AE 2020 Low Speed Aerodynamics (3-0-3)

Catalog Description: AE 2020: Low speed Aerodynamics. Basic results, conservation laws, potential, airfoil and wing analysis. Boundary layers on plates and airfoils. Pressure gradients. Introduction to turbulent and vortex-dominated flows.

Text: At the level of John D. Anderson, Fundamentals of Aerodynamics, 4th edition, McGraw Hill

Course Coordinator: L. N. Sankar, Regents' Professor

Learning Objectives:

1. How aerodynamic lift, drag and pitching moment are generated.
2. Basic physical approaches to describing fluid dynamics.
3. Potential flow concept to describe and predict aerodynamics.
4. Thin-airfoil theory.
5. Finite-Wing effects and their modeling.
6. Lifting-line approach for calculating lift and induced drag on wings.
7. Boundary-layer concept for modeling the effects of viscosity.
8. Simple models of the boundary layer.
9. Physical concepts of turbulence and its effects.

Expected Outcomes: Students will be able to (a) model internal flows through specified geometries and compute resulting forces; (b) compute aerodynamic forces and moments on airfoils of specified shape; (c) compute lift, drag, and pitching moments on unswept tapered, twisted wings; (d) compute laminar and turbulent boundary layer characteristics using integral and empirical methods.

Prerequisites: AE 1350, Physics 2121, Math 2401

Lecture Topics

1. Conservation Laws: Laws of physics: Mass, momentum & energy conservation. Simplifications. Relating line, area and volume integrals. Incompressible & steady flows. Euler's equation, Bernoulli's equation, pressure coefficient. (6 hours)

2. Fluid Motion: Streamlines, translation, dilatation, rotation and vorticity, strain rate, viscosity, circulation (3 hours)

3. Potential Flow Method: Velocity potential; Laplace equation; superposition of solutions, boundary conditions. Elementary solutions: uniform flow, source/sink, doublet, vortex, lift and drag coefficients. (6 hours)

4. Airfoils: Specifying circulation and the Kutta condition. Airfoil shape. Vortex sheet. Thin airfoil theory, lift curve slope, center of pressure, aerodynamic center. (6 hours)

5. Wings: Observed characteristics, trailing vortices, vortex sheet, starting vortex, downwash, induced drag. Vortex filament and Biot-Savart Law, Helmholtz's vortex theorem. Prandtl's lifting line theory, Glauert solution, elliptical lift distribution, induced drag. (6 hours)

6. Viscosity; Stokes relations; Simple solutions of the Navier-Stokes equations. (3 hours)

7. Derivation of incompressible boundary layer equations: exact solutions. Blasius Solution: Boundary layer over a flat plate (3 hours)

8. Von Karman Integral Momentum Equation: general discussion of pressure gradient effects on boundary layer growth (3 hours)

9. Turbulence and its effects; Turbulent flow over a flat plate: Squire-Young relation (6 hours)

10. Exams (3 hours)

Revised by Lakshmi N. Sankar on May 22, 2007