EML 5709 **Fall 2010**

Fluid Mechanics

Van Dommelen

1 Catalog Description

Introductory conceps,description, and kinematical concepts of fluid motion, basic field equations, thermodynamics of fluid flow, Navier-Stokes equations, elements of the effects of friction and heat flow, unsteady one-dimensional motion, selected nonlinear steady flows.

2 Credit Hours

3

3 Prerequisites

Graduate standing in Mechanical Engineering. (Assumes undergraduate fluid mechanics.)

4 Textbooks

Panton, Ronald L, *Incompressible Flow.* John Wiley & Sons, Inc, Third Edition, 2005. ISBN-10 0-471-26122-X; ISBN-13 978-0-471-26122-3

The following references are useful:

1. Batchelor, G. K, *An Introduction to Fluid Mechanics.* Cambridge University Press 1988.
2. Currie, I. G, *Fundamental Mechanics of Fluids.* McGraw-Hill Second Edition 1993. ISBN 0-07-015000-1.
3. Karamcheti, Krishnamurty *Principles of Ideal–Fluid Aerodynamics.* Robert E. Krieger Publishing Co, 1980.
4. Liepmann, H. W, and Roshko, A, *Elements of Gasdynamics.* John Wiley & Sons, 1957.
5. Schlichting, H, *Boundary Layer Theory.* McGraw-Hill, 1968.
6. Spiegel, Murray R, *Complex Variables.* Schaum's Outline Series, McGraw-Hill, 1964. ISBN 07-060230-1.
7. Homsey, G.M., *Multimedia Fluid Mechanics DVD-ROM* Cambridge University Press[1]

5 Instructor

Dr. Leon Van Dommelen:

Office hours M 5-6 pm, T 2:30-3:30 pm, F 10-11 am, or by appointment, in A242 CEB[2]

Phone (850) 410-6324. I tend to forget to check my voice mail.

E-mail dommelen@eng.fsu.edu

Web page `http://www.eng.fsu.edu/~dommelen/index.html`

Contact information See web page[3]

[1] `http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521721691`
[2] `http://www.eng.fsu.edu/~dommelen/contact`
[3] `http://www.eng.fsu.edu/~dommelen/contact`

6 Teaching Assistant

None

7 Schedule

Class times: MWF 12:55-1:45 in A125 CEB (A building).
Schedule:

- 08/23/10 M
- 08/25/10 W [1 Kinematics: to PIV of jelly fish]
- 08/27/10 F [2 Kinematics: Fields and Euler/Lagrange, to Blasius]
- 08/30/10 M [3 Kinematics: Flow lines, to Onera visualization]
- 09/01/10 W Due: HW 1 [4 Kinematics: The material derivative, to Stokes]
- 09/03/10 F [5 Summarize the deformation of continuous media movie on the class movie page[4]]
- 09/06/10 M LABOR DAY
- 09/08/10 W Due: HW 2 [6 Control Volumes: Intro, to stationary versus moving]
- 09/10/10 F [7 Kinematics: Compressible and incompressible flow, to Newton]
- 09/13/10 M [8 Control Volumes: conservation of mass]
- 09/15/10 W Due: HW 3 [9 Control Volumes: conservation of momentum, to fire hose example]
- 09/17/10 F [10 Control Volumes: elbow, airfoil examples. Take with grain of salt]
- 09/20/10 M [11 Control Volumes: Energy conservation]
- 09/22/10 W [12 Kinematics: 2D Flow and Vorticity. Ignore streamfunction.]
- 09/24/10 F Due: HW 4 [13 Dynamics: 168-172 and Turbulence: 800-802 (CFD)]
- 09/27/10 M [14 Dynamics: Navier-Stokes equations, to unsteady airfoil]
- 09/29/10 W Due: HW 5 [15 Dynamics: Boundary conditions]
- 10/01/10 F [16 Similarity and scaling: Virtual labs: oscillation in a U tube]
- 10/04/10 M [no video]
- 10/06/10 W Due: HW 6 [17 Dynamics: Reynolds Number: 191-199]
- 10/08/10 F [18 Similarity: Dimensionless numbers: 521-530]
- 10/11/10 M [no video]
- 10/13/10 W Due: HW 7 [no video]
- 10/15/10 F Mid Term Exam

[4] `http://www.eng.fsu.edu/~dommelen/courses/flm/movies/`

- 10/18/10 M [19: Dynamics: 162, 165, 192, 193, 198. Similarity: 505]
- 10/20/10 W Due: HW 8 [no video]
- 10/22/10 F [no video]
- 10/25/10 M [no video]
- 10/27/10 W Due: HW 9 [20: Dynamics: Potential flows 270-276]
- 10/29/10 F Last day to drop [21: Kinematics: 2D flow and vorticity]
- 11/01/10 M [22: Dynamics: Potential flows 277-287]
- 11/03/10 W [23: Kinematics: Streamlines and the streamfunction]
- 11/05/10 F Due: HW 10 [no video]
- 11/08/10 M [no video]
- 11/10/10 W [no video]
- 11/12/10 F Due: HW 11 [24: Dynamics: Forces: 245-251]
- 11/15/10 M [25: Dynamics: Forces: 252-260]
- 11/17/10 W [26: Dynamics: Forces: 261-269]
- 11/19/10 F Due: HW 12 [no video]
- 11/22/10 M [27: Boundary layers: 602-611]
- 11/24/10 W Due: HW 13 [28: Boundary layers: 622-624,629-636]
- 11/26/10 F THANKSGIVING ==========
- 11/29/10 M [29: Boundary layers: 638-648]
- 12/01/10 W [30: Boundary layers: 676-685]
- 12/03/10 F (Review) Due: HW 14 [no video]
- 12/06/10 Monday 10-12 noon Final (in the usual classroom).
- 12/14/10 FSU grades due 4:00 pm
- 12/15/10 FSU grades available online

8 Goals

- Refresh the students' memory about undergraduate fluid mechanics.
- Introduce students to the fundamentals of graduate Fluid Mechanics.
- Introduce techniques of dealing with the partial differential equations of fields.
- Help students prepare for the Ph.D. Preliminary exam.

9 Course Outline

The course will likely cover:

- *Definitions.* Fluids, material regions, control volumes.
- *Continuum Mechanics.* The continuum approximation and its limitations. Free path length. Density and velocity.
- *Kinematics* Lagrangian and Eulerian derivatives. Particle paths, streamlines, steady flows. Lagrangian and Eulerian time derivatives. Decomposition of particle evolution in strain and rotation. Vorticity. Linear shear flow. Circulation.
- *Basic Laws.* Integral conservation of mass, momentum, and energy and the second law in integral and differential forms. Reynolds transport/Leibnitz theorem. Divergence theorem. Relationships to computational fluid dynamics. Stress tensor. Inviscid flow. Expansion coefficient. Integral conservation laws for arbitrary regions.
- *Newtonian Fluids.* Newtonian and inviscid stress tensors, Stokes' hypothesis. Fourier's law. Navier-Stokes equations.
- *Example Incompressible Flows.* Duct flow, Bernoulli law, effects of viscosity, entrance length, friction factor, critical Reynold number, head loss. Stokes' second problem, similarity.
- *Vorticity Dynamics* Vorticity and circulation. Kelvin's theorem. Boundary layers and wakes. Starting vortices.
- *2D Ideal Flows* Velocity potential and streamfunction. Boundary conditions. Bernoulli law for unsteady potential flows.
- *Boundary Layers.* The limit of small viscosity: boundary layer equations. Boundary layer along a flat plate and similarity. Boundary layer thickness, wall shear, displacement thickness.
- *Turbulent Flows.* Reynolds decomposition, Reynolds stresses, mixing length and dimensional analysis models.

10 Methods of Instruction

Lectures, problem solving sessions, examinations, web-based information.

11 Student Evaluation

The course grade will be computed as:

- Homework: 20%
- Midterm: 40%
- Final: 40%

Historically, the B/B– boundary has been at 75%.
Grading is at the discretion of the instructor.
You can miss two homeworks, their grades will be taken from the average of your other grades. You still need to know the material for the final, but you can study the posted solutions.

12 Important Regulations

Must check dates

Immediately check all dates listed in this syllabus for any conflicts.

Honor policy

Students are expected to uphold the Student Code of Conduct, Academic Honor Code published in their University Bulletin and/or Student Handbook. You must read your honor policy if you have not yet done so. Violations of your honor code may result in reduced grades and more serious actions.

Students are bound by their university's Academic Honor Code and are subject to sanctions if they are found in violation of the Code. Possible sanctions include but are not limited to: (1) a failing grade on an exam or assignment, (2) a failing grade in the course, (3) dismissal from the academic program, or (4) dismissal from the university.

Florida A&M Student Code of Conduct as published in the Student Handbook. Academic Dishonesty.[5]

The Florida State University Academic Honor Policy outlines the University's expectations for the integrity of students' academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process. Students are responsible for reading the Academic Honor Policy and for living up to their pledge to "... be honest and truthful and ... [to] strive for personal and institutional integrity at Florida State University." (Florida State University Academic Honor Policy[6].)

Homework

Homework should be neat.

Working together on homework is encouraged, but copying is not allowed.

Homework must be handed in at the *start* of the lecture at which it is due. It may *not* be handed in at the departmental office or at the end of class. Homework that is not received at the start of class on the due date listed above cannot be made up unless permission to hand in late has been given *before* the homework is due, or it was not humanly possible to ask for such permission before the class. If there is a chance you may be late in class, hand the homework in to the instructor the day before it is due. (Shove it under his door if necessary.) This also applies to Web students: they must E-mail the homework before the time the class starts.

Copying

Copying of homework, assignments, or tests is never allowed and will result in a failing or zero grade for the copied work, and other actions. It will also result in a failing or zero grade of the person whose work is being copied if that person could reasonably have prevented the copying.

However, *working together* is typically allowed and encouraged for most homeworks, (and sometimes for other take-home assignments,) as long as you present the final results in your own words and using your own line of reasoning. Since close similarities between solutions will reduce credit, it is better not to formally put down anything until you have figured out the problem, and then let each person write their own solution. If it is unclear whether working together is allowed on any assignment, check with the instructor beforehand.

Attendance

FSU students are dropped if not present the first day of classes. FAMU students are dropped if not attending at the end of the first week.

Excused Absences: Absence for participation in recognized university activities, properly certified personal illness, or recognized emergencies may be excused by the Dean's office. Please note that the College of Engineering has a restrictive interpretation of what is considered a valid excuse for an absence. If an

[5] `http://www.famu.edu/index.cfm?judicialAffairs&StudentCodeofConduct`

[6] `http://www.fsu.edu/~dof/forms/honorpolicy.pdf`

absence is to be excused, make sure you check beforehand. In case of excused absence, the instructor will work with you to help you make up for missed time and catch up or have an I grade assigned.

The instructor will make sure that make-up tests are no simpler than the original, but he will try to make them similarly difficult. However, he cannot make allowances for increased difficulty due to the small sample size.

Unexcused Absences: An undergraduate student having more than four unexcused absences will be dropped from the course and assigned the grade F. Tests and exams missed because of unexcused absence receive the grade 0.

Daily e-mail check: Students must daily check their e-mail at the address they provided at the start of class. They must ensure that they receive an welcome e-mail at the beginning of the semester, or contact the instructor to correct their recorded e-mail address immediately. Any test, exam, or homework that the student did not know about since the student did not check their e-mail that day receives a zero grade. No exceptions.

Failure to properly complete homework, tests, assignments, etcetera due to changes in date, assignment, etcetera, that you did not know about due to unexcused absence, lateness, or inattentiveness will not be excused and cannot be made up.

Departmental

The Department's Policy is clearly outlined at the following web location:

`http://www.eng.fsu.edu/me/ugradpro/classes/policy/index.html`

College

College of Engineering Undergraduate Policy: As current policy, the College does not use plus +, or minus − grades in engineering courses (page 4, COE Handbook[7]). A student may continue in the B.S. degree program unless one or more of the following conditions arise (page 5, COE Handbook[8]):

1. A grade below C in the second attempt of the same engineering course
2. More than three (3) repeat attempts in engineering courses.
3. Violation of academic honor code as defined in university bulletin or catalog
4. Use of grade forgiveness (currently available for FAMU students only) in more than two (2) courses.

ADA

Some of these rules may not apply if you fall under the Americans with Disabilities Act.

Students with disabilities needing academic accommodation should:

- register with and provide documentation to the appropriate university office. For FAMU students, this is the Learning Development and Evaluation Center (LEDC). For FSU students this is and Student Disability Resource Center (SDRC);
- bring a letter to the instructor indicating the need for accommodation and what type.

This should be done during the first week of class.

For more information about services available to students with disabilities:

- FAMU Students should contact the Learning Development and Evaluation Center (850)599-3180;
- FSU Students should contact the Student Disability Resource Center (850) 644-9566.

Exceptions

The instructor might wave some regulation on a case-by-case basis depending on his subjective determination of fairness and appropriateness. This will occur only under exceptional circumstances and should not be assumed. Especially, never assume that a seemingly minor regulation will be waived because the

[7] `http://www.eng.fsu.edu/documents/handbook1.pdf`
[8] `http://www.eng.fsu.edu/documents/handbook1.pdf`

instructor has waived it in the past. A second appeal to waive a minor regulation will probably indicate to the instructor that the regulation is not being taken seriously and most likely refused. Any appeal to the instructor will further be refused a priori unless it is made at the earliest possible moment by phone and/or by E-mail. Do not wait until you are back in town, say.

Change policy

Except for changes that substantially affect implementation of the grading policy or grading scale, this syllabus is a guide for the course and subject to change with advance notice.

13 Computer Requirements

Students must have an E-mail address and daily check their E-mail. Students must be able to use a Web browser such as Firefox. The class web page can be accessed at:

`http://www.eng.fsu.edu/~dommelen/courses/flm`

If you are taking this class remotely, contact the FEEDS office[9] for requirements.

[9] `http://www.eng.fsu.edu/feeds`