AER307H1F Aerodynamics: Introduction and Course Outline

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1 Textbook and Additional References

Course Textbook:

J.D. Anderson, *Fundamentals of Aerodynamics*, 3rd edition, McGraw-Hill, 2001.

Additional References:

I.H. Abbott and A.E. von Doenhoff, *Theory of Wing Sections*, Dover, 1959.
R.T. Jones, *Wing Theory*, Princeton, 1990.
A.M. Kuethe and C.-Y. Chow, *Foundations of Aerodynamics*, 5th edition, Wiley, 1997.
J. Moran, *An Introduction to Theoretical and Computational Aerodynamics*, Wiley, 1984.

Computational Fluid Dynamics Reference:

H. Lomax, T.H. Pulliam, and D.W. Zingg, *Fundamentals of Computational Fluid Dynamics*, Springer-Verlag, 2001.

2 Mark Breakdown

Assignments: 10 %
Laboratory: 15 %
Tests: 25 %
Final Exam: 50 %

Details:

There will be 2 assignments.
There will be 3 "closed-book" tests. They will be held on October 3, October 31, and November 21.
The final exam is type X, i.e. "open-book."

3 Course Outline

N.B. The numbers in parentheses refer to the corresponding sections of the text. Sections 1, 2, and 3 are taught independently from the text. Similar topics are covered in the following sections of the text: 2.3, 2.4, 2.5, 2.7, 2.10, 7.2, 7.4, 7.5, 8.3, 15.3, 15.4, 15.5, and 17.3. Section 12 is also taught independently from the text. The computational fluid dynamics reference book on page 1 provides supplementary material for Section 12.

1. **Fundamental Concepts**
   - (a) The continuum hypothesis
   - (b) Frames of reference, steady flow
   - (c) Attached and separated flow, streamlines
   - (d) Boundary layers and wakes
   - (e) Laminar and turbulent flow, transition
   - (f) Pressure distributions, lift curves, and drag polars
   - (g) Transonic flows, shock waves
2. **The Basic Equations of Fluid Dynamics**
   - (a) General form of a conservation law
   - (b) The equation of mass conservation
   - (c) The equation of momentum conservation
   - (d) The equation of energy conservation
3. **The Dynamic Levels of Approximation**
   - (a) The Navier-Stokes equations
     - i. The perfect gas model
     - ii. The first law of thermodynamics
     - iii. Entropy and the second law of thermodynamics
     - iv. The speed of sound
     - v. The incompressible fluid model
   - (b) The Reynolds-averaged Navier-Stokes equations
   - (c) The boundary-layer approximation
   - (d) The Euler equations
     - i. Properties of discontinuous solutions
   - (e) The potential-flow model

4. **Some Basic Concepts in Aerodynamics**
   (a) Aerodynamic forces and moments (1.5)
   (b) Center of pressure (1.6)
   (c) Types of flow (1.10)
   (d) Pathlines and streamlines of a flow (2.11)
   (e) Angular velocity, vorticity, and circulation (2.12, 2.13)
   (f) Stream function (2.14)
      i. Relationship between the stream function and the velocity potential
5. **Fundamentals of Inviscid, Incompressible Flow**
   (a) Bernoulli's equation (3.2)
   (b) Incompressible potential flow: Laplace's equation (3.7)
   (c) Elementary solutions of Laplace's equation
      i. Uniform flow (3.9)
      ii. Source flow (3.10)
      iii. Combination of a uniform flow with a source and sink (3.11)
      iv. Doublet flow (3.12)
      v. Nonlifting flow over a cylinder (3.13)
      vi. Vortex flow (3.14)
      vii. Lifting flow over a cylinder: The Kutta-Joukowsky theorem (3.15, 3.16)
6. **Incompressible Flow over Airfoils**
   (a) Airfoil characteristics (4.3)
   (b) Source and vortex sheets (4.4)
   (c) The Kutta condition (4.5)
   (d) Kelvin's circulation theorem and the starting vortex (4.6)
   (e) Classical thin airfoil theory
      i. The symmetric airfoil (4.7)
      ii. The cambered airfoil (4.8)
   (f) Panel methods (3.17, 4.10)
   (g) Low-speed airfoil design (4.11)
7. **Incompressible Flow over Finite Wings**
   (a) Downwash and induced drag (5.1)
   (b) The vortex filament, the Biot-Savart law, and Helmholtz's theorems (5.2)

    (c) Prandtl's classical lifting-line theory (5.3)
        i. Elliptical lift distribution
        ii. General lift distribution

8. **Subsonic Compressible Flow over Airfoils: Linear Theory**
    (a) The velocity potential equations (11.2)
    (b) The linearized velocity potential equation (11.3)
    (c) Prandtl-Glauert compressibility correction (11.4)
    (d) Critical Mach number and drag-divergence Mach number (11.6, 11.7)
    (e) Supercritical airfoils (11.9)

9. **Normal Shock Waves, Oblique Shock Waves, and Expansion Waves**
    (a) The basic normal shock equations (8.2)
    (b) Special forms of the energy equation (8.4)
    (c) Calculation of normal shock-wave properties (8.6)
    (d) Propagation of disturbances in subsonic and supersonic flow (9.1)
    (e) Oblique-shock relations (9.2)
    (f) Prandtl-Meyer expansion waves (9.6)

10. **Linearized Supersonic Flow and Hypersonic Flow**
    (a) Derivation of the linearized supersonic pressure coefficient formula (12.2)
    (b) Application to supersonic airfoils (12.3)

11. **Introduction to Boundary Layers**
    (a) Boundary-layer properties (17.2)
    (b) The Blasius solution (18.2)

12. **Introduction to Computational Fluid Dynamics**
    (a) Overview
    (b) Finite-difference methods
    (c) Time-marching methods
        i. Explicit methods
        ii. Implicit methods