Boundary Layers and Convection
ASEN-5519-004
Spring Semester 2019

Syllabus

Time: Tue. & Thurs. 3:30pm-4:45pm

Location: ECCR 139

Instructor: Asst. Prof. John Farnsworth
Office: ECNT 118
Phone: (303)735-7287
Email: john.farnsworth@colorado.edu
Office Hours: Tues. 12:30pm - 1:30pm & Thurs. 2:00pm - 3:00pm

Course Assistant/Grader: Swapnali Parab
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Website: Canvas (https://canvas.colorado.edu)

Objective: To establish a fundamental understanding of the theory associated with viscous flow and to introduce methods for performing engineering calculations of skin friction and heat transfer rates.

Description: This course presents an introduction to the principles of viscous fluid flow and methods for performing engineering calculations of quantities such as skin friction and heat transfer rates in boundary layers. The first portion of the course material will focus on basic principles of fluid mechanics. We will derive the Navier-Stokes equations and discuss some simple solutions to these equations. The second portion of the course will concentrate on the application of these principles to boundary layers. We will derive the boundary layer equations and discuss their approximate and almost exact solutions.

Prerequisites: Graduate Fluids (ASEN 5051), B+ or better in Aerodynamics (ASEN 3111) or permission of instructor.

Required Text:
F. White, *Viscous Fluid Flow*. McGraw-Hill, 3rd ed., 2006. (Any Edition is Acceptable)
Webpage: https://www.mheducation.com/highered/product/viscous-fluid-flow-white/M0072402318.html

Supplemental References:
1. J. Schetz and R. Bowersox, *Boundary Layer Analysis*. AIAA Education Series, 2nd ed., 2011. **Webpage:** https://arc.aiaa.org/doi/book/10.2514/4.868245

Online Supplemental Material: https://arc.aiaa.org/doi/suppl/10.2514/4.868245/suppl_file/index.html

2. H. Schlichting and K. Gersten, *Boundary Layer Theory*. Springer, 9th ed., 2017.
Webpage: https://www.springer.com/us/book/9783662529171
Note: *An electronic copy of this book can be downloaded through the publisher webpage (above) while you are connected to the CU Campus Network as a part of the CU Library subscriptions.*

Content: An outline of the course content is included below:

1. Introduction to viscous flows.
2. Concept of a fluid; Kinematics of fluid motion; Properties of a fluid.
3. Conservation laws for a continuum: mass, momentum and energy; Navier-Stokes equations.
4. Simple viscous solutions of Navier-Stokes equations, for example: Couette flow, Poiseuille flow.
5. Boundary layer equations; Incompressible boundary layers: Flow over a flat plate, Falkner-Skan solution, separation, stability, transition to turbulence, approximate solution techniques.
6. Thermal boundary layers: uncoupled solution to energy equation.
7. Compressible boundary layers: energy integral and Reynolds analogy.
8. Computational approaches applied in all topics.

Student Learning Outcomes: The basic learning objectives for the course are outlined below:

1. Understand concept of viscous fluid flows and basic conservation laws (to derive basic governing equations).
2. Be able to find solution to simple viscous flows.
3. Ability to derive boundary layer equations and find their solution (including similarity analysis and integral methods).
4. Develop basic understanding of transition and turbulence as well as compressible boundary layers.

Class Format: The class meets twice a week for an hour and fifteen minutes of formal lecture and discussion. Prior to lecture students should complete the assigned readings to come prepared for lecture and discussion. Random, spot reading quizzes will be conducted to asses preparedness and reward class attendance and participation. Homework problems will be assigned on a weekly basis due one week from the day assigned. Two exams, one mid-term and one final, will be utilized to asses the students aptitude in the course material.

Grading: The following presents the planned grading structure for the course. Be aware, that this is subject to change, however the class will be thoroughly notified and polled for agreement.

Spot/Pop Reading Quizzes	10%
Homework Assignments	20%
Mid-term Exam	35%
Final Exam	35%
Total	**100%**

-Grades will be posted to the class website (Canvas).

Important Notes:

1. Homework assignments will be posted weekly on Tuesdays and are due the following on Wednesday by 5pm placed either in the instructors mail box (ECAE 197) or under the instructors office door (ECNT 118). That said it is recomended that you turn the assignments in by the start of class on the Tuesday prior to the due date. If you must miss class for an excused absence, you may submit your homework early. Late assignments are aged as follows: 1) before start of next class period (90%), 2) before start of second class period (80%), and 3) before solution is posted (50%).
2. Collaboration is permitted on homework. You may discuss the means and methods for formulating and solving problems and even compare answers, but you are not free to copy someone's assignment. **Copying material from any resource (including solutions manuals) and submitting it as one's own is considered plagiarism and is an Honor Code violation (and will be reported as such). Remember, the less you think about the problems yourself, the less you actually learn, and the more difficult it will be to succeed on exams (which are worth 70% of your final grade).**
3. Collaboration on quizzes or exams, using another student's work as your own, or allowing another student to use your work as their own is academic misconduct and is not tolerated. If you are caught in any of these activities, you will receive a grade of "F" for the course and a report as an Honor Code Violation for further review and action.
4. Attendance to all scheduled lecture/discussion periods is expected. In addition to announced exams, random quizzes may be given during any lecture/discussion. Like the scheduled quizzes and exams, there are no make-ups.
5. Some assignments require access to a computer, basic programming skills, and familiarity with some programming languages and/or environments similar to what is covered in introductory computing courses.
6. This class is not graded on a "curve"; there are absolute expectations of performance. However, we reserve the right to normalize the class grades based on the highest performance in the class.

Final Exam Policy: The final examination will administered during the assigned final exam period for the course and will be cumulative for the semester. Collaboration on the exam will not be tolerated. Students who are caught in violation of these policies will receive an "F" for the course and reported to the Dean's office for further punitive action. Additionally students

should be aware of the university's Final Exam Policy.

Exam Schedule:

Mid-term Exam:
Date: Tuesday 12 March 2019
Time: 3:30pm - 4:45pm
Location: ECCR 139

Final Exam:
Date: Sunday 5 May 2019
Time: 4:30pm - 7:00pm
Location: ECCR 139 (tentative)

Accommodation for Disabilities: If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website.

Classroom and On-Campus Behavior: Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the Student Code of Conduct.

Discrimination and Harassment: The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Honor Code: All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Religious Holidays: Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, you must let the instructors know of any such conflicts within the first two weeks of the semester so that we can work with you to make reasonable arrangements. For full details see the campus policy regarding religious observances.

Schedule (Tentative)

Week	*Dates*	*Tuesday*	*Thursday*	*Assignments*
1	Jan. 15 & 17	Syllabus and Introductory Thoughts	1.3 - Properties of a Fluid 1.4 - Boundary Conditions	**R:** 1.1 - 1.4
2	Jan. 22 & 24	1.3 - Properties of a Fluid 1.4 - Boundary Conditions	2.3 - Cons. of Mass 2.4 - Cons. of Momentum	**R:** 2.1 - 2.4
3	Jan. 29 11 & 31	2.5 - Cons. of Energy 2.8 - Math. Char. of Eqns.	2.9 - Non-dimensional Form 2.10 - Vorticity	**R:** 2.5 - 2.10
4	Feb. 5 & 7	2.11 - Stream Function 2.12 - Non-inertial	2.13 - Control Volume 3.2 - Couette Flow	**R:** 2.11 - 3.3
5	Feb. 12 & 14	3.3 - Poiseuille Flow	3.6 - Asymptotic Suction 3.8 - Similarity Solutions	**R:** 3.4 - 3.10
6	Feb. 19 & 21	3.8 - Similarity Solutions	4.1 - Laminar BLs 4.2 - Lam. BL Eqns.	**R:** 4.1 - 4.3
7	Feb. 26 & 28	4.3 - BL Sim. Sols. (Blasisus Soln)	4.3 - BL Sim. Solns. (Falkner Skan Solns)	**R:** 4.3
8	Mar. 5 & 7	4.4 - Free Shear Flows (Plane Jet)	4.4 - Free Shear Flows (Plane Wake) - Review	**R:** 4.4
9	Mar. 12 & 14	**Mid-Term Exam**	4.12 - 3D Laminar BLs	**R:** 4.12
10	Mar. 19 & 21	5.1 - Stability of Laminar Flows (K-H Instability)	5.2 - Stability of Parallel Viscous Flow (O-S Eqn.)	**R:** 5.1-5.2
11	Mar. 26 & 28	**No Class** (Spring Break)	**No Class** (Spring Break)	
12	Apr. 2 & 4	5.3 - Parametric Effects of Linear Stability Theory	**No Class** (Prof. Farnsworth on Travel)	**R:** 5.3
13	Apr. 9 & 11	5.4 - Transition to Turbulence	5.5 - Engineering Prediction of Transition	**R:** 5.4 - 5.5
14	Apr. 16 & 18	6.1 - Turbulent Mean Flow 6.2 - Reynolds Equations	6.3 - Turbulent BL Eqns 6.4 - Turb. Velocity Profiles	**R:** 6.1 - 6.4
15	Apr. 23 & 25	6.5 - Turbulent Pipe and Channel Flow	6.6 - Turbulent BL on Flat Plate	**R:** 6.5 - 6.6
16	Apr. 30 & May 2	6.7 - Turbulence Modeling 6.9 - Free Turbulence	Catch-Up & Review	**R:** 6.7 - 6.10