Spring 2013 Course Syllabus
updated 01-09-2013

AAE 334: AERODYNAMICS

"Recently, interest has been centered on another branch of fluid mechanics, namely, on the mechanics of compressible fluids. The aeronautical engineer is pounding hard on the closed door leading into the field of supersonic motion"

TH. Von Karman in his paper
"Compressibility Effects in Aerodynamics", *J. Aeronautical Sciences*, Vol. 8 (9), 1941

This course is extending the theoretical framework built in AAE333 Fluid Mechanics to include compressible flow. The theory is applied to calculation of forces and moments on airfoils and wings in incompressible, subsonic and supersonic flight. The course also provides an introduction to transonic and hypersonic flow.

Day & Time: MWF 12:30 - 1:20 pm **Room:** ARMS 1010
Main course page with homework, practice exams and Q&A will be available on www.piazza.com
Grades will be posted on Blackboard Learn https://mycourses.purdue.edu

Instructor: Prof. Alina Alexeenko (U-lek-se'-en-ko) alexeenk@purdue.edu ARMS 3231
Phone: 496-1864 Office Hours M, W 2 – 3 or by appointment

Teaching Assistants Samantha Alberts alberts1@purdue.edu Nicholas Husen nhusen@purdue.edu

	Samantha Alberts	Nicholas Husen
Office Hours	W 8–10:30 am in ARMS 3154	T 9 – 11 am in ARMS 3118
	Th 4 – 6 pm in ARMS 3118	Th 1 – 4 pm in ARMS 3118

Course Objectives include developing abilities to:
1) Calculate thin airfoil performance parameters for incompressible flow
2) Calculate general wing loading by lifting line theory and compare to elliptic loading case.
3) Compute isentropic stagnation conditions and apply in problem solving.
4) Compute jumps in properties across steady shocks and expansions
5) Determine supersonic airfoil performance by shock-expansion method
6) Determine supersonic airfoil performance by linearized supersonic theory
7) Apply subsonic compressibility corrections to incompressible results
8) Determine critical Mach number for sub-sonic flight
9) Determine supply or back pressures for supersonic nozzle operating conditions

Necessary Background: Introductory fluid mechanics and thermodynamics.

Textbook:
E.L. Houghton, P.W. Carpenter, S. Collicott, D. Valentine, "Aerodynamics for Engineering Students", Butterworth-Heinemann, 2012 (6th edition)
<u>or</u>
John D. Anderson Jr., "Fundamentals of Aerodynamics," McGraw Hill, 2007 (5th edition).

Additional references: (on reserve in Engineering Library)
1. Modern compressible flow: with historical perspective (3rd ed.)
John D. Anderson, Jr., McGraw Hill, 2003
2. A. M. Kuethe and C.-Y. Chow, "Foundations of Aerodynamics," John Wiley, 1998 (5th ed.).

Outline

1. Introduction to Compressible Flow. Thermodynamics review. Review of governing equations.

2. Quasi-one-dimensional Compressible Flow. Steady one-dimensional flow of compressible fluids. Isentropic flow. Normal shocks. Nozzles, diffusers and supersonic wind tunnels.

3. Two-dimensional Compressible Flow. Oblique shocks. Shock reflections. Prandtl-Meyer expansion fan. Shock-expansion theory for airfoils. Swept wings. Linearized supersonic flow. Linearlized subsonic flow. Critical Mach number, transonic flow, area rule. Hypersonic flow.

4. Incompressible Flow over Airfoils. Thin airfoil theory. Thick airfoils. Panel methods. Stall and high lift devices.
5. Viscous flow, boundary layers. Lifting line theory and induced drag. Tapered planforms. Twisted wings. Wing sweep. Vortex lattice method. Multiple lifting surfaces. Stability and trim.

Grading:

Homework & Quizzes	25%
Exam 1	25% or 10%
Exam 2	25% or 10%
Final Exam (day of the final exam)	25% or 40%

"In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. Here are ways to get information about changes in this course remotely:
a) announcements at course web-page on Blackboard Learn;
b) email communications from instructor and TA.

Your final grade will be computed two ways. First your homework, Exam 1, Exam 2, and the Final Exam will each be weighted at 25% of your final grade. In the second case, the lower of Exam 1 and Exam 2 will be weighted at 10%. The higher of Exam 1 and Exam 2 and your homework will be weighted at 25% of your grade, and your Final Exam will be counted as 40% of your final grade. You will receive the higher of these two final grades.

If a quiz is given it will be unannounced and during class. No makeup quizzes will be given.

The details of the exams will be discussed in class.

Homework will be handed out on Fridays (with a few exceptions) and due in a week. Homework is due at the beginning of class; homework handed in at the end of class will be considered late. Late homework will be accepted (unless stated otherwise) up to class time on the Monday following the due date for 90% credit. No Homework will be accepted later than that, and all problems must be handed in at the same time. Exceptions will be granted only with permission and only under special circumstances. Unless otherwise noted, each problem will be graded on a scale of 0-5. Solution sets for the homework will be made available, and you are encouraged to check the solutions for any details you may have missed or to see alternate approaches. You may get help from one another on the homework, but you must hand in your own work. In writing up your homework follow the guidelines given below.

Guidelines for Homework (from Fox & McDonald)
Your work must be neat and easy to follow. If it is not, no credit will be given.

1. State briefly and concisely (in your own words --- do not just repeat the problem statement) the information given.

2. State the information to be found.

3. Draw a schematic of the system or control volume to be used in the analysis. Be sure to label the boundaries of the system or control volume and label appropriate coordinate directions.

4. Give the appropriate mathematical formulation of the basic laws that you consider necessary to solve the problem.

5. List the simplifying assumptions that you feel are appropriate in the problem. (Sometimes it is not clear ahead of time what assumptions are needed to make a problem tractable. In such cases, proceed to solve the problem and take note of the assumptions you make along the way.)

6. Carry the analysis to completion algebraically before substituting numerical values.

7. Substitute numerical values (using a consistent set of units) to obtain a numerical answer. The number of significant digits in the answer should be consistent with the given data. (All numerical answers must have the appropriate units given, unless the answer is nondimensional.)

8. Check the answer and review the assumptions made in the solution to make sure they are reasonable.

9. Label the answer. Many times the answer will be a formula rather than a number. You should check that the units are consistent in each of the terms, and that reasonable answers are obtained in limiting cases (by letting variables take on large or small values).

Academic Integrity

Students are reminded of the Student Code of Honor that states: The purpose of the Purdue University academic community is to search for truth and to endeavor to communicate with each other. Self-discipline and a sense of social obligation within each individual are necessary for the fulfillment of these goals. It is the responsibility of all Purdue students to live by this code, not out of fear of the consequences of its violation, but out of personal self-respect. As human beings we are obliged to conduct ourselves with high integrity. As members of the civil community we have to conduct ourselves as responsible citizens in accordance with the rules and regulations governing all residents of the state of Indiana and of the local community. As members of the Purdue University community, we have the responsibility to observe all University regulations.

To foster a climate of trust and high standards of academic achievement, Purdue University is committed to cultivating academic integrity and expects students to exhibit the highest standards of honor in their scholastic endeavors. Academic integrity is essential to the success of Purdue University's mission. As members of the academic community, our foremost interest is toward achieving noble educational goals and our foremost responsibility is to ensure that academic honesty prevails." http://www.purdue.edu/univregs/pages/stu_conduct/code_of_honor.html

Academic dishonesty will result in a zero for that assignment/exam and may result in a failing grade for the class. Furthermore, for all cases of academic dishonesty a report will be submitted to the Office of the Dean of Students, which may result in further disciplinary action. For more information go to: http://www.purdue.edu/odos/osrr/

Textbook Errata

If you find a mistake in the 6th edition of Houghton *et al*, please, send a description and correction by email to the instructor for a possible extra credit.

Greek Alphabet

Α, α	alpha	(al-fah)	Β, β	beta	(bay-tah)	Γ, γ	gamma	(gam-ah)
Δ, δ	delta	(del-ta)	Ε, ε	epsilon	(ep-si-lon)	Ζ, ζ	zeta	(zay-tah)
Η, η	eta	(ay-tah)	Θ, θ	theta	(thay-tah)	Ι, ι	iota	(eye-o-tah)
Κ, κ	kappa	(cap-pah)	Λ, λ	lambda	(lamb-dah)	Μ, μ	mu	(mew)
Ν, ν	nu	(new)	Ξ, ξ	ksi	(zie)	Ο, ο	omicron	(om-e-cron)
Π, π	pi	(pie)	Ρ, ρ	pho	(roe)	Σ, σ, ς	sigma	(sig-mah)
Τ, τ	tau	(taw)	Υ, υ	upsilon	(up-si-lon)	Φ, φ	phi	(fie)
Χ, χ	chi	(kie)	Ψ, ψ,	psi	(sigh)	Ω, ω	omega	(oh-may-gah)

AAE334, Schedule and Reading Assignments, Spring 2013

	Monday	Wednesday	Friday
Week 1 (1/07-1/11)	Intro to Compressible Flow A 7.1; *H 6.1*	Thermodynamics Review A 7.2-3*; H 1.3.8*	Thermodynamics Review A 7.2-3; *H 1.3.8*
Week 2 (1/14-1/18)	**No Class** Martin Luther King Jr. Day	Review of Governing Eqs A 7.4, 7.5; *H 2.2*	Intro to Shock Waves A 7.6, 8.1-3; *H 6.3*
Week 3 (1/21-1/25)	Intro to Shock Waves A 7.6, 8.1-3; *H 6.3*	Isentropic Flow A 8.4-5; *H 6.2*	Normal Shock Waves A 8.6; *H 6.4*
Week 4 (1/28-2/1)	Nozzle Flow A 10.1-3; *H 6.4.11*	Nozzle Flow A 10.4-6; *H 6.4.11*	Unsteady 1D Gas Dynamics Not in Text
Week 5 (2/4-2/8)	2D Compressible Flow A 9.1-5; *H 6.5*	2D: Oblique Shock A 9.1-5; *H 6.6*	2D: Oblique Shock A 9.1-5; *H 6.6*
Week 6 (2/11-2/15)	2D: Shock/BL Interaction A 9.10; *H 8.12.3*	Review **EXAM 1**	2D: Prandtl-Meyer Expansion Fan A 9.6-9; *H 6.6*
Week 7 (2/18-2/22)	2D: Shock-Expansion Theory A 9.6-9; *H 7.1.4*	2D: Linearized Potential Flow A 11.1-3; *H 7*	2D: Linear Supersonic Theory A 12; *H 7.1.3*
Week 8 (2/25-3/1)	2D: Linear Subsonic Theory A 11.4-6, *H 7.1.2*	2D: Critical Mach number A 11.4-6; *H 7.1.1*	Transonic Flow A 11.8-15; *H 7.1.1*
Week 9 (3/4-3/8)	Transonic Flow A 11.8-15; *H 7.1.1*	Supercritical Airfoils, Swept wings, Area rule A 11.8-15; *H 7.1.2*	Review
Week 10 (3/18-3/22)	Hypersonic Flow - Intro A 14; *NIT*	Hypersonic – Heat Transfer A 14; *NIT*	Incompressible Flow over Airfoils A 4, 3.15-20; *H 4.1*
Week 11 (3/25-3/29)	Review **EXAM 2**	Thin Airfoil Theory A 4.8-9; *H 4.2-4*	Thick Airfoils A 3.17; *H 4.9*
Week 12 (4/1-4/5)	Panel Methods A 4.10-16; *H 4.10*	Stall and High-Lift Devices A 4.10-16; *H 4.5-8*	Viscous Flow 4.12; 15-20; *H 8.1*
Week 13 (4/8-4/12)	Boundary Layers 4.12; 15-20; *H 8.2-8*	Prandtl Lifting Line Theory A 5.1-3; *H 5.5.1,5.6*	PLLT: Elliptic Lift Distribution A 5.1-3; *H 5.5.3*
Week 14 (4/15-4/19)	PLLT: General Lift Distribution A 5.3.2-4; *H 5.5.4*	Tapered Wings; Rescaling L and D with AR; Twisted Wing A 5.3.2-4; *H 5.6-7*	Winglets, Delta Wings A 5.4-9; *H 5.6-7*
Week 15 (4/22-4/26)	Vortex Lattice Method A 5.4-9; *H 5.8*	Stability and Trim Not in Text	Review