UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE (UCTATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BME 2023
COURSE TITLE	: SOLID MECHANICS
SEMESTER/SESSION	: 1-2022/2023
DURATION	: 3 HOURS

Instructions:

1. This booklet contains **FIVE (5)** questions, answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise up your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS 9 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

a) A circular metal column is to support a load of 500 kN and must not compress more than 0.1mm. The modulus of elasticity is 210 GPa. The column is 3 m long.

i. **Describe** the modulus of elasticity (1 mark)

ii. **Compute** the cross sectional area of the column (3 marks)

iii. **Compute** the diameter of the column (1 mark)

b) Each of the links *AB* and *CD* is made of aluminum (E = 75 GPa) and has a cross-sectional area of 258 mm^2 shown in Figure 1. Knowing that they support the rigid member *BC*,

i. **Compute** the force at AB, F_{AB} and CD, F_{CD} (4 marks)

ii. **Compute** The deflection of point *B*, δ_{AB}. (3 marks)

iii. **Compute** The deflection of point *C*, δ_{CD}. (3 marks)

iv. **Determine** The deflection of point *E*, δ_E. (5 marks)

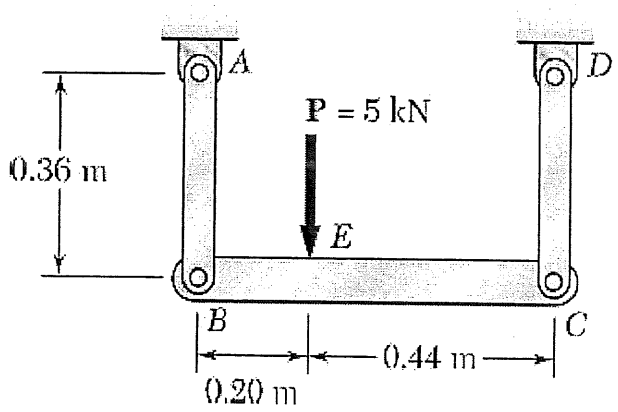

Figure 1

QUESTION 2

a) A shaft is made of tube. The ratio of the inside diameter to the outside diameter is 0.5. The material must not experience a shear stress greater than 600 kPa. The shaft must transmit 2.0 MW of mechanical power at 1500 rev/min.

i. **Explain** the meaning of modulus of rigidity (1 mark)

ii. **Compute** the torque applied to the shaft (2 marks)

iii. **Compute** the outer diameter (D_o) of the shaft (2 marks)

iv. **Compute** the inner diameter (D_i) of the shaft (1 marks)

b) Two horizontal shaft AD is attached to a fixed base at D and is subjected to the torques shown in Figure 2. A 44 mm diameter hole has been drilled into portion CD of the shaft. Knowing that the entire shaft is made of steel which G=77 GPa,

i. **Compute** the Polar moments of inertia of each portion (3 marks)

ii. **Compute** the torque of each portion (3 marks)

iii. **Compute** the angle of twist each portion (in degree) (6 marks)

iv. **Determine** the angle through end A rotates (in degree) (2 marks)

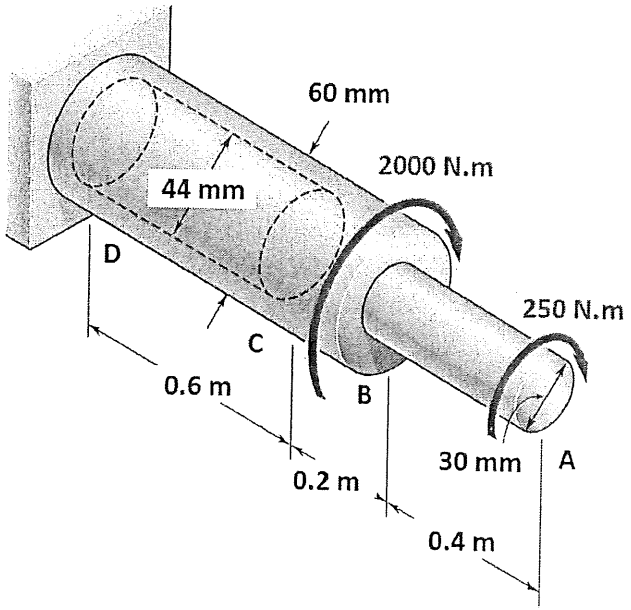

Figure 2

QUESTION 3

a) Two vertical forces are applied to a beam as shown in Figure 3.

i. **Compute** the reaction values R_A and R_D (1 mark)

ii. **Show** that the maximum bending moment is 1.5kNm (4 marks)

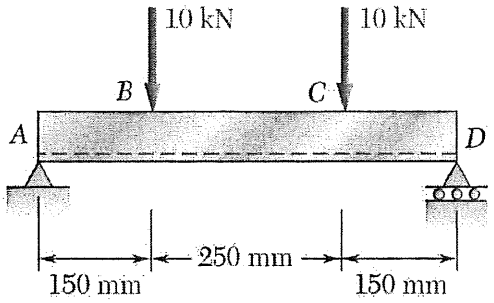

Figure 3

b) The structure in Figure 4 consists of a simply supported beam with loaded as shown. Knowing that the allowable normal stress for the grade of steel to be used is 160 Mpa.

i. **Compute** the reaction values R_A and R_D (2 marks)

ii. **Sketch** the free body diagram for the beam (2 marks)

iii. **Sketch** the shear force diagram for the beam (4 marks)

iv. **Sketch** the bending moment diagram for the beam (5 marks)

v. **Solve** the minimum section modulus (S_x) (2 marks)

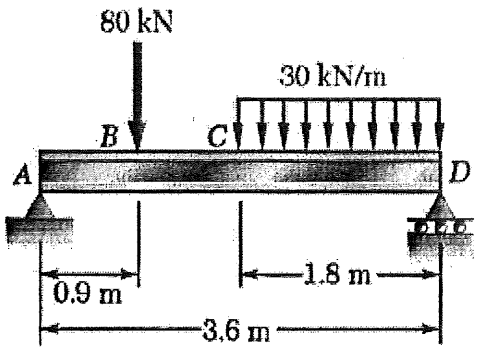

Figure 4

QUESTION 4

Two vertical forces are applied to a beam as shown in Figure 5. While, the cross sectional of the beam is shown as in Figure 6. If the maximum bending moment is 1.5kN.m,

a) **Compute** the area of the U-shape (4 marks)
b) **Determine** the centroid of the U-shape (4 marks)
c) **Determine** Centroidal moment of Inertia (I_{gg}) (4 marks)
d) **Compute** Maximum Tensile stress (4 marks)
e) **Compute** Maximum Compressive stress (4 marks)

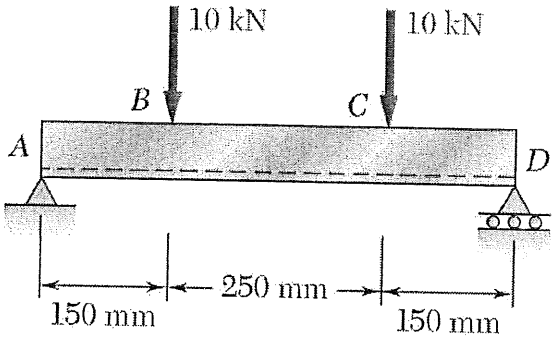

Figure 5

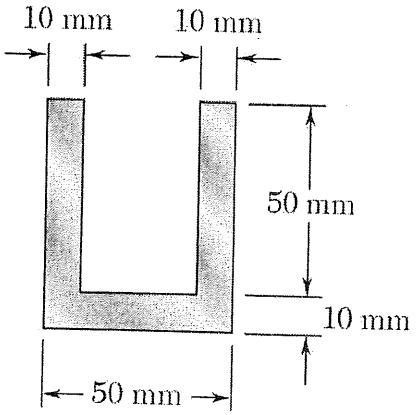

Figure 6

QUESTION 5

a) The couple M is applied to a beam of the cross section in a plane forming an angle β with the vertical shown in Figure 7.

i. **Compute** the moment acted on both axis, M_y and M_z (2 marks)

ii. **Compute** second moment of inertia for both axis, I_y and I_z (3 marks)

iii. **Determine** the stresses at point **A, B and D** (3 marks)

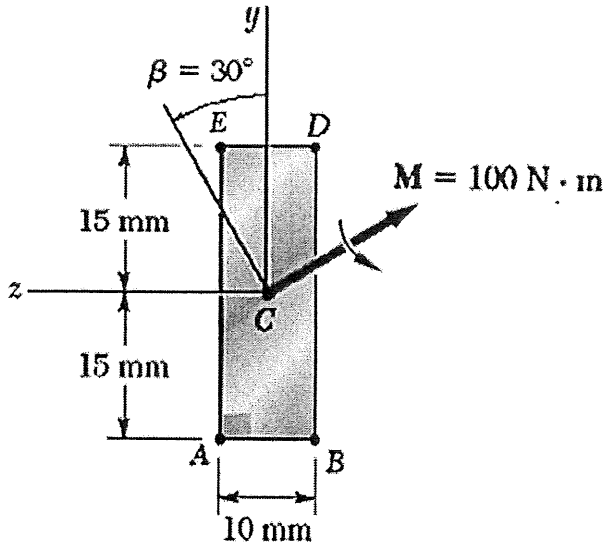

Figure 7

b) A vertical 4.8 KN force is applied on a rectangular 80 by 120 mm wooden post as shown in Figure 8.

i. **Compute** the moment acted on both axis, M_x and M_z (2 marks)

ii. **Compute** the cross sectional area and second moment of inertia for both axis, I_x and I_z (3 marks)

iii. **Compute** the stresses due to centric load (4.8 kN) and the bending couples M_x and M_z (3 marks)

iv. **Determine** the stresses at point **A, B, C and D** (4 marks)

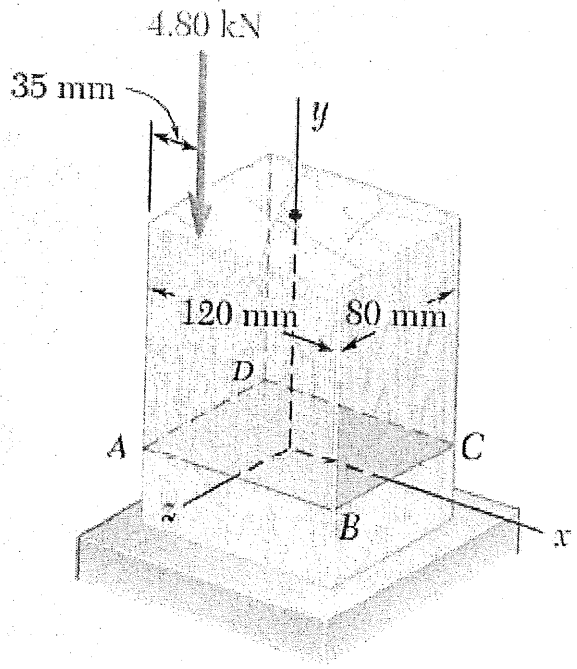

Figure 8

----------End of questions----------

Criteria	Marks
All questions answered will be marked according to the answer scheme	/100

FORMULA

STRESS STRAIN

Normal stress

$$\sigma = \frac{F}{A}$$

strain

$$\varepsilon = \frac{x}{L}$$

Modulus of Elasticity

$$E = \frac{\sigma}{\varepsilon}$$

Elongation

$$\delta = \frac{FL}{EA}$$

TORSION

Angle of twist

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

Power Transmission

$$P = 2\pi NT$$

$$\frac{T}{J} = \frac{2\tau}{D}$$

Polar second moment of area

Solid

$$J = \frac{\pi D^4}{32}$$

Hollow

$$J = \frac{\pi D^4 - d^4}{32}$$

SHEAR FORCE AND BENDING MOMENT

Minimum section Modulus

$$S_{\min} = \frac{|M|_{\max}}{\sigma_{all}}$$

Relationship between load, shear and bending moment.

$$V_B - V_A = -wx \ (area\ under\ load\ curve\ between\ B\ and\ A)$$

$$M_B - M_A = V \ (area\ under\ shear\ curve\ between\ B\ and\ A)$$

BENDING STRESS

Centroid

$$\bar{Y}\sum A = \sum \bar{y}A$$

2nd Moment of area for rectangular shape

$$I = \frac{1}{12}bh^3$$

Parallel axes theorem

$$I = I + Ad^2$$

Normal stress from neutral axis

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

NON SYMMETRIC BENDING

$$\sigma_1 = -\frac{F}{A} \quad \sigma_2 = \frac{M_x}{S_x} \quad \sigma_3 = \frac{M_y}{S_y} \qquad \sigma_A = -\frac{M_z Y_A}{I_z} + \frac{M_y Z_A}{I_y}$$

$$\sigma = \pm\sigma_0 \pm \sigma_1 \pm \sigma_2$$