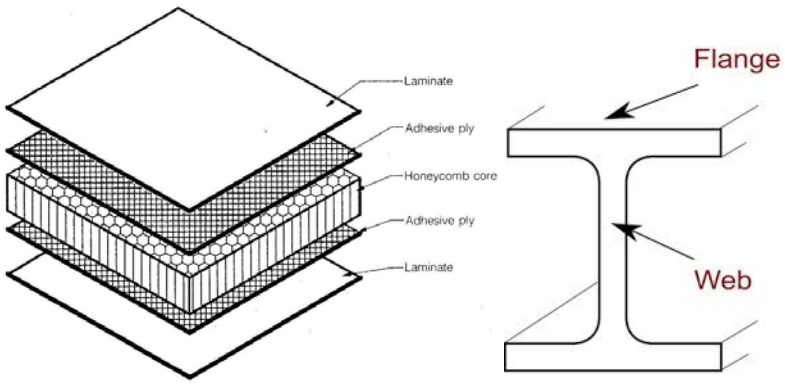


Figure 1: Construction of a sandwich panel.

Relative Bending Stiffness	**1**	**7.0**	**37**
Relative Bending Strength	**1**	**3.5**	**9.2**
Relative Weight	**1**	**1.03**	**1.06**

Figure 2: Structural efficiency of sandwich panels in terms of weight.

[c] A sandwich composite in **Figure 3** is subjected to bending moment, M = $4x10^6$ N mm, directed as shown.

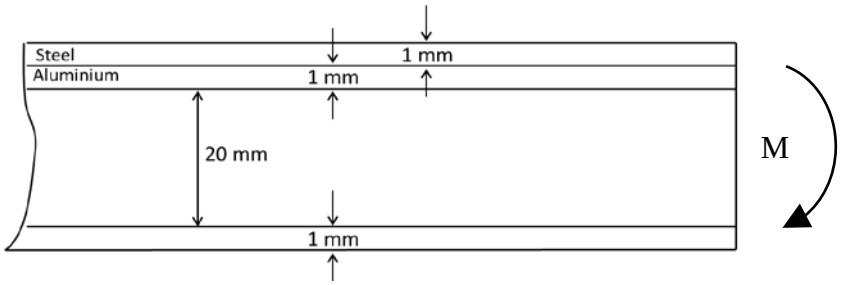


Figure 3 : Sandwich composite beam with upper facing from different materials.

Given:

Beam width = 1000 mm
E_{steel} = 210 000 N/mm^2
$E_{aluminium}$ = 70 000 N/mm^2

(i) Calculate the stress in the facings, σ_{F1} and σ_{F2} of the sandwich composite.

(25 marks)

(ii) Calculate and compare the stress in the steel and aluminium sheets of the upper facing (skin).

(25 marks)

(iii) Evaluate which facing material is subjected to higher stress? Give reason for your answer.

(10 marks)

5. [a] Automated fibre placement (AFP) and automated tape lay-up (ATL) are current manufacturing processes used by the aerospace industry to manufacture aircraft and spacecraft components. Elaborate **FIVE** benefits by using these processes in aerospace manufacturing.

(50 marks)

[b] Marine industry is one of an established industry that uses composite material in their application. What manufacturing process would you recommend to produce a hull of a ship? Discuss your decision in term of the suitability of the process, productivity and the cost.

(50 marks)

*Jawab **SEMUA** soalan.*

1. [a] *Secara amnya, bahan komposit ialah kombinasi dua atau lebih bahan berlainan. Dengan menggunakan perkataan sendiri, berikan pengertian penuh bahan komposit.*

(50 markah)

[b] *Bahan komposit menjadi semakin penting di dalam pembinaan struktur aeroangkasa. Terangkan mengapa bahan komposit termaju merupakan pilihan utama dalam industri aeroangkasa, dengan bantuan **Jadual 1** dan dari sumber lain yang diketahui.*

(50 markah)

Jadual 1: Sifat mekanikal bahan logam dan komposit.

Material	Density	Tensile Modulus	Tensile Strength	Specific Modulus	Specific Strength
	ρ (g/mm^3)	E (GPa)	σ (MPa)	(E/ρ)	(σ/ρ)
Aluminium 7075 T6	0.0028	72	570	25.7	203.6
Steel Maraging 300	0.008	207	2000	25.9	250
Carbon/Epoxy M46J UD	0.0018	250	1415	138.9	786.1

2. [a] *Beberapa sifat mekanikal dan fizikal bahan komposit searah polimer diperkuat dengan gentian karbon telah disenaraikan seperti berikut. Kategorikan sifat-sifat tersebut samada didominasi oleh bahan gentian atau bahan matriks dan berikan alasan sewajarnya.*

(i) Modulus tegangan

(ii) Kekuatan mampatan

(iii) Ketahanan hentaman

(iv) Ketahanan bahan kimia

(v) Kekuatan tegangan

(vi) Kekonduksian haba melalui ketebalan

(vii) Keliatan patah

(viii) Kekonduksian elektrik melalui planar

(ix) Modulus lenturan

(x) Kekuatan selepas hentaman

(40 markah)

[b] Tiga bahan matriks polimer telah disenaraikan sebagai bahan untuk komponen kapal terbang. Sebagai jurutera rekacipta, nilai bahan-bahan tersebut dari segi sifat, kelebihan dan kekurangan masing-masing.

(i) Poliester

(ii) Polikarbonat

(iii) Getah nitril (NBR)

(60 markah)

3. *[a] Hukum percampuran boleh digunakan untuk menganggarkan sifat-sifat bahan komposit diperkuat gentian dalam arah satah. Senaraikan semua anggapan dalam Hukum Percampuran kemudian tunjukkan bahawa Hukum Percampuran untuk kekakuan bahan komposit searah boleh ditulis sebagai:*

$$E_1 = E_{1f}V_f + E_mV_m$$

(20 markah)

[b] Dua pilihan bahan prepreg telah dikemukakan untuk sebuah bahagian sayap kapal terbang. Nilai kedua bahan prepreg tersebut dan tentukan bahan yang akan menghasilkan sifat mekanikal searah satah terbaik.

	Prepreg A	**Prepreg B**
Jenis gentian	AS4 Karbon	IM7 Karbon
Diameter gentian	7.1 µm	5.2 µm
Beban maksimum gentian, F_{max}	0.6585 N	0.4455 N
Terikan ke kegagalan gentian, ε_f	1.8%	1.9%
Jenis matriks	8552 Epoxy	3501 Epoxy
Modulus Matriks, E_m	4.67 GPa	4.24 GPa
Jumlah pecahan gentian	65%	60%

(40 markah)

[c] Bahagian sayap yang serupa telah diperbuat daripada bahan komposit searah diperkuat dengan gentian karbon. Pemalar elastik untuk laminar tersebut diberikan seperti berikut:

E_1	130 GPa
E_2	8.6 GPa
G_{12}	4.8 GPa
v_{12}	0.335

Untuk membolehkan pembuatan, laminar tersebut akan diputar pada 45° dari paksi x. Tentukan matriks kekakuan terubah untuk laminar yang diputarkan tersebut. Diberikan:

$$Q_{11} = \frac{E_1}{1 - v_{12}v_{21}}$$

$$Q_{22} = \frac{E_2}{1 - v_{12}v_{21}}$$

$$Q_{12} = \frac{v_{12}E_2}{1 - v_{12}v_{21}} = \frac{v_{21}E_1}{1 - v_{12}v_{21}}$$

$$Q_{66} = G_{12}$$

$$\bar{Q}_{11} = Q_{11}\cos^4\theta + 2(Q_{12} + 2Q_{66})\sin^2\theta\cos^2\theta + Q_{22}\sin^4\theta$$

$$\bar{Q}_{12} = (Q_{11} + Q_{22} - 4Q_{66})\sin^2\theta\cos^2\theta + Q_{12}(\sin^4\theta + \cos^4\theta)$$

$$\bar{Q}_{22} = Q_{11}\sin^4\theta + 2(Q_{12} + 2Q_{66})\sin^2\theta\cos^2\theta + Q_{22}\cos^4\theta$$

$$\bar{Q}_{16} = (Q_{11} - Q_{12} - 2Q_{66})\sin\theta\cos^3\theta + (Q_{12} - Q_{22} + 2Q_{66})\sin^3\theta\cos\theta$$

$$\bar{Q}_{26} = (Q_{11} - Q_{12} - 2Q_{66})\sin^3\theta\cos\theta + (Q_{12} - Q_{22} + 2Q_{66})\sin\theta\cos^3\theta$$

$$\bar{Q}_{66} = (Q_{11} + Q_{22} - 2Q_{12} - 2Q_{66})\sin^2\theta\cos^2\theta + Q_{66}(\sin^4\theta + \cos^4\theta)$$

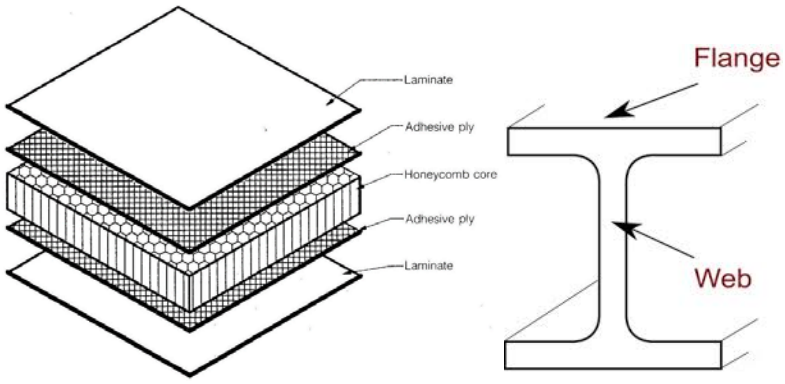
(***40 markah)***

4. *[a]* *Komposit terapit merupakan salah satu kumpulan komposit yang digunakan secara meluas dalam industri aeroangkasa. Berikan pengertian komposit terapit.*

(20 markah)

[b] *Komponen-komponen pembinaan terapit komposit adalah muka (kulit), teras dan bahan pelekat teras-muka. Dengan bantuan* ***Rajah 1 dan 2****, terangkan bagaimana pembinaan bahan terapit komposit dianologikan kepada rasuk-I. Bandingkan kecekapan bahan komposit terapit dengan panel padu.*

(20 markah)

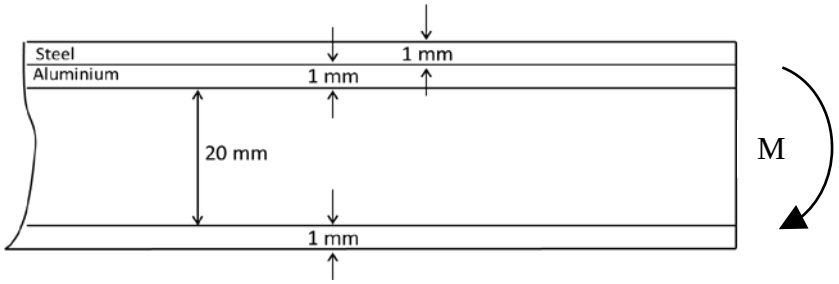


Rajah 1: Pembinaan bahan komposit terapit*.*

Relative Bending Stiffness	**1**	**7.0**	**37**
Relative Bending Strength	**1**	**3.5**	**9.2**
Relative Weight	**1**	**1.03**	**1.06**

Rajah 2: Kecekapan struktur bahan komposit terapit berdasarkan jisim.

*[c] Komposit terapit seperti **Rajah 3** telah dikenakan momen lentur, M = 4x106 N mm, arah seperti digambarkan dalam rajah.*



Rajah 3: Rasuk komposit terapit dengan muka atas daripada bahan berlainan.

Diberi:

Lebar rasuk = 1000 mm
E_{steel} = 210 000 N/mm2
$E_{aluminium}$ = 70 000 N/mm2

(i) Kirakan tegasan pada muka, σ_{F1} dan σ_{F2} bagi komposit terapit tersebut.

(25 markah)

(ii) Kira dan bandingkan tegasan pada kepingan steel dan aluminium bagi muka atas bahan terapit.

(25 markah)

(iii) Semak muka bahan manakah yang mengalami tegasan yang lebih tinggi? Beri sebab kepada jawapan anda.

(10 markah)

5. [a] *Peletakan gentian automatik (AFP) dan peletakan pita automatik (ATL) merupakan proses terkini yang digunakan dalam industri aeroangkasa dalam pembuatan komponen kapal terbang dan kapal kapal angkasa. Perincikan* ***LIMA*** *faedah proses-proses pembuatan ini dalam pembuatan aeroangkasa.*

(50 markah)

[b] *Industri marin adalah salah satu industri yang telah mantap yang mengaplikasi penggunaan bahan komposit. Cadangkan proses pembuatan untuk menghasilkan struktur utama badan kapal? Bincangkan pilihan anda dari segi kesesuaian proses, produktiviti dan kos.*

(50 markah)

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