

ENAE 674 – Aerodynamics of Compressible Fluids
Spring 2007

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Hours: Tuesday/Thursday 11:00 – 12:15 AM (Lecture)

Location: CSS 0201

Texts: Modern Compressible Flow with Historical Perspective, Anderson (LR Supplemental)
Elements of Gasdynamics, Liepmann and Roshko (TH Supplemental)
Compressible-fluid Dynamics, Thompson (TH Supplemental)
Introduction to Fluid Mechanics, Fox and McDonald (FM Supplemental)

Objective: Introduce students to the flow of inviscid, compressible fluids. Topics to be addressed include one-dimensional flow of a perfect gas, shock waves, the effects of heat transfer and friction, shock tubes, nozzle design using the method of characteristics, and potential flow solutions for two-dimensional situations.

Grading: 40% Homework
20% Midterm I
20% Final
20% Project

Homework: Will consist of problems from Anderson and supplemental problems posted on the website. Due dates will vary but you should expect approximately one homework assignment every 2 weeks. Homework will be collected and returned in class. Students taking the course through ITV can either e-mail me the homework by the due date or put it in the mail postmarked by the due date.

Exams: Will cover lecture material, problems from Anderson and the supplemental problems.

Project: To be determined.

Prereqs: Undergraduate courses in differential equations, thermodynamics, incompressible and compressible flow (ENAE 311 and ENAE 414 or ENME 331 or ENME 640 or equivalent).

Policies: Late and illegible/messy homework will not be accepted.

Supplemental readings		
#	Author	Title
1	Rutherford Aris	Vectors, Tensors and the Basic Equations of Fluid Mechanics
2	Ronald Panton	Incompressible Flow

Topical outline:

1. Introduction
2. Review of key concepts
 - a. Vector theorems
 - b. Indicical notation
 - c. Conservation equations
 - i Reynolds transport theorem
 - ii Integral and Differential forms of mass, momentum, and energy conservation
 - iii Unsteady Bernoulli
 - d. Thermodynamics
 - e. Crocco's equation
3. One-dimensional flow
 - a. Governing equations
 - b. Concept of 'total' conditions
 - c. Isentropic flow relations
 - d. Sonically referenced conditions
 - e. Normal shocks
 - f. Hugoniot relations
 - g. Fanno and Rayleigh lines
 - h. Flows with heat addition
 - i. Flows with friction
 - j. Detonations/Deflagrations
4. Oblique shock waves
 - a. Mach waves and the Mach angle
 - b. Property changes across oblique shocks
 - c. Graphical representations of oblique shock waves (shock polars and pressure-deflection diagrams)
 - d. Shock reflections and intersections
 - e. Intersecting shock waves
5. Expansion waves
 - a. Prandtl-Meyer expansion waves
 - b. Reflections from free boundaries
6. Simple supersonic flows over bodies
 - a. Airfoils and Shock-Expansion theory
 - b. Curved shocks
 - c. Detached shocks/3D effects
7. Quasi-one dimensional flow
 - a. Governing equations
 - b. Area-Mach number relation
 - c. Nozzles and diffusers
 - d. Wind tunnels
 - e. Inlet starting problem
 - f. Generalized One-Dimensional flow and 'Influence coefficients'
8. Unsteady wave motion
 - a. Property changes across a moving wave
 - b. Piston theory
 - c. Weak disturbances
 - d. Finite disturbances
 - e. Shock tubes
 - f. Method of characteristics
9. Potential flow
 - a. Velocity potential equation
 - b. Linearized 2-D: Pressure coefficients for thin airfoils and slender bodies
 - c. Conical flow
 - d. Transonic flow

10. Viscous effects
 - a. Compressible Couette flow
 - b. Shock thickness and viscous effects
 - c. Compressible boundary layers
11. Experimental methods
 - a. Pitot probes
 - b. Total temperature probes
 - c. Shadowgraph imaging
 - d. Schlieren imaging

NOTE: Topics 10 and 11 will be covered if there is time.

ENAE 674 – Tentative Schedule					
Lec.	Date	Reading (Anderson)	Lecture topics	Supplemental reading and topics	HW (Anderson)
1	1/25	1.1-1.7	Introduction, review of vector identities, indicial notation, thermodynamics	LR: 1.1-1.12 R1, R2, TH: 2.1-2.7	
2	1/30	2.1-2.8	Review of conservation equations	LR: 2.1-2.3, R1, FM: 4.2-4.7, 5.6, 5.7	
3	2/1	6.1-6.7	Review of conservation equations	LR: 2.4-2.6, R1	
4	2/6	3.1-3.5	Governing equations of 1-D flow	LR: 2.7-2.8	
5	2/8	3.6-3.7	Normal shocks and Hugoniot relations	LR: 2.13, TH: 7.1-7.4	
6	2/13	3.8-3.9	Flows with heat addition and friction	TH: 6.4	3.5, 3.8, 3.12
7	2/15	4.1-4.4	Oblique shocks	LR: 4.1-4.4.8, TH: 7.5-7.6	
8	2/20	4.5-4.6	Shock polar and reflected shocks from solid boundaries		4.4, 4.6, 4.9, 4.13
9	2/22	4.7-4.11	Pressure-deflection diagrams, intersecting shock waves, and detached shock waves		
10	2/27	4.13-4.14	Prandtl-Meyer expansion waves	LR: 4.9-11, TH: 9.1-9.2, 10.1-10.2	
11	3/1		Reflections of expansion waves	LR: 4.12-4.13	
12	3/6	5.1-5.4	Quasi-one dimensional flow, Area-Mach number relation. Possible Guest Lecturer	LR: 5.1-5.3	5.4, 5.9, 5.11, 5.14, 5.15
13	3/8	5.5-5.10	Nozzles and diffusers	LR: 5.4-5.6	5.18, 5.19
14	3/13		Influence coefficients		
15	3/15		Midterm I		
	3/20		Spring Break		
	3/22		Spring Break		
16	3/27		No lecture: 5 th US Combustion Inst. mtg.		
17	3/29	7.1-7.6	Unsteady wave motion	LR: 3.1-3.7	7.1-7.4
18	4/3	7.7-7.10	Shock tubes	LR: 3.8-3.12	7.5, 7.7, 7.8, 7.10, 7.11
19	4/5	11.1-11.4	Method of characteristics	LR: 12.1-12.5, TH: 9.3-9.5	
20	4/10	11.5-11.7	Method of characteristics	LR: 12.8-12.12	
21	4/12	8.1-8.3	Compressible potential flow		
22	4/17	9.1-9.7	Linearized 2-D: Thin airfoils and slender bodies	LR: 10.1-10.7	
23	4/19	10.1-10.3	Transonic flow, conical flow	LR: 11.1-11.5, TH: 10.3	
24	4/24		Compressible Couette flow	LR: 13.1-13.4	
25	4/26		Compressible laminar boundary layer	LR: 13.5-13.13.10	
26	5/1		Normal shocks with viscosity	LR: 13.12-13.13, TH: 8.11	
27	5/3		Compressible turbulent boundary layer	LR: 13.14-13.16	
28	5/8		Project presentations?		
29	5/10				
	5/12		Final exam 8:00 AM -10:00 AM		