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DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING

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Unsteady Aerodynamics and Aeroacoustics
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HOMEWORK 2

1. For harmonic oscillations, the Theodorsen function $C(\omega)$ accounts for the contribution of the wake to the lift and moment. Plot a vector diagram of the real and imaginary parts of its complex conjugate $\overline{C}(\omega)$ versus the frequency $\omega \in \{0, \infty\}$. Also plot its magnitude and phase.

2. Translatory oscillations are an approximation of bending oscillations. Plot a vector diagram of the total lift coefficient of a thin airfoil undergoing bending oscillations versus the reduced frequency. Also plot its magnitude and phase.

3. Pitching oscillations are an approximation of torsional oscillations. Plot a vector diagram of the total lift coefficient of a thin airfoil undergoing torsional oscillations about the midchord versus the reduced frequency. Also plot its magnitude and phase. Repeat if the oscillations are about the airfoil leading edge.

4. Calculate the wok W done by bending and pitching oscillations over a cycle. Consider first the case of low frequency where the lift can be approximated by the quasi-steady lift. Then calculate the work at any frequency and plot W versus ω. Comment on the contribution of the apparent mass lift and the wake effect on W. What can you say about the stability of a wing in bending and torsional oscillations at low Mach number flow?

Hint:

- If a periodic force $\mathbf{f}$ is acting on a body moving with a velocity $\mathbf{v}$,

$$W = \int_0^T \mathbf{f} \cdot \mathbf{v}\, \mathbf{dt},$$

where T is the period.

- Verify that for a harmonic oscillation where $\mathbf{f}$ and $\mathbf{v}$ are given in complex form

$$W = \frac{T}{2} Re\{\mathbf{f} \cdot \overline{\mathbf{v}}\},$$

where Re denotes the real part.