MECH 3640 Aerodynamics Fall 2023

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Course Objectives: The main objective is to provide you with a basic understanding of the physical principles and complex flow phenomena that govern the motion of flight vehicles in aerospace engineering, from subsonic to supersonic speeds. This understanding will enable you to calculate forces such as lift and drag in simplified situations, and to appreciate other physical effects that arise in practice.

We will build on the knowledge acquired in MECH 2210 (or its equivalent), applying and extending those concepts to aerospace applications. We will begin by examining inviscid incompressible flow around wing cross-sections (2D airfoils). From there, we will branch out to explore 3D effects for wings of finite span, viscous effects, and compressibility effects in high-speed flows.

Textbook + Reference Materials: *Fundamentals of Aerodynamics* (Anderson J.D., 5th or 6th edition, 2011/2017) is the main textbook for this course. It can be accessed electronically (for free! ☺) via the HKUST Library website.

Assessment:

20% Homework: eight assignments in total
40% Project: wind tunnel experiments + numerical simulations
40% Final exam

Course Outline

1. Introduction + Basic Concepts in Fluid Dynamics [L1−4]
   - A brief history of flight
   - Conservation laws for mass and momentum
   - Streamlines, vorticity, stream function, velocity potential, Laplace's equation
   - Terminology in aerodynamics
   - Circulation, irrotationality, linear superposition of potential flows
   - Bernoulli's equation, Kutta−Joukowski theorem for lift prediction
2. Incompressible flow around airfoils (2D) [L5−7]
   - Vortex strength distribution, streamline condition, Kutta condition
   - Thin airfoil theory (TAT): lift and moment coefficients for symmetric and cambered airfoils, angle-of-attack effects, airfoil-shape effects
   - Lift and drag polar curves, stall characteristics, high-lift devices
   - Failure of TAT: vortex panel method as an alternative tool
3. Incompressible flow around wings (3D) [L8−10]
   - Effects of finite wingspan: trailing vortices, downwash velocity, induced drag
   - Flow physics near the wingtip: 2D airfoils vs 3D wings
   - Lifting line theory (LLT): lift and induced drag for untwisted elliptical wings and twisted generic wings
   - Design considerations: wing taper, aspect ratio, wingtip devices, parasite drag
   - Failure of LLT: vortex lattice method as an alternative tool
4. Viscous Effects in Incompressible Flow [L11−12]
   - Blasius' theory for a laminar boundary layer over a flat plate
   - Basic characteristics of turbulent flows
5. Basic Concepts in Compressible Flow [L13]
   - Speed of sound, Mach cones, isentropic flow in a duct
   - Choking, supersonic flow in 1D converging−diverging nozzles
6. Shock Waves + Expansion Fans [L14−16]
   - Normal shocks, oblique shocks
   - Prandtl−Meyer expansion fans
7. Airfoils in Compressible Flow [L17−18]
   - Derivation of the full potential equation
   - Linearized potential equation for small disturbances
   - Subsonic regime: Prandtl−Glauert similarity transformation, similarity rules, subsonic wings
   - Supersonic regime: wave equation, linearized pressure coefficient, calculation of lift and wave drag, comparison with shock-expansion theory
8. Airfoils in Transonic Flow [L19−20]
   - Critical Mach number, transonic drag rise, drag-divergence Mach number
   - Design considerations: sweep-back, supercritical airfoils, area rule