The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX5302/DMX5532 Strength of Materials II**
Academic Year	: 2020/21
Date	:07 January 2022
Time	: 2.00 pm – 5.00 pm
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **six (6)** questions.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. This is a Closed Book Test (CBT).
5. Answers should be in clear handwriting.

Q1 (a) Write down the general equations for radial and hoop stresses for thick cylinders. (2 marks)

(b) Figure Q1 below shows variation of radial and hoop stresses of a thick cylinder as a function of $1/r^2$ (r is the radius at the stress point) when the cylinder is subjected to an internal pressure, P_i.

Radii of the cylinder are 0.05m and 0.1 m.

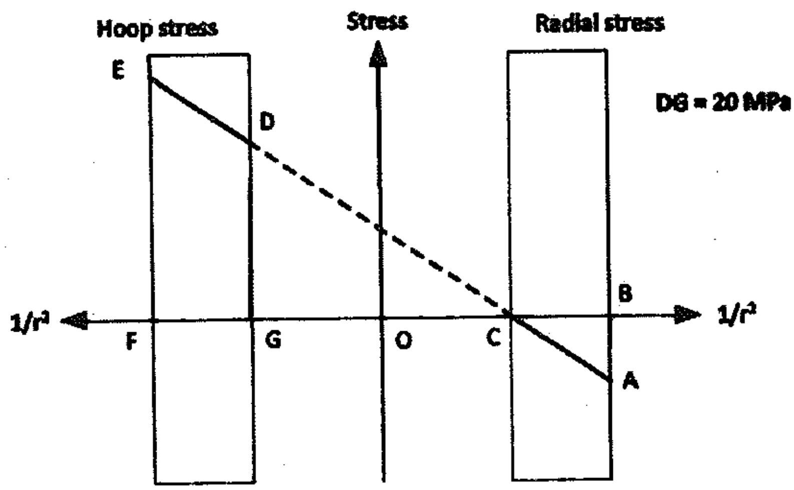

Figure Q1

Find the following

(i) Value of the applied internal pressure (4 marks)

(ii) Maximum stress in the cylinder (4 marks)

(iii) longitudinal stress if the cylinder has closed ends (5 marks)

(iv) Value of pressure applied on the external surface that will make the hoop stress at the inner surface zero. (5 marks)

Q2 (a) A compound cylinder has been made up of the same material, with inner and outer radii 0.15 m and 0.3 m respectively. The intermediate radius is 0.225 m. Total interference at the interface is 0.3 mm. Modulus of Elasticity of the material is 150 GPa. (6 marks)

Find the interface pressure.

You may use the following equation with usual notation.

$$\delta_{total} = \frac{r}{E}(\sigma_{H/o} - \sigma_{H/i})$$

(b) The compound cylinder in (a) is subjected to an internal pressure **p** such that additional hoop stress induced on the inner surface of the outer cylinder, due to applied internal pressure **p**, is equal to half of the already existing stress. (7 marks)

Sketch radial stress and hoop stress against $1/r^2$ before and after the pressure is applied on the same coordinate system.

Hint: Consider the compound cylinder as a single cylinder when internal pressure is applied.

(c) Find the following with aid of the graphical sketch of stresses in (b). (7marks)

(i) Applied internal pressure

(ii) New interface pressure of the compound cylinder

Q3 (a) A steel tube with the cross section shown in Figure Q3-a carries a torque T. The tube is 1.5 m long and has a constant wall thickness of 8 mm.

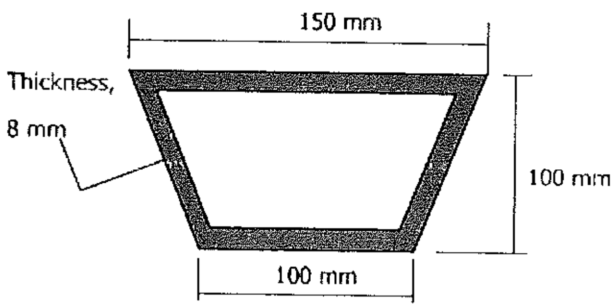

Figure Q3-a

Find the following, neglecting stress concentrations at corners.

(i) Torsional stiffness k = T/θ of the tube (5marks)

(ii) Shear stress in the wall of the tube, if the tube is twisted through 0.5 deg. (5marks)

Use modulus of rigidity for steel as 75 GPa.

You may use the following equations with usual notation applicable for thin-walled tubes in torsion.

$$\tau = \frac{T}{2At} \qquad \theta = \frac{TL}{4GA^2}\frac{z}{t}$$

(b) An aluminum tube, 1 m long, has the semicircular cross section shown in Figure Q3-b.

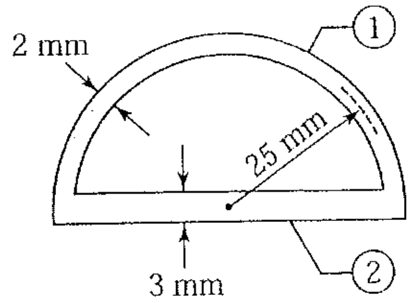

Figure Q3-b

Find the following.

(i) Torque that causes a maximum shear stress of 60MPa (5 marks)

(ii) Corresponding angle of twist of the tube if the value of modulus of rigidity is 28 GPa. (5 marks)

Q4 (a) What is meant by the Shape Factor in bending of beams causing stresses beyond the elastic limit? (2 marks)

(b) Determine the yield moment, the plastic moment, and the Shape Factor for a rectangular section beam of breadth **b** and depth **d**. (3 marks)

(c) A cantilever beam having square cross section carries a uniformly distributed load of **w**/m. The length of the beam is 2 m. The elastic limit of the beam material is 400 MPa.

Calculate the following

(i) Beam cross sectional dimensions, if w = 5 kN/m and the bending stress reaches the elastic limit. (5 marks)

(ii) Value of w when the plastic hinge is created at the point of maximum bending moment with the beam sectional dimensions found in (i) above. (5 marks)

(iii) Distance from the free end of the cantilever to the point where plastic yielding has taken place to a half depth on either side to the neutral axis. (5 marks)

Q5 (a) I - section beam is subjected to a force P as shown in Figure Q5(a).

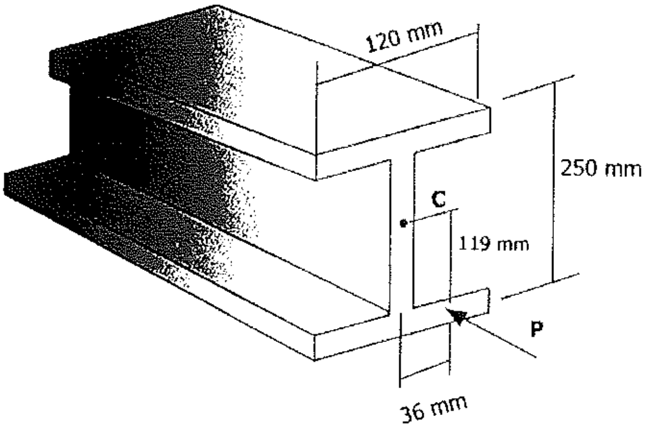

Figure Q5(a)

Find the value of P, not to exceed the compressive stress induced in the beam section 80 MPa. (10 marks)

The following information is given for the beam section with usual notation.

$$I_{xx} = 5.2 \, x \, 10^{-5} \, m^4$$

$$I_{yy} = 2.8 \, x \, 10^{-6} \, m^4$$

$$A = 4.8x \, 10^{-3} \, m^2$$

(b) A cantilever beam having a square section carries a concentrated load of 5 kN at its free end as shown in Figure Q5(b). The load is at 30° to the vertical principal axis and its line of action passes through the centroid.

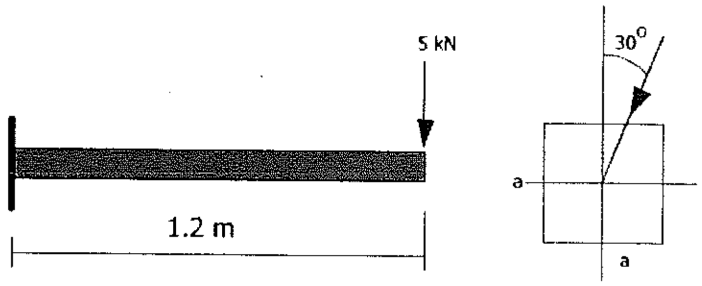

Figure Q5(b)

Find the dimension of the square section if the maximum tensile stress in the beam is 200 MPa. (10 marks)

Answer Q6(A) **OR** Q6(B)

Q6 (A) An electric motor dives a shaft that runs two belt drives. The torques to be overcome by the motor are shown in the Figure Q6a. The Modulus of Rigidity of the shaft material is 27 GPa.

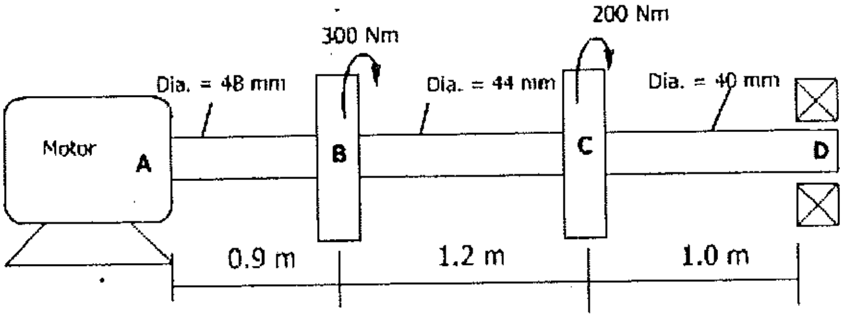

Figure Q6a

Find the following

(a) Torque on shafts AB, BC, and CD (6 marks)

(b) Maximum shear stresses for all shaft sections (6 marks)

(c) Angle of twist at B (8 marks)

Q6(B) (a) Derive an expression for the coordinate transformation matrix for Xi = (X1, X2, X3) to Xi'= (X1', X2', X3') coordinate system (see Figure Q6b). (6 marks)

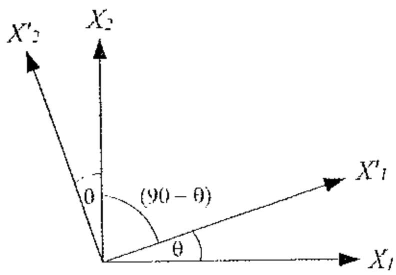

Figure Q6b

(b) The stress at a point is given by the following matrix.

$$\sigma = \begin{bmatrix} 3 & 1 & 4 \\ 1 & 2 & -5 \\ 4 & -5 & 0 \end{bmatrix} \text{MPa}$$

Determine the stresses with respect to the X'I = (X'1, X'2, X'3) coordinate system, if the transformation matrix is given as below. (6 marks)

$$[T] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{2} & \frac{\sqrt{3}}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{1}{2} \end{bmatrix}$$

(c) The stress at a point in a machine component is given by the following stress tensor. (8 marks)

$$\sigma = \begin{bmatrix} 12 & 5 & 0 \\ 5 & 8 & 0 \\ 0 & 0 & 10 \end{bmatrix} \text{MPa}$$

Calculate the following.

(i) First invariant of this stress tensor

(ii) Principal stresses associated with this stress tensor