ENG17

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BSc (HONS) MOTORSPORT TECHNOLOGY

SEMESTER ONE EXAMINATION 2024/2025

ENGINEERING PRINCIPLES 2

MODULE NO: MSP5025

Date: Tuesday 7th January 2025 **Time: 2:00pm – 4:00pm**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

You MUST answer ALL of Section A

Answer THREE of FIVE questions from Section B

Marks for parts of questions are shown in brackets. Maximum mark is 100.

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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BSc (Hons) Motorsport Technology
Semester One Examination 2024/25
Engineering Principles 2
Module No. MSP5025

Section A – YOU MUST ANSWER THIS QUESTION

Q1. Figure 1a shows the symmetrical cross section of a solid rectangular beam. Figure 1b shows the loading conditions for the simply supported beam. The beam is made from steel with a modulus of elasticity, E = 200 GPa.

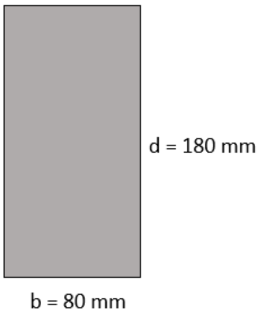

Figure 1a- Cross section

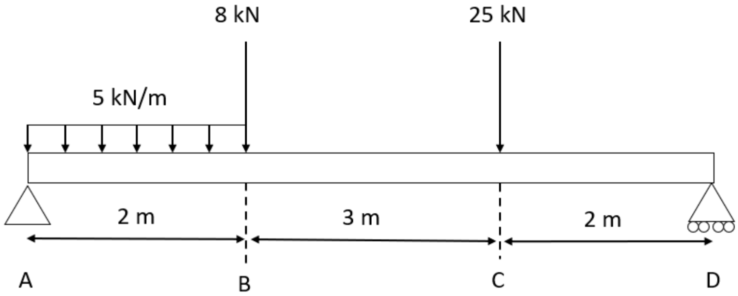

Figure 1b- Beam loading

a) Find the support reactions at A and D.

(6 marks)

b) Calculate and plot the bending moment distribution across the beam, show that the maximum bending moment is 43.1 kNm.

(10 marks)

c) Using the maximum moment from part b) find the maximum bending stress in the beam.

(8 marks)

d) Using the bending moment equation generated in part b) Use Macauley's method to find the deflection at the centre of the beam.

(16 marks)

Total for Q1 - 40 marks

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Section B – ANSWER ANY THREE QUESTIONS FROM THIS SECTION

Q2. A pressure vessel is made of a ductile material is subjected to a two-dimensional stress system as in Figure 2 below. The stress in the x direction is 60 MPa in tension, 30 MPa compressive in the y direction, and there is a shear stress of 20 MPa.

a) Determine, by calculation, the direct and shear stress on the plane AB which is inclined 30 degrees from the y direction, as shown in figure 2.

(6 marks)

b) Find the inclination of the principal plain for which maximum normal stress occurs and the inclination of the principal plain for which shear stress occurs.

(7 marks)

c) Hence calculate the principal normal stresses and maximum shear stress.

(7 marks)

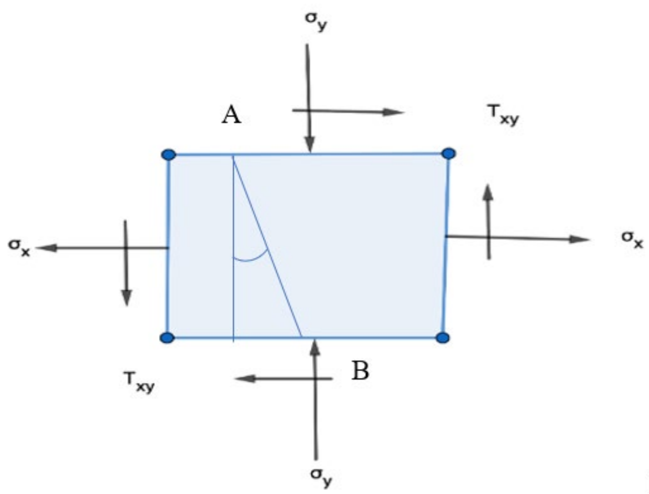

Figure 2-Stress system

Total for Q2 – 20 marks

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Q3. Struts and columns are structural components that have a compressive load acting upon them.

A solid cylindrical column of cast iron is placed vertically and has one end fully fixed with the other end pinned, the column has a diameter of 75 mm, and it is 4.2 m in height.
Take the modulus of elasticity, E=80 GPa, the material constant as c=1/1600, and the elastic limit stress as σ_c= 550 MPa.

a) Find the radius of gyration of the strut, k.

(4 marks)

b) Determine the Euler crippling load, P_{CR}, and Euler crippling stress, σ_{CR}, of the cylindrical column.

(8 marks)

c) Calculate the critical stress, σ_R, using Rankine-Gordon's formula and compare this to the Euler crippling stress found in part b)

(5 marks)

d) By considering the slenderness ratio, briefly discuss the nature in which this column is likely to fail and suggest which method (Euler or Rankine-Gordon) is most accurate in this case.

(3 marks)

Total for Q3 – 20 marks

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Q4) The Bernoulli equation is frequently used in fluid mechanics. It is often misused or misinterpreted.

a) Discuss three limitations or restrictions that should be considered when using the equation.

(6 marks)

b) Consider the scenario in Figure 3. Fuel is being syphoned from a car into a canister. The atmospheric pressure for the day is 101 kPa. By applying Bernoulli's equation between point 1 and 2 find the velocity of the fuel at point 2.

(5 marks)

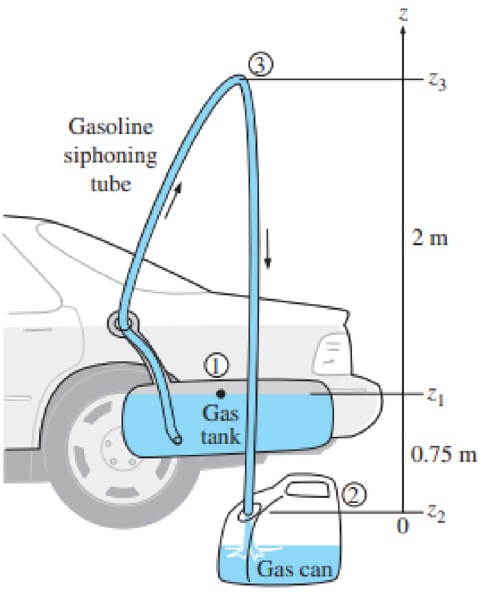

Figure 3-Fuel canister

c) Find the time it would take to syphon 5 litres of fuel from the car. You may assume 1 litre of fuel occupies a volume equal to 0.001 $\boldsymbol{m^3}$.

(5 marks)

d) Find the pressure of the fluid at position 3, you can assume the density of the fuel is 750 kgm^{-3}.

(4 marks)

Total for Q4 – 20 marks

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Q5) A large fuel tank pictured in figure 4 has a rectangular service hatch fitted in the side of the tank. The hatch has a height of 0.85m and width of 1.2m. The top of the hatch is hinged and located 1.5m from the surface of the fuel. The fuel has a density of $800\ kgm^{-3}$.

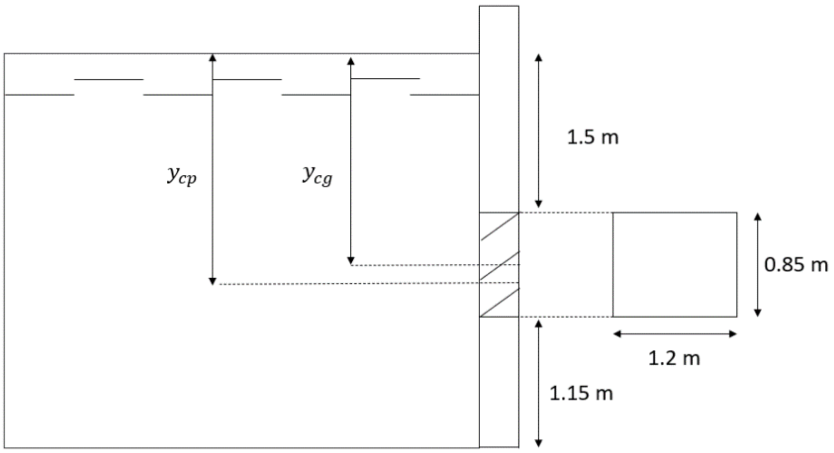

Figure 4-Fuel tank

a) Calculate the total resultant force acting over the hatch area.

(4 marks)

b) Using the parallel axis theorem, calculate the distance of the centre of pressure on the hatch from the surface.

(6 marks)

c) Calculate the moment produced about the hinge.

(4 marks)

d) Some changes to the design of the tank are being considered. What effect will the following have on the centre of pressure location **and** the force applied to the hatch;

I. Increasing the width of the gate
II. Increasing the depth (1.15m) from the bottom of the hatch
III. Increasing the fuel density

(6 marks)

Total for Q5 – 20 marks

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Q6.

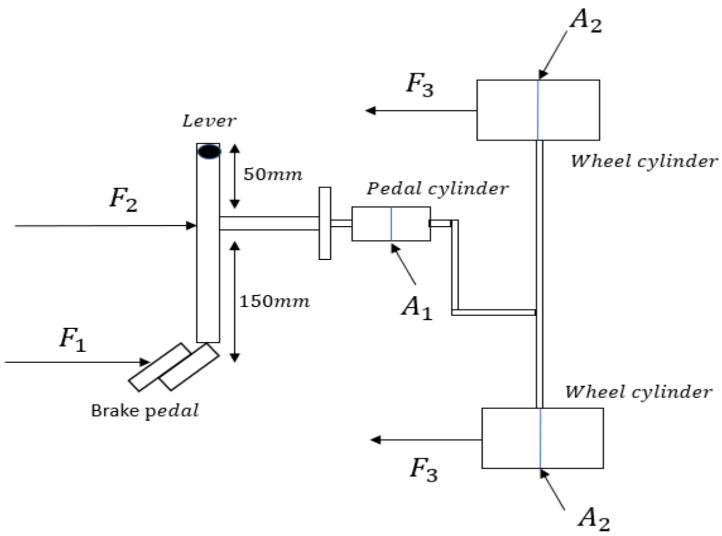

Figure 5-Hydraulic braking system

Figure 5 shows a hydraulic braking system. F_1 represents the force applied during braking by a foot. The lever than amplifies this force to F_2. The hydraulic system and pedal cylinder are responsible for further increasing the force. The hydraulic system then connects to the wheel cylinders which increases the force by a significant amount to F_3 which is in turn applied by the calipers to the brake pads and then wheel.

a) Given that a braking foot force, F_1, of 200N is applied at the brake pedal. By considering the moment generated across the level, which is hinged at the top, find the equivalent force F_2 that is applied to the braking system.

(5 marks)

b) The force creates an increase in pressure in the braking system, explain Pascal's principle in relation to the fluid.

(3marks)

c) The diameter of the piston in the pedal cylinder is 30mm. The piston in the wheel cylinder is 210mm. Find the equivalent force exerted on the wheels, F_3.

(6marks)

d) What would be the impact of making the following changes;
   i. The brake lines losing hydraulic fluid
   ii. A similar hydraulic fluid is used with higher density
   iii. Adding 2 extra wheel cylinders to the system

(6marks)

Total for Q6 – 20 marks

END OF QUESTIONS

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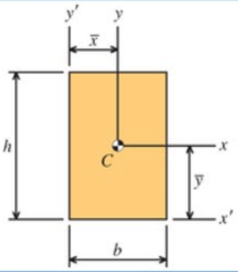
FORMULA SHEET

Bending And Deflection

2nd moment of area for basic shapes:

Rectangle



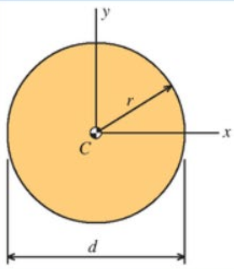
$A = bh$

$\bar{y} = \dfrac{h}{2}$ $\quad I_x = \dfrac{bh^3}{12}$

$\bar{x} = \dfrac{b}{2}$ $\quad I_y = \dfrac{hb^3}{12}$

$I_{x'} = \dfrac{bh^3}{3}$ $\quad I_{y'} = \dfrac{hb^3}{3}$

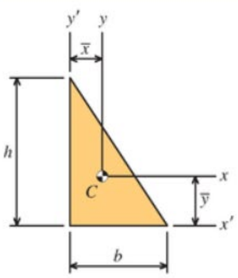
Circle



$A = \pi r^2 = \dfrac{\pi d^2}{4}$

$I_x = I_y = \dfrac{\pi r^4}{4} = \dfrac{\pi d^4}{64}$

Right Triangle



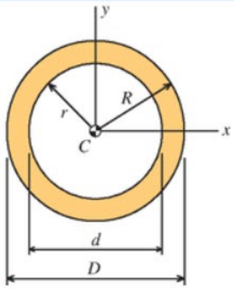
$A = \dfrac{bh}{2}$

$\bar{y} = \dfrac{h}{3}$ $\quad I_x = \dfrac{bh^3}{36}$

$\bar{x} = \dfrac{b}{3}$ $\quad I_y = \dfrac{hb^3}{36}$

$I_{x'} = \dfrac{bh^3}{12}$ $\quad I_{y'} = \dfrac{hb^3}{12}$

Hollow Circle



$A = \pi(R^2 - r^2) = \dfrac{\pi}{4}(D^2 - d^2)$

$I_x = I_y = \dfrac{\pi}{4}(R^4 - r^4)$

$= \dfrac{\pi}{64}(D^4 - d^4)$

Bending equation: $\sigma = \dfrac{My}{I}$

Beam deflection (v): $\dfrac{d^2 v}{dx^2} = \dfrac{M(x)}{EI}$

Parallel axis theorem: $I_{xx} = I_{\overline{xx}} + Ay^2 \quad I_{yy} = I_{\overline{yy}} + Ax^2$

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Struts

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

$$Slenderness\ ratio(SR) = \frac{L_e}{k}$$

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	$\frac{l}{2}$	$\frac{\pi^2 EI}{l_e^2} = \frac{4\pi^2 EI}{l^2}$

$$\text{Crippling Euler Load, } P_{CR} = \frac{\pi^2 EI}{{l_e}^2}$$

$$\text{Crppling Euler stress,} \qquad \sigma_{CR} = \frac{\pi^2 E}{\left(\frac{l_e}{k}\right)^2}$$

$$\text{Rankine} - \text{Gordon critical load,} \qquad P_R = \frac{A.\sigma_c}{1 + c\left(\frac{l_e}{k}\right)^2}$$

$$\text{Rankine} - \text{Gordon critical stress,} \qquad \sigma_R = \frac{\sigma_c}{1 + c\left(\frac{l_e}{k}\right)^2}$$

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Complex Stresses and Strains

$$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \left(\frac{\sigma_x - \sigma_y}{2}\right) cos(2\theta) - \tau sin(2\theta)$$

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

$$tan(2\theta_p) = \frac{-2\tau}{\sigma_x - \sigma_y}$$

$$tan(2\theta_s) = \frac{\sigma_x - \sigma_y}{2\tau}$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2}$$

$$\tau_{max} = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2}$$

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Fluid Mechanics

Parallel axis theorem: $I_{CG} = I_{\overline{xx}} + Ay^2 \quad I_{yy} = I_{\overline{yy}} + Ax^2$

First moment of area: $I = Ay$

Centre of Pressure: $\bar{h} = \frac{I_{CG}}{I}$

Bernoulli's Principle:

$$P_1 + \frac{\rho v_1^2}{2} + \rho g h_1 = P_2 + \frac{\rho v_2^2}{2} + \rho g h_2$$

$$\dot{m} = \rho A v$$

$$\dot{V} = Av$$

Pressure at depth:

$$P = \rho g h$$

Hydraulics:

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

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