FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF METALLURGICAL ENGINEERING

SOLID MECHANICS

EMR 2202

Final Examination Paper

JUNE 2019

This examination paper consists of 5 pages

Time Allowed: 3 hours

Total Marks: 100

Examiner's Name: Mr. Quinton Dean Chingoka

INSTRUCTIONS

1. Answer ANY **FOUR QUESTIONS**
2. Each question carries 25 marks
3. Use of calculators is permissible

Additional Requirements

List of formulae

MARK ALLOCATION

Question 1 to 6	**25 Marks**
Part Questions	**As shown in each part question**
Total Attainable	**100**

Question 1

A slender rod of initial length 2cmis extended(uniformly) to a length 4cm. It is then compressed to a length of 3cm.

a) i) Calculate the engineering strain and true strain for extension. (4 marks)

ii) Calculate the engineering strain and true strain for compression. (4 marks)

iii) Calculate the engineering strain and true strain for one step, i.e. extension from 2cm to 3cm. (4 marks)

iv) from the above calculations (i, ii, iii), which of the strain measures is additive? (1mark)

b) Consider a material in plane stress conditions. An element at a free surface of this material shown on diagram below the left. Taking the coordinate axes to be orthogonal to the surface as shown (so that the tangential stress is σ_{xx} one has);

$$\left[\sigma_{xx}\ \sigma_{xy}\ \sigma_{yx}\ \sigma_{yy}\right] = \left[\sigma_{xx}\ 0\ 0\ 0\right]$$

i) What are the two principal in-plane stresses at the point? Show the maximum and minimum. (8 marks)

ii) What are the shear stresses acting on these planes and how are they related to maximum shear stress.
(4 marks)

Question 2

The stresses at a point are given as;

$\boldsymbol{\sigma_x}$=-10MPa ; $\boldsymbol{\sigma_y}$=30MPa; $\boldsymbol{\sigma_z}$=50MPa

$\boldsymbol{\tau_{xy}}$=60MPa; $\boldsymbol{\tau_{yz}}$=20MPa; $\boldsymbol{\tau_{zx}}$= -10MPa

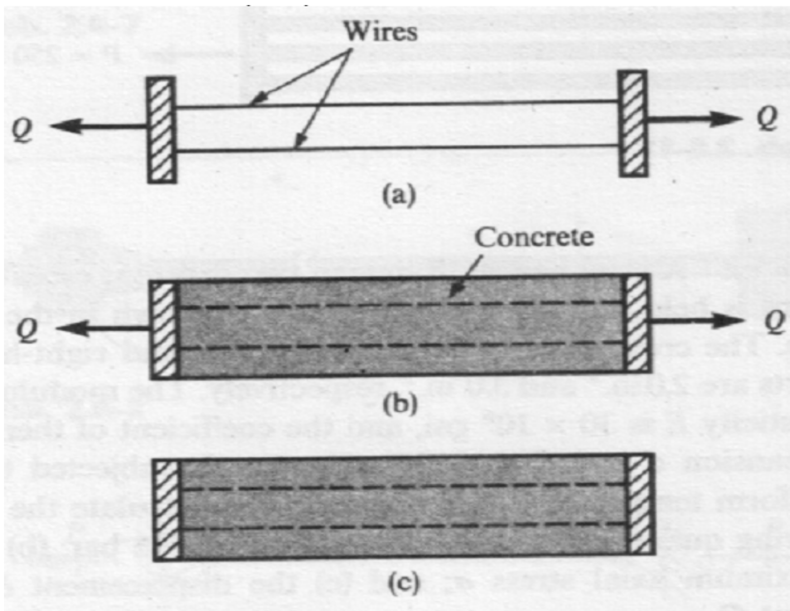
a) Determine the principal stresses. (10 marks)

b) Using Mohr's Circle, determine the normal and shearing stress on a plane normal to a line inclined 30^{o} clockwise from the major principal axis. (15 marks)

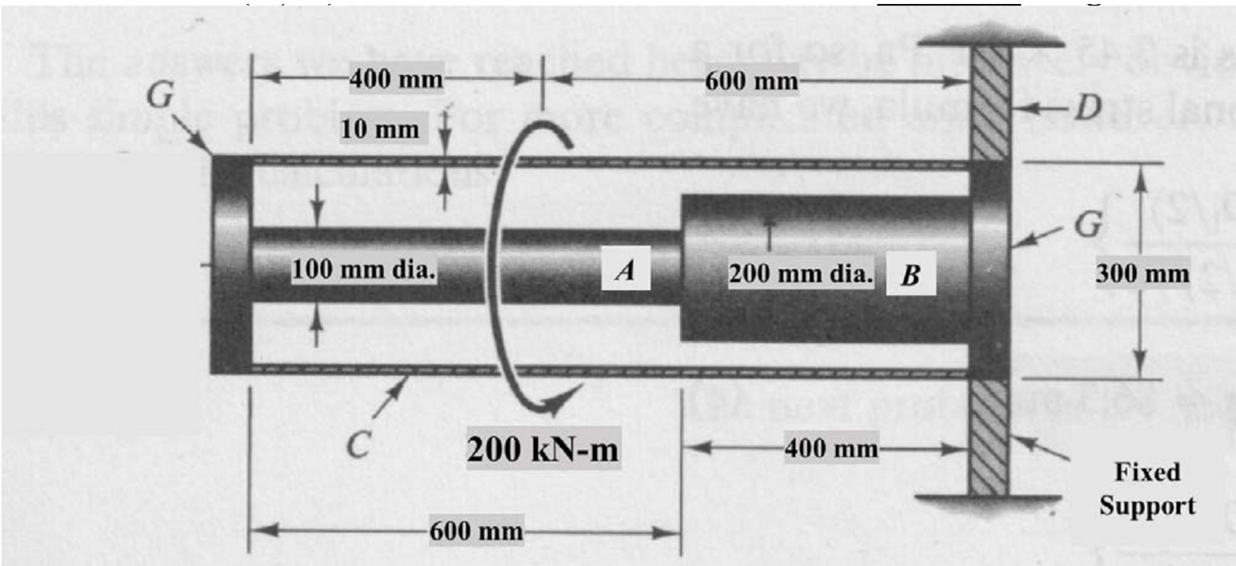
Question 3

High strength steel wires are stretched by applying a force **Q** which produces an initial stress σ_o = 820 MPa as shown in Fig. (a). Concrete is then poured around the stretched wires to form a beam as shown in Fig. (b). After the concrete sets properly, the force **Q** is removed as shown in Fig. (c). Thus, the beam is left in a pre-stressed condition with the wires in tension and concrete in compression. The moduli of elasticity of steel and concrete are in the ratio of 8:1. The areas of concrete and steel are in the ratio 30:1.

a) Calculate the final stresses in steel ($\boldsymbol{\sigma_s}$) and concrete ($\boldsymbol{\sigma_c}$). (10 marks)

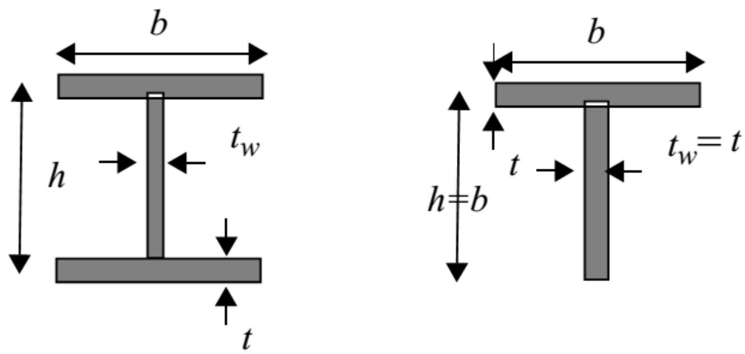


b) A system of two concentric torsion members connected at their ends by rigid disks G is shown in Fig. below. The outside member **G** is a tube with outside diameter 300mm and thickness 10mm.The inside member consists of solid shafts **A** of diameter 100mm and **B** of diameter 200mm. Shafts **A** and **B** and tube **C** are made of the same material having shear modulus 100 GPa. At the right end the rigid disk is fixed in support **D**. A torque of 200 KNm is applied to the outside tube as shown in Fig. below. Determine the maximum shear stress in tube **C** ($\boldsymbol{\tau_c}$ max) and the rotation of the left end rigid disk (**ϕG**). (15 marks)



Question 4

$$I \sim 2\,(h/2)^2(bt)$$



For a beam with a T section as shown above:

i) Locate the centroid of the section. (5 marks)

ii) Construct an expression for the moment of inertia about the centroid. (5 marks)

iii) Locate where the maximum tensile stress occurs and express its magnitude in terms of the bending moment and the geometry of the section. Do the same for the maximum compressive stress. In this assume the bending moment puts the top of the beam in compression. (10 marks)

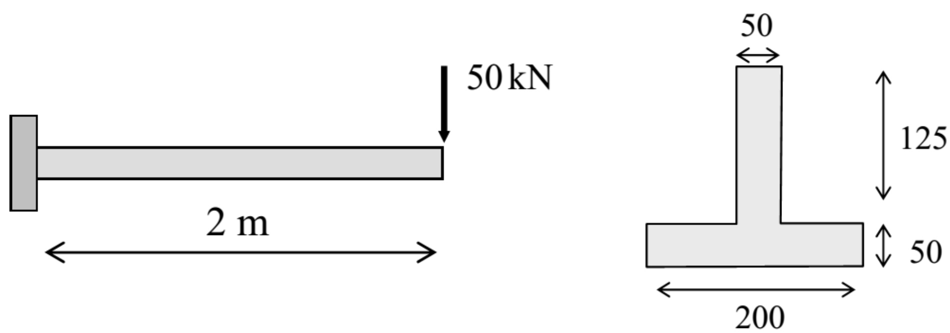
iv) If you take b equal to the h of the I beam, so that the cross-sectional areas are about the same, compare the maximum tensile and compressive stresses within the two sections. (5marks)

Question 5

Consider the cantilever beam shown below. Determine the maximum shearing stress and determine the maximum shearing stress 25mm from the top of the beam adjacent to the wall. The cross section of the "T" shape shown, for which;

$$I = 4x10^{6} mm^{4}$$

Use shear force formula derived for a rectangular bar, *b* is the thickness of the beam at the point where the shear force is being evaluated. (25 marks)



Question 6

a) State and explain using relevant equations, the three failure theories. (15 marks)

b) Using a graphical diagram show how the three theories are correlated. (10 marks)