BMEN 3010: Biomedical Engineering 1 Prof. Nerurkar
Module 1: Solid Biomechanics
Fall 2025

Homework Policy

Homework Policy

1) You are welcome to discuss class concepts and the homework problems with one another. However, all final answers, calculations, and explanations on the homework you turn in must be your own work.
2) You may not use copies of homework assignments or solutions (from previous years or the current year) or accept help from students who took the class in previous years. You may not share your graded homework with next year's class or help them with their assignments.
3) Late homework will be penalized by 10% of its full grade per day late. If you anticipate problems or delays they must be reported to Prof Nerurkar at no less than 24 hours before the due date / time.

SEAS Contract of Academic Integrity

I affirm that I will not plagiarize, use unauthorized materials, or give or receive illegitimate help on assignments, papers, or examinations. I will also uphold equity and honesty in the evaluation of my work and the work of others. I do so to sustain a community built around this Code of Honor.

I certify that my work on this assignment is original and in compliance with the class homework policy and the SEAS Code of Honor.

Signature_____ Date _____

To my knowledge, no member of this class has violated the homework policy, breached the SEAS Code of Honor, or acted unethically with respect to this class.

Signature_____ Date _____

Name (Print)_____

If you are unable to sign this coversheet, please meet with Professor Nerurkar as soon as possible to discuss the issue.

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Module 3: Solid Biomechanics
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Homework 2

DUE BY UPLOAD TO GRADESCOPE NO LATER THAN 11:59PM ON 09/23

1. (2 points) In class on Monday 11/27, we performed a static analysis of forces in the knee joint. Using the equations derived in class, calculate the muscle force F_m, the reaction force through the joint, F_j, and angle of joint reaction force α, for full extension of the knee (β = 90°), partial flexion of the knee (β = 45°), and an extreme flexion of the knee (β = 30°). Express forces F_m and F_j in terms of body weight W, and use the values below for the remaining constants. Finally, comment on how joint forces compare to body weight as a function of extension/flexion. Is this what you expected, why or why not?
   a = 0.08h (where h = height)
   b = 0.14h
   c = 0.28h
   θ = 15°
   w_t = 0.06W

2. (1 point) In class, we drew 6 of 9 Cartesian components of stress in a cube. Draw a cube and coordinate axes, then label the full 9 components of stress on the surfaces.

3. (1 point) Why is stress a second order tensor (associated with two directions), even though the associated force is only a vector (associated with one direction)?

4. (2 points) If displacement in a material is given below, calculate the 2-D strain matrix:
$$u_1 = 0.05x_1 + 0.025x_2 + 0.05$$
$$u_2 = x_1 - 0.02x_2 - 0.05$$

5. (2 points) In a tissue undergoing deformation, the state of strain at a point is given by:
$$\boldsymbol{\epsilon} = \begin{bmatrix} 5 & 3 & 0 \\ 3 & 4 & -1 \\ 0 & -1 & 2 \end{bmatrix} \times 10^{-3}$$
   Determine the change in angle between two collagen fibrils emanating from this point, that are initially perpendicular to each other, and parallel to the vectors $2\mathbf{e}_1+2\mathbf{e}_2+\mathbf{e}_3$ and $3\mathbf{e}_1-6\mathbf{e}_3$. For simplicity, assume that the tissue can be modeled as a continuum, and the collagen fibrils deform as line elements within this continuum (in other words they deform according to the strain matrix described above). Hint: begin by finding unit vectors associated with two directions.

6. (1 point) Give an example of how at a single location, a tissue in the body could experience
   a. compressive stress, but tensile strain, along the same direction.
   b. tensile stress, but compressive strain, along the same direction

7. (1 point): In class on Wednesday 9/10, we solved a sample statics problem of a bar suspended by two cables, without any context for what the bar is made of or why it is suspended by cables. Propose a biomedical context for this problem. Yes, I may use the best answer in next year's class ☺