The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, AUTUMN SEMESTER 2016-2017

MECHANICS OF SOLIDS 2

Time allowed TWO Hours

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced

Answer FOUR questions

Only silent, self-contained calculators with a Single-Line Display or Dual-Line Display are permitted in the examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn examination paper over until instructed to do so

In this examination candidates are required to answer FOUR out of SIX questions. If a candidate answers more than the required number of questions, all questions will be marked and the highest marks will be used in the final examination mark.

ADDITIONAL MATERIAL: Formula Sheet
Graph Paper

INFORMATION FOR INVIGILATORS:

Question papers should be collected in at the end of the exam – do not allow candidates to take copies from the exam room.

1. An angled bar of diameter 4mm, fixed at the wall as shown in Figure Q1, is subjected to a load *P* of magnitude 10 N. The length between Point A and B is L_{AB} = 100 mm, while the length between Point B and C is L_{BC} = 150 mm.

   (a) Determine the state of stress on a plane stress element located at position A, include a sketch.

   [11]

   (b) Determine the magnitude of the in-plane principal stresses and maximum shear stress for this case at point A, include a sketch of Mohr's Circle on the graph paper provided.

   [14]

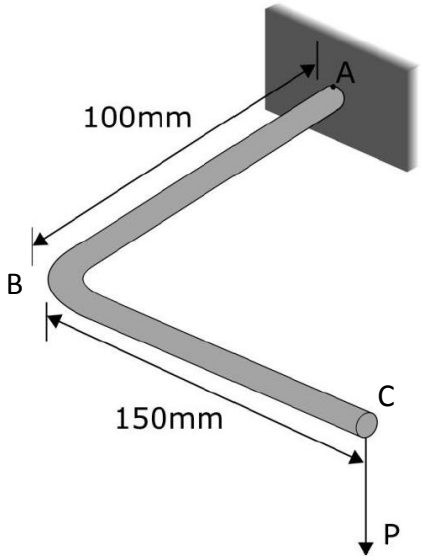

Figure Q1

2. A rigid mechanical component as shown in Figure Q2 is hinged at point A and held by two cables, BE and CF, point D is horizontally connected by another cable to a load, *W*, downward through a pulley P.

Cable BE has a diameter of 12 mm, while CF is 20 mm.
The ultimate tensile loads of the cables BE and CF are 102 kN and 231 kN respectively.

The modulus of elasticity of the cables *E*, is 140 GPa, and the coefficient of thermal expansion *α*, is 12 x 10^{-6} /°C.

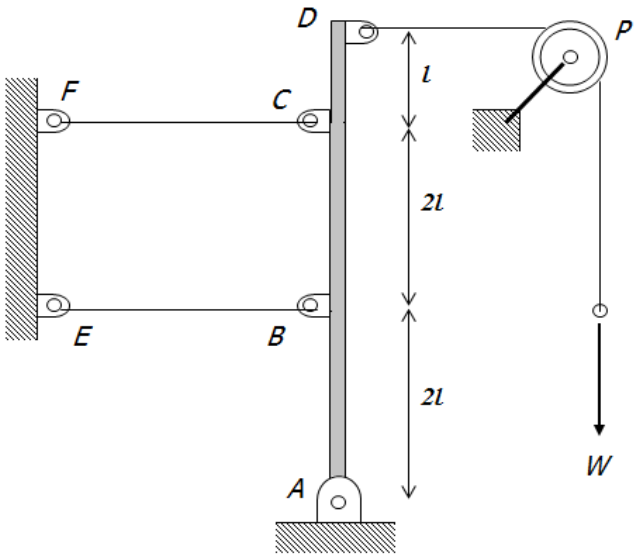

Figure Q2

(a) The system is in equilibrium, calculate the reactions on the wall at points E and F in terms of *W*.

[10]

(b) If the temperature is increased by 60°C, determine the reactions on the wall at E and F in terms of *W*.

[10]

(c) If each cable is required to have a safety factor of 5 against tensile failure, determine the maximum allowable load *W*.

[5]

Turn over

3. The cross-section of a straight I-section beam is shown in Figure Q3. It is loaded in pure bending about the Y-Y axis until the full thickness of each flange and 5 mm into each end of the web has yielded. The material can be assumed to be elastic-perfectly-plastic with a yield stress of 245 MPa and a Young's modulus of 205 GPa.

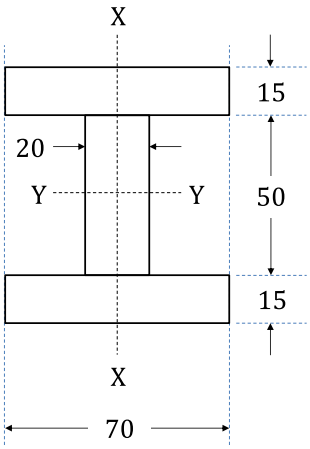

Figure Q3

(a) Determine the bending moment required and the radius of curvature of the beam when the bending moment is applied.

[13]

(b) Sketch the residual stress state in the beam and determine the residual radius of curvature of when the bending moment is removed.

[12]

4. (a) With the aid of suitable diagrams, explain the development of a fatigue crack from initiation in an un-cracked component with smooth surfaces, to complete failure.

[10]

(b) Sketch a typical S-N curve for a generic material. Annotate the sketch with details of the main features.

[5]

(c) A component is made from a material with an ultimate tensile strength of 300MPa. The component will be cyclically loaded such that the mean stress is 65MPa. Using a modified Goodman line, determine the maximum allowable stress amplitude if a safety factor of 1.1 is required. Assume an endurance limit for the material of 100MPa and a fatigue notch strength reduction factor of 1.75 for the component.

[10]

5. The pin-jointed framework ABC is subjected to an external load as shown in Figure Q5. If each member has a length of 800 mm, a cross-section of 20 x 20 mm^2 and are made of steel with a value of Young's modulus of 200 GPa:

(a) Construct the stiffness matrix of the structure.

[12]

If the applied load, *F*, is 25 kN:

(b) Determine the horizontal and vertical reaction forces at points A and C.

[13]

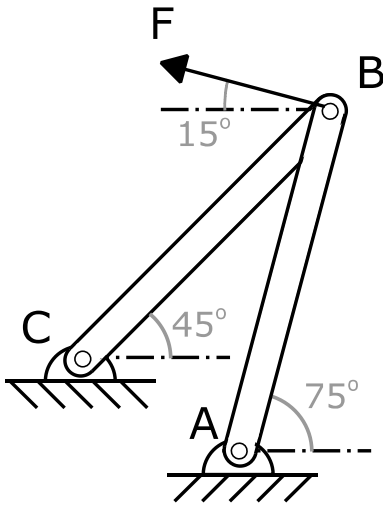

Figure Q5

6.

(a) With the aid of suitable diagrams, describe the typical failure of brittle and ductile materials under torsional loading.

[6]

(b) Sketch and annotate the yield loci for Tresca and von Mises for a two-dimensional stress state.

[3]

(c) Sketch and annotate the yield surfaces for Tresca and von Mises for a three-dimensional stress state.

[3]

(d) Explain the decomposition of the principal stress state in three-dimensions into hydrostatic and deviatoric components.

[3]

(e) A shaft, of 40mm diameter, is to be made from a material with a uniaxial yield stress of 800 MPa. A torque, T, of 2 kNm is applied to the shaft. Assuming a safety factor of 2, determine the maximum bending moment, M, that can be applied to the shaft to avoid yield considering both the Tresca and von Mises yield criteria.

[10]

END