Name..Student I.D...............................

Department of Mining and Materials Engineering

Faculty of Engineering

Prince of Songkla University

Mid-Term Exam for Semester: 2 Academic Year: 2014

Date: March 19, 2015 Time: 09.00-12.00

Subject: 237-320 Mechanical Behavior of Materials Room: A203

Instruction

1. There are 4 problem sets. Please do all of them. Write your answers in the space provided. If you need more space, you can write on the back of paper.
2. Text books, course notes and other studying materials are not allowed.
3. Dictionary, calculator, and stationery are allowed.
4. This mid-term exam is accounted for 25% of the total grade.

Asst. Prof. Dr. Thawatchai Plookphol

Problem No.	Full Score	Student's Score
1.	40	
2.	15	
3.	20	
4.	25	
Total	100	

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1 A 3-D state of stress is given by

$$\overline{\overline{\sigma}} = \begin{bmatrix} 50 & -20 & 0 \\ -20 & 80 & 60 \\ 0 & 60 & -70 \end{bmatrix} \text{ MPa.}$$

1.1 Determine the three principal stresses. (15 points)

1.2 Determine the direction of the highest principal stress (σ_1). (10 points)

1.3 Determine the maximum shear stress. (5 points)

1.4 Draw 3-D Mohr's circles from the principal stresses and mark the principal stresses and the maximum shear stress on the Mohr's circles. (10 points)

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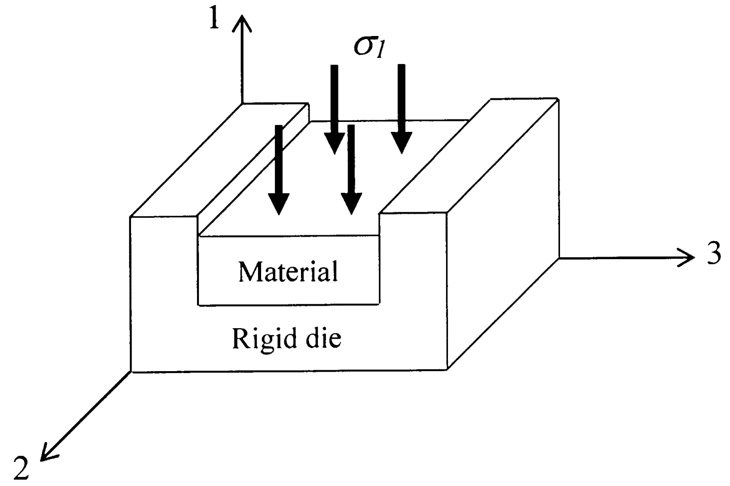
2. A sample of material subjected to a compressive stress σ_1 is confined so that it cannot deform in the 3-direction as shown in the figure below. Assume that there is no friction against the die, so that deformation can freely occur in the 2-direction. Assume further that the material is isotropic and exhibits linear elastic behavior.



If σ_1 has a magnitude of -100 MPa and the material is made of copper alloy E = 110 GPa, and ν = 0.33. Determine the followings:

2.1 The stress that develops in the 3-direction (σ_3). (5 points)

2.2 The strain in the 1-direction (ε_1). (5 points)

2.3 The strain in the 2-direction (ε_2). (5 points)

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3. Copper single crystal has compliance (S) constants of

$S_{11} = 14.9$ TPa^{-1}
$S_{12} = -6.2$ TPa^{-1}
$S_{44} = 13.3$ TPa^{-1}.

3.1 Calculate Young's moduli (E) in the [100], [110] and [111] directions. (15 points)
3.2 What conclusion can be drawn from the result in 3.1? (5 points)

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4. An aluminum crystal is subjected to stress $[\sigma]$,

$$[\sigma] = \begin{bmatrix} 50 & 20 & 0 \\ 20 & 100 & 50 \\ 0 & 50 & -100 \end{bmatrix} \text{ MPa.}$$

The crystal has compliance constants of

$S_{11} = 15.7$ TPa^{-1}
$S_{12} = -5.7$ TPa^{-1}
$S_{44} = 35.1$ TPa^{-1}.

Calculate the strain $[\varepsilon]$ that is caused by the applied stress $[\sigma]$. (25 points)

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Formula

For 3 - D stress :

$$\det\begin{bmatrix} \sigma-\sigma_{xx} & -\tau_{yx} & -\tau_{zx} \\ -\tau_{xy} & \sigma-\sigma_{yy} & -\tau_{zy} \\ -\tau_{xz} & -\tau_{yz} & \sigma-\sigma_{zz} \end{bmatrix}=0$$

$$I_1=\sigma_{xx}+\sigma_{yy}+\sigma_{zz}$$

$$I_2=\sigma_{xx}\sigma_{yy}+\sigma_{yy}\sigma_{zz}+\sigma_{zz}\sigma_{xx}-\tau_{xy}^2-\tau_{yz}^2-\tau_{zx}^2$$

$$I_3=\sigma_{xx}\sigma_{yy}\sigma_{zz}+2\tau_{xy}\tau_{yz}\tau_{zx}-\sigma_{xx}\tau_{yz}^2-\sigma_{yy}\tau_{zx}^2-\sigma_{zz}\tau_{xy}^2$$

$$\sigma^3-I_1\sigma^2+I_2\sigma-I_3=0$$

Direction of the greatest principal stress (σ_1)

$$(\sigma_{xx}-\sigma_1)l_1+\tau_{xy}m_1+\tau_{xz}n_1=0$$

$$\tau_{zx}l_1+\tau_{zy}m_1+(\sigma_{zz}-\sigma_1)n_1=0$$

$$l_1^2+m_1^2+n_1^2=1$$

where, l_1, m_1, n_1 are direction cosines of σ_1

Plane strain situation : $\varepsilon_3=0,\ \sigma_3\neq 0$

$$\sigma_3=\nu(\sigma_1+\sigma_2)$$

$$\varepsilon_1=\frac{1}{E}\left[(1-\nu^2)\sigma_1-\nu(1+\nu)\sigma_2\right]$$

$$\varepsilon_2=\frac{1}{E}\left[(1-\nu^2)\sigma_2-\nu(1+\nu)\sigma_1\right]$$

$$\varepsilon_3=0$$

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For cubic crystals :

$$\frac{1}{E} = S_{11} - 2\left[\left(S_{11} - S_{22}\right) - \frac{1}{2} S_{44} \right]\left(l^2 m^2 + m^2 n^2 + l^2 n^2\right)$$

$$[\varepsilon] = [S][\sigma]$$

$$[\varepsilon] = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix}$$

$$[\sigma] = \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_4 \\ \tau_5 \\ \tau_6 \end{bmatrix}$$

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{12} & 0 & 0 & 0 \\ \cdot & S_{11} & S_{12} & 0 & 0 & 0 \\ \cdot & \cdot & S_{11} & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & S_{44} & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & S_{44} & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & S_{44} \end{bmatrix}$$