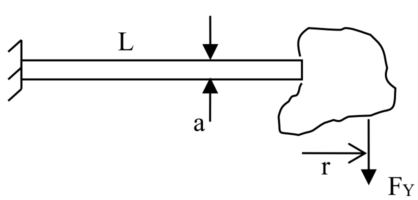
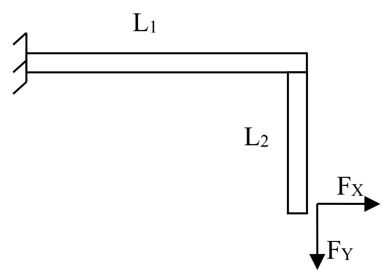
EE 147/247A Prof. Pister
Fall 2021

Homework Assignment #4

Due on bcourses Thursday 9/30/2021 (late 9 AM Friday)

1. The structure on the left below consists of a rigid body attached to the end of a beam of length L, width a, and thickness b. The goal is that a vertical force F_y generates only deflection in the y direction, and no rotation θ at the tip of the beam. The force acts at a distance r from the end of the beam.
    a. Write an expression for the rotation of the tip of the beam as a function of the moment arm r.
    b. Solve for the value of r that sets the tip rotation to 0.
    c. Compare the stiffness of the mechanism in part b to the simple beam (i.e. F_y applied at r=0).
2. Repeat the previous problem, but with the goal of getting zero tip deflection.
    a. Expression for deflection of the tip
    b. Find r that sets tip deflection to 0
    c. Sketch the shape of the beam under load.
3. In the structure on the right below, the two beams both have a width a and thickness b.
    a. Choose L_2 such that the spring constants in the x and y directions are equal.
    b. For your choice in part a, calculate the compliance C_{xy}, which relates the force in the y direction to the displacement in the x direction. $x=C_{xy} Fy$
    c. For your choice in part a, calculate the compliance C_{yx} and explain what it means.





4. Design a suspension in POLYMUMPS to have a stiffness of 1 N/m in x and y with no cross-coupling.
5. [247] In the structure on the right above, is it possible to attach a rigid body to the end of L2 and choose the point of action of the two forces such that $C_{xy}=C_{yx}=0$? If so, sketch your design.
6. A mechanical spring/mass/damper resonator with a Q of 4 is driven at resonance by an external sinusoidal force. The amplitude of motion is $x_o\sin(\omega t)$. On a plot with the horizontal axis representing the magnitude of $\sin(\omega t)$ forces, and the vertical axis representing the magnitude of $\cos(\omega t)$ forces,
    a. plot the spring, inertial, and damping forces. Make sure to show the relative scale of each.
    b. What is the overall resulting force which must be supplied externally?

    The frequency of the driving force is reduced by a factor of 2, to $\omega_n/2$, and the magnitude of the force is adjusted to maintain the same amplitude x_o as above.
    c. plot the spring, inertial, and damping forces. Make sure to show the relative scale of each, and keep the spring force the same length as part (a).
    d. What is the overall resulting force which must be supplied?

The frequency of the driving force is increased 2 ω_n, and the magnitude of the force is adjusted to maintain the same amplitude x_o as above.

e. plot the spring, inertial, and damping forces. Make sure to show the relative scale of each and, keep the spring force the same length as part (a).
f. What is the overall resulting force which must be supplied?

7. The same resonator is driven with an external force $f_o\sin(\omega t)$, which at low frequency generates a displacement $x_o\sin(\omega t)$. Plot the spring, inertial, and damping forces
   a. at $\omega_n/10$
   b. at ω_n
   c. at 10 ω_n

   Don't forget that at each frequency, the sum of the resonator forces must equal the external force!
   d. What is the phase of the displacement (relative to the input force) in each of the three cases above?
8. For a comb drive resonator with K=1 N/m, w=1krad/s, Q=10, and N=10 comb fingers, calculate the amplitude, phase, and frequency of all components of the deflection due to a 15 V 1 krad/s AC signal applied to one comb and a 15V DC signal applied to the body of the resonator.
   a. There are forces at three different frequencies being applied to the resonator. What are they?
   b. What is the steady-state response of the resonator to each of these forces?
   c. What is the overall steady-state response?