THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

This exam paper must not be removed from the venue

Venue _____
Seat Number _____
Student Number |__|__|__|__|__|__|__|__|
Family Name _____
First Name _____

School of Mechanical and Mining Engineering
Semester Two Examinations, 2023
AERO4300 Aerospace Composites

This paper is for St Lucia Campus students.

Examination Duration: 120 minutes

Planning Time: 10 minutes

Exam Conditions:

• This is a Closed Book examination - specified written materials permitted
• Casio FX82 series or UQ approved and labelled calculator only.
• During Planning Time - Students are encouraged to review and plan responses to the exam questions
•This examination paper will be released to the Library

Materials Permitted in the Exam Venue:
(No electronic aids are permitted e.g. laptops, phones)

One A4 sheet of handwritten or typed notes double sided is permitted.

Materials to be supplied to Students:
Additional exam materials (e.g. answer booklets, rough paper) will be provided upon request.

1 x 14-Page Answer Booklet

Instructions to Students:
If you believe there is missing or incorrect information impacting your ability to answer any question, please state this when writing your answer.

Answer questions for Part A on this examination paper.
You must write your name and student number on the front cover of this examination paper.
Write answers to Part B in the answer booklet.
Answer all questions.

For Examiner Use Only

Question	Mark

Total _____

Detailed Instructions for This Examination:

This examination consists of two parts, labelled Part A and Part B. The total marks available are 50 marks. The marks associated with each Part, and the suggested time to complete it, are given below:

- Part A: Short answer questions (~60 min; 25 marks)
- Part B: Composite mechanics questions (~60 min; 25 marks)

How to answer the questions:

- Answer questions for Part A on this examination paper.
- Write answers to Part B in the answer booklet.
- Ensure that you have filled in your full name and eight digit student number on both the exam paper and answer booklet.

PART A: Composite materials and processes (Marks = 25)

Question 1 (2 marks):

List 4 different forms fibre reinforcement typically comes in:

-
-
-
-

Question 2 (1.5 marks):

For an intermediate modulus (IM) carbon fibre and an E-glass fibre, provide the properties in the table below.

Property	**IM Carbon Fibre**	**E-Glass**	**Units**
Elastic modulus			GPa
Tensile strength			MPa
Density			g/ccm

Question 3 (1 mark):

Explain why the tensile strength of a reinforcing fibre increases with a decrease in fibre diameter.

Question 4 (3 marks):

List the three heat treatment stages of the carbon fibre manufacturing process **(1.5 marks)** and explain what happens to the fibre in each treatment stage (**1.5 marks**).

Question 5 (2 marks):

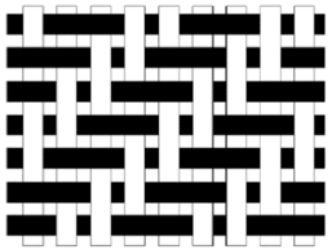
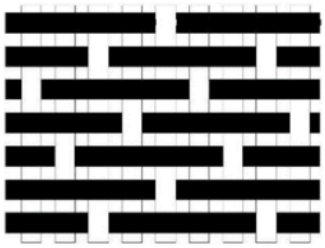
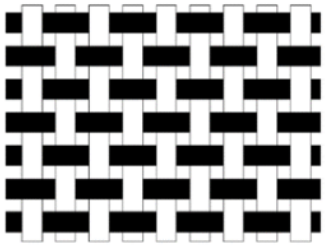
Explain why thermoplastic polymers are better suited for short-cycle-time manufacturing processes (**1 mark**). Explain what issue is encountered when rapidly cooling a semi-crystalline thermoplastic from melt (**1 mark**).

Question 6 (1 mark):

For an application that requires good visual appearance and good drapability of the fabric, what weave type do you recommend?

Question 7 (1.5 marks):

Label the following woven fabric patterns.

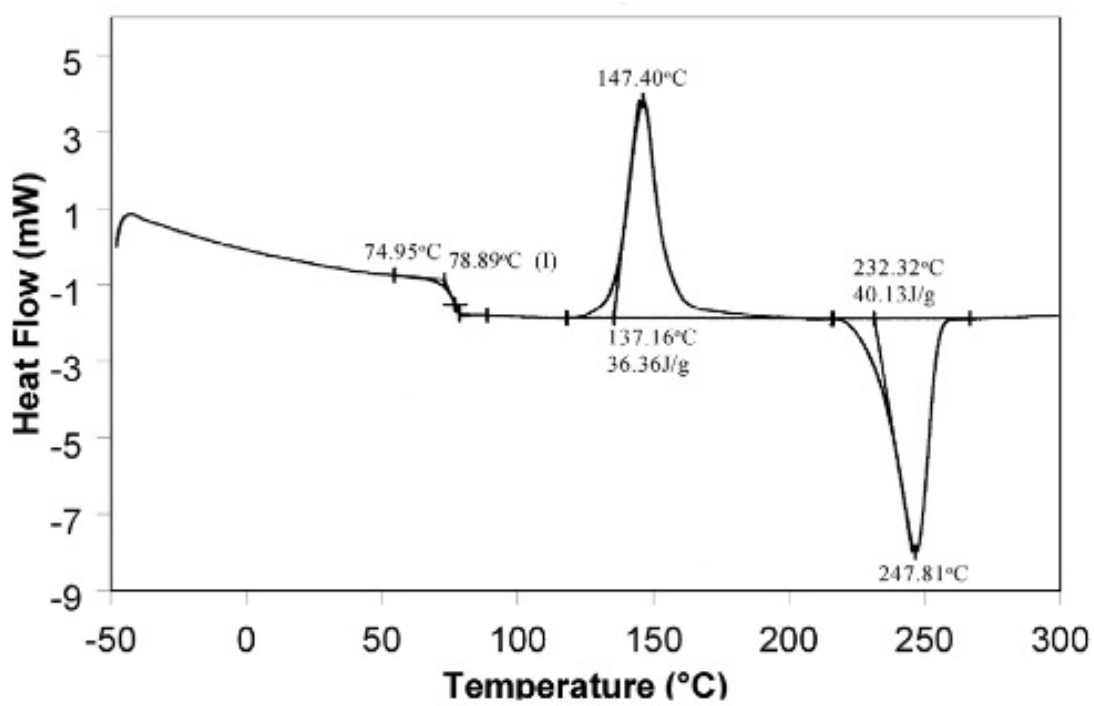
Question 8 (2 marks):

Name the two chemical reaction types that are most commonly encountered in the curing of commercially used thermoset resins (**1 mark**). For each chemical reaction type, provide a resin type that follows this reaction pathway (**1 mark**).

Question 9 (3 marks):

For the Differential Scanning Calorimetry (DCS) curve shown below:

- Label each transition point directly in the DSC plot (**1.5 marks**)
- In the table below, list which polymer type this is (i.e. thermoset, amorphous thermoplastic or semi-crystalline thermoplastic) (**0.5 marks**)
- In the table below, provide the recommended processing temperature (**0.5 marks**)
- In the table below, explain what could be done to reduce the peak at 147 °C (**0.5 marks**)



List the polymer type:
Recommended processing temperature:
Required processing change to reduce peak at 147 °C:

Question 10 (3 mark):

In the table below, list each of the four fundamental processing steps that each polymer matrix composite manufacturing process goes through (**1 mark**). For both filament winding and resin transfer moulding, list the sequence in which these steps are undertaken (**1 mark each**).

List the four processing steps: 1. 2. 3. 4.
Process step sequence for filament winding:
Process step sequence for resin transfer moulding:

Question 11 (5 marks):

For each of the **five** components pictured, suggest the most suitable polymer, fibre, and manufacturing method (**1 mark** for each component). Write your answers in the second, third, and fourth table columns.

Component	**Polymer**	**Fibre**	**Manufacturing method**
 Pressure vessel			

Component	Polymer	Fibre	Manufacturing method
 Composite structural members for jetty			
 Structural strengthening of a concrete structure with fibre reinforced plastics			
 Automotive component with continuous fibre reinforcement (high production volume)			

Component	Polymer	Fibre	Manufacturing method
 Titan submarine composite pressure hull			

PART B: Composite Mechanics Questions (Marks = 25)

WRITE YOUR ANSWERS TO PART B IN THE ANSWER BOOKLET

Question B1 Classical Laminate Theory (4 marks)

a) Describe one application where the use of non-symmetric laminate stacking sequences can be beneficial. Explain why. (1 mark)

b) Two laminates are made from the same pre-preg materials. Are the *A*-matrices of the two laminates with the stacking shown below identical? Explain why they are or explain which components of the two matrices are different. (1 mark)

Stacking sequence laminate 1: $[0\ +45\ -45\ 90]_s$

Stacking sequence laminate 2: [+45 -45 90 0 0 90 -45 +45]

c) Are the *D*-matrices of the two laminates in question B1b) the same? Explain why or why not. (1 mark)

d) Identify the non-zero and the zero components in the *A*-matrix and the *D*-matrix of a laminate with a balanced, symmetric stacking sequence. (1 mark)

Question B2 Laminate Strength and Failure Theories (4 marks)

a) Describe what fundamental composite material characteristic is included in the Tsai-Hill failure criterion compared to the maximum stress failure criterion. Illustrate this difference by sketching the failure envelopes of the two criteria for the unidirectional, off-axis tensile test. Copy Figure B2 below into the answer booklet and add the failure envelopes. (2 marks)

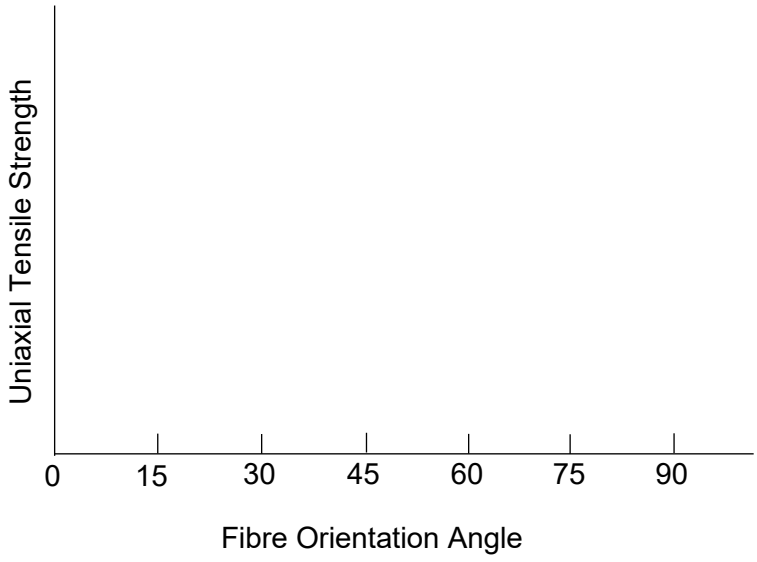


Figure B2

b) Explain if a standard rule of mixture model can be used to accurately predict the tensile strength X_1^T of a unidirectional lamina loaded in the fibre direction. Justify your answer. (2 marks)

Question B3 Nondestructive Testing (4 marks)

a) At what times are you expecting the backwall echoes to arrive for the two samples inspected by pulse-echo ultrasonics in the thickness direction shown in Figure B3? (2 marks)

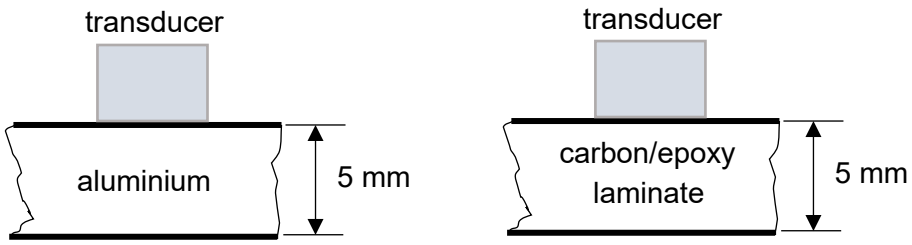


Figure B3

b) List in decreasing preference three nondestructive evaluation methods you recommend to detect skin-core disbond damage in a sandwich panel with 1.5 mm thick carbon epoxy skins and a 25 mm thick Nomex honeycomb core. Copy Table B3 below into the answer booklet and fill in the cells. (2 marks)

Table B3

Name of Method (in decreasing order of preference)	**Description of Method** (less than 30 words, consider using sketches to illustrate the method)

Question B4 (7 marks)

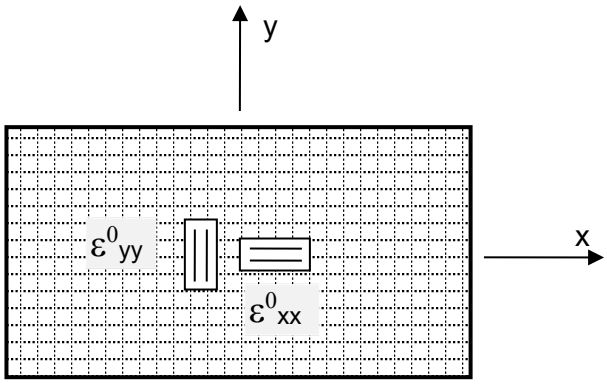
A carbon fibre-reinforced lamina has the following reduced stiffness and in-plane strength properties:

$$Q_{11} = 250 \quad Q_{12} = 10 \quad Q_{22} = 25 \quad Q_{66} = 15 \quad [\text{GPa}]$$

$$X_1^T = X_1^C = 800 \quad X_2^T = 100 \quad X_2^C = 250 \quad X_S = 70 \quad [\text{MPa}]$$

a) Sketch the failure envelopes in the $\sigma_{11} - \sigma_{22}$ and the $\sigma_{22} - \sigma_{12}$ principal stress spaces for the maximum stress failure criterion. (1 mark)

b) A cross-ply $[0\ 90]_s$ laminate made from the same material is under in-plane loading, which results in the global membrane strains shown in Figure B4:



$$\epsilon_{xx}^0 = 1000 \quad \epsilon_{yy}^0 = 300 \quad \gamma_{xy}^0 = 0 \quad [\mu\text{m/m}]$$

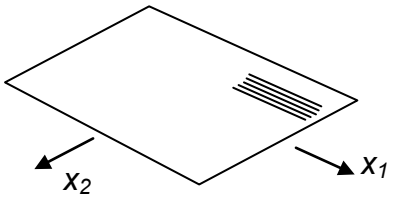
Figure B4

Determine the safety factors for failure of the *0°* and *90°* plies. What is the expected failure mode? (4 marks)

c) Describe what changes to the answers in question B4 b) are expected, if the Tsai-Hill failure criterion is used? (2 marks)

Question B5 (6 marks)

A unidirectional fibre-reinforced pre-preg material has the properties shown.



E_{11} = 165 GPa
E_{22} = 12 GPa
ν_{12} = 0.3
G_{12} = 8 GPa
t = 0.125 mm

By immersing a unidirectional ply of the material in sea water the following ultimate swelling strains are measured:

$$\varepsilon_{11} = 2*10^{-4} \qquad \varepsilon_{22} = 1.2*10^{-3} \qquad \varepsilon_{12} = 0$$

a) What material is analysed in this question? Justify your answer. (1 mark)

b) Determine the residual stresses and global swelling strains for a $[0\ 90]_s$ cross ply laminate of this material immersed in sea water. (4 marks)

c) Discuss possible positive and negative effects hygro-thermomechanical residual stresses may have on the mechanical behaviour of a laminate. (1 mark)

END OF EXAMINATION