MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

P.O. Box 972-60200 – Meru-Kenya.
Tel: +254(0) 799 529 958, +254(0) 799 529 959, +254 (0)712 524 293
Website: www.must.ac.ke Email: info@mucst.ac.ke

**UNIVERSITY EXAMINATIONS 2024/2025**

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR DEGREE OF BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

**EMT 3400: SOLID AND STRUCTURAL MECHANICS III**

**DATE: JANUARY 2025** **TIME: 2 HOURS**

**INSTRUCTIONS:** Answer Question ONE and any other TWO questions.

**QUESTION ONE (30 MARKS)**

a) Define the following terms

i) Principal stress (1 mark)

ii) Principal plane (1 mark)

iii) Kernel of a section (1 mark)

iv) Slenderness ratio (1 mark)

b) State the following theories of failure

i) Guest's theory (1 mark)

ii) Saint Venant theory (1 mark)

c) An elemental cube is subjected to tensile stress of 30 N/$mm^2$ and 10 N/$mm^2$ on two mutually perpendicular planes and a shear stress of 10 N/$mm^2$ on these planes. Draw the Mohr's circle of stress and hence or otherwise determine:

i) the magnitudes and directions of principal stresses (4 marks)

ii) The greatest shear stress (3 marks)



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d) Two wooden pieces 10cm $\times$ 10cm in cross-section are glued together along line AB as shown in figure Q1(d). What maximum axial pull force P can be applied if the allowable shearing stress along AD is 1.2 N/$mm^2$? (4 marks)

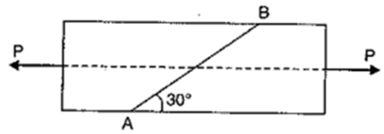


Figure Q1(d)

e) A rectangular column of width 200 mm and of thickness 150 mm carries a point load of 240 kN at an eccentricity of 10 mm as shown in Figure Q1(e).

a) Determine the maximum and minimum stresses in the section (4 marks)

b) Using a neat sketch, show the distribution of the stresses along the width of the section (1 mark)

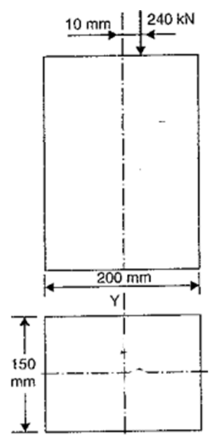


Figure Q1(e)

f) The maximum allowable shear stress in a hollow shaft of external diameter equal to twice the internal diameter is 80 N/$mm^2$. Determine the diameter of the shaft if it is subjected to a torque of $4\times 10^6$ $Nmm$ and a bending moment of $3 \times 10^6$ $Nmm$ (4 marks)

g) According to the theory of maximum shear stress, determine the diameter of a bolt which is subjected to an axial pull of 9kN together with a transverse shear force of 4.5 kN. Elastic limit in tension is 225 N/$mm^2$, factor of safety = 3 and Poisson's ratio = 0.3. (4 marks)



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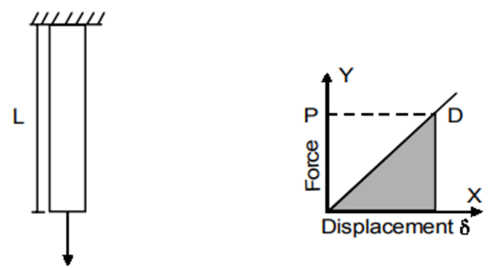
**QUESTION TWO (15 MARKS)**

a) Figure Q2(a)-(i) shows a bar of length L and cross-sectional area a hanging vertically fixed at the top and subjected to a normal pull, P. The load is then increased gradually from zero and a graph of force, P, against corresponding displacement$\delta$, drawn as shown in figure Q2(a-(ii) Show that the strain energy per unit volume, $u$, is given by:

$$u = \frac{\sigma^2}{2E}$$

Where $\sigma$ = stress induced in the material

E = Young's Modulus of elasticity (5 marks)




(i) (ii)

Figure 2(a)

b) The principal stresses at a point in ana elastic material are 200N/$mm^2$ (tensile), 100 N/$mm^2$ (tensile) and 50 N/$mm^2$ (compressive). If the stress at the elastic limit in simple tension is 200 N/$mm^2$, determine whether the failure of the material will occur according to the maximum principal strain theory. Take Poisson's ratio = 0.3. (4 marks)

c) Determine the diameter of a bolt which is subjected to an axial pull of 9 kN together with a transverse shear force of 4.5 kN using maximum principal stress theory (6 marks)

**QUESTION THREE (15 MARKS)**

a) Define the following terms eccentricity (1 mark)

b) A rectangular column of width 200 mm and of thickness 150 mm carries a point load of 240 kN at an eccentricity of 50 mm as shown in Figure Q3(b).



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i) Determine the maximum and minimum stresses in the section (5 marks)

ii) Using a neat sketch, show the distribution of the stresses along the width of the section. (1 mark)

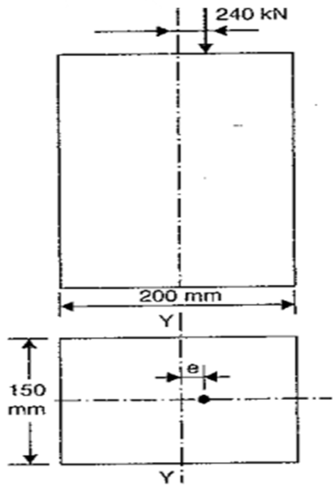


Figure Q3(c)

c) A hollow rectangular column of external depth 1 m and external width 0.8 m is 10 cm thick. A vertical load of 200 kN is acting with an eccentricity of 15 cm as shown in Figure Q3(c).

i) Calculate the maximum and minimum stresses in the section (7 marks)

ii) Using a neat sketch, show the distribution of the stresses along the width of the section (1 mark)

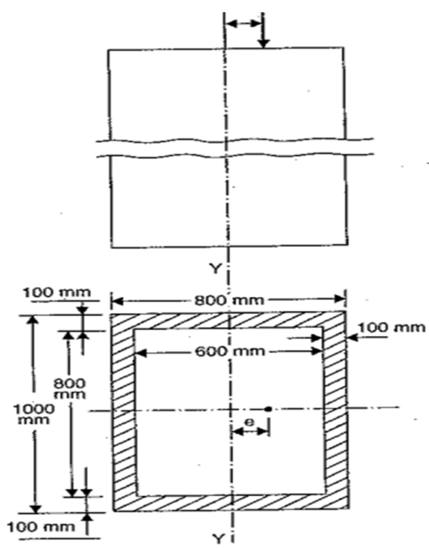


Figure Q3(c)



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**QUESTION FOUR (15 MARKS)**

a) State the three forces which columns are subjected to, resulting in the failure of the columns (3 marks)

b) A column, AB, hinged at both of its ends A and B, and of length l and uniform cross-sectional area, is subjected to an axial compressive load, P, as shown in Figure Q4(b). The load is increased until the column just buckles, and deflects into a curved form ACB. If the lateral deflection at a distance x from the end A is y, show that the crippling load, P is given by:

$$P = \frac{\pi^2 EI}{l^2}$$

Where E = Young's modulus of elasticity

I = Moment of inertia of the column cross-section (6 marks)

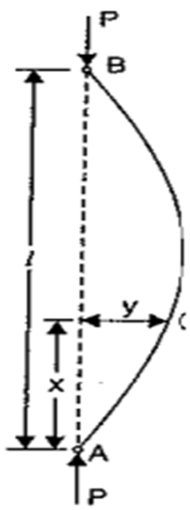


Figure Q4(b)

c) A column of timber section 15 cm × 20 cm is 6 m long both ends being fixed. If the Young's modulus for timber = 0.0175 MN/$mm^2$, determine:

(i) Crippling load (4 mks)

(ii) Safe load for the column if factor of safety is 3 (2 mks)



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**QUESTION FIVE (15 MARKS)**

Figure Q5 shows a rectangular member, ABCD of uniform cross-sectional area, A and of unit thickness subjected to direct stresses in two mutually perpendicular directions accompanied by a simple shear stress. The tensile stress, $\sigma_1$ acts on the face BC while the tensile stress, $\sigma_2$ acts on faces AB and CD. The simple shear stress, $\tau$, acts on faces BC and AD. Show that the normal stress, $\sigma_n$ and tangential stress, $\sigma_t$ acting on oblique section FC, which is inclined at an angle $\theta$ with the normal cross-section BC is given by

$$\sigma_n = \frac{\sigma_1+\sigma_2}{2} + \frac{\sigma_1-\sigma_2}{2}.\cos 2\theta + \tau \sin 2\theta$$

$$\sigma_t = \frac{\sigma_1-\sigma_2}{2}.\sin 2\theta - \tau \cos 2\theta$$ (15 mks)

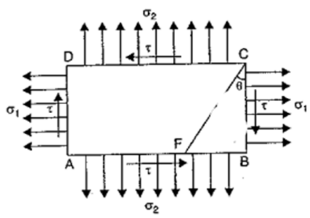


Figure Q5



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