INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester Examination 2019-20

Date of examination: Sep. 20, 2019   Session: AN   Duration: 2 hrs   Full Marks: 60
Subject No.: ME31013   Subject: Mechanics of Solids
Department: Mechanical Engineering
Specific charts, graph paper, log book, etc. required: NO
Special Instructions (if any): Answer all parts of a question together.

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1. A delta strain rosette consists of three strain gauges placed as shown in Figure 1. The arm a is along the positive x axis. The strain gauge readings are $\epsilon_a = 2450 \times 10^{-6}$, $\epsilon_b = 1360 \times 10^{-6}$, and $\epsilon_c = -1310 \times 10^{-6}$.

    (a) Determine the state of strain, i.e. find the strain components ϵ_{xx}, ϵ_{yy}, and ϵ_{xy}.

    (b) What is the change in the angle from the initial angle of 60° between the arms a and b?

    $[6 + 4 = 10$ marks$]$

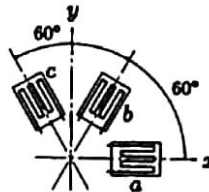

Figure 1

2. The cantilever beam shown in Figure 2 is subjected to a moment, M, applied at the free end. Using the standard strength of materials stress formulations, i.e. using the stress components: $\sigma_{xx} = -My/I$, $\sigma_{yy} = 0$, $\sigma_{xy} = 0$ (with I being the second moment of area), determine the displacement fields, $u(x,y)$ and $v(x,y)$. $[10$ marks$]$
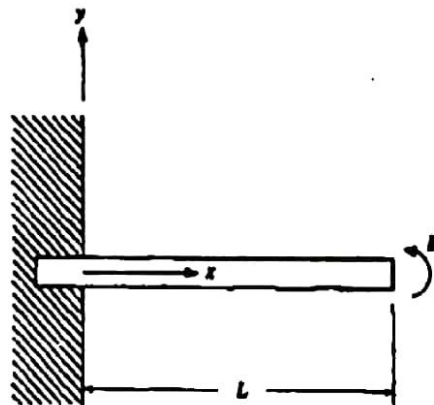

Figure 2

1

3. The state of stress at a particular point relative to xyz coordinate system is given by the stress matrix

$$[\sigma] = \begin{bmatrix} 14 & 7 & -7 \\ 7 & 10 & 0 \\ -7 & 0 & 35 \end{bmatrix} \text{ MPa.}$$

Determine the normal stress and the magnitude and direction of the shear stress on a surface passing through the point and parallel to the plane given by the equation $2x - y + 3z = 9$. **[10 marks]**

4. For the stress matrix given below, determine the principal stresses and the direction cosines associated with the normal to the surfaces of the maximum principal stress. **[10 marks]**

$$[\sigma] = \begin{bmatrix} 3 & 1 & 1 \\ 1 & 0 & 2 \\ 1 & 2 & 0 \end{bmatrix} \text{ MPa}$$

5. The cantilever beam shown in Figure 3 is subjected to a distributed shear stress $\tau_0 x/L$ on the upper face. The beam has length L, height $2h$, and unit depth into the plane of the paper.
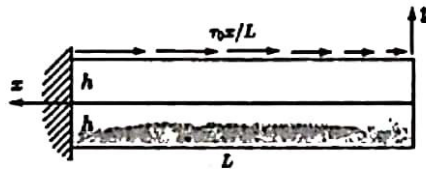

Figure 3

The following Airy stress function is given

$$\phi = C_1 y^2 + C_2 y^3 + C_3 y^4 + C_4 y^5 + C_5 x^2 + C_6 x^2 y + C_7 x^2 y^2 + C_8 x^2 y^3.$$

(c) What conditions must be met so that the biharmonic equation is satisfied?

(b) Write all the boundary conditions. (*Hint:* Use integrated boundary conditions on the vertical faces.)

(c) Determine the constants and hence the stresses in the beam.

[2 + 8 + 10 = 20 marks]

———————— END OF QUESTION PAPER ————————