UNIVERSITY OF JOHANNESBURG

PROGRAM	:	**NATIONAL DIPLOMA MECHANICAL ENGINEERING**
SUBJECT	:	**STRENGTH OF MATERIALS 3**
CODE	:	**SOM312**
ASSESSMENT	:	**MAIN EXAMINATION**
		28 MAY 2019
DURATION	:	**12:30 – 15:30**
WEIGHT	:	**40:60**
TOTAL MARKS	:	**106**
FULL MARKS	:	**100**
EXAMINER	:	Mr. M Nkosi
MODERATOR	:	Dr. Tekweme
NUMBER OF PAGES	:	6 PAGES

REQUIREMENTS : HOT-ROLLED SECTION STEEL TABLES BOOKLET.

INSTRUCTIONS

1. ANSWER ALL QUESTIONS.
2. SHOW ALL CALCULATIONS AND DRAW APPROPRIATE SKETCHES.
3. ANSWERS WITHOUT UNITS WILL BE IGNORED.
4. ALL DIMENSIONS ARE IN mm UNLESS STATED OTHERWISE.
5. SOME HELPFUL FORMULAS ARE PROVIDED IN THE ANNEXURE.
6. FOR VALUES NOT SUPPLIED, REASONABLE ENGINEERING ASSUMPTIONS SHOULD BE MADE.
7. THE GRAVITATIONAL ACCELERATION SHOULD BE TAKEN AS 9.81 m/s^2.

QUESTION 1

At temperature of 110 °C, a 305 mm long composite rod consists of a 195 mm length of copper rod, 16 mm in diameter, joined rigidly to the end of a 118 mm length of steel rod, 12 mm in diameter. (Given, E_{CU} = 100 GPa; E_{ST} = 200 GPa; $\alpha_{CU} = 20 \times 10^{-6}$/°C; $\alpha_{ST} = 12 \times 10^{-6}$/°C). If the ends of the composite rod are rigidly clamped at 110 °C to restrict any contraction on cooling:

(a) calcualte the stress induced in copper and steel if the temperature d to 15 °C, (10)

(b) calculate the final position of the junction between the two materials after the decrease in temperature, and (6)

[16]

QUESTION 2

A 16 mm diameter hole which is 70 mm deep runs through a 190 mm long rod with a 24 mm diameter. The remaining portion of the rod is solid. The rod receives 15 N.m of energy. Given, E = 100 GPa:

(a) Calculate the stress induced in each section. (8)

(b) Calculate the change in length of the rod. (4)

(c) Calculate the load required to induce this energy if it is allowed to fall freely from a height of 80 mm. (3)

[15]

QUESTION 3

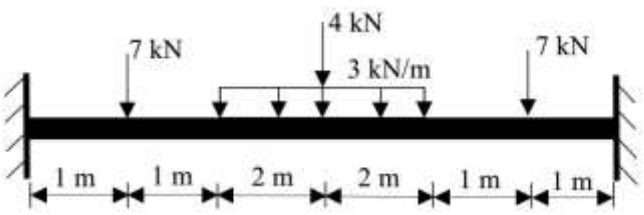

Figure 3.1

Based on figure 3.1 presented above:

(a) draw the shear force diagram of the entire beam, (7)

(b) draw the bending moment diagram of the entire beam, and (18)

(c) determine the point of contraflexure. (4)

[29]

QUESTION 4

A built-up beam is made of a rectangular section and channel as shown in figure 4.1 below. The vertical Y-Y centroidal axis of the built-up cross-section passes through the vertical centroid of the built-up cross-section.

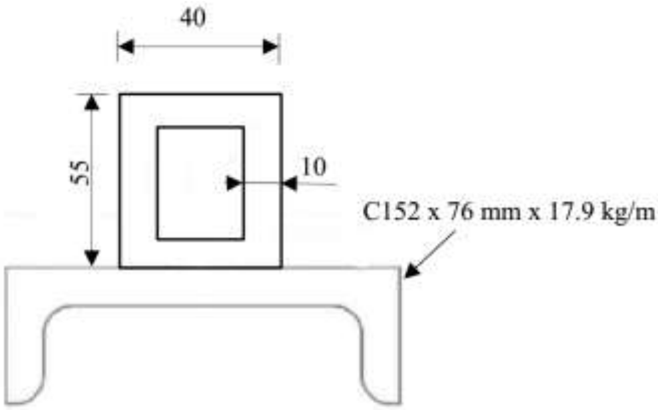

Figure 4.1

Use the Section Steel Tables provided to calculate:

(a) the position of the horizontal X-X centroid axis from the bottom, (5)

(b) the Second Moment of Area, I_X about the X-X centroid axis, and, (7)

(c) the Second Moment of Area, I_Y about the Y-Y centroid axis (6)

[18]

QUESTION 5

A simple supported beam 3 m long has a rectangular cross-section 60 mm wide and 160 mm deep. It carries a uniformly distributed load of 6 kN/m over the entire span and a point load of 2 kN at the centre of the span. The beam is also subjected to an axially applied compressive force of 5 kN.

(a) Calculate the maximum resultant direct stress in the beam. (7)

(b) Plot the stress distribution diagram. (7)

[14]

QUESTION 6

Two close-coil helical springs connected in series form a composite spring. The first spring is made of bronze with a mean coil diameter of 28 mm and a wire diameter of 3.5 mm, and has 10 coils. The second spring which is made of steel, has a mean coil dimeter of 22 mm, a wire dimeter of 3 mm, and 12 coils. Given, G_{BR} = 40 GPa and G_{ST} = 80 GPa.

(a) Calculate the stiffeness of the composite spring. (6)

(b) Calculate the maximum load that can be supported by the composite spring, if the allowable stresses are limited to 235 MPa and 115 MPa in the steel and bronze respectively. (4)

(c) Calculate the strain energy induced in the composite spring. (4)

[14]

TOTAL MARKS = 106

ANNEX A: FORMULA SHEET

1. Temperature Stresses	Free expansion: $\Delta l = l\alpha\Delta T$ Length change due force: $\Delta l = \frac{\sigma l}{E}$
2. Strain Energy	Stress due to gradually applied load, P: $\sigma = \frac{P}{A}$ Stress due to suddenly applied load, P: $\sigma = \frac{2P}{A}$ Stress due to impact load, P: $\sigma = \frac{P}{A}\left[1 \pm \sqrt{1 + \frac{2AhE}{Pl}}\right]$ General strain energy: $U = \frac{\sigma^2}{2E} \times volume\ of\ material$ Strain energy, when P is gradually applied: $U = \frac{1}{2}P\Delta l$ Strain energy, when P is suddenly applied: $U = P\Delta l$ Strain energy, when P falls from a height h: $U = P(h + \Delta l)$ Impact loads on structures: $\frac{\delta}{\delta_s} = \frac{\sigma}{\sigma_s} = \left[1 \pm \sqrt{1 + \frac{2h}{\delta_s}}\right]$ Weight moving at a constant velocity: $\frac{\delta}{\delta_s} = \frac{\sigma}{\sigma_s} = \left[1 + \sqrt{\frac{v^2}{g\delta_s}}\right]$
3. Second Moment of Area	Distance to centroid of cross-section with n sub-cross-sections: $\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2 + \cdots + A_n\bar{y}_n}{A_1 + A_2 + \cdots + A_n}$ Rectangular: $I_X = \frac{bd^3}{12}, I_Y = \frac{db^3}{12}$ Cylindrical (solid): $I_X = I_{YY} = \frac{\pi D^4}{64},\ J = \frac{\pi D^4}{32}$ Cylindrical (hollow): $I_X = I_{YY} = \frac{\pi(D^4 - d^4)}{64},\ J = \frac{\pi(D^4 - d^4)}{32}$ Parallel axis theorem: $I_{NA} = I_X + Ah^2$ Perpendicular axis theorem: $I_Z = I_X + I_Y$
4. Direct Stresses due to Bending	Bending moment equation: $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$ Section modulus (elastic): $Z_e = \frac{I}{y_{max}}\ \left(= \frac{M_{max}}{\sigma_{max}}\right)$ Bending stress from eccentric longitudinal point loading, P: $\sigma = \frac{P}{A} \pm \frac{P\hat{x}x}{I_Y} \pm \frac{P\hat{y}y}{I_X}$
5. Shear Stresses due to Bending	Shear stress (general): $\tau = \frac{VA\bar{y}}{Ib}$ Shear stress (b x d rectangular cross-section): $\tau = \frac{6V}{bd^3}\left(\frac{d^2}{4} - y^2\right)$

	Shear stress (maximum): $\tau = \frac{3V}{2bd} = 1.5 \times \tau_{mean}$ Total rivet strength: $R = \frac{\pi d^2}{4} \times \mathrm{f} \times \mathrm{n} \times \mathrm{c} = Q = \frac{VA\bar{y}}{I}$ Pitch of the rivets: $p = \frac{unit\ length \times number\ of\ rows\ of\ rivets}{n}$
6. Shear forces and Bending Moments	Sum of all vertical shear forces: $\sum V_y = 0$ Sum of all bending moments about point A: $\sum M_A = 0$
7. Close-Coiled Helical Springs	Shear stress (torsion): $\tau = \frac{8WD}{\pi d^3}$ Spring extension: $\delta = \frac{8WD^3 n}{Gd^4}$ Strain energy: $U = \frac{1}{2}W\delta = \frac{16T^2 Dn}{Gd^4} = \frac{4W^2 D^3 n}{Gd^4} = \frac{\tau^2}{4G} \times wire\ volume$ Stiffness: $S = \frac{Gd^4}{8D^3 n}$ Two springs in series: $\delta = \delta_1 + \delta_2,\ U = U_1 + U_2, S = \frac{S_1 S_2}{S_1 + S_2}$ Two springs in parallel: $\delta = \delta_1 = \delta_2, U = U_1 + U_2, S = S_1 + S_2$