**BioE 102 Midterm 1**
Fall 2020
Take-home Exam

**Issued:** Tuesday October 20th at 6:00pm
**Due:** Three hours after opening of exam on Gradescope AND before October 20th at 11:59 PM.

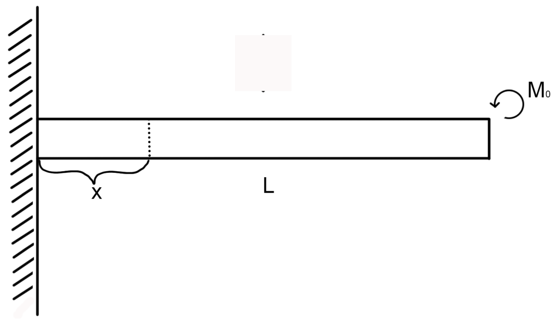
**Q1** Honor Code
5 Points

**Instructions**

- This midterm is open book. So long as you do not violate UC Berkeley, state, or US Federal regulations, you may - during the midterm - access or use (a) any reference in print or electronic form; and (b) any computing, communication, or other electronic device, to advance or verify your solutions. Citing the output of any such reference does not discharge from you the responsibility of providing sufficient explanation of your work.
- For each problem, you must upload a scan of your solution.
- You must show your work on all problems to get full credit. The minimum requirements for showing work are explicitly writing out relevant equations, and demonstrating a clear line of logic from your setup of the problem to your answer.
- Please write neatly and legibly, because if we can't read it, we can't evaluate it.
- **Pledge of Academic Integrity** Hand-copy, sign, and date the text of the Pledge of Academic Integrity below. Upload a scan of your signature to answer this question.

*By my honor, I affirm that as a member of the UC Berkeley community, I have acted with honesty, integrity, respect for others, and professional responsibility—and in a manner consistent with the letter and intent of the campus Code of Student Conduct.*

**Q2** Beam Mechanics
15 Points




The beam above is of length L, a moment $M_0$ is applied to its end, and its bending rigidity is EI.

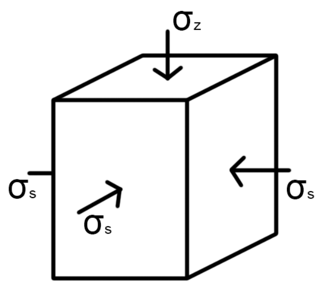
**Part A** (6 Points)
We draw a cut distance x from the left side of the cantilevered beam above. What is the moment M(x) applied to the left side of the cut?

Justify your answer with a FBD.

**Part B** (2 Points)
What are the boundary conditions of the beam?

**Part C** (7 Points)
Calculate the curvature of the beam and integrate to find the deformation function w(x).

**Q3** Generalized Hooke's Law
10 Points

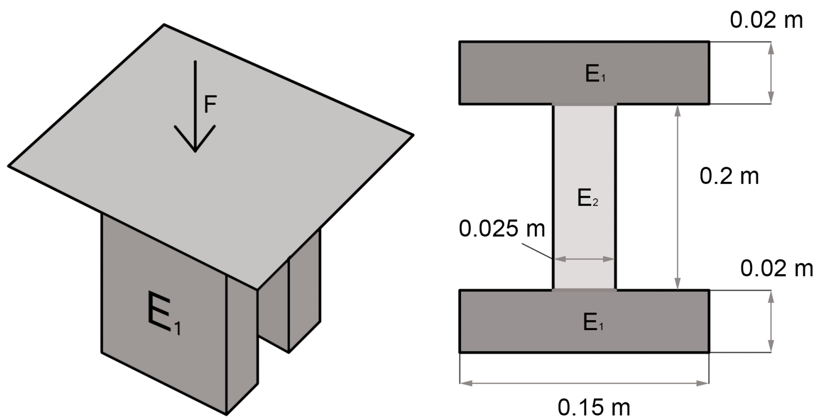



The block above is pushed downwards by a stress $\sigma_z$ in the z direction (and supported by the ground), and squeezed in the x and y directions by the stress $\sigma_s$. The block has Poisson's ratio $\nu$ and modulus of elasticity *E*.

**Part A** (5 Points)
If $\epsilon_{zz} = 0$, then solve for $\sigma_s$ in terms of *E*, $\nu$, and $\sigma_z$.

**Part B** (5 Points)
If the block is originally a cube with side length 1 m, then what are its new dimensions under the stresses derived above? Leave your answer in terms of *E*, $\nu$, and $\sigma_z$.

**Q4** Composite Compression
10 Points



Top-down view of support.

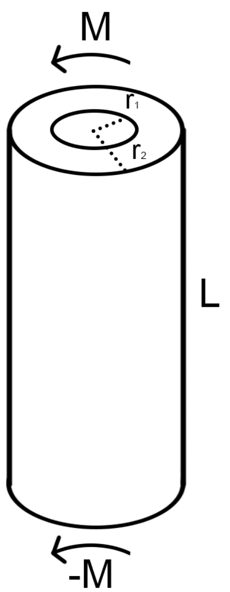
A table is supported by an I-shaped structure of height 0.25 m. It is made of two materials according to the dimensions shown above.

For the materials, $E_1$ = 10 MPa, while $E_2$ = 5 MPa. Both materials have a negligible Poisson's ratio.

**Part A** (7 Points)
The table is pushed down by a force of F = 25 kN. The tabletop always stays flat, so the strain in each material will be the same. How far will it move downwards?

**Part B** (3 Points)
What is the effective modulus of elasticity for the combined materials? (Averaged over the whole support, what is stress / strain?)

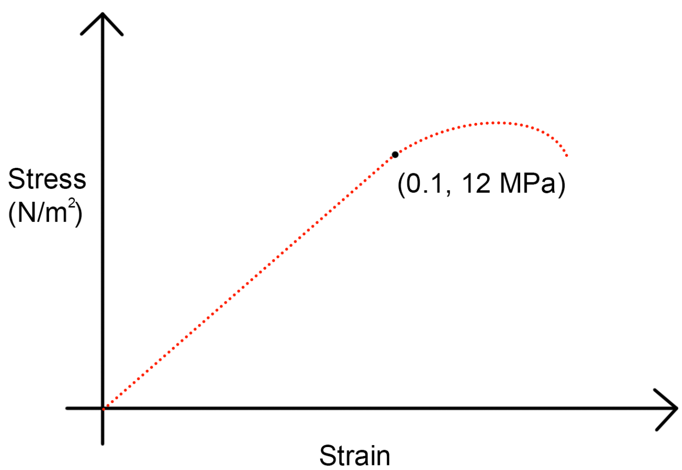
**Q5** Twisted Cylinder
15 Points




The cylinder above has height L, inner radius $r_1$, and outer radius $r_2$. It is twisted by a moment *M*.

**Part A** (5 Points)
Calculate the angle by which the cylinder will twist in radians in terms of the shear modulus *G* and the variables given above.

**Part B** (10 Points)
The graph below plots shear stress against strain for the cylinder's material.




Let $r_1$ = 0.1 m, $r_2$ = 0.2 m, and L = 1 m. What moment *M* can be exerted before the twist θ is no longer linearly related to *M*?

**Q6** Class Question
10 Points

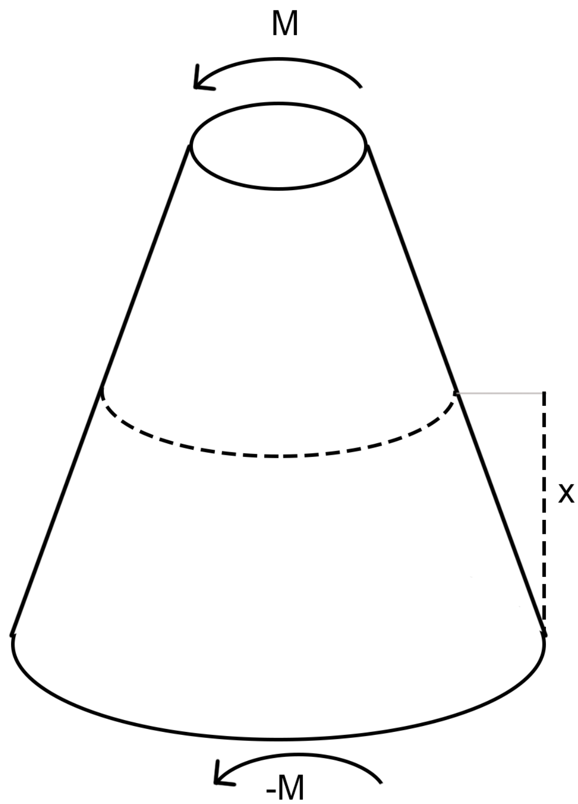
**Part A** (5 Points)
Give two specific examples of immune cells changing behavior in response to mechanical stimuli.

**Part B** (5 Points)
When and how can the modulus of elasticity of cells change during chemotherapy?

**Q7** Lab Question
10 Points

Answer in a maximum of 3 sentences:
How can we justify modeling an arterial wall tissue as an isotropic material? Can we use the same reasoning if we are to mechanically model an endothelial cell adhered to the basement membrane (extracellular matrix)?

**Q8** Challenge Problem
5 Points




The truncated cone above has a top radius of 0.2m, a bottom radius of 0.4m, and a height of 1m. So, the radius at height x is $r(x) = 0.4 - 0.2x$.

**Part A** (1 Points)
We use the cut method at height x, and extract the lower part of the cone. What is the moment applied to this section at its top? Justify your answer with a FBD.

**Part B** (1 Points)
What is the polar moment of inertia for a cross-section of the cylinder at height x, J(x)?

**Part C** (3 Points)
How far will the top face of the cylinder rotate under a moment M?

**Hint:** You will have to integrate over all cross-sections of the cone. For a very thin section, with width *dh*, the change in radius is negligible, so the rotation *dθ* can be calculated normally.