

**Boundary Layers and Convection**  
**ASEN-5121-001(B)**  
Spring Semester 2022

**Syllabus**

(Revised by: J. Farnsworth - January 14, 2022)

**Time:** Tue. & Thurs. 2:30pm-3:45pm

**Physical Classroom:** AERO N240

**Instructor:** Asst. Prof. John Farnsworth

Office: AERO 365

Phone: (303)735-7287

Email: [john.farnsworth@colorado.edu](mailto:john.farnsworth@colorado.edu)

Office Hours: TBD

**Website:** Canvas (<https://canvas.colorado.edu>)

*copies of the individual chapters can be downloaded from the above site. A physical copy of this book has also been placed on the course reserves at the Gemmill (Engineering, Math, Physics) Library.*

**Supplemental References:**

1. F. White, *Viscous Fluid Flow*. McGraw-Hill, 3rd ed., 2006.

**Webpage:** <https://www.mheducation.com/highered/product/viscous-fluid-flow-white/M0072402318.html>

**Note:** *There is no electronic/online access to this book from the CU Library, but a physical copy of this book has also been placed on the course reserves at the Gemmill (Engineering, Math, Physics) Library.*

- Pohlhausen Method
- Thwaites-Walz Method
- Impact of Suction & Injection
- Integral Energy Equation
- Unheated Starting Length Problem
- Varying Wall Temperature & Pressure Gradients
- Integral Species Equation
- Relationship between Wall Friction, Heat Transfer, & Mass Transfer
- 3. Incompressible Laminar Boundary Layer Flows
  - Exact Solutions for Parallel Flows (Couette, Poiseuille, Stokes Flows)
  - Similarity Solutions for the Momentum Equation
  - Blasius Solution for a Flat Plate
  - Falkner-Skan Solutions for a Flat Plate with Pressure Gradient
  - Similarity Solutions for the Energy Equation
  - Similarity Solutions with Suction & Injection
  - Summary of Numerical Solution Methods
- 4. Compressible Laminar Boundary Layer Flows
  - Viscous Heating
  - Influence of Prandtl Number
  - Compressibility Transforms
  - Integral Method for Compressible Flow
  - Solution for Compressible Flow over a Flat Plate
  - Stagnation Point Solutions for Compressible Flow
  - Flows with Mass Transfer
  - Real Gas Effects
  - Pressure Gradients & Separation in High-Speed Flows
  - Interactions in Hypersonic Flows
- 5. Laminar Free Shear Flows
  - Simple Shear Layers
  - Jets & Wakes
- 6. Transition to Turbulent Flows
  - Stability of Laminar Flows (In General)
  - Stability of an Inviscid Flows (Kelvin-Helmholtz Instability)
  - Stability of Parallel Flows
  - Prediction of Transition
  - Classification & Evolution of Transition

Impact of Freestream Turbulence, Pressure Gradient, Wall Roughness, Mach Number, Suction/Injection, and Heating/Cooling on Transition

7. Incompressible Turbulent Boundary Layer Flows

The Nature of Turbulent Flow

Reynolds-Averaged Navier-Stokes Equations

Description of the Mean Flow over a Flat Plate

Effect of Roughness, Suction/Injection, & Pressure Gradient

Other Empirical Turbulence Information

Mean Flow Integral Methods

Mean Flow Model for Eddy Viscosity and Mixing Length

Summary of other Turbulence Modeling Approaches

**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:**

Concept Quizzes	10%
Homework Assignments	25%

and analysis project will be assigned in place of regular homework assignments. The project will include two parts: 1) the analysis of experimental boundary layer data (provided by the instructor) and 2) the computational simulation of boundary layers using computational fluid dynamics. As part of this project, students will be expected to demonstrate the prediction and analysis methods and tools developed through the semester on actual boundary layer data to demonstrate a comprehensive understanding of the subject. The project will be due by 11:59pm on April 28, 2022 (the last day of class). To summarize the project activities and results students will each submit a report, no longer than 10 pages inclusive of all figures, tables, and references in a PDF format to Canvas.

As with the homework assignments, collaboration is permitted, but students are each expected to complete an individual project, in full. 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 textbooks, technical papers and reports) and submitting it as one's own is considered plagiarism and is an Honor Code violation (and will be reported as such).** Additionally, each report will be analyzed for plagiarism to ensure that it is the original work of the student. Additional details on the expectations and implementation will be provided when the project is officially assigned and released to the students around week 10 (the week before spring break).

**Concept Exams:** Three concept exams, two mid-term and one final, will be utilized to assess the students' aptitude in the course material. The exams will be closed-book and collaboration will not be permitted. The exams will focus on conceptual assessment of understanding of the content discussed in the class. Much of the content covered in these exams will build on the content taught in the course.

**Exam Schedule:**

**Mid-term Concept Exam 1:**

Date: Thursday 10 February 2022

Time: 2:30pm - 3:45pm

Location: AERO N240

**Mid-term Concept Exam 2:**

Date: Thursday 17 March 2022

Time: 2:30pm - 3:45pm

Location: AERO N240

**Final Concept Exam (Cumulative):**

Date: Sunday 01 May 2022

Time: 4:30pm - 7:00pm

Location: AERO N240 (tentative)

**Classroom Behavior:** Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. 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. For more information, see the policies on [classroom behavior](#) and the [Student Conduct & Conflict Resolution policies](#).

**Requirements for COVID-19:** As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to [Student Conduct and Conflict Resolution](#). For more information, see the policy on [classroom behavior](#) and the [Student Code of Conduct](#). If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity

and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the [Public Health Office \(contacttracing@colorado.edu\)](mailto:contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the [Public Health Office \(contacttracing@colorado.edu\)](mailto:contacttracing@colorado.edu).

**Class Specific Policies:** Generally speaking, late submissions of assignments will not be accepted, and there will be no make-up quizzes or exams. That being said please contact the instructor if you are unable to submit an assignment or take a quiz or exam due to illness, technical issues, or other challenging extenuating circumstances. Reasonable accommodations will be made, where appropriate, provided you contact the instructor before the assignment due date or quiz/exam date. Specifically, students should contact the professor via a direct email at least 24hrs ahead of the specific deadline or quiz/exam. During standard class periods, when exams are not being administered, students are not required to notify the professor of absences due to illness and quarantine. If a student tests positive for COVID-19, they are NOT required to disclose this to the professor. Note that based upon current health situation of the professor and/or students, the professor may move class or office hours to a remote format in order to protect the health and safety of the full class. For these situations, the professor will aim to provide the class notification at least 24hrs ahead of time via an announcement through the course website.

**Accommodations 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](mailto:dsinfo@colorado.edu) for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) on the Disability Services website.

**Preferred Student Names and Pronouns:** CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

**Honor Code:** All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: 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](mailto:honor@colorado.edu); 303-492-5550). Students 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 on the [Honor Code website](#).

**Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation:** CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against 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 email [cureport@colorado.edu](mailto:cureport@colorado.edu). Information about university policies, [reporting options](#), and the support resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](#).

**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, please notify the professor as soon as possible and at least one week prior to any assignment deadline or exam/quiz which conflicts with religious obligations; so that appropriate accommodations can be made.

See the [campus policy regarding religious observances](#) for full details.

## Schedule (Tentative)