UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA **MECHANICAL ENGINEERING**
SUBJECT	:	**STREGNTH OF MATERIALS 3**
CODE	:	**SOM 312**
DATE	:	SUPPLEMENTARY EXAMINATION 17 JULY 2013
DURATION	:	(SESSION 1) 08:00 – 11:00 HRS
WEIGHT	:	40:60
TOTAL MARKS	:	100

ASSESSOR	:	A. MASHAMBA
MODERATOR	:	P. STACHELHAUS
NUMBER OF PAGES	:	6 PAGES + 2 ANNEXURE

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.

QUESTION 1

A copper rod and a steel rod are rigidly fixed at one end so that they share a common longitudinal axis as shown in Figure Qn.1. The copper rod is 400 mm long and 40 mm in diameter and the steel rod is 600 mm long and 30 mm in diameter. The free ends of the co-axial rods are separated by a gap of 0.800 mm.

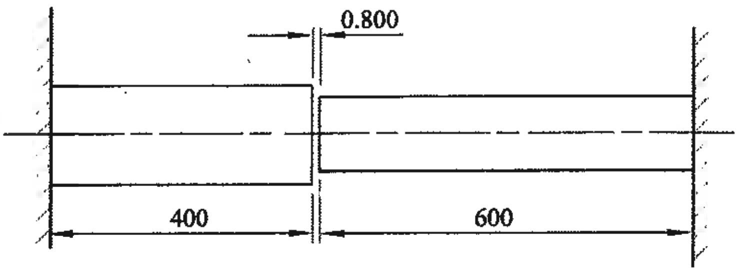

Figure Qn.1

a) If the copper and steel rods must be simultaneously heated to a temperature change ΔT before the free ends of the two rods just touch, calculate;

i) the temperature change, ΔT, (2)

ii) the axial elongation of the copper rod and (2)

iii) the axial elongation of the steel rod. (2)

b) After the free ends of the copper and steel rods are just touching, the rods are further heated to a new temperature change ΔT_2 such that the compressive stress in the copper rod is 50 MPa. Calculate;

i) the stress in the steel rod and (4)

ii) the new temperature change, ΔT_2. (6)

$E_{steel} = 200\ GPa$, $E_{copper} = 100\ GPa$, $\alpha_{steel} = 12 \times 10^{-6}/°C$, $\alpha_{copper} = 17 \times 10^{-6}/°C$.

[16]

QUESTION 2

A steel connecting rod is 400 mm long and has an outside diameter of 40 mm. Both ends of the connecting rod have holes of 20 mm in diameter and 100 mm deep as shown in Figure Qn.2.

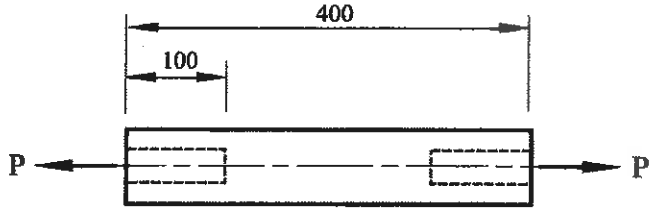

Figure Qn.2

If a suddenly applied axial tensile load, P kN, induces a maximum stress of 200 MPa in the connecting rod, calculate;

b) the suddenly applied load, P, (5)

c) the energy absorbed by the connecting rod and (6)

d) the maximum extension of the bar. (3)

$E = 200\ GPa$ **[14]**

QUESTION 3

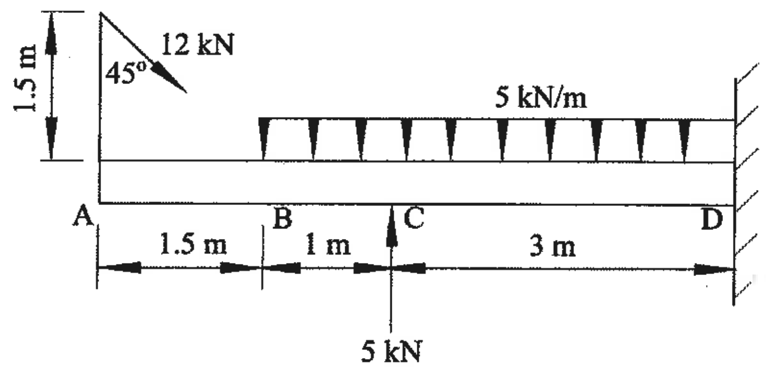

Figure Qn.3

For the beam shown in Figure Qn.3:

a) Calculate the vertical reaction and fixing moment at the wall; (4)

b) Sketch the shear force diagram and (5)

c) Sketch the bending moment diagram. (8)

[17]

QUESTION 4

A 254 x 146 mm x 37.2 kg/m I-section (parallel flange) is welded to a 160 × 65 mm Channel section to make a built-up cross-section as shown in Figure Qn.4. Use the Section Steel Tables provided to calculate;

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

b) the Second Moment of Area, I_X about the centroid axis, X-X. (8)

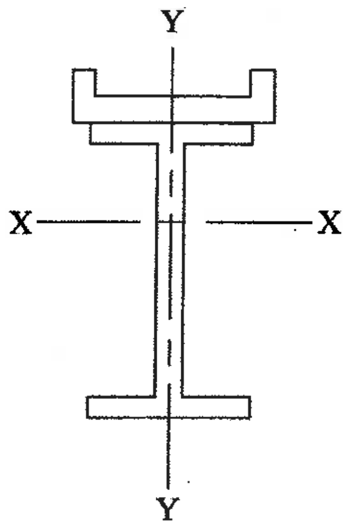

Figure Qn.4

[13]

QUESTION 5

A simply-supported steel beam is 1.2 m long and carries a uniformly distributed load of 20 kN/m as shown in Figure Qn.5(a). The beam has a rectangular cross-section that is 200 mm wide and 100 mm high as shown in Figure Qn.5(b). A longitudinal compressive point load of 300 kN is applied at both ends of the beam as shown in Figure Qn.5(a). The longitudinal compressive point load is positioned on the Y-Y centroid axis but is 25 mm below the X-X centroid axis of the beam's cross-section as illustrated in Figure Qn.5(b).

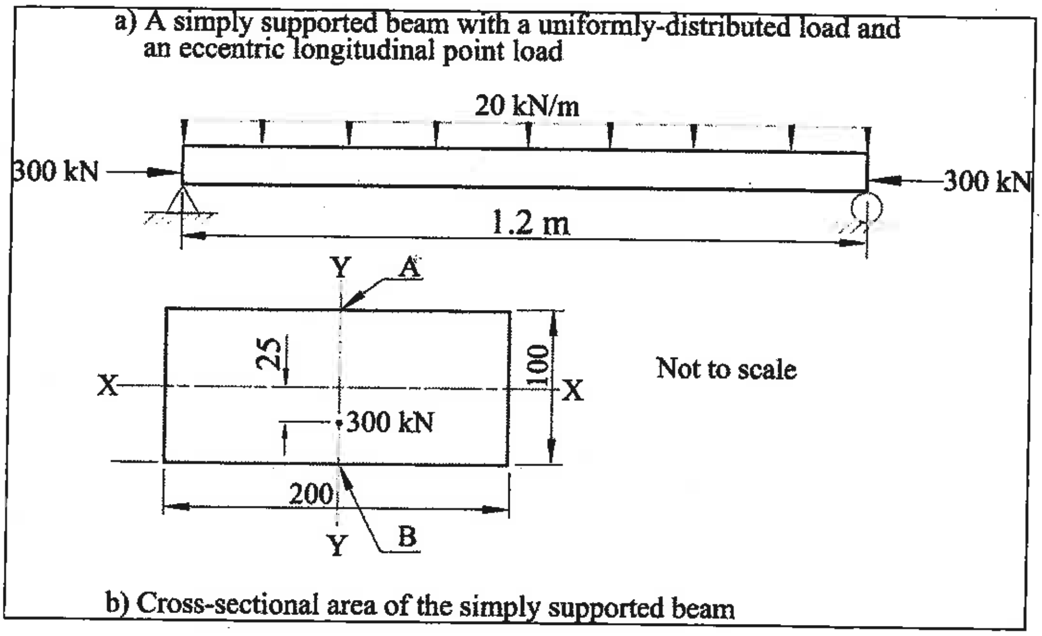

Figure Qn.5

a) Calculate the maximum resultant stress experienced by the beam on the surface where Point A lies. (9)

b) Calculate the maximum resultant stress experienced by the beam on the surface where Point B lies. (7)

[16]

QUESTION 6

An I-section beam has a web of dimensions 400 mm × 15 mm and flanges of dimensions 200 mm × 15 mm. The beam must withstand a maximum bending moment of 220 kNm and a maximum shear force of 0.8MN when the web is vertical.

Calculate;

a) the maximum bending stress induced in the section and (6)

b) the maximum shear stress that will be experienced by the beam due to the maximum shear force only. (7)

[13]

QUESTION 7

A compound spring consists of two steel close-coiled springs that are arranged one inside the other. The outer spring has a wire diameter of 5 mm and a mean coil diameter of 50 mm. The inner spring has a wire diameter of 4 mm, a mean coil diameter of 40 mm, 10 coils and is 10 mm shorter that the outer spring. If a load of 100 N compresses the compound spring by 15 mm, calculate

a) the stiffness of the compound spring, (6)

b) the number of coils in the outer spring and (2)

c) the total strain energy stored in the compound spring. (3)

$G = 80\ GPa$

[11]

TOTAL MARKS = 100

ANNEXTURE 1: 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: $U = P\Delta l$ 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): $I_X = I_Y = \frac{\pi D^4}{64}, J = \frac{\pi D^4}{32}$ Cylindrical (hollow): $I_X = I_Y = \frac{\pi(D^4 - d^4)}{64}, J = \frac{\pi(D^4 - d^4)}{32}$ 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: $\delta = \frac{8WD^3n}{Gd^4}$ Strain energy: $U = \frac{1}{2}W\delta = \frac{16T^2Dn}{Gd^4} = \frac{4W^2D^3n}{Gd^4} = \frac{\tau^2}{4G} \times$ $wire\ volume$ Stiffness: $S = \frac{W}{\delta} = \frac{Gd^4}{8D^3n}$ Two springs in series: $\delta = \delta_1 + \delta_2,\ U = U_1 + U_2, S = \frac{S_1S_2}{S_1+S_2}$ Two springs in parallel: $\delta = \delta_1 = \delta_2, U = U_1 + U_2, S = S_1 = S_2$