Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	SOLID MECHANICS 1
COURSE CODE	:	BDA 10903
PROGRAMME CODE	:	BDD
EXAMINATION DATE	:	JULY / AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTIONS	:	(1) ANSWER **ALL** QUESTIONS IN **PART A** ANSWER **TWO (2)** QUESTIONS IN **PART B** (2) THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK** (3) STUDENT ARE PROHIBITED TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

PART A: ANSWER ALL QUESTIONS

Q1 **Figure Q1** shows few loadings are applied at points A and B of the solid cast-iron bracket. Knowing that the bracket has a diameter of 20mm,

(a) Determine the internal loadings at point H.

(6 marks)

(b) Calculate the stresses at point H

(5 marks)

(c) Determine the state of plane stress at point *H* and show it on the element.

(3 marks)

(d) Determine the principal stresses and the maximum shearing stress at point H.

(6 marks)

Q2 The internal loadings at a section of the beam are shown in **Figure Q2**.

(a) Compute the cross-sectional area of the beam

(2marks)

(b) Compute the moment of inertia about

(i) the Z axis

(2 marks)

(ii) the Y axis

(2 marks)

(c) Determine the uniform normal stress distribution due to the normal force

(2 marks)

(d) Determine the normal stress due to bending moment about Z axis at point A

(2 marks)

(e) Determine the normal stress due to bending moment about Y axis at point A

(2 marks)

(f) If the above normal stress is added algebraically, the resultant normal stress at point A.

(2 marks)

(g) Determine the principal stresses at point A. Also compute the maximum in-plane shear stress at this point.

(6 marks)

Q3 A cylindrical pressure vessel is constructed from a long, narrow steel plate by wrapping the plate around a mandrel and then welding along the edges of the plate to make a helical joint (**Figure Q3**). The helical weld makes an angle α=65° with the longitudinal axis. The vessel has inner radius r = 1.75m and wall thickness t = 20 mm. The material is steel with modulus E = 200GPa and Poisson's ratio v = 0.30. The internal pressure p is 800 kPa. Calculate the following quantities for the cylindrical part of the vessel:

(a) the circumferential and longitudinal stresses σ_1 and σ_2, respectively

(5 marks)

(b) the normal stress σ_w and shear stress τ_w acting perpendicular and parallel, respectively, to the welded seam.

(15 marks)

PART B: ANSWER TWO (2) QUESTIONS ONLY

Q4 (a) If a twisting moment of 1200 Nm is impressed upon a 4.4-cm-diameter shaft, what is the maximum shearing stress developed? Also, what is the angle of twist in a 160-cm length of the shaft? The material is steel for which $G = 85$ GPa.

(10 marks)

(b) A hollow 3-m-long steel shaft must transmit a torque of 24 kN · m. 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)

Q5 A beam *ABC* with an overhang at the left-hand end is shown in **Figure Q5**. The beam is subjected to a uniform load of intensity q=2.0 kN/m on the overhang *AB* and a counterclockwise couple M_0= 12.0 kNm acting midway between the supports at *B* and *C*.

(a) Draw the shear-force diagrams for this beam

(10 marks)

(b) Draw the shear-force and bending-moment diagrams for this beam

(10 marks)

Q6 (a) The composite bar shown in **Figure Q6(a)** is rigidly attached to the two supports. The left portion of the bar is copper, of uniform cross-sectional area 90 cm^2 and length 30 cm. The right portion is aluminum, of uniform cross-sectional area 20 cm^2 and length 20 cm. At a temperature of 26°C the entire assembly is stress free. The temperature of the structure drops and during this process the right support yields 0.025 mm in the direction of the contracting metal. Determine the minimum temperature to which the assembly may be subjected in order that the stress in the aluminum does not exceed 160 MPa. For copper $E = 100$ GPa, $\alpha = 17 \times 10^{-6}$/°C, and for aluminum $E = 80$ GPa, $\alpha = 23 \times 10^{-6}$/°C.

(10 marks)

(b) The rigid bar *AD* is pinned at *A* and attached to the bars *BC* and *ED*, as shown in **Figure Q6(b)**. The entire system is initially stress free and the weights of all bars are negligible. The temperature of bar *BC* is lowered 23°C and that of bar *ED* is raised 23°C. Find the normal stresses in bars *BC* and *ED*. For *BC*, which is brass, assume $E = 90$ GPa, $\alpha = 20 \times 10^{-6}$/°C, and for *ED*, which is steel, take $E = 200$ GPa and $\alpha = 12 \times 10^{-6}$/°C. The cross-sectional area of *BC* is 500 mm^2 and of *ED* is 250 mm^2.

(10 marks)

-END OF QUESTIONS-

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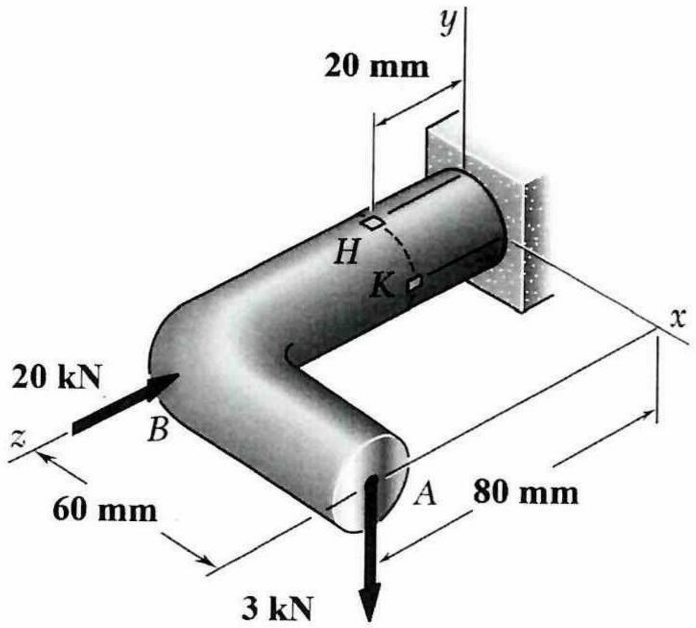

Figure Q1: Solid cast-iron bracket

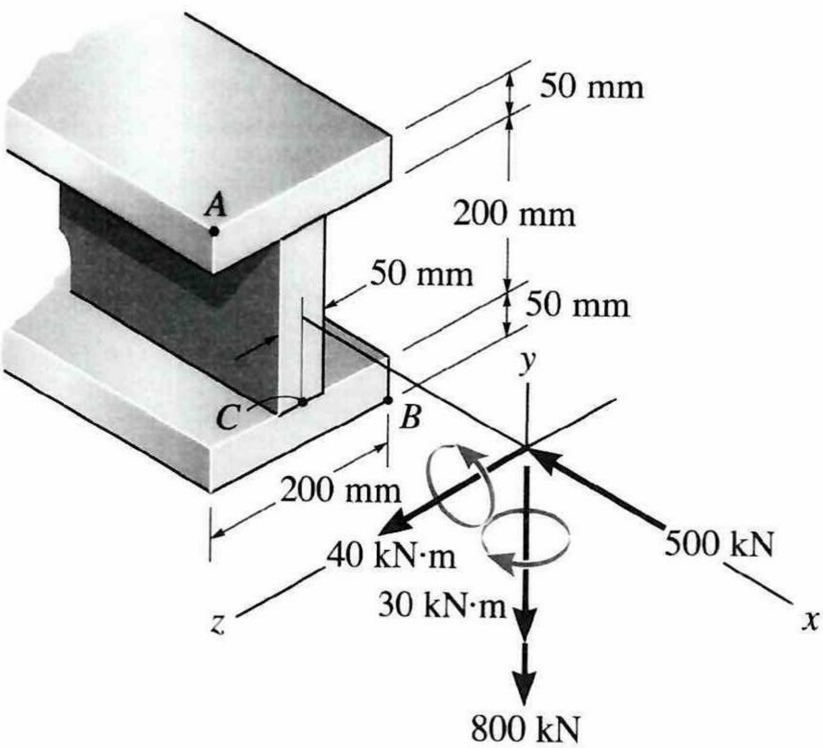

Figure Q2: The internal loadings at a section of the beam

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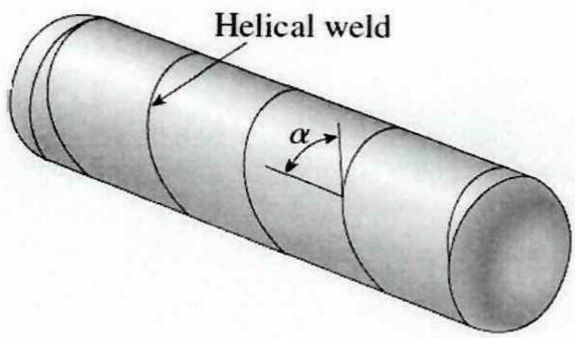

Figure Q3: Cylindrical pressure vessel with a helical weld

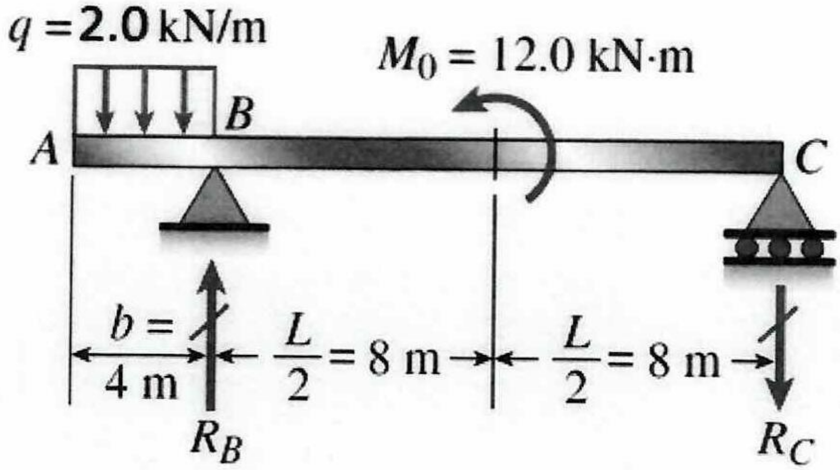

Figure Q5: An overhang beam ABC

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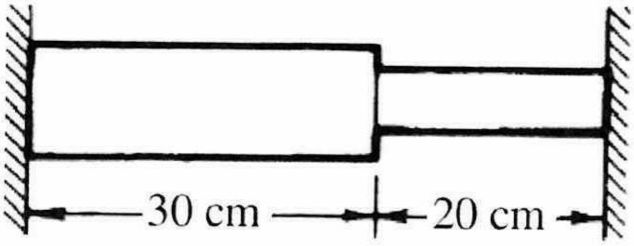

Figure Q6(a) : A composite bar

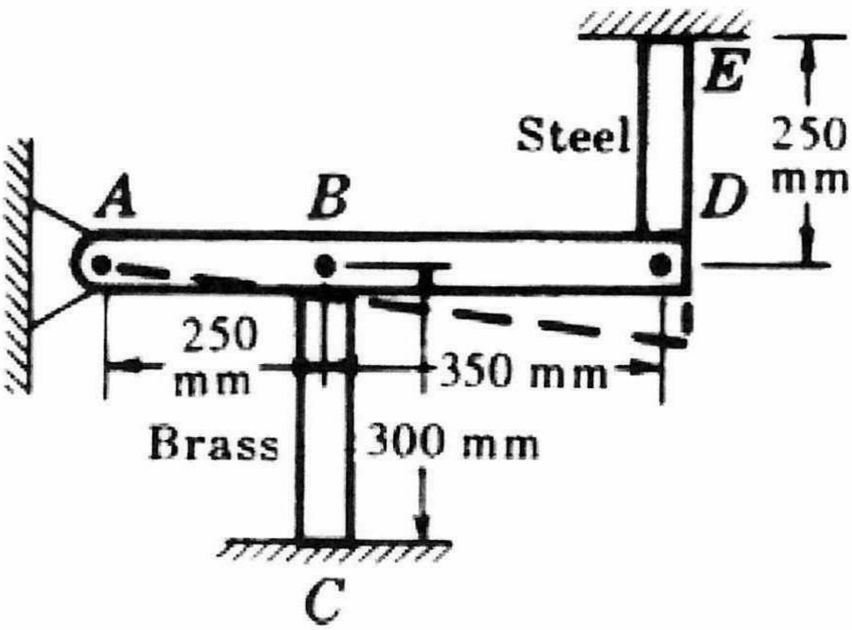

Figure Q6(b): A rigid bar AD

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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 $P = T\omega = 2\pi f T$

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

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