

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

EXAMINATION PERIOD
JUNE 2017

CYFNOD ARHOLIADAU
MEHEFIN 2017

MODULE CODE:
M5X02064: CAE & Stress analysis (PART TIME)

TIME: 2 HOURS

ANSWER THREE OUT OF FOUR QUESTIONS

Equipment or materials required – None

Adnoddau neu ddefnyddiau sydd eu hangen – Dim

A formula sheet is provided for reference.

University approved calculators are permitted.

Assume 'g' = 9.81 m/s².

Question 1

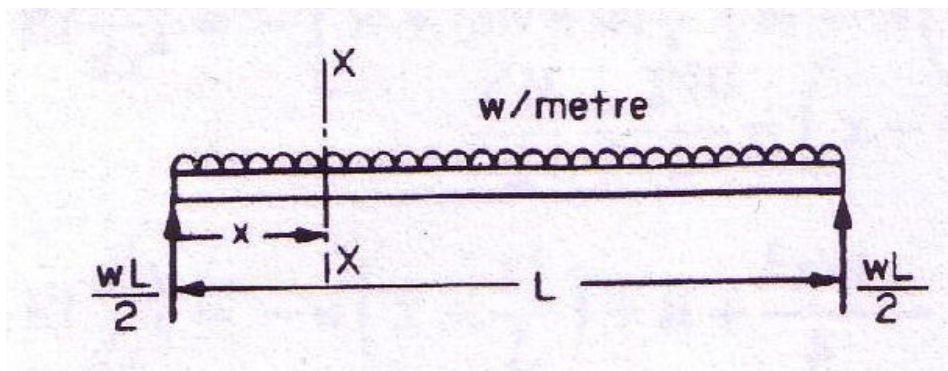
- a. The below figure shows a simply supported beam with a uniformly distributed load.

i. Prove that the maximum deflection, $y_{\max}$ is given by $y_{\max} = \frac{-5WL^4}{384EI}$

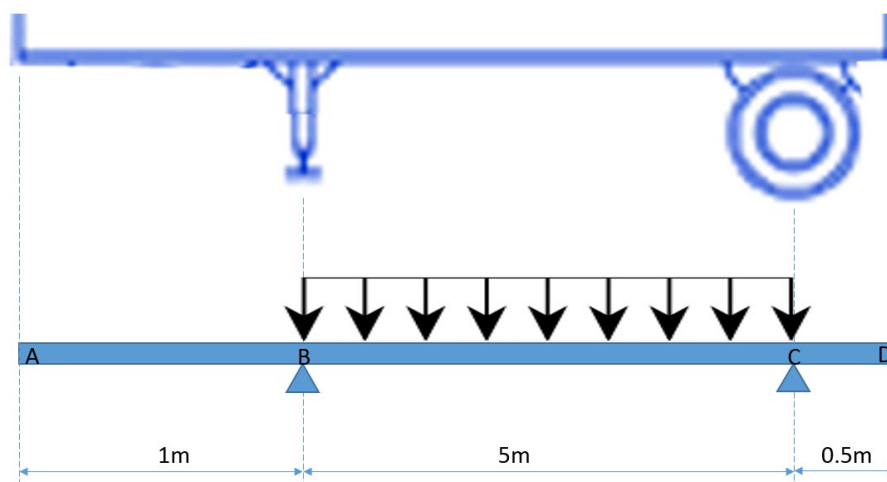
[8 Marks]

ii. Prove that the maximum slope is given by $\left(\frac{dy}{dx}\right)_{\max} = \pm \frac{WL^3}{24EI}$

[2 Marks]



b.



- i. The above figure shows a HGV trailer that may be considered to be a simply supported beam with the rear axle at location C and a supporting leg at position B. The hitch to the cab is located at position A and the rear of the trailer is at location D. In order to allow the hitch to attach to the cab it must not deform upwards by more than 10mm. As such, what flexural stiffness must the trailer supporting structure have to support a uniformly distributed weight of 5000kg between the supporting leg and the rear axle such that the trailer can still be coupled to the cab?

[5 Marks]

- ii. If the structural part of this trailer consists of an I beam that is loaded about the xx axis, using the table below, what would the mass of this I beam be if it was made from steel ($E=210\text{GPa}$) and it runs the length of the trailer?

[5 Marks]

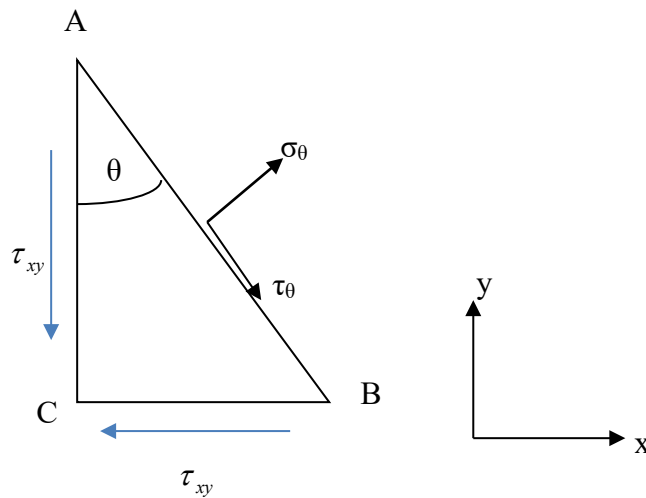
Size D x B (mm)	Mass per metre (kg)	Thickness		I_{xx} (cm^4)	I_{yy} (cm^4)
		Web, t (mm)	Flange, T (mm)		
910.3 x 304.1	222	15.9	23.9	375924	11223
840.7 x 292.4	194	14.7	21.7	279450	9069
762 x 266.7	173	14.3	21.6	205177	6846
677.9 x 253.0	125	11.7	16.2	118003	4379
617.5 x 307.0	113	14.1	23.6	151631	11412
533.1 x 209.3	92	10.2	15.6	55353	2392
467.4 x 192.8	98	11.4	19.6	45717	2343
457.2 x 151.9	67	9.1	15	28577	878
402.3 x 142.4	46	6.9	11.2	15647	539
364 x 173.2	67	9.1	15.7	19522	1362
352.8 x 126.0	39	6.5	10.7	10087	357
310.9 x 166.8	54	7.7	13.7	11710	1061
312.7 x 102.4	33	6.6	10.8	6487	193
254 x 101.6	22	5.8	6.8	2867	120
203.2 x 133.4	25	5.8	7.8	2356	310

Question 2

Design processes are adopted by industry to manage the design of a product so as to ensure the manufactured product is 'fit for purpose' and is successfully marketable. One such design process is formalised as British Standard BS7000 Part2 (2015).

- a. Briefly explain the core sequential phases adopted in most design processes, how these relate to one another, and the importance of an iterative approach when undertaking a design problem.
[6 marks]
- b. Discuss the advantages of using Computer Aided Engineering (CAE) tools within a design solution, particularly when considering a product that is to be manufactured.
[4 marks]
- c. One CAE tool readily adopted for numerical stress analysis is Finite Element Analysis (FEA). Explain, with the aid of a suitable sketch, how a linear spring is considered as the fundamental mechanical device to determine the stress field of a complex geometric shape.
[5 marks]
- d. Explain the general procedure undertaken to determine the stress field in an object when applying FEA, alluding to such terms as discretisation, field variables, governing equations and boundary conditions.
[5 marks]

Question 3



- a. The element shown above is subjected to shear stresses (τ_{xy}) only. Given that $\sin \theta \cos \theta = \frac{1}{2} \sin 2\theta$, prove that, for this complex stress system, the stress perpendicular to the inclined plane is given as;

$$\sigma_{\theta} = \tau_{xy} \sin 2\theta$$

[7 marks]

- b. For the element shown above, the angle θ is 30° and the shear stress τ_{xy} is -30 MPa. Determine the values of stress acting perpendicular and parallel to the inclined plane.

[4 marks]

- c. If the shearing stress described in section b was reversed in direction and a tensile stress of 40MPa was applied in the x direction at the same time, calculate the magnitude of the principal stresses and the direction of the planes on which they act.

[6 marks]

- d. Sketch a suitable diagram showing the complex stress system described in part (c), along with the principal stresses and the planes on which they act within the element.

[3 marks]

Question 4

- a. By means of a suitably labelled sketch, show that the longitudinal stress in a thin-walled cylinder is defined as:

$$\sigma_L = \frac{pd}{4t}$$

[6 marks]

- b. A mild steel cylinder with rigid end plates is 400 mm in diameter with a wall thickness of 1 mm. If the length of the cylinder is 800 mm and is subject to an internal pressure of 5 MN/m², determine the change in internal diameter and change in length. Young's Modulus for mild steel is given as 208 GN/m² and Poisson's ratio is 0.3.

[4 marks]

- c. The cylinder in part (b) above is pressurised by being filled with a liquid, and the internal volume is found to increase by $2.5 \times 10^{-6} \text{ m}^3$. Determine:

- (i) the values of circumferential and longitudinal stress, and

[6 marks]

- (ii) the changes to these values if joint efficiencies of 30 % (hoop) and 60 % (longitudinal) are assumed.

[4 marks]

Formula Sheet

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

$$\cos^2 \theta = \frac{1}{2}(1 + \cos 2\theta)$$

$$\sin^2 \theta = \frac{1}{2}(1 - \cos 2\theta)$$

$$\sigma_{\theta} = \frac{1}{2} (\sigma_x + \sigma_y) + \frac{1}{2} (\sigma_x - \sigma_y) \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\tau_{\theta} = \frac{1}{2} (\sigma_x - \sigma_y) \sin 2\theta - \tau_{xy} \cos 2\theta$$

$$\sigma_{1,2} = \frac{1}{2} \left[(\sigma_x + \sigma_y) \pm \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2} \right]$$

$$\tan \theta = \frac{\sigma_p - \sigma_x}{\tau_{xy}}$$

$$\sigma_L = \frac{pd}{4t}$$

$$\Delta L = \frac{pd}{4tE} (1 - 2\nu)L$$

$$\Delta V = \frac{pd}{4tE} (5 - 4\nu)V$$

$$\sigma_H = \frac{pd}{2t\eta_L}$$

$$\sigma_L = \frac{pd}{4t\eta_C}$$