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Faculty of Applied Design
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EXAMINATION SOLUTIONS: SESSION 2013 2014

School:	LOGISTICS & MANUFACTURING		
Programme:	MECHANICAL & MANUFACTURING ENGINEERING	Year:	3
Module/Unit:	ADVANCED STRESS - RESIT		
Author:	MELVIN LAKE / RICHARD THOMAS	Page:	1 of

Question No	Question	Marks
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Question No	Question	Marks
①	WHILST ALUMINIUM OFFERS NO ADVANTAGE IN TERMS OF TENSILE LOADING, DUE TO ITS LOW DENSITY, LARGER SECTIONS CAN BE USED WHICH OFFER BENEFITS IN TERMS OF BENDING & BUCKLING DUE TO THE INCREASED SECOND MOMENT OF AREA WHEN COMPARED TO STEEL ALTERNATIVES.	(2)
②	COMPLETE SECTION $I_{xx} = 2 \times I_{xx}(\text{C}) + 2 \times I_{xx} \text{ PLATE}$ $= 2 \times 1.5 \times 10^{16} + 2 \times (I_c + Ah^3)$ $= 2 \times 1.5 \times 10^{16} + 2 \times \left(\frac{bd^3}{12} + Ah^3 \right)$ $= 2 \times 1.5 \times 10^{16} + 2 \times \left(\frac{150 \times 2^3}{12} + 150 \times 2 \times 76^3 \right)$ $= 3 \times 10^{16} + 3.29 \times 10^{16}$ $= \underline{6.29 \times 10^{16} \text{ mm}^4}$	(2)

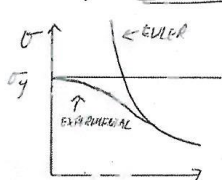
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Question No	Question	Marks
	$I_{yy} = 2 \times I_{yy}' + 2 \times I_{yy} \text{ PLATE}$ $= 2 \times (I_{yy} + Ah^2) + 2 \times I_{yy} \text{ PLATE}$ $= 2 \times (5.5 \times 10^5 + 384 \times 60^2) + 2 \times \frac{2 \times 150^3}{12}$ $= 7.86 \times 10^6 + 1.13 \times 10^6$ $= \underline{4.99 \times 10^6 \text{ mm}^4}$ $\therefore I_{xx} > I_{yy}$ so it will buckle about I_{yy} (b)(ii) RADIUS OF GYRATION $K = \sqrt{\frac{I_{yy}}{A}}$ $= \sqrt{\frac{4.99 \times 10^6}{1368}}$ $= \underline{60.4 \text{ mm}}$ SLENDerness RATIO = $\frac{L}{K} = \frac{L}{60.4 \times 10^{-3}} = \underline{16.6}$	(2) (1) (1) (1)

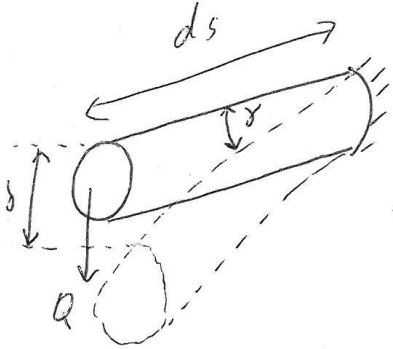
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Question No	Question	Marks
(iv)	EULER, FIXED END/FREE END $P_c = \frac{\pi^2 EI}{4L^2} = \frac{\pi^2 \times 200 \times 10^3 \times 4.99 \times 10^{-6}}{4 \times 1^2}$ $= \underline{\underline{2.46 \times 10^6 N}}$	(3)
(v)	RANKINE GORDON $P_A = \frac{\sigma_y A}{1 + a \left(\frac{L}{K} \right)^2}$ $= \frac{320 \times 10^6 \times 1.368 \times 10^{-3}}{1 + \frac{1}{2500} \times 16.6^2}$ $= \frac{437760}{1.0367}$ $= \underline{\underline{0.42 \times 10^6 N}}$	(3)
(vi)	 SLENDERNESS RATIO EULER IS ONLY VALID FOR LARGE SLENDERNESS RATIOS. FOR SMALLER VALUES RANKINE GORDON SHOULD BE USED $\Rightarrow$ IN THIS CASE THIS IS LIKELY TO BE MORE ACCURATE.	(2)

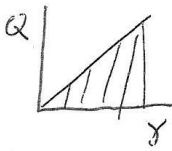
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Question No	Question	Marks
2a i	 SHEAR MODULUS $G = \frac{\text{SHEAR STRESS}}{\text{SHEAR STRAIN}}$ $= \frac{\tau}{\gamma}$ $= \frac{Q}{\gamma A} \quad \left(\text{SINCE } \tau = \frac{Q}{A} \right)$ $\therefore \gamma = \frac{Q}{AG}$	2

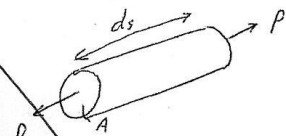
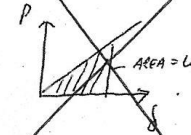
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Question No	Question	Marks
2a 11	 STRAIN ENERGY = $\frac{1}{2} QY$ IN SMALL ELEMENT $= \frac{1}{2} Q \frac{Q}{AL}$ $= \frac{1}{2} \frac{Q^2}{AL}$ TOTAL STRAIN ENERGY = $\int_0^L \frac{Q^2}{2AL} ds$ $\therefore U = \frac{Q^2 L}{2AL}$	① ② ①

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Question No	Question	Marks
2a(i)	 $E = \frac{\sigma}{\epsilon}$ $= \frac{P}{A} \div \frac{\delta}{ds} = \frac{P ds}{A \delta} \quad \therefore \delta = \frac{P ds}{AE}$	2
2a(ii)	 FOR SMALL SECTION $U = \frac{1}{2} P \delta$ $= \frac{1}{2} P \times \frac{P ds}{AE} = \frac{P^2 ds}{2AE}$ FOR TOTAL BAR $U = \int_0^L \frac{P^2 ds}{2AE} = \frac{P^2 L}{2AE}$	4
2a(iii)	RESILIENCE = STRAIN PER UNIT VOLUME $U = \frac{P^2 L}{2AE}$ $= \frac{\sigma^2 A^* L}{2AE}$ $= \frac{\sigma^2 AL}{2E}$ $\therefore \frac{U}{AL} = \frac{\sigma^2}{2E}$ = RESILIENCE	4

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Question No	Question	Marks
2b(i)	$\sigma = \frac{F}{A} \quad \therefore F = \sigma \times A = 300 \times 10^6 \times (15 \times 15) \times 10^{-6}$ $= \underline{67.5 \text{ kN}}$ $A_{CEA} = 15 \times 15 \times 10^{-6} = \underline{225 \times 10^{-6} \text{ m}^2}$ $U = \frac{P^2 L}{2AE} = \frac{67500^2 \times 1}{2 \times 225 \times 10^{-6} \times 200 \times 10^9} = \underline{50.6 \text{ J}} \quad (3)$	
2b(ii)	$P.E. = mgh$ $= mg(h + \delta L) \quad (1)$ $E = \frac{U}{\epsilon} = \sigma \cdot \frac{\delta L}{L} = \frac{\sigma L}{\delta L} \quad \therefore \delta L = \frac{\sigma L}{E}$ $\text{from (1)} \quad P.E. = mg\left(h + \frac{\sigma L}{E}\right) \quad (2)$ THE ENERGY IS ASSOCIATED W/ SHAFT. $U = \frac{P^2 L}{2AE} = \frac{\sigma^2 A^2 L}{2AE} = \frac{\sigma^2 AL}{2E} = \frac{\sigma^2 V}{2E} \quad (3)$ EQUATING (2) & (3) $\frac{\sigma^2 V}{2E} = mg\left(h + \frac{\sigma L}{E}\right)$ $\frac{\sigma^2 V}{2Emg} = h + \frac{\sigma L}{E} \quad \therefore h = \frac{\sigma^2 V}{2Emg} - \frac{\sigma L}{E} \quad (4)$	

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2b(iii)	$h = \frac{\sigma^2 V}{2Emy} - \frac{\sigma L}{E}$ $= \frac{(75 \times 10^6)^2 \times (2.25 \times 10^{-4} \times 1)}{2 \times 200 \times 10^9 \times 200 \times 9.81} - \frac{75 \times 10^6 \times 1}{200 \times 10^9}$ $= 1.61 \times 10^{-3} - 3.75 \times 10^{-4}$ $= 1.2 \times 10^{-3}$ $= \underline{\underline{1.2 \text{ mm}}}$	3	