AAE 51100
Introduction to Fluid Mechanics
Fall 2020

MWF 12:30–1:20 PM, WANG 2555

Credits: 3.0, CRN: 10078

https://purdue.brightspace.com/d2l/home/47920

Instructor

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Teaching Assistant

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Course Description

The basic conservation equations are derived for a compressible viscous fluid, and then are specialized for applications in potential flow, viscous flow, and gas dynamics. The course begins with an overview of algebra and calculus with Cartesian tensors. It moves on to cover fluid kinematics, integral and differential conservation equations for compressible flow, constitutive equations, and vorticity dynamics. The next unit of the course focuses on incompressible potential flow, covering complex analysis, velocity potential, stream function, the method of images, conformal mapping, the Schwarz-Christoffel Transformation, and axisymmetric and three-dimensional potential flow. The final unit of the course emphasizes incompressible viscous flow, including viscosity-dominated flow, creeping flow, laminar boundary layers, laminar-turbulent transition, and turbulent flow.

Prerequisites

An undergraduate course in fluid mechanics, such as AAE 333 or ME 309, although some students with backgrounds in physics or computer science have successfully taken this course without having had a previous course in fluid mechanics. A successful student will need a working knowledge of vector calculus and ordinary differential equations, some understanding of partial differential equations and complex variables, and an ability to program in Matlab or python.

Course Notes

The lecture notes will be made available on Brightspace. The notes contain copyrighted material; therefore, do not post the PDF files on the Internet or share them with anyone not enrolled in this class this semester. They are only intended for the benefit of students in this course. The same copyright restrictions apply to homework assignments and solutions.

Course Level

The material in this course is taught at an introductory graduate level. AAE 511 is intended to be a master's level course. It is also an appropriate course to broaden or strengthen the background of doctoral students. Undergraduate students have successfully completed this course, and some have done very well. Generally speaking, however, this course has proved to be a challenge to undergraduates. Therefore, I recommend undergraduate students meet with me to discuss whether they should take this course.

Recommended Text

Fundamental Mechanics of Fluids (Fourth Edition)
I. G. Currie, CRC Press 2013, ISBN 9781439874608
https://www.crcpress.com/Fundamental-Mechanics-of-Fluids-Fourth-Edition/Currie/p/book/9781439874608

Learning Outcomes

Students will develop a strong foundation in the fundamentals of fluid mechanics, including the following skills:

- Demonstrate mastery of essential technical material in the area of aerodynamics
- Formulate and solve fluid mechanics problems
- Communicate technical information in clear, concise writing
- Develop skills and experience that enable life-long learning and good professional conduct

Assignments

There will be weekly homework assignments, except during the weeks of the exams. Assignments will generally be made available on Fridays and due on the second following Monday (after 10 days). The homework problems will be posted on Brightspace, and students are responsible for accessing them and submitting the solved problems online by the due date. No late homework is allowed (without special arrangements made for extraordinary circumstances).

You may get help from one another on the homework, but you must hand in your own work. All sources and collaborations must be appropriately cited in homework and projects: list these at the end of the homework that you turn in. **Copying homework solutions from others is cheating and will be treated as a violation of academic integrity standards.** The work must be legible and well organized. If the homework requires writing a computer program, then a listing of the program must be turned as part of your solution. Some of the homework problems will require the use of Matlab or python. You are encouraged to attend the online office hours to get help with the homework, including help with programming, if needed.

Grading

The grading in the course will be based upon scores on the homework and exams with the following weights:

Homework	30%	
Midterm Exam I	20%	TBA: around Oct. 1
Midterm Exam II	20%	TBA: around Nov. 10
Final Exam	30%	TBA: week of Dec. 7

Note: exams may require the use of a calculator for some problems. An acceptable calculator is either the TI-30Xa or TI-30XIIS scientific calculator, in accordance with AAE department policy.

In the event of a major campus emergency or other unusual circumstances, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. To get information about changes in this course, check the course website (Brightspace) and contract the instructor by email (jpoggie@purdue.edu).

Guidance in the Event of Quarantine or Isolation

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email. We will make arrangements based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

Course Schedule

A separate document will be posted on Brightspace providing the course schedule. The initial course schedule will be approximate. Check Brightspace frequently for updates.

Attendance Policy during COVID-19

Students should stay home and contact the Protect Purdue Health Center (496-INFO) if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades. All lectures will be recorded, and they will be available on Brightspace for all students in the class. Nonetheless, the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via email or phone at 765-494-1747. Our course Brightspace includes a link on Attendance and Grief Absence policies under the University Policies menu.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask in classrooms and campus building, at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Related Considerations:

1. *A listing of recommended safe practices for the specific class or laboratory setting (other PPE or safety behavior) can be found at the links below.*
    - Overarching SOP for Classrooms, Instructional Laboratories, and Experiential Courses
2. *References Supporting Protect Purdue Compliance:*
    - Office of the Dean of Students Protect Purdue Compliance Plan: Ask, Offer, Leave, Report
    - Office of the Dean of Students Managing Classroom Behavior and Expectations

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. More details are available on our course Brightspace table of contents, under University Policies.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247. More details are available on our course Brightspace under Accessibility Information.

Mental Health Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email. You are expected to read your @purdue.edu email on a frequent basis.

If you experience any symptoms of COVID-19 or suspect you may have been exposed to someone with COVID-19 stay home and call the Protect Purdue Health Center at 765-496-INFO. Keep your cell phone on to receive a

Purdue ALERT text message, but please silence it during class. The computer at the instructor's podium is connected to the Purdue network, and it will receive any Desktop Popup Alerts.

Outline
AAE 511

Governing Equations

I. Basic Conservation Laws
- A. Introduction
- B. Review of Vector Analysis and Tensor Index Notation
- C. Conservation of Mass
- D. Conservation of Momentum
- E. Conservation of Energy
- F. Constitutive Relations
- G. Global Conservation Laws
- H. Summary of Governing Equations
- I. Nondimensionalization

II. Flow Kinematics, Vortex Dynamics, and Alternate Forms of the Governing Equations
- A. Flow Lines
- B. Circulation
- C. Vortex Lines
- D. Helmholtz's Vorticity Theorems
- E. Kelvin's Theorem
- F. Euler Equations
- G. Bernoulli's Equation
- H. Euler n-Equation
- I. Vorticity Equation
- J. Inviscid Motion of Vortex Lines
- K. Equations of Motion in Non-Inertial Reference Frames

Ideal Fluid Flow

III. Two-dimensional Potential Flow
- A. Velocity Potential
- B. Stream Function
- C. Boundary Conditions
- D. Complex Potential
- E. Review of Complex Variables
- F. Complex Velocity
- G. Basic Flows
- H. Flows in Sectors and Around Corners
- I. Method of Images & the Milne-Thomson Circle Theorem
- J. Circular Cylinder with Circulation

K. Blasius Integral Laws
L. Conformal Mapping
M. Kutta Condition
N. Schwarz-Christoffel Transformation

IV. Three-dimensional Potential Flow
A. Velocity Potential and Stream Function for Axisymmetric Flows
B. Basic Flows
C. Butler's Sphere Theorem
D. D'Alembert's Paradox
E. Apparent Mass (Added Mass)
F. Non-Axisymmetric Flows

Viscous Flows of Incompressible Fluids

V. Exact Solutions
A. Couette Flow
B. Poiseuille Flow
C. Stokes' First and Second Problems
D. Other Exact Solutions

VI. Boundary Layers
A. Boundary Layer Approximation
B. Blasius Solution
C. Boundary Layer Thicknesses
D. Response of a Boundary Layer to Pressure Gradients
E. Falkner-Skan Flows
F. Approximate Boundary Layer Methods
G. Thwaites' Method
H. Transition to Turbulence & Linear Stability Theory
I. Turbulent Flow & Turbulence Modeling

VII. Low-Reynolds-Number Solutions
A. Stokes Equations
B. Uniform Flow over a Sphere
C. Uniform Flow over a Cylinder