First Semester Examination
2023/2024 Academic Session

February 2024

ESA225 – Strength of Materials

Duration : 3 hours

Please check that this examination paper consists of SIX (6) pages of printed material before you begin the examination.

Instructions : Answer **FOUR (4)** questions. **All questions are COMPULSORY**.

1. A solid constant-diameter shaft is subjected to the torques shown in **Figure 1**. The bearings shown allow the shaft to turn freely.

   (a). **Plot** a torque diagram showing the internal torque in segments 1, 2 and 3 of the shaft. Use the sign convention.

   (7 marks)

   (b). If a solid 1.905 cm diameter shaft is subjected to that particular torque. **Determine** the maximum shear stress magnitude in the shaft.

   (9 marks)

   (c). If the allowable shear stress in the shaft is 80 MPa, **determine** the minimum acceptable diameter for the shaft.

   (9 marks)

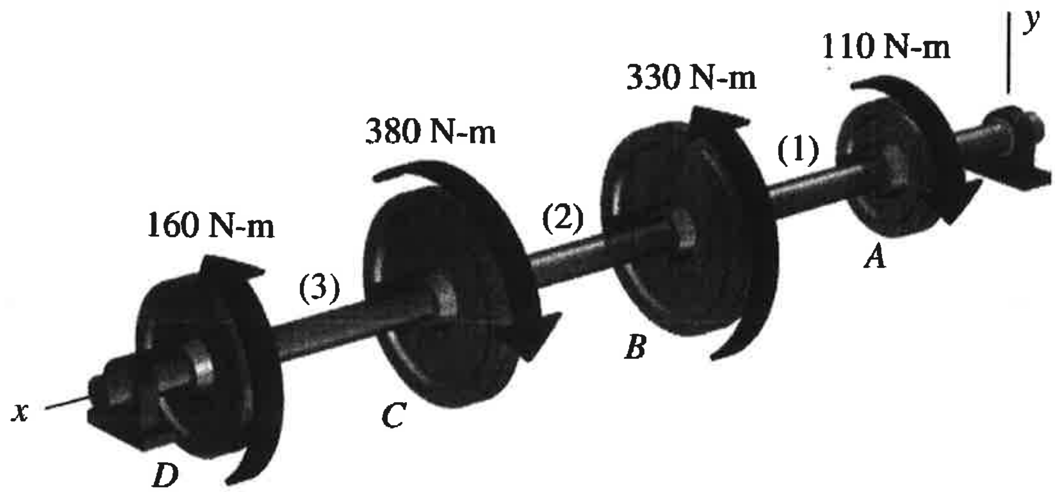

Figure 1

2. The beam is bolted or pinned on left hand side and supported by a roller on the right hand side. A uniform distributed loading exerted on the beam over its 6-m length. The simply supported beam in **Figure 2** has the cross-sectional area shown in **Figure 3**.

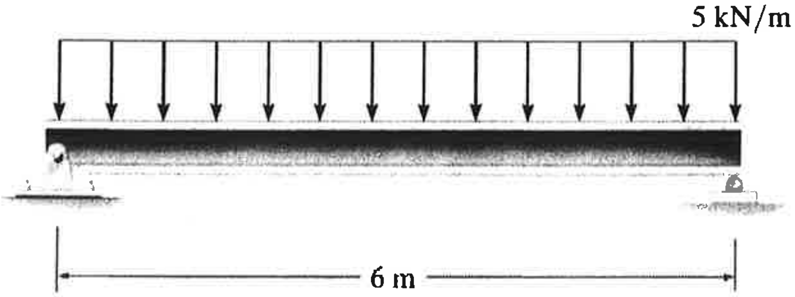

Figure 2

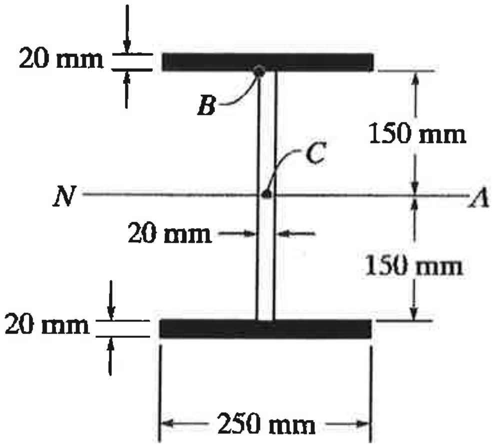

Figure 3

(a). **Draw** the shear and moment diagrams for the beam shown in **Figure 2**. **Find** the maximum internal moment in the beam.

(10 marks)

(b). **Determine** the absolute maximum bending stress in the beam and **draw** the stress distribution over the cross-section at this location.

(10 marks)

(c). **Calculate** the stress at point B?

(5 marks)

3. A 5 m long simply supported timber beam carries two concentrated loads of 14 kN and 42 kN, as shown in **Figure 4(a)**. The cross-sectional dimensions of the beam are shown in **Figure 4(b)**.

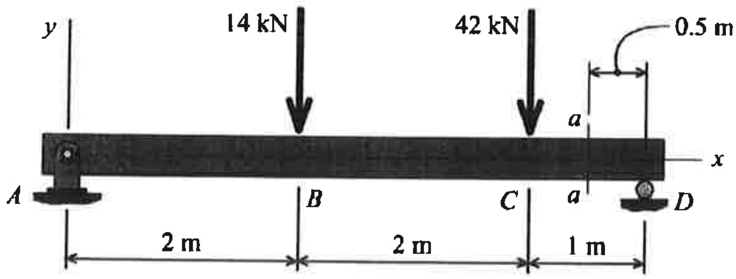

Figure 4(a)

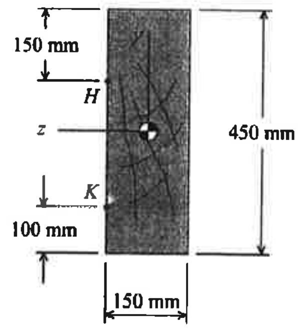

Figure 4(b)

(a). **Draw** the shear force and bending moment diagrams for the beam shown in **Figure 4(a)**.

(10 marks)

(b). At section a–a, **compute** the magnitude of the shear stress in the beam at point H.

(3 marks)

(c). At section a–a **compute** the magnitude of the shear stress in the beam at point K.

(3 marks)

(d). **Determine** the maximum horizontal shear stress that occurs in the beam at any location within the 5 m span length.

(4 marks)

(e). **Solve** the maximum compression bending stress that occurs in the beam at any location within the 5 m span length.

(5 marks)

4. The frame as shown in **Figure 5** is subjected to a combined load of 400 N horizontal force and 350 Nm couple moment.

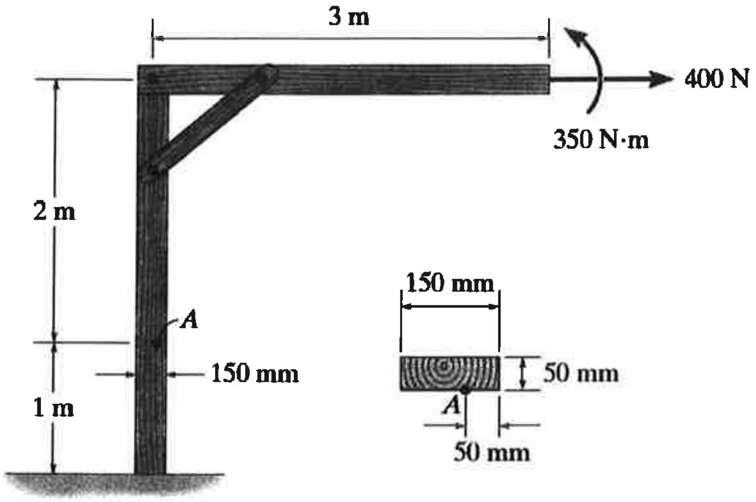

Figure 5

(a). With the help from free body diagram, **calculate** the moment at point A.

(5 marks)

(b). **Determine** the principal stresses at point A.

(8 marks)

(c). Based on question 4(b), **sketch** the stress element.

(2 marks)

(d). From the stress element, **construct** the Mohr's circle and **determine** the absolute maximum shear stress at point A.

(10 marks)

APPENDIX

Formula table

$\delta_T = L\alpha(\Delta T)$	$\delta = \frac{PL}{EA}$	
$\sigma = \frac{P}{A}$	$\sigma = \frac{My}{I}$	$I = \frac{1}{12}bh^3$
$\tau = \frac{Tc}{J}$	$\Phi = \frac{PL}{JG}$	$J = \frac{\pi}{32}d^4$
$\tau = \frac{VQ}{It}$	$\bar{y} = \frac{\sum \tilde{y}A}{\sum A}$	$Q = \bar{y}'A'$
$\sigma_{avg} = \frac{\sigma_x + \sigma_z}{2}$	$\tau_{abs(max)} = \frac{\tau_{Max} - \tau_{min}}{2}$	$I_{x'} = \sum\left(\bar{I} + Ad^2\right)$

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