UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	SOLID MECHANICS I
COURSE CODE	:	BDA10903
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2019/JANUARY2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** QUESTIONS **ONLY**

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

Q1 (a) A square brass bar must not stretch more than 2.5mm when it is subjected to a tensile load. Knowing that modulus of elasticity, E brass is 105 GPa and that the allowable tensile strength, σ_{allow} is 80 MPa, determine:

(i) the maximum allowable length of the bar. (3 marks)

(ii) the required dimensions of the cross section if the tensile load is 40 kN. (3 marks)

(b) A pin connected structure is loaded and supported as shown in **Figure Q1(b)**. Member *CD* is rigid and is horizontal before the load P is applied. Member *A* is an aluminum alloy bar with a modulus of elasticity of 75 GPa and a cross sectional area of 1000 mm^2. Member *B* is a structural steel bar with a modulus elasticity of 200 GPa and a cross sectional area of 500 mm^2.

(i) Draw the free body diagram of the structure (2 marks)

(ii) Determine the normal stress in bars *A* and *B* (8 marks)

(iii) Calculate the vertical component of the displacement of point *D* (4 marks)

Q2 A shear force diagram for a simply supported beam is as shown in **Figure Q2**.

(a) Based on the shear force diagram, draw the beam with related load or forces acting on the beam. (8 marks)

(b) Draw the moment diagram for the beam. (10 marks)

(c) Determine the maximum bending moment of the beam (2 marks)

Q3 A stress distribution for a homogeneous beam of a given cross-sectional area is shown in **Figure Q3**. The beam is subjected to an internal moment *M* at the cross section. Determine:

(a) the centroid for the cross-sectional area of the beam, (5 marks)

(b) the moment of inertia for the beam about a neutral axis, (5 marks)

(c) the internal moment *M* acted on the beam, and (5 marks)

(d) bending stress at point *B*. (5 marks)

Q4 (a) A hollow 3 m long steel shaft must transmit a torque of 25 kNm. The total angle of twist in this length is not to exceed 2.5° and the allowable shearing stress is 90 MPa. Determine the inside and outside diameters of the shaft if $G = 85$ GPa

(10 marks)

(b) A stepped shaft as shown in **Figure 4(b)** is made of aluminium and brass. The region *AB* is aluminium, having G = 28 GPa, and the region *BC* is steel, having G = 84 GPa. The aluminium portion is of solid circular cross section 45 mm in diameter, and the steel region is circular with 60 mm outside diameter and 30 mm inside diameter. Determine the maximum shearing stress in each material. Ends *A* and *C* are rigidly clamped . Calculate the torque required on the screw to raise a load of 25 kN

(10 marks)

Q5 (a) A rubber ball is inflated to a pressure of 80 kPa. At that pressure the diameter of the ball is 208 mm and the wall thickness is 1.2 mm. The rubber has a modulus of elasticity E=3.5 MPa and Poisson's ratio ν= 0.45. Determine the maximum stress and strain in the ball.

(8 marks)

(b) A cylinder has an internal diameter of 230 mm, has walls of 5 mm thick and is 1 m long. It is found to change in internal volume by 12.0 x 10^{-6} m^3 when filled with a liquid at a pressure P. If E= 200 GPa and ν = 0.25, and assuming rigid end plates, determine:

(i) the value of hoop and longitudinal stresses (8 marks)

(ii) the necessary change in pressure P to produce a further increase in internal volume of 15%. The liquid may be assumed incompressible.

(4 marks)

Q6 (a) Explain what is principal stress. (2 marks)

(b) Describe how principal stress can be calculated. (2 marks)

(c) An axial force of 900 N and a torque of 2.50 Nm are applied to the shaft as shown in **Figure Q6(c)**. If the shaft has a diameter of 40 mm;

(i) determine the principal stresses at a point P on its surface and show them on a sketch of a properly oriented element, (8 marks)

(ii) determine the maximum shear stresses and associated normal stresses and show them on a sketch of a properly oriented element. (8 marks)

- END OF QUESTION-

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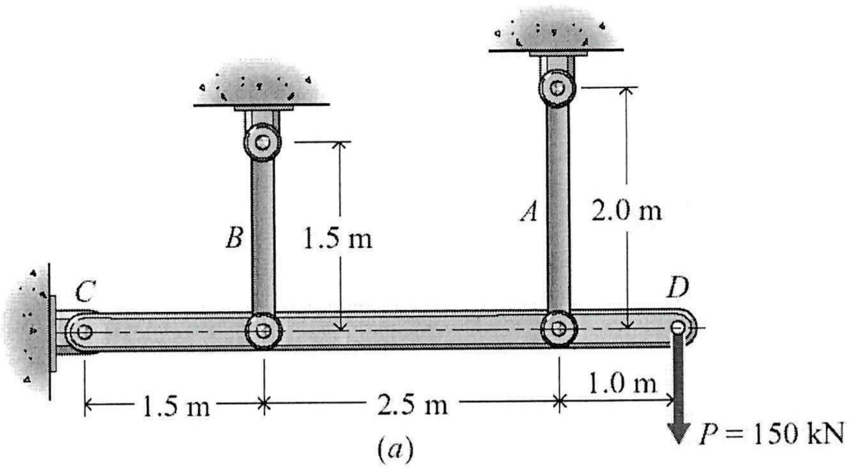

Figure Q1(b)

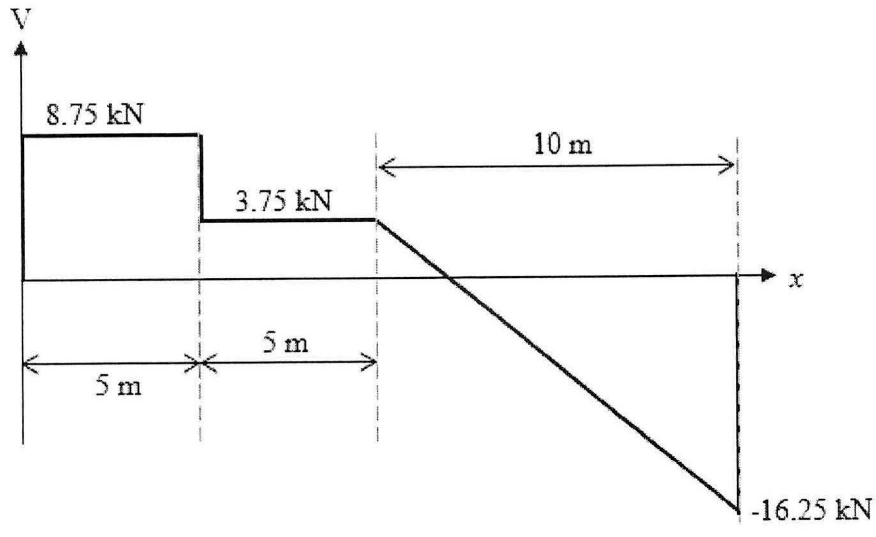

Figure Q2

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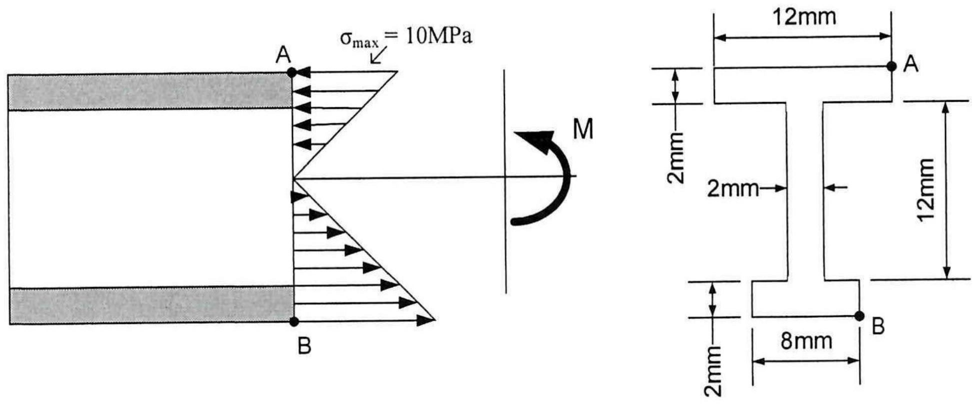

Figure Q3

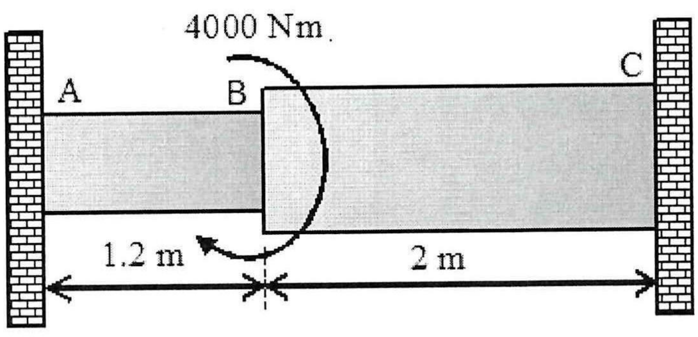

Figure Q4(b)

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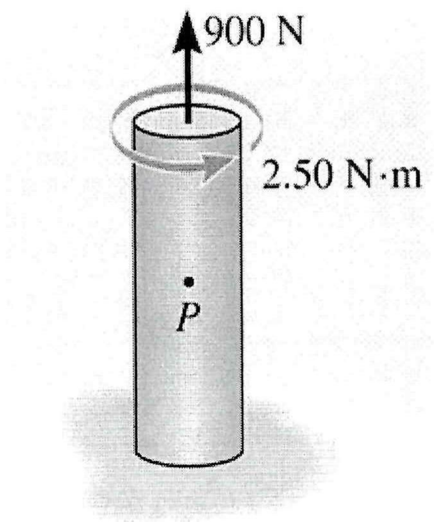

Figure Q6(c)

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Fundamental Equations of Mechanics of Materials :

Axial Load

Normal Stress $\sigma = P/A$

Displacement $\delta = \int_0^L \frac{P(x)dx}{A(x)E}$

$\delta = \sum \frac{PL}{AE}$

$\delta_T = \alpha \Delta T L$

Torsion

Shear stress in circular shaft

$\tau = \frac{T\rho}{J}$

where

$J = \frac{\pi}{2} c^4$ solid cross section

$J = \frac{\pi}{2}\left(c_o^4 - c_i^4\right)$ tubular cross section

Power $P = T\omega = 2\pi fT$

Angle of twist $\phi = \int_0^L \frac{T(x)dx}{J(x)G}$

$\phi = \sum \frac{TL}{JG}$

Average shear stress in a thin-walled tube

$\tau_{avg} = \frac{T}{2tA_m}$

Shear Flow $q = \tau_{avg} t = \frac{T}{2A_m}$

Bending

Normal stress $\sigma = \frac{My}{I}$

Unsymmetric stress

$\sigma = -\frac{M_z y}{I_z} + \frac{M_y z}{I_y}, \quad \tan\alpha = \frac{I_z}{I_y}\tan\theta$

Material Property Relations

Poisson's ratio

$\upsilon = -\frac{\varepsilon_{lat}}{\varepsilon_{long}}, \qquad G = \frac{E}{2(1+\upsilon)}$

Shear

Average direct shear stress $\tau_{avg} = V/A$

Transverse shear stress $\tau = \frac{VQ}{It}$

Shear flow $q = \tau t = \frac{VQ}{I}$

Stress in Thin-Walled Pressure Vessel

Cylinder $\sigma_1 = \frac{pr}{t} \quad \sigma_2 = \frac{pr}{2t}$

Sphere $\sigma_1 = \sigma_2 = \frac{pr}{2t}$

Stress Transformation Equations

$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$

$\tau_{x'y'} = -\frac{\sigma_x + \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta$

Principal Stress

$\tan 2\theta_p = \frac{\tau_{xy}}{(\sigma_x - \sigma_y)/2}$

$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

Maximum in-plane shear stress

$\tan 2\theta_s = -\frac{(\sigma_x - \sigma_y)/2}{\tau_{xy}}$

$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$\sigma_{avg} = (\sigma_x + \sigma_y)/2$

Absolute maximum shear stress

$\tau_{abs\,max} = \frac{\sigma_{max} - \sigma_{min}}{2} \qquad \sigma_{avg} = \frac{\sigma_{max} + \sigma_{min}}{2}$

Relations Between w, V, M

$\frac{dV}{dx} = -w(x), \quad \frac{dM}{dx} = V$