ENAE 674 – Aerodynamics of Compressible Fluids
Spring 2014

Instructor: Christopher Cadou
3179D Glenn L. Martin Hall (EGR)
301-405-0829
cadou@eng.umd.edu

Hours: Tuesday/Thursday 12:30-1:45 PM (Lecture)

Location: EGR3102

Texts:
- Modern Compressible Flow with Historical Perspective, Anderson
- Elements of Gasdynamics, Liepmann and Roshko (LR 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 Canvas (umd.instructure.com). Due dates will vary but you should expect approximately one homework assignment every 2 weeks. Homework will be collected and returned in class.

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. Indicial 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	1/28	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	2/4	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	2/11	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	2/18	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	2/25	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	3/4		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	3/11	5.5-5.10	Nozzles and diffusers	LR: 5.4-5.6	5.18, 5.19
14	3/13		Midterm I		
	3/18		Spring Break		
	3/20		Spring Break		
15	3/25		Influence coefficients		
16	3/27	7.1-7.6	Unsteady wave motion	LR: 3.1-3.7	7.1-7.4
17	3/29	7.7-7.10	Shock tubes	LR: 3.8-3.12	7.5, 7.7, 7.8,.7.10, 7.11
18	4/1	11.1-11.4	Method of characteristics	LR: 12.1-12.5, TH: 9.3-9.5	
19	4/3	11.5-11.7	Method of characteristics	LR: 12.8-12.12	
20	4/8	8.1-8.3	Compressible potential flow		
21	4/10	9.1-9.7	Linearized 2-D: Thin airfoils and slender bodies	LR: 10.1-10.7	
22	4/15	10.1-10.3	Transonic flow, conical flow	LR: 11.1-11.5, TH: 10.3	
23	4/17		Compressible Couette flow	LR: 13.1-13.4	
24	4/22		Compressible laminar boundary layer	LR: 13.5-13.13.10	
25	4/24		Normal shocks with viscosity	LR: 13.12-13.13, TH: 8.11	
26	4/29		Compressible turbulent boundary layer	LR: 13.14-13.16	
27	5/1		Project presentations		
28	5/6		Project presentations		
29	5/8		Project presentations		
30	5/13		Project presentations		
	5/20		Final exam 1:30PM -3:30 PM		