[ENG25]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) AUTOMOTIVE PERFORMANCE ENGINEERING (MOTORSPORT)

SEMESTER TWO EXAMINATION 2022/2023

ENGINEERING SCIENCE II

MODULE NO: MSP5016

Date: Friday 12th May 2023 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer FOUR questions.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

CANDIDATES REQUIRE:

Formula Sheets (attached after questions).

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Q1. Beam deflection

A cantilever beam AB of length L is 5m long shown in Figure Q1 is needed. It will be used in aerospace to support a wing of a military plane. It has to carry a uniformly distributed load of intensity w_o = 8 KN/m, The modulus of elasticity E=205 GPa.

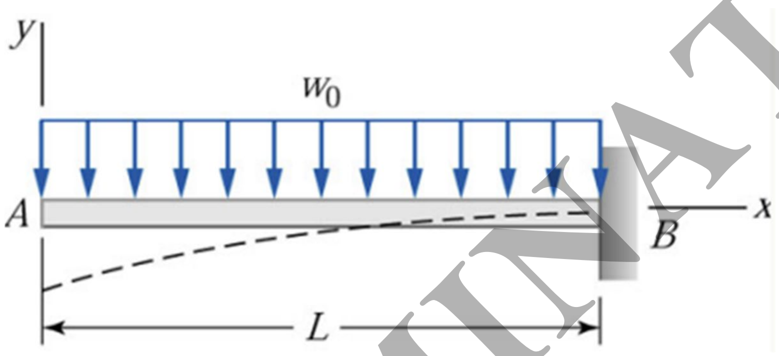

Figure Q1

a) Derive the equations for slope and deflections at free end of the beam.
(15 marks)

b) Calculate the flexural rigidity (EI) of the beam if the maximum allowable deflection is not to exceed 3 mm at the free end.
(5 marks)

c) Determine the dimension of the cross-section of beam if it has a solid circular cross section.
(5 marks)

Total 25 Marks

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Q2. Thick cylinder

A thick cylinder pressure vessel as shown in Figure Q2 has an outside diameter of 180 mm and an inside diameter of 100 mm. It is pressurised internally until the outside layer has a circumferential stress of 42 MPa. If the modulus of elasticity E = 70 GPa and poissons ratio,ν = 0.28.

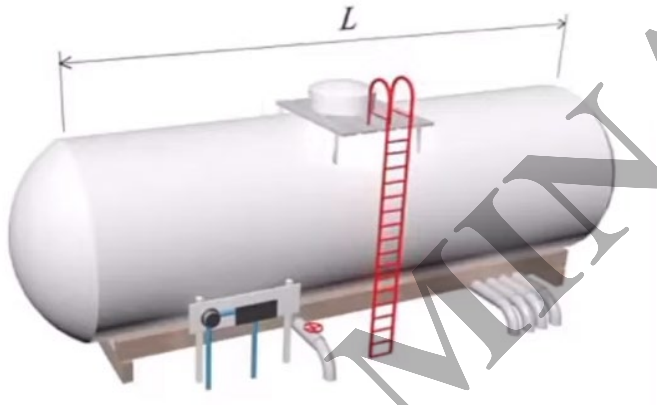

Figure Q2

Calculate:

a) The hoop stress at the inner and outer radii of the pressure vessel

(15 marks)

b) The longitudinal stress.

(5 marks)

c) Sketch the hoop and radial stress distribution across the cylinder wall.

(5 marks)

Total 25 Marks

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Q3. Struts

A hollow cylindrical column of cast iron is placed vertical and is hinghed at both ends, the column has external diameter of 120 mm and internal diameter of 80 mm, and it is 4.2 m in height. Take modulus of elasticity, E=80 KN/mm^2 and material constant c=1/1600, crushing stress as σ_c= 550 N/mm^2

a) Determine the Euler's crushing load of the hollow cylindrical column.
(10 marks)

b) Compare this load with the crushing load as given by Rankine's
(10 marks)

c) For what length of strut does the Euler's formula cease to apply.
(5 marks)

Total 25 Marks

Q4: Vibrations

An oscillating system has an axial stiffness of 2200 N/m and is subjected to damping where the damping coefficient is 130 N/(m/s).

Determine:

a) The mass of the system of its undamped natural frequency of 1.6 Hz.
(5 marks)

b) The damping ratio of the system.
(5 marks)

c) The periodic time and damping frequency.
(5 marks)

d) The second positive amplitude after one periodic time of the first positive amplitude is 0.2 m.
(5marks)

e) Develop the x= f(t) diagram for the d) part of the question.
(5marks)

Total 25 Marks

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Q5: Mohr circle and Principal Stresses

A pressure vessel is made of a ductile material is subjected to a two dimensional stress system as shown on its element shown in Figure Q5 below.

The stress in X direction is 50 MPa in tension, 30 MPa compressive in Y direction, and shear stress of 20 MPa in clockwise and anticlockwise direction.

a) Sketch a Mohr's Stress Circle from the information provided in Figure Q5, labelling σ_1, σ_2 the principal stresses and the maximum shear stress τ_{max}. Select a suitable scale for the Mohr's Stress circle. (10 marks)

b) Determine from the circle

(i) the direct and shear stress on a plane AB which is making and angle of 25 degress, the plane AB is is perpendicular to the σ_x

(5 marks)

(ii) the magnitude and direction of the principal stress

(5 marks)

(iii) the magnitude and direction of the shear stress.

(5 marks)

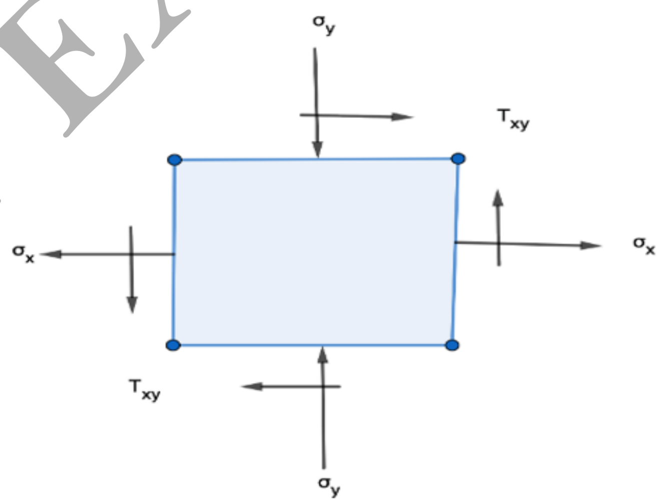

Figure Q5

Total 25 Marks

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Q6: Unsymmetrical bending

A beam cross section of various length and thickness is showm in the Figure Q6, the beam is unequal in nature and when the loads are applied on the beam, the beam exihibit unsymmetrical bending.

For the beam determine.

a) the centroid of the cross section of the unequal beam.
(9 marks)

b) the position of principal axis and
(8 marks)

c) the values of the principal moments of the area
(8 marks)

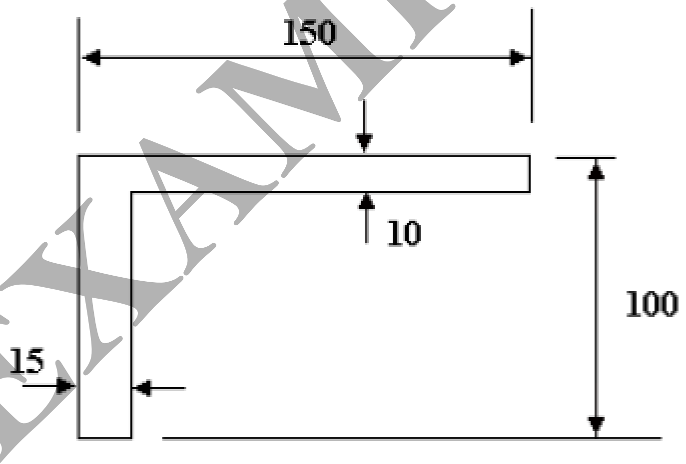

Figure Q6

Total 25 Marks

END OF QUESTIONS

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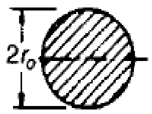
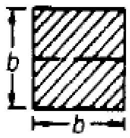
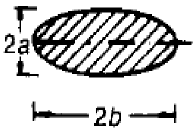
FORMULA SHEET

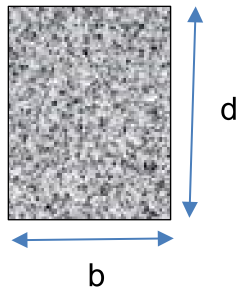
Deflection:

$$M_{xx} = EI \frac{d^2y}{dx^2}$$

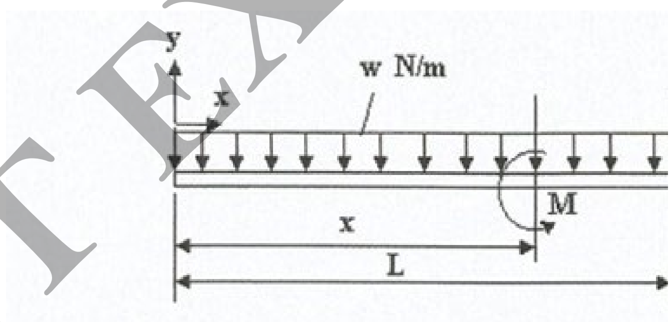
Section Shape	$A(m^2)$	$I_{xx}(m^4)$
	πr^2	$\frac{\pi}{4} r^4$
	b^2	$\frac{b^4}{12}$
	πab	$\frac{\pi}{4} a^3 b$

For solid rectangular Cross-section

$$I_{xx} = \frac{bd^3}{12}$$



Cantilever beam with UDL:



M: maximum bending moment ($M_{max}=\omega L^2/2$)
Maximum bending stress:

$$\sigma_{bending} = \frac{My}{I}$$

M: maximum bending moment
Y: distance from neutral axis
I: second moment of area

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Slope at the ends:

$$\frac{dy}{dx} = \frac{\omega L^3}{6EI}$$

Maximum deflection at the middle:

$$y = -\frac{\omega L^4}{8EI}$$

Plane Stress:

a) **Stresses in function of the angle Θ:**

$$\sigma_x(\theta) = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos(2\theta) + \tau_{xy}\sin(2\theta)$$

$$\sigma_y(\theta) = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos(2\theta) - \tau_{xy}\sin(2\theta)$$

$$\tau_{xy}(\theta) = -\frac{\sigma_x - \sigma_y}{2} sin(2\theta) + \tau_{xy} cos(2\theta)$$

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Lame's equation

The equations are known as "Lame's Equations" for radial and hoop stress at any specified point on the cylinder wall. Note: R_1 = inner cylinder radius, R_2 = outer cylinder radius

$$\sigma_C = a + \frac{b}{r^2}$$

$$\sigma_R = a - \frac{b}{r^2}$$

The corresponding strains format is:

$$\varepsilon_c = 1/E\ \{\sigma_c - \nu(\sigma_r + \sigma_L)\}$$

$$\varepsilon_r = 1/E\ \{\sigma_r - \nu(\sigma_c + \sigma_L)\}$$

$$\varepsilon_L = 1/E\ \{\sigma_L - \nu(\sigma_c + \sigma_r)\}$$

$$\sigma_L = \frac{P_1 R_1^2 - P_2 R_2^2}{(R_2^2 - R_1^2)} = \text{Lamé constant } A$$

$$\tau_{max} = \frac{\sigma_c - \sigma_r}{2} = \frac{b}{r^2}$$

Vibrations:

Free Vibrations:

$$f = \frac{1}{T} \qquad \omega_n = 2\pi f = \sqrt{\frac{k}{\mathrm{M}}}$$

Damped Vibrations:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{\mathrm{M}}} \qquad c = \zeta 2m\,\omega_n \qquad \zeta = \frac{c}{c_c}$$

$$f_d = f_n\sqrt{1-\zeta^2}$$

$$\left(\frac{x_1}{x_r}\right) = e\text{^}\zeta\omega_n(r-1)T$$

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Stress

σ = Force/Area = F/A

Hook's law

σ = E·ε

ε = ∆L/L

Quadratic equation: $ax^2+bx+c=0$

Solution:

$$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Allowable stress: $\sigma_{allowable}$

$$\sigma_{allowable} = \frac{\sigma_{yield}}{Factor\ Of\ Safety}$$

Struts:

$$I = k^2 A$$

$$k = \sqrt{\frac{I}{A}}$$

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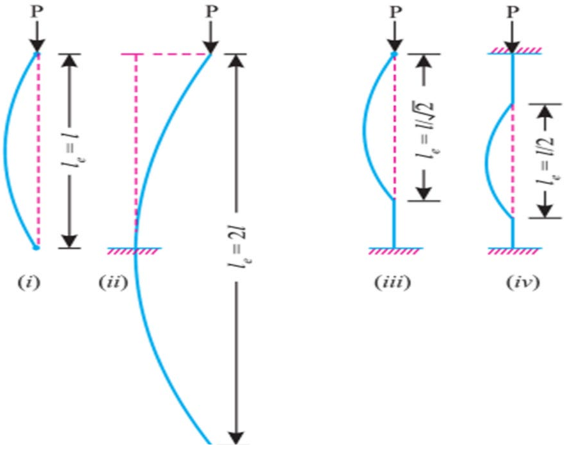
<u>Euler validity</u>

$$Slenderness\ ratio = SR = \frac{L_e}{k} \geq \pi\sqrt{\frac{E}{\sigma_{yield}}}$$



(i) *Both ends pin jointed or hinged or rounded or free.*
(ii) *One end fixed and other end free.*
(iii) *One end fixed and the other pin jointed.*
(iv) *Both ends fixed.*

Case	*End conditions*	*Equivalent length, l_e*	*Buckling load, Euler*
1	*Both ends hinged or pin jointed* or *rounded or free*	l	$\frac{\pi^2 EI}{l_e^2} = \frac{\pi^2 EI}{l^2}$
2.	*One end fixed, other end free*	$2l$	$\frac{\pi^2 EI}{l_e^2} = \frac{\pi^2 EI}{4l^2}$
3.	*One end fixed, other end pin jointed*	$\frac{l}{\sqrt{2}}$	$\frac{\pi^2 EI}{l_e^2} = \frac{2\pi^2 EI}{l^2}$
4.	*Both ends fixed or encastered*	$\frac{l}{2}$	$\frac{\pi^2 EI}{l_e^2} = \frac{4\pi^2 EI}{l^2}$

Studying Rankine's formula,

$$P_{Rankine} = \frac{\sigma_c \cdot A}{1 + a\cdot\left(\frac{l_e}{k}\right)^2}$$

We find,

$$P_{Rankine} = \frac{\text{Crushing load}}{1 + a\left(\frac{l_e}{k}\right)^2}$$

The factor $1 + a\left(\frac{l_e}{k}\right)^2$ has thus been introduced to *take into account the buckling effect.*

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$$a = \frac{\sigma_c}{\pi^2 \cdot E}$$

Centroid.

$$I_{xy} = Ahk = A\bar{y}\,\bar{x}$$

$$I_{right\,edge} = I_{yy} + Ax^2$$

$$I_{bottom\,edge} = I_{xx} + Ay^2$$

$$\tan 2\theta = \frac{2I_{xy}}{I_{yy} - I_{xx}}$$

$$I_u = \frac{1}{2}(I_{xx} + I_{yy}) + \frac{1}{2}(I_{xx} - I_{yy})\sec 2\theta$$

$$I_v = \frac{1}{2}(I_{xx} + I_{yy}) - \frac{1}{2}(I_{xx} - I_{yy})\sec 2\theta$$

END OF PAPER