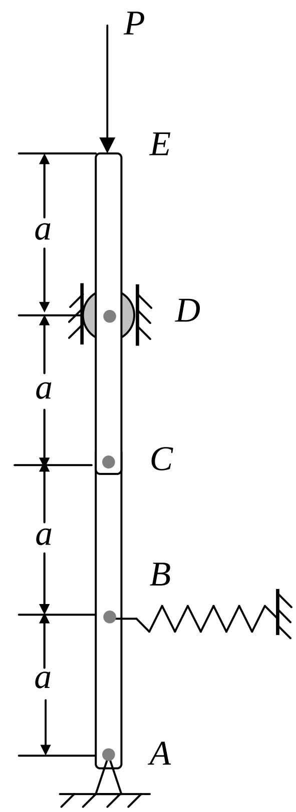
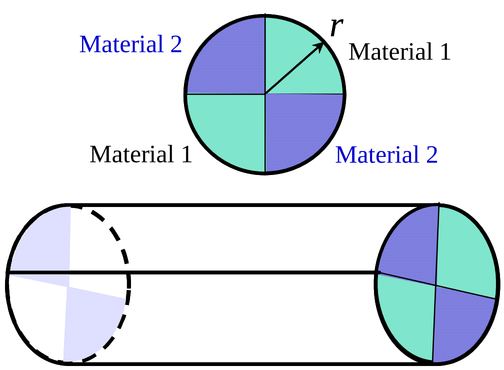
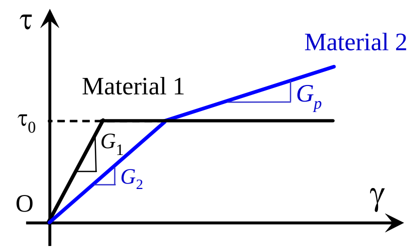
Problem 1: Bar AC is attached to a hinge at A and to a spring of constant k that is undeformed when the bar is vertical. Knowing that the spring can act in either tension or compression, determine the range of values of P for which the equilibrium of the system is stable in the position shown. Both bars AC and CE are rigid with a hinge joint at C.



Problem 2: A composite shaft made of two different materials is designed to transmit torques applied at its ends. The shear stress-strain curves for the materials are shown in the figure, where τ_0 is the yield stress in shear for both materials. In answering the following questions, you can assume that the two materials are perfectly bonded.





(a) Illustrate qualitatively the distribution of stress on a cross section at various levels of applied torque. Assume planar sections remain planar. State the additional assumptions behind your analysis;

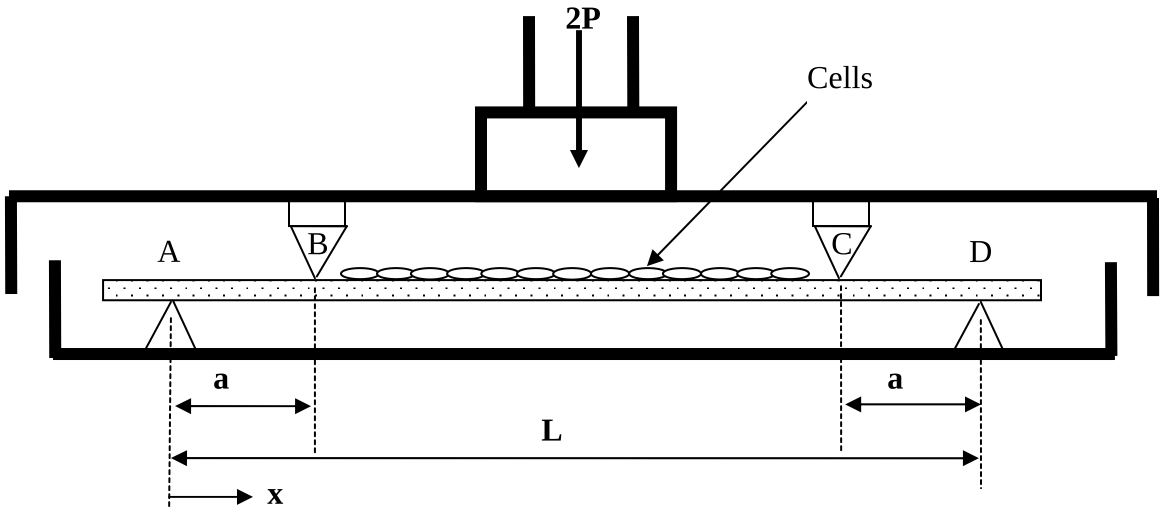
(b) Find the torque required to cause initial yielding;

(c) Find the torque required to cause a maximum shear stress of $2\tau_0$ in the shaft;

(d) If, from the condition of (c), the torque is gradually decreased to zero, calculate the residual stress at the outer edge $r = r_c$ for both materials;

(e) Is the stress distribution you illustrated in part (a) the fully accurate solution? Why or why not (e.g., list any conditions wherein your analyses or stated assumptions may not be reasonable)?

Problem 3: You want to study the effects of strain on living cells. To perform the experiment you construct the device shown below within a petri dish. Your device deforms a thin beam made of plastic with modulus **E** and moment of inertia **I** as shown. You culture living cells on top of the plastic beam and assume they are firmly attached to the surface but thin enough and compliant enough to not affect the beam behavior. Note that the deformation of the beam at points B and C is equal to the experimentally controlled displacement (**d**) of the petri dish top. The beam is homogenous and has a rectangular cross-section such that you may assume that the distance from the neutral axis to the top surface of the beam is half the beam thickness (**t**). The distances **a** and **L** are given as shown below.



Given: E, I, d, t, a, and L

A. As the petri dish top is moved down, will the cells on the surface be subjected to compressive or tensile strain?

B. Moving the petri dish top down a distance **d** causes equal loads of magnitude **P** to be applied to points B and C. Using the second order approach <u>set up</u> the deflection equations and <u>list</u> the boundary and continuity conditions to find the beam deflection expression $v_2(x)$ in terms of P for $a \leq x \leq (L-a)$. <u>Do not solve</u>.

C. The solution for $v_2(x)$ is given below. Find $v_2(x)$ in terms of d (note that $v_2(x)$=d at x=a).

$$v_2(x) = Pa(3x^2+a^2-3Lx)/6EI$$

D. Assuming a linear elastic isotropic beam, find an expression for strain at the top of the beam in terms of **a**, **d**, **t**, and **L**.

E. What can you say about $M(x)$, $\sigma(x)$, and $\varepsilon(x)$ for $a \leq x \leq (L-a)$? Why might this be advantageous for your experiment?