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**UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

**FINAL EXAMINATION  
SEMESTER I  
SESSION 2019/2020**

COURSE NAME : AIRCRAFT STRUCTURE  
COURSE CODE : BDU 20103  
PROGRAMME CODE : BDC/BDM  
EXAMINATION DATE : DECEMBER 2019/JANUARY 2020  
DURATION : 3 HOURS  
INSTRUCTION : ANSWER ONLY **FIVE (5)** QUESTIONS  
FROM **SIX (6)** QUESTIONS PROVIDED

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

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- Q1** (a) Briefly explain about plane strain and plane stress. (4 marks)
- (b) The  $60^\circ$  strain rosette is mounted on the aircraft A320 wing as shown in **Figure Q1(b)**. Due to the loadings during flight test, the readings from the gauges give  $\varepsilon_a = 60(10^{-6})$ ,  $\varepsilon_b = 135(10^{-6})$  and  $\varepsilon_c = 264(10^{-6})$ . Determine:
- (i) The average normal strain.
  - (ii) The in-plane principal strains and the directions in which they act. Sketch the deformed element for principal strains.
  - (iii) The principal stresses at that point. (16 marks)
- Q2** (a) Define the elastic curve. State two disadvantages of the Integration Method in solving complex beam deflection problems. (6 marks)
- (b) In the laboratory testing, the wing spar of Learjet 29 is subjected to a triangular distributed loading as shown in **Figure Q2(b)**.  $W_0$  and  $L$  are given as 10 kN/m and 6 m, respectively and  $EI$  is constant. Determine:
- (i) Reactions at the supports and sketch the Free Body Diagram of the spar.
  - (ii) The equations of the elastic curve for  $0 \leq x \leq L/2$  (in terms of  $EI$ ).
  - (iii) The maximum displacement of the spar (in terms of  $EI$ ). (14 marks)
- Q3** (a) Define the column and critical load. (4 marks)
- (b) Explain buckling of column phenomenon and state the assumption made in applying Euler's formula to determine critical load. (4 marks)
- (c) Aircraft simulator joystick can be modeled as shown in **Figure Q3(c)**. The control rod BC has a diameter of 25 mm and is made of A-36 steel. Determine:
- (i) Axial force in rod BC,  $F_{BC}$  and sketch the Free Body Diagram of the lever OAB.
  - (ii) Force  $P$  that can be applied to the handle so that the rod BC does not buckle. (12 marks)

- Q4** (a) Briefly explain the strain energy. (6 marks)
- (b) A half wingspan of Lake Renegade LA-270 aircraft can be modeled as cantilever beam subjected to a uniform distributed load,  $w$  shown in **Figure Q4(b)**. If the beam has a cross section of  $a^2$  (use form factor,  $f_s = 6/5$ ), determine the strain energy in the beam due to shear.  $EI$  and  $G$  are constant. (7 marks)
- (c) The A-36 steel wing stringer with a radius of 30 mm is subjected to torsional loadings as shown in **Figure Q4(c)**. Sketch the Free Body Diagram for each portion and determine the torsional strain energy in the shaft. Modulus of Rigidity for the steel,  $G = 75$  GPa. (7 marks)
- Q5** (a) Explain the main difference between thick and thin cylinders. Discuss the characteristics of thick cylinders. (6 marks)
- (b) A compound tube used in Boeing 777 flap/slat actuator system is formed by shrinking a tube of 250 mm internal diameter and 25 mm wall thickness onto another tube of 250 mm external diameter and 25 mm wall thickness. The cross section of the tube is shown in **Figure Q5(b)**. Both tubes are made of the same material. The stress set up at the junction owing to shrinkage is 10 MPa. The compound tube is then subjected to an internal pressure of 80 MPa. Determine the final stress setup across the section. (14 marks)
- Q6** (a) State two elastic failure theories. (2 marks)
- (b) Explain the following failure modes; yielding, fracture, and buckling. (6 marks)
- (c) The state of plane stress shown occurs at a critical point of Cessna 172 landing gear is shown in **Figure Q6(c)** where  $\sigma_x = 85$  MPa,  $\sigma_y = -45$  MPa  $\tau_{xy} = 25$  MPa. As a result of several tensile tests, it has been found that the tensile yield strength is  $\sigma_Y = 250$  MPa for the grade of steel used. Determine:
- (i) Principal stresses and maximum shear stress.
- (ii) The factor of safety with respect to yield, using the maximum shearing stress theory and the maximum distortion energy theory (12 marks)

- END OF QUESTIONS -

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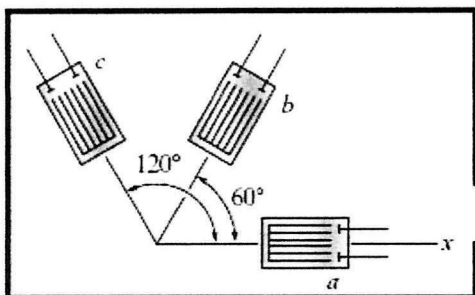


Figure Q1(b)

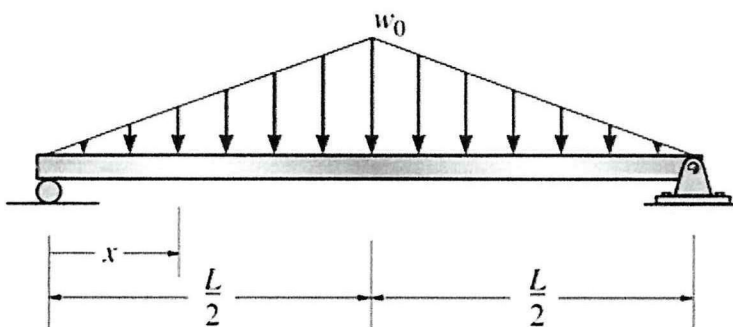


Figure Q2(b)

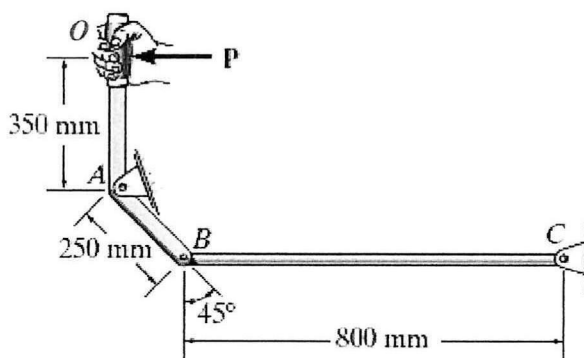


Figure Q3(c)

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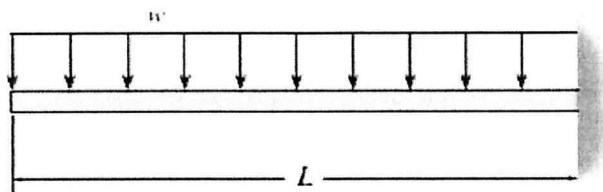


Figure Q4(b)

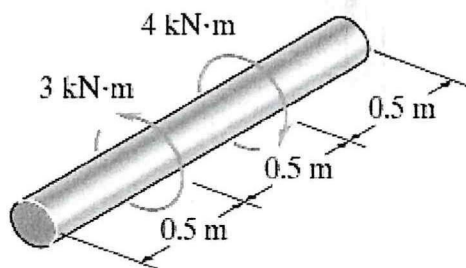


Figure Q4(c)

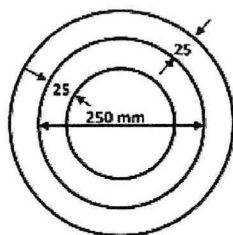
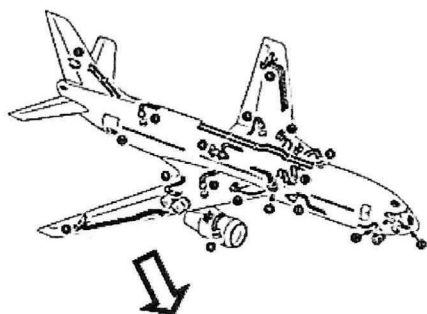


Figure Q5(b)

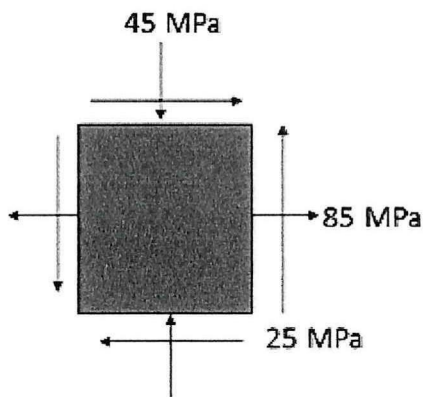


Figure Q6(c)

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Formulas**Plane Strain Analysis**

$$\text{Principal strains, } \varepsilon_{1,2} = \frac{\varepsilon_x + \varepsilon_y}{2} \pm \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$\text{Direction axis of principal strain, } \tan 2\theta_p = \frac{\gamma_{xy}}{\varepsilon_x - \varepsilon_y}$$

$$\text{Maximum in-plane shear strain, } \frac{\gamma_{max, in-plane}}{2} = \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$\text{Average normal strain, } \varepsilon_{ave} = \frac{\varepsilon_x + \varepsilon_y}{2}$$

$$\text{Direction axis of shear strain, } \tan 2\theta_s = -\left(\frac{\varepsilon_x - \varepsilon_y}{\gamma_{xy}}\right)$$

$$\text{Strain Rosettes, } \varepsilon_a = \varepsilon_x \cos^2 \theta_a + \varepsilon_y \sin^2 \theta_a + \gamma_{xy} \sin \theta_a \cos \theta_a$$

$$\text{Hook's Law, } \varepsilon_1 = \frac{\sigma_1}{E} - \frac{\nu}{E} \sigma_2; \quad \varepsilon_2 = \frac{\sigma_2}{E} - \frac{\nu}{E} \sigma_1$$

**Deflection of Beams**

$$\text{Boundary Conditions, } EI \frac{d^4 y}{dx^4} = w(x)$$

$$EI \frac{d^3 y}{dx^3} = V(x)$$

$$EI \frac{d^2 y}{dx^2} = M(x)$$

$$y_{a-a} = \iint \frac{M_{a-a}}{EI} + C_1 x + C_2$$

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**Buckling of Columns**

$$\text{Critical Load, } P_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

$$\text{Critical Buckling Stress, } \sigma_{cr} = \frac{P_{cr}}{A}$$

**Strain Energy**

$$\text{In bending, } U_i = \int \frac{M^2 dx}{2EI}$$

$$\text{In torsion, } U_i = \int \frac{T^2 dx}{2GJ}; U_i = \frac{\Sigma T^2 L}{2GJ}$$

**Lame's Theory**

$$\text{Radial stress, } \sigma_R = A - \frac{B}{r^2}$$

$$\text{Hoop stress, } \sigma_H = A + \frac{B}{r^2}$$

**Elastic Failure Theories**

$$\text{Maximum shear stress theory, } \tau_y = \frac{1}{2} \sigma_y$$

$$\text{Factor of Safety, } F.S = \frac{\tau_y}{\tau_{max}}$$