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Faculty of Applied Design
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EXAMINATION SOLUTIONS: SESSION 2017/2018

School:	ENLWTRINL		
Programme:	EXTREME SPORTS ENGINEERING	Year:	L6
Module/Unit:	MATERIALS & MANUFACTURING FOR NICHE MARKETS (M6X01201)		
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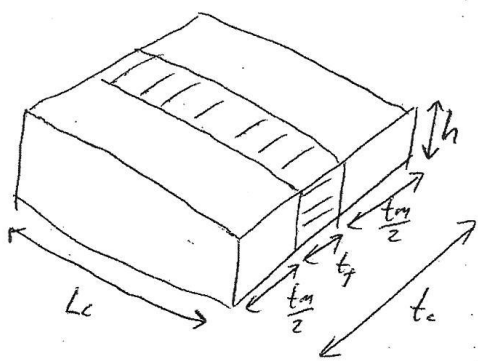
Question No	Question	Marks
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M6X01201		
Question No	Question	Marks
1	PHASES : MATRIX - PRIMARY REINFORCING AGENT - SECONDARY	2
2	MATRIX IS USED TO CLASSIFY COMPOSITES.. METAL MATRIX COMPOSITES (MMC) CERAMIC MATRIX COMPOSITES (CMC) POLYMER MATRIX COMPOSITES (PMC) REINFORCING AGENT FIBRE - GENERALLY CIRCULAR, PRODUCES GREATEST OPPORTUNITY FOR STRENGTH ENHANCEMENT. CAN BE CONTINUOUS OR DIS-CONTINUOUS & ARRANGED IN 1D, 2D OR 3D. PARTICLES - CAN BE MICRO OR MACROSCOPIC. ARRANGED RANDOMLY LEADING TO ISOTROPIC MATERIAL PROPERTIES & THUS GENERALLY NOT AS STRONG AS FIBRE REINFORCEMENT. FLAKES - 2D PARTICLES - LOW COST.	3
		2
		2

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Question No.	Question	Marks
(6)	 $\Delta_c = \Delta_f + \Delta_m$ $t_c \epsilon_c = t_f \epsilon_f + t_m \epsilon_m$ $t_c \frac{\sigma_c}{E_c} = t_f \frac{\sigma_f}{E_f} + t_m \frac{\sigma_m}{E_m}$ $\frac{t_c}{E_c} = \frac{t_f}{E_f} + \frac{t_m}{E_m}$ $\frac{1}{E_c} = \frac{1}{E_f} \frac{t_f}{t_c} + \frac{1}{E_m} \frac{t_m}{t_c}$ $\frac{1}{E_c} = \frac{1}{E_f} \frac{t_f h L_c}{t_c h L_c} + \frac{1}{E_m} \frac{t_m h L_c}{t_c h L_c}$	

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Question No.	Question	Marks
	$\frac{1}{E_2} = \frac{1}{E_f} \frac{V_f}{V_c} + \frac{1}{E_m} \frac{V_m}{V_c}$ $\frac{1}{E_2} = \frac{1}{E_f} V_f + \frac{1}{E_m} V_m$ $\frac{1}{E_2} = \frac{V_f}{E_f} + \frac{V_m}{E_m}$	(7)
(c)	$\frac{1}{E_2} = \frac{V_f}{E_f} + \frac{V_m}{E_m}$ $= \frac{0.75}{90} + \frac{0.25}{3}$ $= 0.0917$ $E_2 = \underline{\underline{10.91 \text{ GPa}}}$	(2)

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Question No	Question	Marks
(2) (20)	$\begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & 0 \\ S_{12} & S_{22} & 0 \\ 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix}$ IF $\sigma_1 \neq 0$, $\sigma_2 = 0$ & $\tau_{12} = 0$ $\epsilon_1 = S_{11} \sigma_1 \quad \therefore S_{11} = \frac{\epsilon_1}{\sigma_1} = \frac{1}{E_1}$ $\epsilon_2 = S_{12} \sigma_1 \quad \therefore S_{12} = \frac{\epsilon_2}{\sigma_1} = -\nu_{12} \frac{\epsilon_1}{\sigma_1} = -\frac{\nu_{12}}{E_1}$ IF $\sigma_2 \neq 0$, $\sigma_1 = 0$ & $\tau_{12} = 0$ $\epsilon_2 = S_{22} \sigma_2 \quad \therefore S_{22} = \frac{\epsilon_2}{\sigma_2} = \frac{1}{E_2}$ IF $\tau_{12} \neq 0$, $\sigma_1 = 0$ & $\sigma_2 = 0$ $\gamma_{12} = S_{66} \tau_{12} \quad \therefore S_{66} = \frac{\gamma_{12}}{\tau_{12}} = \frac{1}{G_{12}}$	(1) (1) (1) (1)

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Question No	Question	Marks
①	$\therefore [S] = \begin{bmatrix} \frac{1}{E_1} & \frac{-\nu_{12}}{E_1} & 0 \\ \frac{-\nu_{12}}{E_1} & \frac{1}{E_2} & 0 \\ 0 & 0 & \frac{1}{G_{12}} \end{bmatrix}$	①
②	NOW IF $\sigma_1 \neq 0, \sigma_2 = 0$ & $\tau_{12} = 0$ $E_2 = S_{12}\sigma_1 \quad \therefore S_{12} = \frac{E_2}{\sigma_1} = \frac{-\nu_{12} E_1}{\sigma_1} = \frac{-\nu_{12}}{\frac{E_1}{\sigma_1}} *$ HOWEVER IF $\sigma_2 \neq 0, \sigma_1 = 0$ & $\tau_{12} = 0$ $E_1 = S_{12}\sigma_2 \quad \therefore S_{12} = \frac{E_1}{\sigma_2} = \frac{-\nu_{21} E_2}{\sigma_2} = \frac{-\nu_{21}}{\frac{E_2}{\sigma_2}} **$ COMPARING * & ** $S_{12} = \frac{-\nu_{12}}{E_1} = \frac{-\nu_{21}}{E_2}$	③

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Question No	Question	Marks
③	$S_{11} = \frac{1}{E_1} = \frac{1}{181 \times 10^9} = 0.5525 \times 10^{-11} \text{ Pa}^{-1}$ $S_{12} = \frac{-\nu_{12}}{E_1} = \frac{-0.28}{181 \times 10^9} = -0.1547 \times 10^{-11} \text{ Pa}^{-1}$ $S_{22} = \frac{1}{E_2} = \frac{1}{10.3 \times 10^9} = 0.9709 \times 10^{-10} \text{ Pa}^{-1}$ $S_{44} = \frac{1}{G_{12}} = \frac{1}{7.17 \times 10^9} = 0.1395 \times 10^{-9} \text{ Pa}^{-1}$ $\therefore [S] = \begin{bmatrix} 0.5525 \times 10^{-11} & -0.1547 \times 10^{-11} & 0 \\ -0.1547 \times 10^{-11} & 0.9709 \times 10^{-10} & 0 \\ 0 & 0 & 0.1395 \times 10^{-9} \end{bmatrix} \text{ Pa}^{-1}$	③

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Question No	Question	Marks
(d)	$\begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} 0.5525 \times 10^{-11} & -0.1547 \times 10^{-11} & 0 \\ -0.1547 \times 10^{-11} & 0.9709 \times 10^{-10} & 0 \\ 0 & 0 & 0.1895 \times 10^{-7} \end{bmatrix} \begin{bmatrix} 2 \times 10^6 \\ -3 \times 10^6 \\ 4 \times 10^6 \end{bmatrix}$ $= \begin{bmatrix} 15.69 \\ -294.4 \\ 557.9 \end{bmatrix} (10^{-6})$ $\therefore$ (i) $\epsilon_1 = 15.69 \mu$ (ii) $\epsilon_2 = -294.4 \mu$ (iii) $\gamma_{12} = 557.9 \mu$	5
(e)	IT IS ASSUMED - THE MATERIAL IS LINEAR - " " " ELASTIC - THERE IS ONE PLANE OF SYMMETRY - $\epsilon_3 = 0$	4

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Question No	Question	Marks
③④	SEVERAL LAMINA ARE USED TO FORM A LAMINATE DUE TO ① A SINGLE LAMINA IS ~0.1-0.2mm THICK, ∴ TO GET ANYTHING OF MEANINGFUL STRENGTH SEVERAL LAMINA MUST BE COMBINED ② A SINGLE LAMINA IS WEAK TRANSVERSE TO THE FIBRES SO SEVERAL LAMINA ARE STACKED WITH VARYING ORIENTATIONS TO OVERCOME THIS	④
⑥	PROBLEMS: - HOW MANY PLYS - WHAT ORIENTATION - WHAT STACKING SEQUENCE OPPORTUNITIES: - OPTIMISATION	④
①	i) $[0/-45/90_2/60/0]$ $\begin{array}{r} 0 \\ -45 \\ 90 \\ 90 \\ 60 \\ 0 \end{array}$	
ii)	$[0/-45/60]_s$ $\begin{array}{r} 0 \\ -45 \\ 60 \\ -45 \\ 0 \end{array}$	
iii)	$[0/-45/60]_s$ $\begin{array}{r} 0 \\ -45 \\ 60 \\ -45 \\ 0 \end{array}$	
iv)	$[0_{GR}/\pm 45_B]_s$ $\begin{array}{r} \text{GRAPHITE } 0 \\ \text{BORON } 45 \\ \text{BORON } -45 \\ \text{BORON } -45 \\ \text{BORON } 45 \\ \text{GRAPHITE } 0 \end{array}$	④

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Question No	Question	Marks
(a) (i) A CROSS PLY ONLY HAS 0/90 PLYS (ii) AN ANGLE PLY ARE ONLY ORIENTATED $\pm \theta$ (iii) SYMMETRICAL ABOUT THE MIDPLANE EXCEPT FOR SIGN (iv) PLYS ARE IN $\pm$ PAIRS		(4)
(c)	HYGROTHERMAL STRESSES & STRAINS ARE CAUSED BY THE DIFFERENT THERMAL EXPANSION COEFFICIENTS OF THE REINFORCEMENT PHASE & THE MATRIX WHEN THE COMPOSITE COOLS DOWN AFTER PROCESSING AT A MICROMECHANICAL LEVEL. IN ADDITION MOISTURE ABSORBED BY THE 2 PHASES RESULTING IN DIFFERENT AMOUNTS OF SWELLING CAN ALSO CAUSE ISSUES. THESE CAN BE MITIGATED IF THE LAMINATE IS SYMMETRICAL	(4)

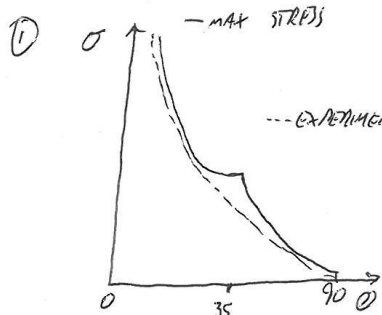
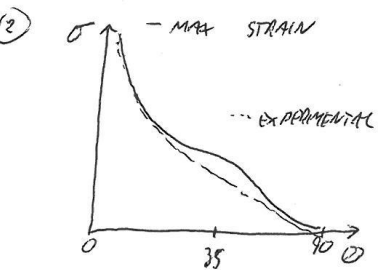
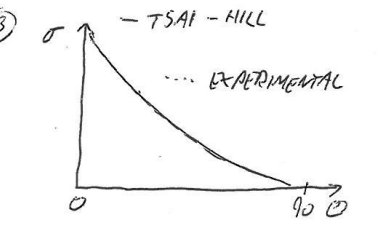
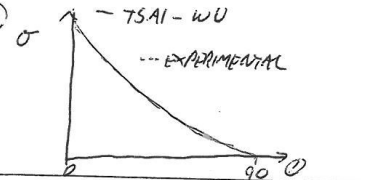
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Question No	Question	Marks
(4) (a)	INSTEAD OF THE PRINCIPAL STRESSES, THE FOLLOWING <u>ULTIMATES</u> ARE CONSIDERED WHEN PREDICTING FAILURE OF A LAMINATE IN THE 12 PLANE: • COMPRESSIVE & TENSILE STRESS - LONGITUDINAL • " " " " - LATERAL • " " " " STRAIN - LONGITUDINAL • " " " " - LATERAL • IN-PLANE SHEAR STRESS • IN-PLANE SHEAR STRAIN	(7)
(b)	FAILURE THEORIES: (1) <u>MAX STRESS FAILURE THEORY</u> - FAILURE PREDICTED IF NORMAL OR SHEAR STRESSES IN LOCAL AXIS EXCEED THOSE OF THE UNIDIRECTIONAL LAMINATE. (2) <u>MAX STRAIN FAILURE THEORY</u> - AS ABOVE BUT WITH STRAINS (3) <u>TSAI-HILL FAILURE THEORY</u> - FAILURE WILL OCCUR WHEN THE DISTORTION ENERGY IS GREATER THAN THE FAILURE DISTORTION ENERGY OF THE MATERIAL: BASED ON VON-MISES FOR ISOTROPIC MATERIALS	

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Question No	Question	Marks
(46)	(4) <u>TSAI-WU FAILURE THEORY</u> - AS TSAI-HILL BUT ACCOUNTS FOR COMPRESSIVE STRESSES ALSO	(8)
(C)	(1)  - MAX STRESS & MAX STRAIN HAVE A CUSP AT ABOUT 35°. MAX STRESS IS MORE PRONOUNCED - TSAI-HILL & TSAI-WU ARE IN GOOD AGREEMENT & CLOSE TO THE EXPERIMENTAL RESULTS (2)  (3)  (4) 	(5)