MACHAKOS UNIVERSITY

University Examinations for 2020/2021 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 302: SOLID AND STRUCTURAL MECHANICS 1

DATE: 12/8/2021 **TIME: 8.30-10.30 AM**

INSTRUCTIONS

Answer question ONE and any other two questions.

QUESTIONS ONE (COMPULSORY) (30 MARKS)

a) What is the prime objective of "mechanics of deformable bodies"? (1 mark)

b) Distinguish between the following loads; (2 marks)

i. Dead

ii. Live

iii. Impact

iv. Shock

c) A shear stress across a plane is always accompanied by a balancing shear stress across the plane normal to it. Provide a proof to this principle of shear stress (5 marks)

d) A hollow circular cylinder 20 mm thick is to support an axial compressive load of 500 kN. The compressive yield stress of the cylinder material is not to exceed 270 MPa. If a factor of safety of 2 is preferred, what is the minimum outside diameter according to Maximum Principal Strain Theory? (3 marks)

e) For design purposes, describe how you would determine the yield stress of a material like aluminium that lacks a clearly defined yield point. (3 marks)

f) A rod of 12 mm diameter was tested for tensile strength with a gauge length of 60 mm. The following observations were recorded: Final length = 80 mm; final diameter 9 mm; Yield load = 3.4 kN and fracture load = 6.1 kN.

i. Determine true strain at fracture (2 marks)

ii. Calculate true stress at fracture (2 marks)

iii. Determine whether the rod is ductile or brittle (2 marks)

g) Fig. Q1 g) shows a plane-stress condition at a point on the surface of a loaded shaft.

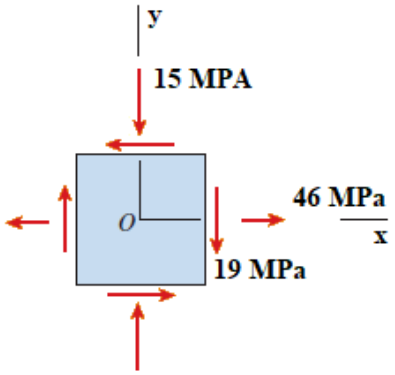

Fig. Q1 g)

Determine the stresses acting on an element that is oriented at a clockwise angle of 15° with respect to the original element. (3 marks)

h) A brass bar, having cross-sectional area of 450 mm^2 is subjected to axial forces as shown in Fig. Q1 h).

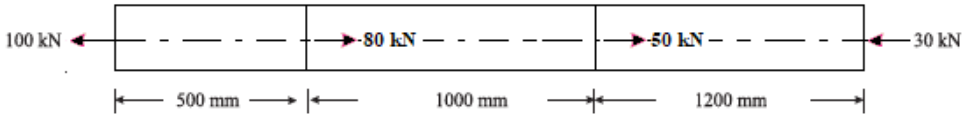

Fig. Q1 h)

Find the total elongation of the bar. Take E as 100 GPa (3 marks)

i) Aluminium alloy bar, fixed at its ends is heated through 15 K. Find the stress developed in the bar. Take Modulus of elasticity and coefficient of linear expansion for the bar material as 80 GPa and 24 x 10^{-6}/K. (2 marks)

j) Differentiate between thick wall and thin wall pressure vessels (2 marks)

QUESTION TWO (20 MARKS)

a) Starting from the transformation equations for plane stress state, show that the principal stresses for that state of stress are given by;

$$\sigma_{1,}\sigma_2 = \frac{\sigma_x+\sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + {\tau_{xy}}^2} \qquad \text{(10 marks)}$$

b) At a point on the surface of a generator shaft the stresses are σ_x, σ_y and τ_{xy} are as shown Fig Q2 b).

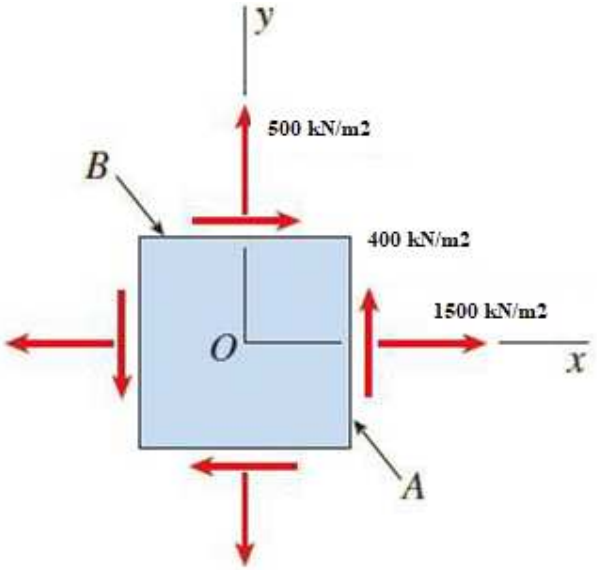

Fig Q2 b)

Draw a Mohr's circle and use it to determine the following quantities: (3 marks)

i. The principal stresses and principal angles (2 marks)

ii. The maximum shear stresses and angles of maximum shear stresses (2 marks)

iii. The stresses acting on an element inclined at an angle $\theta = 45^0$ and sketch its property-oriented element (2 marks)

Consider only the in-plane stresses.

QUESTION THREE (20 MARKS)

a) Starting from first principles and defining the symbols used, show that the elastic equation of torsion is given by;

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{R} \qquad \text{(10 marks)}$$

b) A composite shaft consists of a steel rod 60 mm diameter surrounded by a closely fitting tube of brass. A torque of 10 kN-m applied on the composite shaft is supposed to be shared equally by the two materials.

Determine;

i. The outside diameter of the brass tube (3 marks)

ii. The common angle of twist in a length of 4 m (2 marks)

iii. The strain energy stored in the shaft (1 mark)

iv. Shear stress at the surface of the shaft (1 mark)

Take G for steel to be 84 GPa and for brass 42 GPa

c) A circular bar rigidly fixed at its both ends uniformly tapers from 100 mm at one end to 70 mm at the other end and designed to operate at 25^0C. The bar is fabricated from a material whose yielding stress is 110 MPa. Can this bar be functional at a temperature of 55^0C? Take E as 200 GPa and α as 12 x 10^{-6}/K for the bar material. (3 marks)

QUESTION FOUR (20 MARKS)

a) i. Consider a closely-coiled helical spring subjected to an axial load as shown in Fig. Q4 a

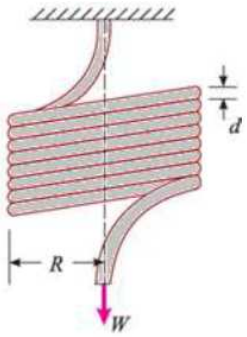

Fig. Q4 a)

Show that the deflection of the spring due to the axial load W is given by;

$$\delta = \frac{8WC^3n}{Gd}$$

Where

C = spring index (D/d)

D = Mean diameter of the spring;

d = diameter of the spring wire;

n = number of active coils;

G = modulus of rigidity of spring material (5 marks)

ii A closely-coiled helical spring with a spring index of 8 and diameter 80 mm has 10 coils. If the spring is subjected to an axial twist of 10 kN-mm, determine the bending stress and the increase in the number of turns. Take E as 200 GPa. (3 marks)

b) An inclined truss is loaded as shown in Fig. Q4 b). Determine the nature and magnitude of forces in all the members except members DE, FD and FE. Hence draw the force diagram (12 marks)

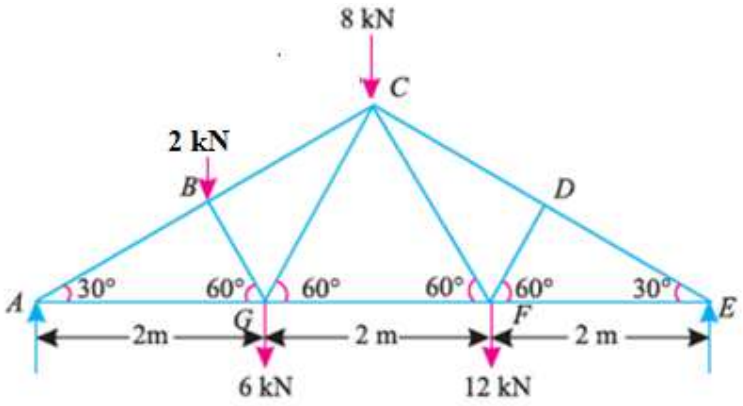

Fig. Q 4b)

QUESTION FIVE (20 MARKS)

a) A thin-walled pressure vessel fabricated from a blank of thickness t and length l has an outside dimeter d. If the vessel is subjected to internal pressure p, show that;

Change in length $\delta l = \frac{pdl}{2tE}\left(\frac{1}{2} - \nu\right)$ and

Change in diameter $\delta d = \frac{pd^2}{2tE}\left(1 - \frac{\nu}{2}\right)$ (8 marks)

b) A thin-walled cylindrical vessel is fabricated from steel plating that has a thickness of 20 mm as shown in Fig. Q5 b).

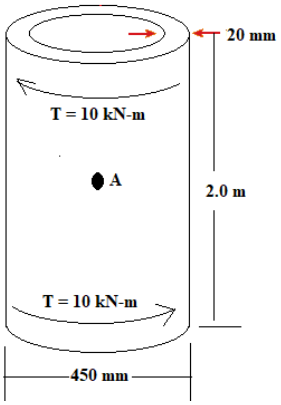

Fig. Q5 b)

The diameter of the pressure vessel is 450 mm and its length is 2.0 m. The vessel is pressurized internally to p MPa and subjected to an external torque of 10 kN-m. If the Yield stress and Poisson ratio of steel are 250 MPa and 0.25 respectively, determine the maximum pressure P that will just avoid failure according to Maximum Strain Energy Theory at point A on the surface. (12 marks)