Aeroelasticity M2795.005900

Final Examination

December 14, 2020 2:00PM-4:00PM

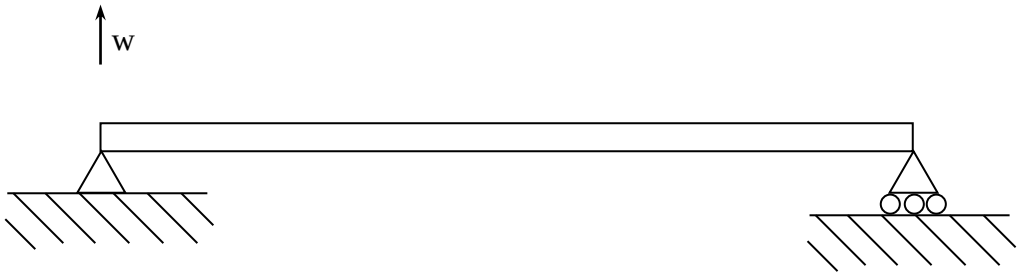
1. (15 Points) In the derivation of Theodorsen's formulation about the unsteady lift and aerodynamic pitching moment, explain **where** and **why** the lift deficiency factor, $C(k)$, expressed below, appears in the formulation.

$$C(k) = \frac{\int_1^\infty \frac{\xi}{\sqrt{\xi^2 - 1}} e^{-ik\xi} d\xi}{\int_1^\infty \frac{\xi + 1}{\sqrt{\xi^2 - 1}} e^{-ik\xi} d\xi}$$

2. (5 Points each) In the original derivation of Theodorsen's unsteady aerodynamics formulation for an oscillating flat-plate airfoil, briefly describe **where** and **why** the following each principle is utilized during the process of the derivation.
   (a) Velocity potential (disturbance potential)
   (b) Flow tangency at the solid surface (No flow through the solid surface)
   (c) Kutta condition at the trailing edge
   (d) Condition of conservation of the circulation (or vorticity)

3. (5 Points each) For the analytic unsteady aerodynamic formulations other than Theodorsen's function, each formulation is related with Theodorsen's function $C(k)$ in a certain way. Briefly explain the reason why such relationship is introduced and how the relationship is described in each following function.
   (a) Wagner's function
   (b) Sears' function
   (c) Kussner's function

4. (25 Points) Find an approximate solution using either Rayleigh-Ritz or Galerkin method for the natural mode shapes (continuous) and frequencies of the simply supported uniform beam without any loads as shown below. Show the procedure and formula for the first/second **natural frequencies**.



Length = L, Flexural stiffness = EI (const.),
Mass/length = m (const.), Area = A (const.)

5. (5 Points each)
   (a) In turbomachinery, it turns out that the mass ratio is much larger than it is in the conventional fixed wings. Describe briefly about its advantage upon the flutter analysis procedure of the turbomachinery.
   (b) Intentional mistuning on the turbine blade component may improve the flutter instability boundary of turbomachinery. Describe briefly about its procedure and provide a representative diagram.
   (c) Campbell diagram is used in the forced vibration and the high-cycle fatigue analysis in the turbomachinery. Describe briefly its procedure and the usage of the Campbell diagram.