PROGRAM	:	BACCALAUREUS INGENERIAE *MECHANICAL ENGINEERING*
SUBJECT	:	**STRENGTH OF MATERIALS 3B**
CODE	:	**SLR 3B21 / SLRBCB3**
DATE	:	SUPPLEMENTARY EXAMINATION JANUARY 2020
DURATION	:	3 HOURS
WEIGHT	:	50:50
TOTAL MARKS	:	100

EXAMINER	:	DR D. M. MADYIRA
MODERATOR	:	PROF R. F. LAUBSCHER
NUMBER OF PAGES	:	6 PAGES

INSTRUCTIONS	:	QUESTION PAPERS MUST **NOT** BE HANDED IN.
REQUIREMENTS	:	ANSWER SHEETS

INSTRUCTIONS TO CANDIDATES:

1. Answer all questions.
2. Explain answers and give all the necessary steps to arrive at the answer – simply giving the answer is not sufficient.
3. The examination is not an open book exam. All required formulae are given in the formulae sheet.
4. Do all the questions in the answer scripts.

QUESTION 1 [25]

A thin-walled tubular section is semi-circular in shape as shown in Figure Q1. Find the maximum torque that the section can carry if the maximum shear stress is limited to 90 MPa. For this torque, determine the angle of twist per unit length. G = 9 GPa. Consider the thickness to be constant throughout.

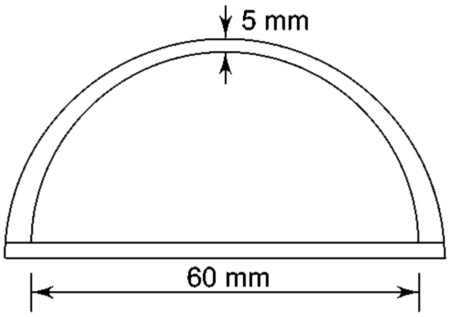


Figure Q1: Curved support bracket

QUESTION 2 [25]

A compound cylinder is formed by shrinking one tube on to another, the inner and outer diameters of the outer tube being 120 mm and 180 mm respectively and that of the inner tube being 60 mm and 120 mm respectively. After shrinking, the radial pressure at the common surface is 30 MPa. If the cylinder is subjected to an internal pressure of 80 MPa, determine the final stresses set up at the various surfaces of the cylinder. What is the resultant pressure at the common surface?

QUESTION 3 [25]

A brass sleeve S is fitted over a steel bolt B (see Figure Q3), and the nut is tightened until it is just snug. The bolt has a diameter d_B = 25 mm, and the sleeve has inside and outside diameters d_1 = 26 mm and d_2 = 36 mm, respectively. Calculate the temperature rise ΔT that is required to produce a compressive stress of 25 MPa in the sleeve. (Use material properties as follows: for the sleeve, $\alpha_S = 21 \times 10^{-6}/^oC$ and E_S = 100 GPa; for the bolt, $\alpha_B = 10 \times 10^{-6}/^oC$ and E_B = 200 GPa.)

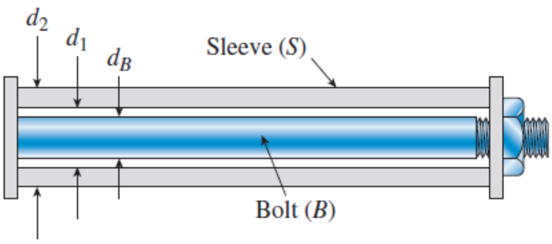


Figure Q1: Bolt and sleeve assembly

QUESTION 4 [25]

An I-section beam is built up of a 200 × 10 mm web plate with 120 × 20 mm flange plates secured by rivets through 40 × 40 × 6 mm angle sections as shown in Figure Q4. Determine the maximum uniformly distributed load which can be applied over a span of 10 m if the permissible bending stress is 90 MPa (assume simply supported). Also find the pitch of the rivets. The rivets are 10 mm diameter with a permissible shear stress of 70 MPa.

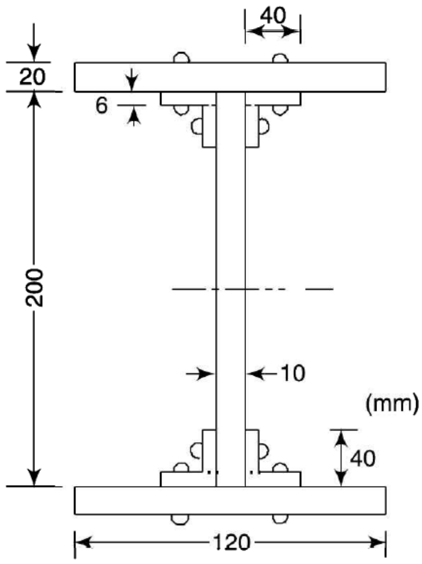


Figure Q4: Fabricated beam section

THE END!

Formula Sheet

Buckling Equations

$$P_{cr} = \frac{\pi^2 EI}{4L^2} \qquad P_{cr} = \frac{\pi^2 EI}{L^2} \qquad P_{cr} \approx \frac{2\pi^2 EI}{L^2} \qquad P_{cr} = \frac{4\pi^2 EI}{L^2}$$

$$\sigma_{max} = \frac{P}{A}\left[1 + \frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{P}{EA}}\right)\right]$$

Initially Curved Sections

$$R = A \Big/ \int_A \frac{dA}{r} \qquad \sigma = \frac{M(R-r)}{rA(\bar{r}-R)}$$

Shear Stresses in Bending

$$\tau_{xy} = \tau_{yx} = \frac{Q}{b \cdot I} \cdot \int_A y \cdot dA = \frac{Q \cdot A \cdot \bar{y}_A}{b \cdot I}$$

Springs

$$\tau_{max} = \frac{8 \cdot F \cdot D}{\pi \cdot d^3} + \frac{4F}{\pi \cdot d^2} \qquad y = \alpha \cdot \frac{D}{2} = \frac{8 \cdot F \cdot D^3 \cdot N}{d^4 \cdot G} \qquad k = \frac{d^4 \cdot G}{8 \cdot D^3 \cdot N}$$

$$\sigma = \frac{M}{I/c} + \frac{F}{A} = K \cdot \frac{32 \cdot F \cdot r_m}{\pi \cdot d^3} + \frac{4 \cdot F}{\pi \cdot d^2} \qquad K \approx \frac{r_m}{r_i} \qquad N = N_T - N_D$$

Thick Cylinders

$$\sigma_r = \frac{1}{k^2 - 1} \cdot \left[p_i \cdot \left(1 - \frac{r_o^2}{r^2}\right) - p_o \cdot k^2 \cdot \left(1 - \frac{r_i^2}{r^2}\right)\right] \qquad \sigma_r = \frac{p_i}{k^2 - 1} \cdot \left(1 - \frac{r_o^2}{r^2}\right)$$

$$\sigma_\theta = \frac{1}{k^2 - 1} \cdot \left[p_i \cdot \left(1 + \frac{r_o^2}{r^2}\right) - p_o \cdot k^2 \cdot \left(1 + \frac{r_i^2}{r^2}\right)\right] \qquad \sigma_\theta = \frac{p_i}{k^2 - 1} \cdot \left(1 + \frac{r_o^2}{r^2}\right)$$

$$k = \frac{r_o}{r_i} \qquad \sigma_r = A - \frac{B}{r^2} \qquad \sigma_\theta = A + \frac{B}{r^2}$$

$$\delta = -u' + u'' = r_m \cdot (\varepsilon_\theta'' - \varepsilon_\theta')$$

$$\varepsilon_\theta'' = \frac{1}{E}\left(\sigma_\theta'' - \nu\sigma_r''\right) \qquad outer\ \ cylinder$$

$$\varepsilon_\theta' = \frac{1}{E}\left(\sigma_\theta' - \nu\sigma_r'\right) \qquad inner\ \ cylinder$$

Rotating Components

$$\frac{d\sigma_r}{dr} + \frac{\sigma_r - \sigma_\theta}{r} + \rho\cdot\omega^2\cdot r = 0$$

$$\sigma_r = A - \frac{B}{r^2} - \left(\frac{3+\nu}{8}\right)\cdot\rho\cdot\omega^2\cdot r^2$$

$$\omega_Y = \frac{1}{r_e}\cdot\sqrt{\frac{8\cdot\sigma_Y}{(3+\nu)\cdot\rho}}$$

$$\sigma_\theta = A + \frac{B}{r^2} - \left(\frac{1+3\cdot\nu}{8}\right)\cdot\rho\cdot\omega^2\cdot r^2$$

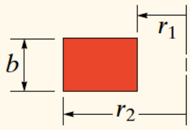
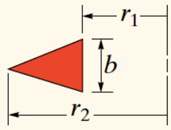
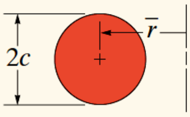
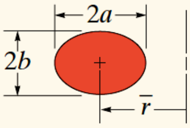
$$\omega_Y = \sqrt{\frac{4\cdot\sigma_Y}{\rho\cdot\left[(3+\nu)\cdot r_e^{\,2} + (1-\nu)\cdot r_i^{\,2}\right]}}$$

$$\sigma_{r1}\cdot z_1 = \sigma_{r2}\cdot z_2 \qquad F_c = m\cdot\omega^2\cdot r$$

Torsion of Non-circular sections

$$T = \alpha bt^2\frac{G\theta}{L} = \beta bt^3\frac{G\theta}{L} \qquad \tau_{\max} = \frac{G\theta t}{L} \qquad T = \frac{1}{3}bt^2\frac{G\theta}{L}$$

b/t	**1**	**1.5**	**2**	**2.5**	**3**	**4**	**6**	**10**	∞
α	0.208	0.231	0.246	0.256	0.267	0.282	0.299	0.312	0.333
β	0.141	0.196	0.229	0.249	0.263	0.281	0.299	0.312	0.333

Shape	$\int_A \frac{dA}{r}$
	$b \ln \frac{r_2}{r_1}$
	$\frac{b\, r_2}{(r_2 - r_1)} \left(\ln \frac{r_2}{r_1} \right) - b$
	$2\pi \left(\bar{r} - \sqrt{\bar{r}^2 - c^2} \right)$
	$\frac{2\pi b}{a} \left(\bar{r} - \sqrt{\bar{r}^2 - a^2} \right)$