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2013ME10679

Major Exam Date: 21/11/2017

Nanomechanics MCL729

Start Time: 10:30 am Duration: 2 Hrs. Total marks: 110

1. Answer the following questions
   a. Explain briefly **any two** of the following terms (a few sentences each) [3x2=6]
      i. Virial stress
      ii. Ergodic Hypothesis
      iii. Lithography
   b. Describe any four factors which can affect an indentation experiment. How can the error introduced due to these factors be accounted for? [4]
   c. What is the difference between a nanoindentor and an AFM from the functional point of view? What are the two different functional modes of an AFM? What is the difference between these two modes? [6]

2.
   a. Show that the stress vector **t** at an arbitrary surface is given by [15]

$$\mathbf{t} = \mathbf{T} \cdot \hat{\mathbf{n}}$$

   where, **T** is the stress tensor and $\hat{\mathbf{n}}$ is the unit normal vector to the arbitrary surface

   [*Hint*: Consider a differential tetrahedron]

   b. Stress at a point in a body of rock is given by [5]

$$\sigma = \begin{bmatrix} -5 & 2 & -3 \\ 2 & 2 & 1 \\ -3 & 1 & -1 \end{bmatrix} Mpa$$

Consider a plane defined by a vector $[V_i] = [1\ 3\ 5]$ m, which is normal to the plane.

Determine the traction vector **t** acting across this plane

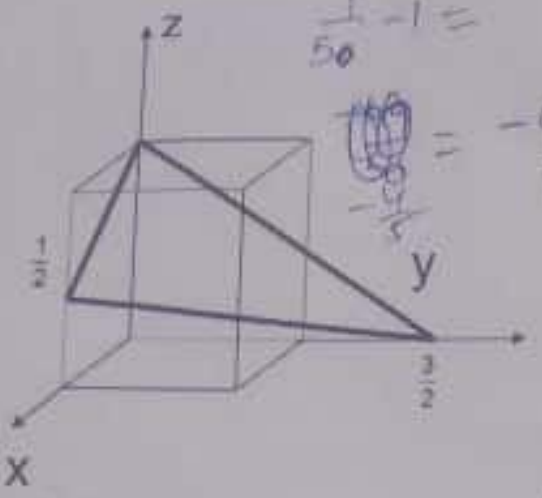
3. Explain the working principle of [6+6]
   a. Laser trap
   b. Biomembrane force probe

4. Fill in the blanks

   a. Myosins are motor proteins which work with actin based motility. Kinesins and Dyneins are the motor proteins which work with tubulin based motility. The power required for these motors to work is obtained from ATP molecules with a rate of 1 molecules per stroke. The force generated by the motor proteins is of the order of pico Newtons. [5]

   b. Miller indices of the plane shown figure below is (623) (346) [2]

5



(c) In high performance computing, 0.88 fraction of the computation should be parallelized in order to achieve a speedup of 50. [4]

5. Establish the need of multiscale methods. Why problems cannot be solved at one scale? Explain any three multiscale methods. What is the difference between serial and concurrent multiscale methods? [3+2+9+3]

6. Spider-Silk and Nacre are two naturally occurring biological materials. How are these materials different from engineering materials in terms of structure and mechanical properties? What makes these materials exhibit remarkable properties as compared to engineering materials? [5+5]

7. What is the principle of working of Gecko's feet? Write in clear points and point out the nanoscale engineering employed by nature. [10]

8. Answer the following

a. What is the difference between isotropic, anisotropic, and orthotropic materials? How many different independent coefficients are required to describe the material matrix for each of these type of materials? [4]

b. What is meant by a perfectly elastic response and an anelastic response? Draw a typical stress-strain graphs depicting these two responses [4]

c. In a cubic material, the elastic moduli can be determined along any orientation using the elastic constants, by following relation

$$\left[\frac{1}{E_{ijk}} = S_{11} - 2(S_{11} - S_{12} - \frac{1}{2}S_{44})(l_{i1}^2 l_{j2}^2 + l_{j2}^2 l_{k3}^2 + l_{i1}^2 l_{k3}^2)\right]$$

Where E_{ijk} is the Young's modulus in [ijk] direction; l_{i1}, l_{j2}, and l_{k3} are direction cosines of the [ijk] direction.

i. Determine the modulus of elasticity for tungsten and iron in the <111> and <100> directions [18]

ii. What conclusions can be drawn about their elastic anisotropy? [2]

[Assume compliance constants as provided in table below (Compliance in units of 10^{-11} Pa)]

Element	S_{11}	S_{12}	S_{44}
Fe	0.80	-0.28	0.86
W	0.26	-0.07	0.66