ENG ME 421 Aerodynamics

2008 - 2009 Catalog Data:
ENG ME 421 Aerodynamics Prereq: ENG ME 303, ENG ME 201, and ENG ME 400. Flow kinematics; pathlines, streamlines, streaklines, rate-of-strain, dilation, vorticity, etc. Stream function and velocity potential in two-dimensional flows. Potential flow theory with application of complex variables and conformal maps. Flow past airfoils, lifting line theory, and the Kutta-Joukowski theorem. Differential approach to fluid flow. Stress tensor in a Newtonian viscous fluid. Continuity, Euler, and Navier-Stokes equations. Introduction to turbulence. Fully-developed laminar and turbulent flows. Laminar and turbulent boundary layers. Introduction to computational fluid dynamics. Cannot be taken for credit in addition to ME 422. Includes lab and project. (Formerly ENG AM 420.) 4 cr.

Class/Lab Schedule: 4 lecture hours per week, 3 two hour labs per semester

Textbook(s) and/or Other Required Material: D. Wilcox, "Basic Fluid Mechanics";
J. Anderson, Fundamentals of Aerodynamics;
V.Yakhot, Fluid Mechanics. My lecture notes, Anderson, Aerodynamics/Abbott and von Doenhoff, Theory of wing sections

Coordinator: Victor Yakhot, Professor, Mechanical Engineering

Prerequisites by Topic:
1. Basic fluid mechanics
2. Vector calculus
3. Ordinary and partial differential equations

Goals:
The primary goal of this course is to provide an understanding of, and ability to solve and analyze, problems pertaining to the aerodynamics of aircraft. This course introduces the student to the "differential" (as opposed to "integral") analysis of inviscid and viscous fluid motion. The students are expected to attain a detailed understanding of flow kinematics (e.g., streamlines, pathlines, vorticity, rate-of-strain, …) and dynamics (the Navier-Stokes and continuity equations, Euler's equations, potential flow theory) and to use these principles for engineering analysis of external fluid flows.

Course Learning Outcomes:
As an outcome of completing this course, students will:
i. Gain ability to analyze and solve problems pertaining to the aerodynamics of aircraft. This includes using analytical approximations such as thin airfoil theory and lifting line analysis as well as basic panel methods for determining aerodynamic loads. (A, E, L)
ii. Be proficient at using the differential approach to solving exterior inviscid and basic viscous fluid mechanics problems. Thus they must gain an ability to solve problems from the broader field of fluid mechanics and not just inviscid, exterior aerodynamic problems. (A, E, L)
iii. Be able to present *complete* solutions to technical problems following an acceptable engineering format. This includes computer generated graphs with sufficient annotation to be explanatory. It also includes physical interpretation of the results and

comments on validity of the derived solution. (E, G, K)
iv. Learn to see equations as representations of physical phenomenon and learn how previous mathematics courses are useful when studying an engineering topic. (A, E)
v. Become proficient with specific computer tools for obtaining and presenting solutions. The students will design their own program in Maple, Excel and MATLAB for a multitude of different fluid/aerodynamic related problems. (K, I)
vi. Gain experience with current software tools for computational solutions to fluid/aerodynamic problems. They will use existing aerodynamic computational tools that run on unix based machines (thus requiring that they learn the basic units of unix). They will learn to validate solutions obtained with such a code before assuming the code is working properly. (D, K, L)
vii. Gain experience using a wind tunnel to measure aerodynamic loads on wing sections and other objects. Both pressure tap-to-manometer and tap-to-transducer measurements will be used to visualize and compute the surface pressure distribution on objects in a flow field. Force balance measurements will be taken to get overall aerodynamic loads. All results will be compares to previously documented results and current computational simulations. (B, D, G, L)

Course Learning Outcomes mapped to Program Outcomes:
(For Program Outcomes, please see attached page or Department Web Site)

Program:	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Course:	i, ii, iv	vii		vi, vii	i-iv		iii, vii		v		iii, v, vi	i, ii, vi, vii		
Emphasis:	5	4	1	3	5	1	3	1	2	1	4	1	1	1

Topics (time spent in weeks):
1. Fluids; continuum description; Elements of kinetic theory; derivation of viscosity and pressure (0.5)
2. Kinematics; acceleration; streamlines/pathlines; fluxes; vorticity (1)
3. Conservation laws; continuity, Euler and Navier-Stokes equations; Euler equation; Boundary conditions; vorticity; vortex force; Hydrostatics : barometric formula; shapes of the fluid surfaces. The Bernoulli equation and its simplest applications (2)
4. Kelvin's theorem; Incompressible fluids; Potential flows; 2D examples: uniform flow; sinks and sources; vortex; doublets and multi-pole expansion; Flow past cylinder; Joukovskii theorem. Drag and lift; Joukovskii theorem; Accelerating cylinder and cylinder + vortex: Panel method (5)
5. Airfoils; nomenclature; vorticity; vortex sheets; forces; flow over plate; thin airfoil theory; flow past 2d airfoil (1.5)
6. Symmetric airfoil; cambered airfoils; X-foil code; Numerical Project (2)
7. Finite wings; downwash and induced drag; vortex filament; Prandtl theory: elliptic lift distribution; aspect ratio (2)

Contribution of Course to Meeting the Professional Component:
Engineering Topics: 100%

Status of Continuous Improvement Review of this Course:
Date Last Reviewed: February 18, 2009 **Reviewed by**: Thermal/Fluid Committee
Prepared by: Victor Yakhot **Date**: 05/21/2009