MECH3640 - Aerodynamics

Course Code: MECH 3640	**Course Title:** Aerodynamics
Required Course/Elective Course: Elective for BEng(MECH)/Required for AE Major & Minor	**Terms Offered (Credits):** Fall (3 credits)
Faculty In Charge: Larry Li	**Pre/Co-Requisites:** CENG2220 or CIVL2510 or MECH2210 or MECH1907

Course Structure: Per week: two lectures (each 1 hour 20 mins) and one tutorial (each 50 mins).

Textbook/Required Material: (1) Lecture notes, (2) Homework assignments, (3) Online supplementary notes, (4) Textbook → *Fundamentals of Aerodynamics* (5th ed. 2010) by John D. Anderson.

Course Description: Irrotational flow, circulation, lift and drag, airfoil, conformal mapping, lifting line theory, elliptical wing, swept wing, delta wing, supersonic flow. For science and engineering students in their second year of study or above.

Course Topics:

1. Introduction & review of basic concepts in fluid dynamics
    a. A brief history of flight
    b. Conservation laws for mass & momentum
    c. Streamlines, vorticity, strain rate, stream function, velocity potential
    d. Terminology in aerodynamics

2. Irrotational flow & the generation of lift
    a. Circulation, irrotationality, linear superposition of potential flows
    b. Bernoulli equation, Kutta−Joukowski Theorem

3. Incompressible thin airfoil theory
    a. Vortex strength distribution & Kutta condition
    b. Lift coefficient for symmetric airfoils (effect of angle of attack)
    c. Lift coefficient for cambered airfoils (effect of airfoil shape)

4. Incompressible finite wing theory
    a. Effects of finite wingspan: trailing vortices, downwash velocity, induced drag
    b. Flow physics near the wingtip
    c. Lift & induced drag for untwisted elliptic wings
    d. For reading: results for non-elliptic wings

5. Viscous effects in incompressible flow
    a. Boundary layer & Blasius theory for flat-plate solution
    b. For reading: approximate methods for curved surfaces
    c. Basic characteristics of turbulent flows

6. Principles of compressible flow
    a. Isentropic variations of thermodynamic properties, speed of sound, Mach cones
    b. Choking & supersonic flow in 1-D converging-diverging duct

7. Shock waves & expansion waves
    a. Normal shocks & oblique shocks
    b. Prandtl−Meyer expansion fans

8. Linearized potential flow theory
    a. For reading: derivation of the full potential equation
    b. Linearized potential equation for small disturbances

9. Airfoils & wings in subsonic flow
    a. Prandtl−Glauert similarity transformation
    b. Similarity rules & subsonic wings

10. Airfoils in supersonic flow
    a. Wave equation & characteristics of supersonic flow
    b. Calculation of lift & wave drag

11. Transonic flow
    a. Critical Mach number, its effects on lift & drag
    b. Design considerations: sweep-back, supercritical airfoils

Course Objectives:	1. To introduce basic terminology used in aerodynamics. 2. To provide an entry-level understanding of the physical principles and complex flow phenomena that govern the motion of flight vehicles in aeronautical engineering, from subsonic to supersonic speeds and with or without significant viscous effects. 3. To provide mathematical tools and knowledge to calculate lift and drag on airfoils/wings in simplified situations, and to appreciate other physical effects that arise in practice.
Course Outcomes:	After completing MECH4610, students will be able to: A. Apply the basic tools of incompressible inviscid aerodynamic analysis to estimate lift for an airfoil. o State the relationship between vorticity, circulation, and lift. o Describe the physical mechanism for lift generation. o State the Kutta condition for an airfoil and explain why this condition must apply. o Use thin airfoil theory to estimate the lift and moment coefficients for a symmetric or cambered airfoil. B. Explain and quantify the effects of viscosity on airfoil performance. o Use Blasius' solution to estimate the thickness, skin friction coefficient and wall shear stress in a laminar boundary layer on a flat plate, given the velocity outside the boundary layer. o Explain the physical cause of flow separation and how it is related to pressure drag. o Explain the main differences between a turbulent boundary layer and a laminar boundary layer. C. Explain the differences in aerodynamic performance between an infinite-span (2D) airfoil and a finite-span (3D) wing. o Explain why lift is lower for a finite-span wing than for a comparable infinite-span airfoil. o Explain the origin and effects of wing-tip vortices. o Describe the cause of induced drag on finite-span wings. o Describe practical techniques for reducing induced drag. o Use results from lifting line theory to estimate 3D wing

	performance from 2D airfoil data. o Apply lifting line theory to estimate the performance of 3D wings of elliptical planform. D. Account for the effects of compressibility in aerodynamic problems. o Analyze isentropic flow in a converging-diverging nozzle with or without a normal shock. o Decompose the flow across an oblique shock into an equivalent flow across a normal shock. o Explain the physical differences between shock waves and expansion waves. o Analyze the flow across a Prandtl-Meyer expansion fan. o Use the Prandtl-Glauert transformation to account for changes in pressure coefficient and lift coefficient as a result of compressibility. o Use results from linearized potential theory to calculate the lift coefficient and wave-drag coefficient in supersonic flow.
Assessment Tools:	Homework assignments 20% Mid-term exam 30% Final exam 50%