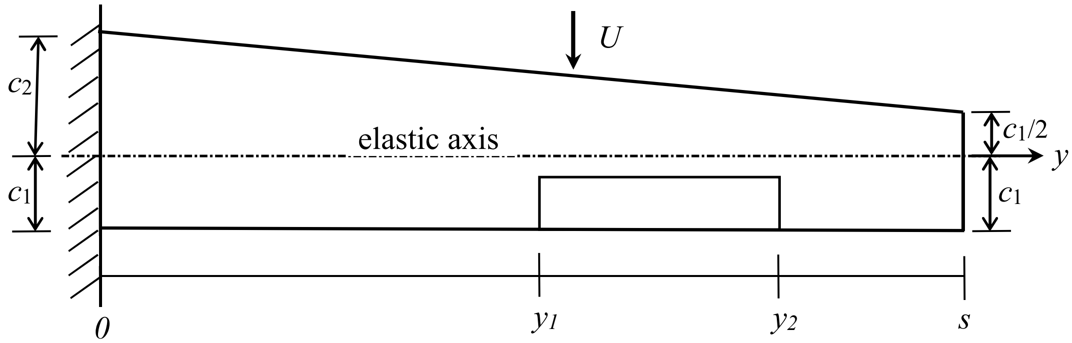
Toronto Metropolitan University
Department of Aerospace Engineering

AER722 Aeroelasticity Design Project I

Due Monday October 21st, 10 am

This static aeroelasticity project helps you to exercise your knowledge of wing divergence, aileron effectiveness/reversal and wing loading in design of a wing model. The model is a cantilever wing with span *s*, and chord *c*(*y*) which varies in spanwise direction as shown in the following planform.



The aerodynamic center is assumed at the quarter chord point from the leading edge, and the elastic axis is a straight line perpendicular to the flow direction. Wind-off angle of incidence of the model varies as $\alpha(\eta) = 5 - 3\eta$ degree where $\eta = y/s$. The wing model has no camber and has lift distribution of the form $C_{L_\alpha} = 2\pi\sqrt{1-\eta^2}$. The coefficients C_{L_β} and C_{M_β} are assumed to be constant along the span and equal to their thin airfoil theory values. The torsional stiffness of the model is given by $GJ(\eta) = 8500(1 - k\,\eta)$ Nm^2/rad, where *k* is a constant to be selected. Assume incompressible uniform flow at standard sea level condition.

a) For a sample set of values, $k = 0.25$, $c_1 = 0.35$m, $c_2 = 0.4$m and $s = 2$m, use the assumed modes method with as many modes as required in the series $f_1 = y, f_2 = 2y^2, \ldots, f_n = ny^n$ to find the divergence dynamic pressure to an estimated error of less than 0.1%. Plot the variation of the divergence dynamic pressure versus the number of modes. Also, find wing tip deflection at 50% of divergence dynamic pressure for this case.

b) Design the wing parameters (span *s*, chord constants c_1 and c_2, and the torsional stiffness parameter *k*) such that the model can generate at least 700 N lift at the airspeed 70 m/s taking the wing deflection into consideration. The ratio s/c_{mean} should also be greater than 3. At this airspeed, the wing-tip deflection should be less than 1.0°, and the wing-root bending moment should not exceed 300 N-m. The wing divergence speed must be higher than 150 m/s.
The design must satisfy the above requirements and the model should have the least value of $\int_0^1 GJ(\eta)c(\eta)d(\eta)$. Use of optimization techniques is not required. All procedures, analysis and calculations must be presented in the project report.

c) For the final design in part b, at U=70 m/s, using the above assumed modes, find and plot the twist variation θ as a function of *y*.

d) For the final design in part b, at U=70 m/s find and plot the lift distribution along the span and compare it with lift distribution that would have been obtained if the wing model was rigid.

e) Using the lift distributions of part d, find the percentage increase in total lift and wing root bending moment on the model due to the aeroelastic effect as compared with a rigid model.

f) For the final design in part b, assume an aileron of chord 0.3 *c* that spans from y_1=0.5 s to y_2=0.8 s and determine the aileron reversal dynamic pressure and the rolling power of the wing at U=70 m/s. Use the single assume mode shape $f = y(4s - 2y)$ for calculations.

g) Study the effect of the aileron chord size on its rolling power.

Project Report format and grading

The report should be in the following format.

1. Standard Cover sheet from the department web site
https://www.torontomu.ca/content/dam/aerospace/forms-resources/undergraduate/AssignmentCover22.pdf

2. Abstract and Introduction (less than 2 page) (10 points)
(4a: Properly defining the design problem, and evaluating adequacy and consistency of the produced problem definition with needs statement and reality. Predicting unstated customer and user needs. Defining design parameter uncertainties and their impacts. Gathering information and identifying constraints.)

3. Computational simulation and programing (15 points)
(5a Proper use of computational tools to simulate systems and processes.)

4. Calculations and solutions (30 points)
(4d Generate solutions: Generating solutions for the complex engineering design problem)

5. Presentation of results in neat graphs (15 points)
(7c: Demonstrating fluency in using communication tools for presentation in engineering contexts. Using graphics to explain, interpret, and assess information.)

6. Analysis, evaluation and discussion of the results (15 points)
(4b: Using feasibility analysis in the aeroelasticity design problem.)
(4c: Objectively determining relative value of feasible alternative solutions of the design problem.)

7. Conclusions and design suggestions (10 points)
(4c: Applying a selection/decision-making technique to select the best design for the aeroelastic model of a cantilevered wing based on the given limitations.)

8. Written Communication skills (5 points)
(7a: Writing the project report using appropriate aerospace engineering conventions. Adapting format, content, organization, and tone for appropriate audiences. Demonstrating the accurate use of technical vocabulary.)

Note:
Email your report and computer program to the TA Siavash at siavash.tavana@torontomu.ca
You may be asked to change your computer program and find other results upon the TA request.
All the marks will be lost if one cannot change one's program and find new results.

Each team member should fill out the peer evaluation form in the next page and email it to the TA.

Project Peer Evaluation Form Your Name:___________________

Peer evaluations are a part of each student's project grade. Please complete this form and email it to the TA.

Using the scale below, evaluate your teammates on their contributions to researching and developing the group report.		
4	Excellent Contributor	The person significantly contributed. Without this person, the quality of our final product would have been considerably diminished.
3	Good Contributor	The person contributed. Without this person, the quality of our final products would have been diminished.
2	Marginal Contributor	The person barely contributed. Without this person, the quality of our final products would have been about the same.
1	Unsatisfactory Contributor	The person failed to contribute in any meaningful way. Other members of the group had to do more because of this person's performance. Without this person, the quality of our final products may actually have been improved.

Using the above codes, evaluate each team member (including yourself):

Team member	**Contribution to the project work**	**Contribution to report**