

# EGR1010 Lab MATLAB

## Supplemental Instruction Assignment #4

### INSTRUCTIONS:

Complete the following assignment and submit with your laboratory notebook. Use the template provided on the course content page on Pilot. *Please follow the instructions for submission located at the end of this document.*

### PROBLEM STATEMENT (PART 1):

You are a first year co-op student at a local aerospace design firm that has been contracted by Cessna to help retro-fit the internal wing structure for the C310 series aircraft shown below.



Figure 1. Cessna C310 Aircraft

The internal structural layout of the aircraft wings is shown in Figure 2. The main component that must be redesigned is known as the *main spar*, which serves as one of two primary load carrying members in the wing. In this project we assume the main spar carries 100% of wing loading.

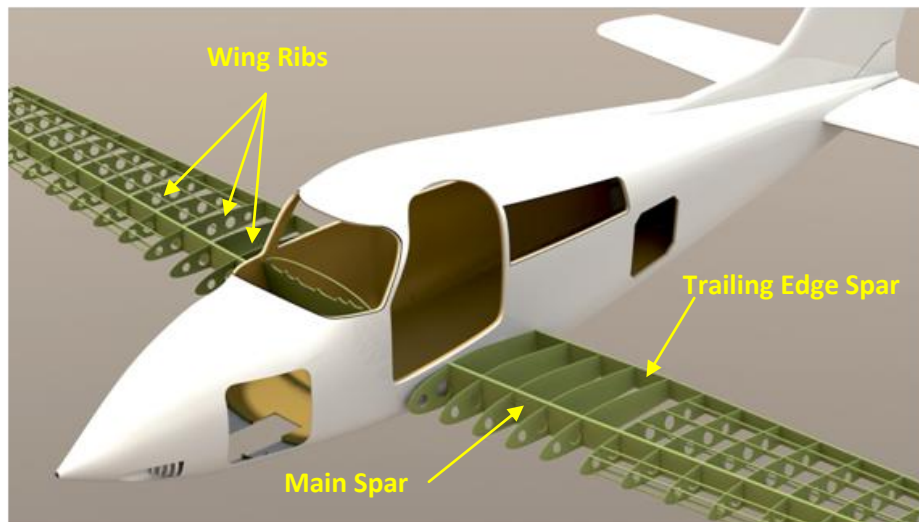


Figure 2. Internal wing structure for C310 aircraft showing ribs and spars.

The lead design engineer asks you and another more experienced co-op student to perform a loads analysis of the main spar and identify the stresses at potentially critical locations in the spar. She tells you that the main spar likely behaves as a beam under bending and the total wing loading has contributions from three primary sources: (i) lift, (ii) engine weight, and (iii) inertial effects/gravity on the fuel (stored in the wing tip tanks) and the wing structure itself. She gives you the diagram in Figure 3, which shows the distributions of these components of loading across the wing for an aggressive "pull up" maneuver.

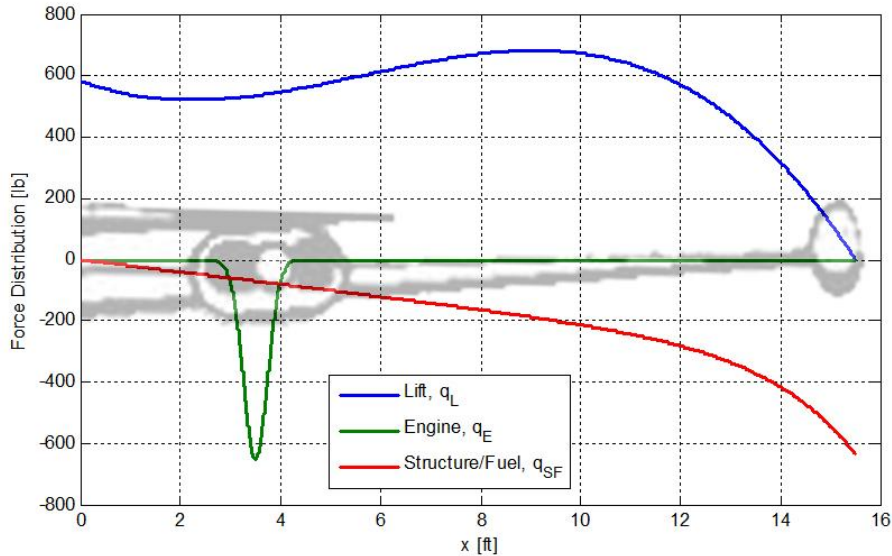


Figure 3. Distributions for the lift, engine weight, and structure/fuel weight acting on wing during maneuver.

She also tells you that the total distributed load on the wing is the summation of these three components, given by Equations (1) to (3).

$$q_L = -x^3 + 20x^2 - 65x + 600 \quad (\text{lb} / \text{ft}) \quad (1)$$

$$q_E = -650e^{-\left(\frac{x-3.5}{0.35}\right)^2} \quad (\text{lb} / \text{ft}) \quad (2)$$

$$q_{SF} = -0.0355e^{0.6x} - 20x \quad (\text{lb} / \text{ft}) \quad (3)$$

The main spar is a square aluminum tube with wall thickness ( $t$ ) of 0.325 inches and length ( $L$ ) 15.5 feet. The outer dimensions of the spar at  $x = 0$  are 3 inches by 12 inches ( $b$  by  $h_o$ ). The tube linearly tapers to a height of 3 inches ( $h_L$ ) at its tip ( $x = L$ ).

The other more experienced co-op student recalls that slender beams usually fail due to bending at their root ( $x = 0$ ) and says that the two of you should investigate the bending and shear stresses there. These values may be found by Equations (4) and (5).

$$\sigma_o = \frac{M_o c}{I} \quad (4)$$

$$\tau_o = \frac{V_o}{A} \quad (5)$$

In Equations (4) and (5),  $\sigma_o$  is the bending stress,  $M_o$  is the bending moment,  $\tau_o$  is the shear stress,  $V_o$  is the shear force,  $c$  is the distance from the neutral axis,  $I$  is the moment of inertia, and  $A$  is the cross-section area all taken at  $x = 0$ .

He sketches the following free-body diagram and comments that from his statics class he knows you can find the bending moment and shear force as equivalent static loading. He states you find this from the resultant of the total load distribution on the beam given by Equation (8). He also states that you must **integrate** the distribution to determine the resultant force  $R$ , and that the force acts through the **centroid** of the distribution by Equations (9) and (10).

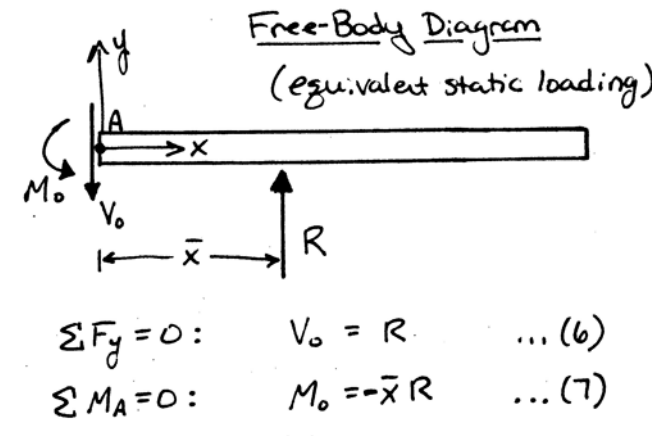


Figure 4. Free-body diagram with equivalent static loading and Equations (6) and (7).

$$q_T = q_L + q_E + q_{SF} \quad (8)$$

$$R = \int_0^L q_T(x) dx \quad (9)$$

$$\bar{x} = \frac{\int_0^L x \cdot q_T(x) dx}{R} \quad (10)$$

You recall from EGR1010 that you can approximate these integrals using a series of inscribed rectangles inside the area you wish to integrate. You profess to the older student that you will compute the values  $R$ ,  $\bar{x}$ ,  $M_o$ ,  $V_o$ , and the stresses using MATLAB!

### MATLAB PROCEDURES:

Complete the following procedures in the supplemental template file available in the course content on Pilot. DO NOT alter the formatting of the existing template, but rather simply add in your code where appropriate.

1. Predefine the scalar variables for the dimensions of the main spar. These are the length  $L$ , spar width  $b$ , spar height at  $x = 0$  ( $h_o$ ), spar height at  $x = L$  ( $h_L$ ), and spar wall thickness  $t$ . ALL DIMENSIONS SHOULD BE ENTERED IN FEET. Suppress output to the command window.

2. Compute the cross-section area ( $\text{in}^2$ ) and moment of inertia ( $\text{in}^4$ ) at the root of the main spar using Equations 11 and 12. Do NOT suppress output to the command window.

$$A = bh_o - (b - 2t)(h_o - 2t) \quad (11)$$

$$I = \frac{1}{12} (bh_o^3 - (b - 2t)(h_o - 2t)^3) \quad (12)$$

3. Using the `staticEquivalentLoading()` function template, create a function that computes and returns as output the resultant force  $R$  and centroid  $\bar{x}$  by approximating the integrals using inscribed rectangles. Inputs to the function should be the number of rectangles and the length of the main spar. Suppress ALL output to the command window inside the function.
  - 3A. Determine the width  $dx$  of each of the inscribed rectangles based on the number of rectangles that are specified. Also create a vector of  $x$  locations at which you will compute the height of the rectangles ranging from beginning at  $dx$  and incrementing by  $dx$  to the total length  $L$ .
  - 3B. Evaluate Equations (1) to (3) to determine the values of the lift, engine weight, and structure/fuel load at each location in the previous vector using element by element math.
  - 3C. Compute the total load exerted on the main spar at these locations via Equation (8).
  - 3D. Determine the resultant load  $R$  by first determining the area of each rectangle inscribed in the area under the total load graph and then summing them together. This provides an approximate to the integral given by Equation (9).
  - 3E. Now find the centroid of the total load distribution via Equation (10). To do this using element by element math, multiply the vector of  $x$  locations onto the vector of total loading evaluated at those locations determined in 3C. Next multiply this new vector by the width of the inscribed rectangles. After summing elements of the resulting vector, dividing by  $R$  yields the centroid.
4. Experiment with the function file to determine the total number of rectangles required. Recall that adding more and more rectangles more the approximation closer and closer to the real value. Do NOT suppress command window output.
5. Compute shear force  $V_o$  and the bending moment  $M_o$  using Equations (6) and (7). These equations are given in Figure 4. Do NOT suppress command window output.
6. Determine the shear stress  $\tau_o$  and bending stress  $\sigma_o$  via Equations (4) and (5), respectively. Note that  $c = -0.5h_o$ . Suppress output to the command window.
7. The results determined in part 6 have units of pounds per square foot. Generally, stresses are reported in pounds per square inch! Convert the stress values to the appropriate units. Do NOT suppress command window output.

### SUBMISSION:

Paste the entire contents of your `staticEquivalentLoading()` function as comment lines into Section (3) where specified. To submit your main code, in the editor window select *File > Publish filename.m*. A new window will open up with an HTML document. **Print this document to turn in.**