1. Consider the cantilever beam of length $L$ shown in Figure 1. Applying a load $P$ to the end of the beam causes the end of the beam to deflect. The deflection of the end of the beam δ is determined with

$$\delta = \frac{PL^3}{3EI}, \tag{1}$$

where $E$ is modulus of elasticity and $I$ is the area moment of inertia. In the lab, you control $P$ = 500 N and measure $L = 10 \pm 0.7$ cm and $I = 8 \pm 0.72 \times 10^{-11}$ m$^4$. You know with negligible uncertainty that $E$ = 70 GPa.

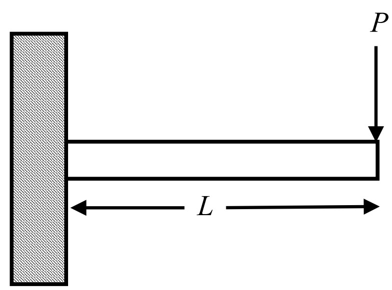


**Figure 1.** Cantilever beam subject to a load at the end.

   a. Determine the uncertainty in the deflection of the end of the beam *by hand* using uncertainty propagation.
   b. Create a MatLab program that determines the uncertainty in the deflection of the end of the beam *numerically* (don't just take the derivative symbolically with MatLab). Compare your result to your result from part a (they should be the same).

2. You want to launch a water balloon into our neighbor's yard. Including wind resistance and assuming you and your target are at the same elevation, the horizontal and vertical positions of the water balloon ($s_x$ and $s_y$) at time $t$ are given by

$$s_x = \frac{v_o m}{k} \cos(\theta)\left(1 - e^{-\frac{k}{m}t}\right), \tag{2a}$$

$$s_y = \frac{m}{k}\left(v_o \sin(\theta) + \frac{mg}{k}\right)\left(1 - e^{-\frac{k}{m}t}\right) - \frac{mg}{k}t, \tag{2b}$$

where $v_o$ is the initial speed of the water balloon, $m$ = 1 kg is the mass of the balloon, θ is the angle at which you launch it, $g$ = 9.81 m/s$^2$ is the gravitational constant, and $k$ = 0.65 kg/sec is related to the drag force. You can launch the water balloon consistently with a velocity $v_o$ = 50.0 ± 5.0 m/s. After doing some calculations you find that launching the balloon at angles of θ = 15° and 39.9° results in the same horizontal distance traveled $s_x$ = 56 m (the perfect distance to make a silent escape). Which angle should you choose to minimize the uncertainty in your horizontal launch distance assuming the uncertainty in launch angle is ±10%? hint 1: don't do this by hand, generalize your uncertainty propagation m-file from problem 1. hint 2: the total travel time can be determined when $s_y$ = 0.

3. Refer to problem 3 of HW 2. Assume a ±10% uncertainty in the measured values of the displacement. Couple your uncertainty propagation m-file with the non-linear fitting m-file you wrote for HW2 to determine the uncertainty in the fitted values $k$ and $c$ (the solution for HW2 is posted on D2L).

4. Help me make the exam. Write one conceptual question related to anything we've discussed thus far. Good examples include multiple-choice questions (like a tough clicker question), questions where you must choose less-than/equal-to/greater-than signs, or questions involving drawing qualitatively-accurate graphs. Keep calculations to a bare minimum. Good questions are:
   a. Short (no long stories or multiple paragraphs full of writing)
   b. Non-intuitive
   c. Unique (something relatively new, but feel free to use clicker questions for inspiration)
   d. Easily interpreted (not a vague question that could have multiple interpretations)

   Review class notes, labs, homework, and clicker questions for inspiration. Write your question at the top of a new page and your solution and explanation on the bottom or back of the page so I can test myself and ensure that I am interpreting your question correctly. If you generate a good question, it may end up on the exam and you'll know the answer!