First Semester Examination
2024/2025 Academic Session

February 2025

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. Rod *BC* shown in **Figure Q1** is made of A-36 steel and has a diameter of 40 mm. Given *E* = 200 GPa and $\upsilon = 0.32$.

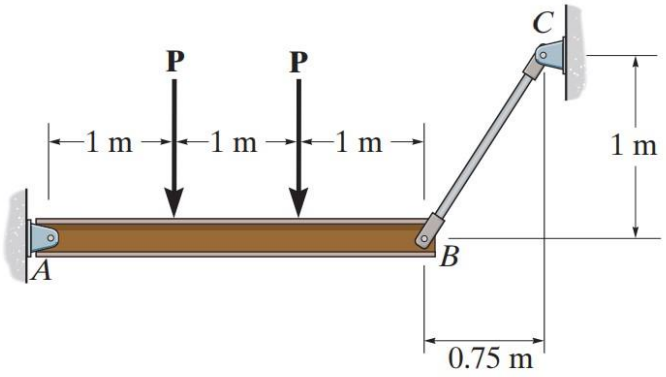

Figure Q1

(a). Using the free-body diagram as a reference, **write** the equations of equilibrium by considering all forces and moments acting on the system.

(5 marks)

(b). If P = 150 kN, **determine** the force developed in rod *BC* and the reactions at the support *A.*

(6 marks)

(c). Using the solution obtained in 1(b), **calculate** the average normal stress experienced by rod *BC*.

(3 marks)

(d). Using the solution obtained in 1(c), **determine** the strain experienced by rod *BC*.

(3 marks)

(e). **Determine** the elastic elongation of rod *BC* and the decrease in its diameter.

(8 marks)

2. The gears attached to the fixed-end steel shaft are subjected to the torques shown in **Figure Q2**. The shear modulus of elasticity is G = 80 GPa and the shaft has a diameter of 14 mm. The shaft turns freely within the bearing at *B*.

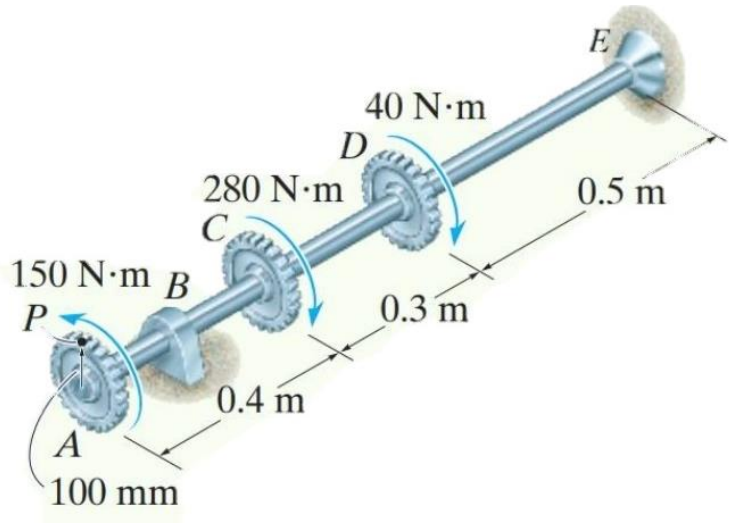

Figure Q2

(a). Using free body diagrams, **determine** the internal loading of T_{AC}, T_{CD} and T_{DE}.

(6 marks)

(b). **Determine** the angle of twist at end of gear *A*.

(8 marks)

(c). Using the solution obtained in 2(b), **determine** the displacement of the tooth P on gear *A*.

(3 marks)

(d). **Sketch** the internal loading diagram obtained from Question 2 (a).

(5 marks)

(e). **Determine** the absolute maximum shear stress developed in the shaft.

(3 marks)

3. A 5 m long simply supported timber beam carries a concentrated load of 46 kN, as shown in **Figure Q3(a)**. The cross-sectional dimensions of the beam are shown in **Figure Q3(b)**.

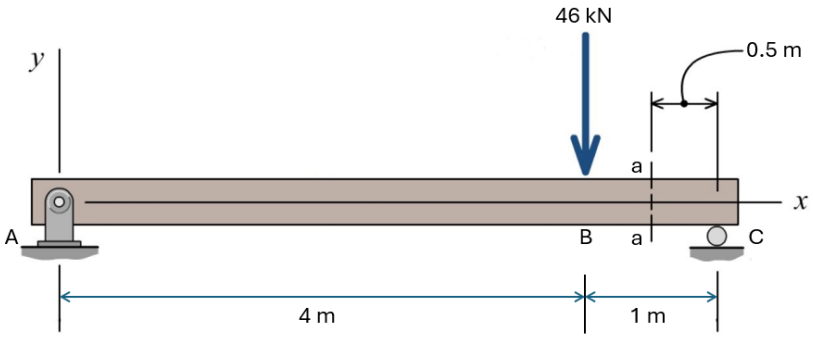

Figure Q3(a)

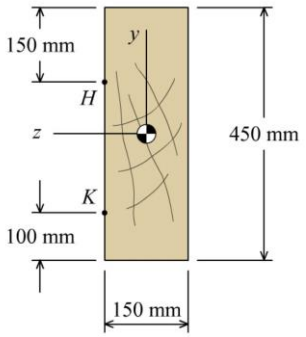

Figure Q3(b)

(a). **Draw** the shear force and bending moment diagrams for the beam shown in **Figure Q3(a)**.

(10 marks)

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

(3 marks)

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

(3 marks)

(d). **Determine** the maximum horizontal transverse shear stress that occurs in the beam.

(4 marks)

(e). **Calculate** the maximum compression bending stress that occurs in the beam.

(5 marks)

4. The wood frame showed in **Figure Q4** is subjected to a combined load of 400 N horizontal force and 350 Nm couple moment. The cross-sectional area at point *A* is also shown in **Figure Q4**.

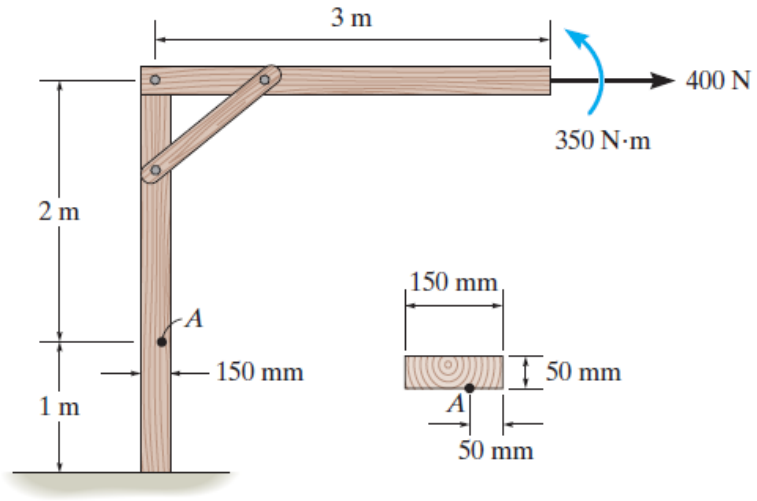

Figure Q4

(a). **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, **draw** the Mohr's circle and **determine** the principal stresses, σ_1 and σ_2 at point *A*.

(10 marks)

Formula table

$\delta_T = L\alpha(\Delta T)$	$\delta = \frac{PL}{EA}$	$\tau = G\gamma$ $\sigma = E\varepsilon$
$G = \frac{E}{2(1+v)}$	$\epsilon_{long} = \frac{\delta}{L}, \epsilon_{lat} = \frac{\delta'}{r}$	$v = -\frac{\epsilon_{lat}}{\epsilon_{long}}$
$\sigma = \frac{P}{A}$	$\sigma = \frac{My}{I}$	$I = \frac{1}{12}bh^3$
$\tau = \frac{Tc}{J}$	$\Phi = \frac{TL}{JG}$	$J = \frac{\pi}{2}c^4$
$\tau = \frac{VQ}{It}$	$\bar{y} = \frac{\sum \bar{y}A}{\sum A}$	$Q = \bar{y}'A'$
$\sigma_{avg} = \frac{\sigma_x + \sigma_z}{2}$	$\tau_{abs(max)} = \frac{\tau_{Max} - \tau_{min}}{2}$	$I_{x'} = \sum(\bar{I} + Ad^2)$

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