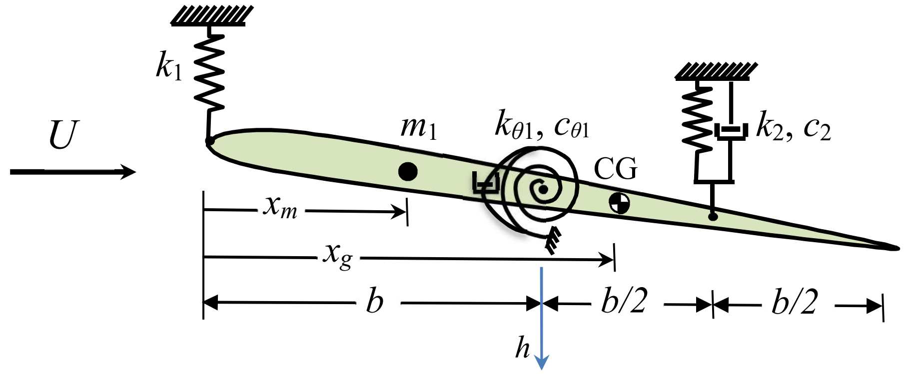
Toronto Metropolitan University
Department of Aerospace Engineering

AER722 Aeroelasticity Design Project II **Due: November 24, 2024**

A two-dimensional, two-degree-of-freedom aeroelasticity model is being designed for wind tunnel testing. A thin airfoil of unit span and chord "c" will be mounted in a wind tunnel via translational springs k_1 at the leading edge, a translational spring and damping k_2 and c_1 at the ¾ chord point, plus a torsional spring $k_{\theta 1}$ and torsional damping $c_{\theta 2}$ at the mid-chord as shown below. A point mass of m_1 is also attached to the airfoil at a distance x_m from the leading edge. The airfoil (excluding the point mass) has mass "m" and moment of inertia about the center of gravity "I_{CG}", with the center of gravity at distance x_g from the leading edge. Assume quasi-steady incompressible aerodynamics for lift and moment calculations.



1) Use both Newton Equations and Lagrangian mechanics to derive the complete equations of motion of the aeroelastic system about the mid-chord point (i.e. h is measured downward at the mid-chord). Present the equations in a following simplified 2x2 matrix form.

$$[M]\begin{Bmatrix}\ddot{h}\\ \ddot{\theta}\end{Bmatrix}+([B_s]+f(U)[B_a])\begin{Bmatrix}\dot{h}\\ \dot{\theta}\end{Bmatrix}+([E]+f(U)[K])\begin{Bmatrix}h\\ \theta\end{Bmatrix}=\begin{Bmatrix}0\\ 0\end{Bmatrix}$$

2) Write a computer program in MATLAB or MAPLE to solve the aeroelastic equations and find the critical speeds (flutter or divergence) for the airfoil with the following parameters:
c =0.5 m, k_1 =5 kN/m, $k_{\theta 1}$ =500 N.m/rad, k_2 =1 kN/m, $c_{\theta 1}$ =0.0 N.m.s/rad, c_1 =0.0 N.s/m,
m =5 kg, I_{CG} =0.05 kg m^2, x_g =0.15 m, m_1 =2 kg and x_m =0.15 m.
Assume incompressible flow with maximum speed U_{max}=100 m/s and density ρ =1.225.

3) For the model with same parameters as in part 2 show the variation of real and imaginary parts of the eigenvalues versus airspeed up to 1.2 times the critical speed.

4) Vary the magnitude of spring constants k_1, k_2, and $k_{\theta 1}$ from 0 to 5 times their given values in part 2, and plot the variation of critical speeds versus these variables.

5) Design the best combination of k_1, k_2, and $k_{\theta 1}$ for maximum critical speed (flutter or divergence) and least amount of stiffness. The sum of spring constants must be less than 10 kN/m (k_1+k_2 $\leq$ 10 kN/m), and each spring must be greater than 1 kN/m. Also, keep $k_{\theta 2}$ less than 700 Nm/rad. All the other parameters are as in part 2.

6) Vary the location of the point mass x_m from 0 to the c, and plot the variation of critical speeds versus x_m. Propose a location for this point mass to maximize the flutter speed. Other parameters are as in part 2.

7) Study the effect of mechanical dampings by varying c_2 from 0 to 20 N.s/m and $c_{\theta 1}$ from 0 to 0.7 N.m.s/rad, and plots the variation of critical speed versus the damping constants. Other parameters are as in part 2.

Project 2 Report format and grading

The report should be in the following format.

1. Standard Cover sheet from the department web site

2. Abstract and Introduction (less than 2 page) (10 points)
   (4a: Problem definition: Selecting and using an appropriate method for the problem definition. 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)
   (4b: Generate solutions: Generating solutions for the Aeroelastic model design problem)

5. Presentation of results in neat graphs (15 points)
   (7c: Communication tools: 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 dynamic aeroelastic model 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 computer program to 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