City & Guilds

# 9210-102
# Level 6 Graduate Diploma in Engineering
## Mechanics of solids and basic structural analysis

**Sample Paper**

**You should have the following for this examination**
- one answer book
- drawing instruments
- non-programmable calculator

**No additional data is attached**

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**General instructions**
- This examination paper is of **three hours** duration.
- This examination paper consists of **nine** questions.
- Answer any **five** questions.
- All questions carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic non-programmable calculator may be used, but you **must** show clearly the steps prior to obtaining final numerical values.
- Drawings should be clear, in good proportion and in pencil. Do not use red ink.

1 a) A solid bar 4.2 m long and 40 mm in diameter was found to extend by 4.2 mm under a tensile load of 45 kN. Find the Elastic Modulus (E) of the bar. (7 marks)

b) This bar will be used as a strut with both ends pinned.

i) Determine the Euler's Crippling load for the bar. Given that the second moment of inertia for circular sections, $I = \pi D^4/64$ where D is the diameter. (9 marks)

ii) Hence calculate the safe load for the bar taking the factor of safety as 4. (4 marks)

2 A stepped steel shaft is shown in Figure Q2. This shaft is subjected to a torque T at the free end and a torque of 2T in the opposite direction at the junction of two sizes. The length and diameter of shaft AB are 1.5 m and 200 mm. The length and diameter of shaft BC are 2.5 m and 150 mm. The modulus of rigidity of the shaft material is 85 GN/m$^2$. Polar moment of inertia (Ip) = $\pi D^4/32$.

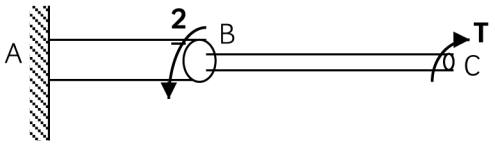


**Figure Q2**

a) Calculate the angle of twist of C relative to B in terms of T. (5 marks)

b) Calculate the angle of twist of B relative to A. (5 marks)

c) Hence write an expression to calculate the total angle of twist at C. (3 marks)

d) If the maximum allowable shear stress of shaft BC is 60 MN/m$^2$, then calculate the maximum permissible torque (T). [Hint: (Torque/Polar moment) = (Shear stress/Radius)]. (4 marks)

e) Hence find the total angle of twist at C. (3 marks)

3 A plane pin jointed truss given in Figure Q3 is subjected to a vertical load 'P' at joint C. The length of the horizontal members is **1.2 b** and the same for vertical members is **b**. The cross sectional area of horizontal members is **a** mm$^2$ and the other members is **2a** mm$^2$. The elastic modulus of material is **E**.

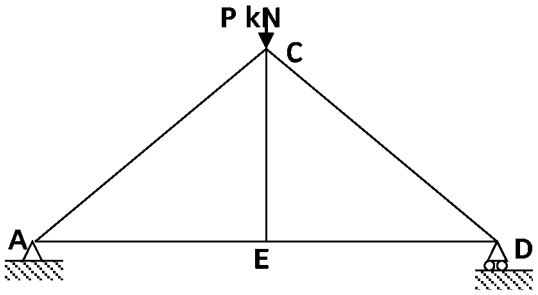


**Figure Q3**

a) Calculate the internal forces due to the externally applied load. (5 marks)

b) Using the theory of virtual energy, calculate the horizontal displacement at D. (15 marks)

4 Figure Q4 shows a schematic diagram of a beam.

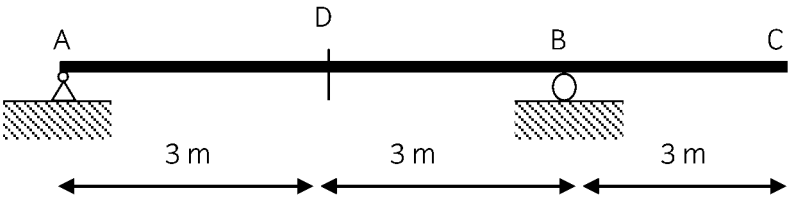


**Figure Q4**

a) Construct the influence line for reaction at support A. (5 marks)
b) Construct the influence line for shear at section D. (5 marks)
c) Construct the influence line for bending moment at D. (5 marks)
d) Construct the influence line for shear after support B, in the region BC. (5 marks)

5 The beam AB is simply supported at A and B and has a span of 7 m. It is loaded with a uniformly distributed load of 20 kN/m over a 4 m length and a concentrated load of 10-kN as shown in Figure Q5.

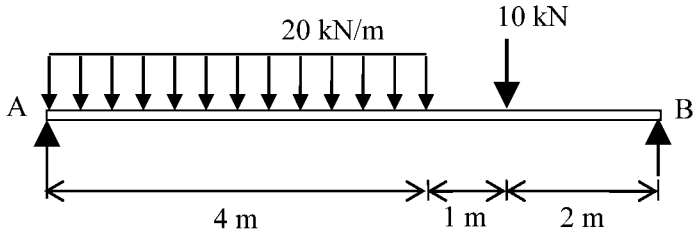


**Figure Q5**

a) Determine support reactions. (4 marks)
b) Draw the shear force diagram and the bending moment diagram for the loaded beam shown in Figure Q5 indicating all values at key points.
(Show relevant calculations) (14 marks)
c) Do any points of contra flexure (inflexion) exist in this loaded beam? (Yes/No)
If your answer is 'Yes', indicate the locations of the points of contra flexure. (2 marks)



See next page

6 The cross-sectional dimensions of an I- beam which is made from three timber boards glued together is shown in Figure Q6. This beam is 6 m long, simply supported at the ends and loaded with a concentrated load of 16 kN at a distance 4 m from the left end support.

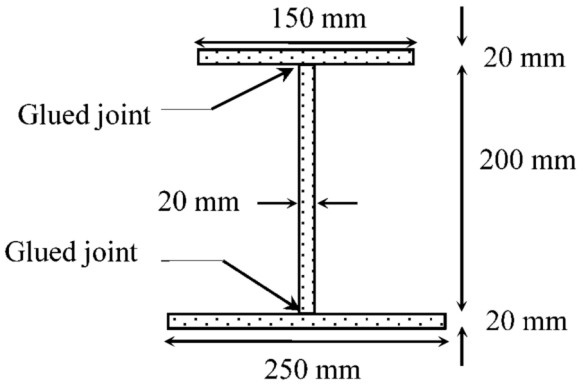


**Figure Q6**

a) What is the absolute maximum shear force in the beam due to the applied 16 kN load? (3 marks)

b) Determine the position of the neutral axis of the beam. (3 marks)

c) Determine the second moment of area of the cross-section about the neutral axis. (4 marks)

d) Determine the maximum shear stress developed in the glued joints. (10 marks)

7 Figure Q7(a) shows a loaded cantilever beam of length L and flexural rigidity EI.

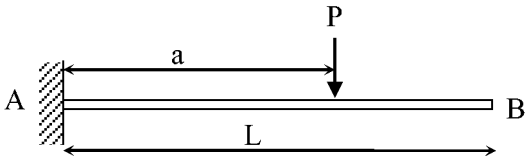


**Figure Q7(a)**

a) Prove that the maximum deflection in the beam, ($\delta$) is, (8 marks)

$$\delta = \frac{Pa^2(3L-a)}{6EI}$$

b) Determine the reaction of the prop, if this loaded beam is propped at the free end as shown in Figure Q7(b). (12 marks)

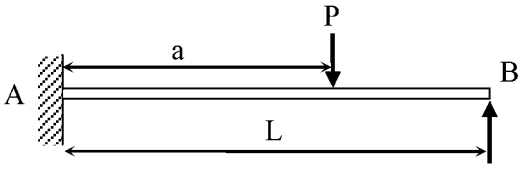


**Figure Q7(b)**

8 Figure Q8 shows a 3 mm thick steel plate, which is under a plane stress system. Assuming the modulus of elasticity of steel as $2 \times 10^5$ N/ mm$^2$ and Poisson's ratio as 0.3,

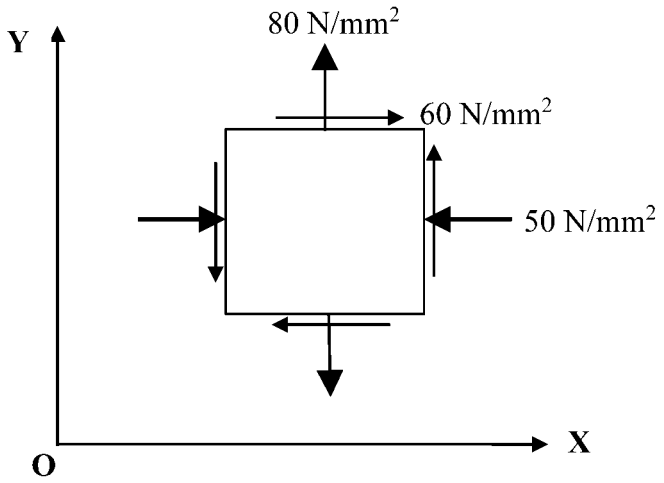


**Figure Q8**

a) Construct the Mohr's circle of stress for the above plane stress system indicating all important points.
(The sign convention to be used is :- Normal tensile stresses : positive Shear stresses which form clockwise moments: positive) (5 marks)

b) Determine the major and minor principal stresses and their directions. (6 marks)

c) If a strain gauge is to be fixed to record the maximum tensile strain, in which direction should it be fixed? (3 marks)

d) Determine the thickness of the plate when it is subjected to the above plane stress system. (6 marks)

9 The overhanging beam (see Figure Q9(a)) is subjected to a uniformly distributed load over the entire length of the beam. The sectional properties and dimensions of the beam are given in Figure Q9(b). For the beam material, If the allowable bending stresses in tension and compression are 30 N/mm$^2$ and 70 N/mm$^2$ respectively, determine the maximum uniformly distributed load that can be applied on this beam. (20 marks)

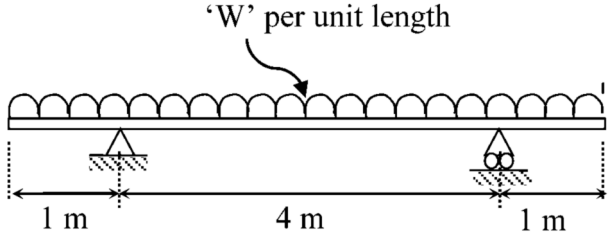


**Figure Q9(a)**

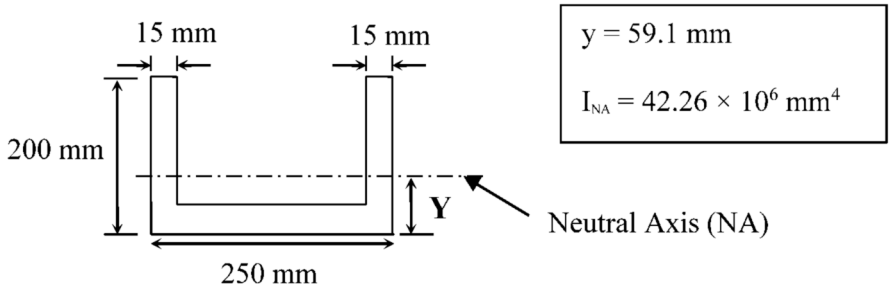


**Figure Q9(b)**