
MA 591 Introduction to Fluid Dynamics

Section 004**FALL 2021****3 Credit Hours**

Course Description

This course covers fundamental topics in fluid dynamics; Euler and Lagrange descriptions of continuum dynamics; conservation laws for inviscid and viscous flows; rotation and vorticity; potential flows; the Navier-Stokes's equation; boundary layer theory; Shocks, and the Riemann problem. As an application, we will set up, analyze, and solve equations predicting blood flow in arteries, other applications of biological flows will also be discussed.

Tentative topics:

1. Introduction to fluid mechanics
 2. Euler's equations
 - a. Streamline
 - b. Balance of Mass
 - c. Balance of Momentum
 - d. Conservation of Energy
 3. Bernoulli's Streamline Theorem
 4. Rotation and Vorticity
 - a. Shear flow
 - b. Line vortex flow
 - c. Vorticity equation
 - d. Kutta-Jakowsky lift theorem
 - e. Bernoulli's law (constant irrotational flow)
 - f. Stokes theorem
 - g. Kutta-Joukowski Hypothesis
 - h. Kelvin's circulation theorem
 5. Viscous flow
 - a. Boundary layer
 - b. Newtonian viscous fluids
 - c. No slip condition
 - d. Reynolds number (large vs. small)
 - e. Introduce Navier Stokes equations
 - f. Simple viscous flows (flat and inclined plane)
 - g. Circular flow
 6. Navier Stokes equations (derivation)
 - a. Stress tensor
 - b. Viscous dissipation of energy
 - c. Non-dimensionalization
 - d. Eulerian/Lagrangian formulations
 - e. Helmholtz-Hodge Decomposition
 - f. Introduction to Stokes equations
 - g. Compressible vs. incompressible flows
 7. Applications
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- a. Flow between stationary plates
 - b. Poiseuille flow
 - c. 1D pipe flow (blood flow)
 - d. Computational project
- 8. Compressible flows
 - a. Gas dynamics analogy to 1D blood flow
 - b. Methods of characteristics
 - c. Piston
 - d. Shocks
 - e. Weak solutions
 - f. Riemann problem
- 9. Stokes flow
 - a. Derivation of Stokes equations
 - b. Flow past a sphere
 - c. Swimming
 - d. Adhesion
- 10. Boundary layers
 - a. 2D boundary layer (steady flow)
 - b. Boundary layer thickness
 - c. Boundary layer on flat plate
 - d. Boundary layer separation
- 11. Instability
 - a. Brief introduction
 - b. Reynold's experiment
 - c. Centrifugal instability
 - d. Shear flow instability

Course Structure

This in person course will consist of 3 contact hours TuTh from 3.00 – 4.15 pm. Homework will be assigned weekly, typed solutions should be handed in either electronically or in class.

Homework: Unless discussed in class, homework assignments must be typed. An un-typed homework will result in a deduction of 10% of the grade for that homework. Homework handed in late will be deducted 5% per day it is late. I expect that all equations are typed using an equation editor in word or latex. Equations should be numbered, and all symbols should be explained. If literature is cited, complete citation record should be added at the end of the homework. For group homework – all students in each group will receive the same grade.

Course material will be available via Moodle (wolfware.ncsu.edu)

Instructor

Mette Olufsen

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Phone: 919 515 2678

Office Location: SAS 3154

Office Hours: By appointment only (via email)

Course Meetings

Days: TuTh

Time: 3.00 - 4:15 pm

Campus: Main

Location: Park Shops 215

All lectures will be recorded and a link to the course will be made available on the course moodle page (wolfware.ncsu.edu)

Test Dates

This course will have a major project and homework. The major project is worth 30% of the final grade. Homework is worth 70% of the final grade.

Final exam (30% of total grade) – Project presentation + report, Tuesday Dec 7th 3.00–6.00 PM.

Course Material

Textbook (optional)

Elementary Fluid Dynamics by D. J. Acheson, Oxford Applied Mathematics and Computing Series, Clarendon Press, Oxford 2009 (reprinted edition).

Textbook (optional)

A Mathematical Introduction to Fluid Mechanics by Alexandre J Chorin and Jerrold E Marsden, Springer Verlag, Third Edition, Corrected fourth printing, 2004. Note it is important you get the corrected fourth printing, since there were many errors in earlier versions.

Requisites and Restrictions

Prerequisites: Knowledge of differential equations, comfortable with vector calculations for functions of several variables, some knowledge of linear algebra, and some knowledge of MATLAB or other programming language.

General Education Program (GEP) Information

GEP Category: Mathematical Sciences

GEP Category Outcomes: Each course in Mathematical Sciences will provide instruction and guidance that help students to: Objective 1. Improve and refine mathematical problem-solving abilities; and objective 2. Develop logical reasoning skills.

How this course will fulfill GEP category outcomes: Learning outcome 1 from above will lead to improvement and refinement of mathematical problem-formulation and problem-solving abilities at the graduate level. Outcome 2 will help students' development of logical reasoning skills. Course learning outcomes and GEP category outcomes will be assessed through online homework and a final project.

GEP co-requisites: This course does not fulfill a General Education Program co-requisite.

Transportation

This course will not require students to provide their own transportation. Non-scheduled class time for field trips or out-of-class activities is NOT required for this class.

Safety & Risk Assumptions

None.

Grading

Grade Components:

Component	Weight	Details
Home-work	70%	Homework assignments weekly must be typed for full grade. Untyped homework will get an automatic 10% deduction.
Final Exam	30%	The final exam will include project presentation and report.

Letter Grades:

This course uses standard NCSU letter grading:

97	≤	A+	≤	100
93	≤	A	<	97
90	≤	A-	<	93
87	≤	B+	<	90
83	≤	B	<	87
80	≤	B-	<	83
77	≤	C+	<	80
73	≤	C	<	77
70	≤	C-	<	73
67	≤	D+	<	70
63	≤	D	<	67
60	≤	D-	<	63
0	≤	F	<	60

Requirements for Credit-Only (S/U) Grading

To receive a grade of S, students are required to take all exams and quizzes, complete all assignments, and earn a grade of C- or better. Conversion from letter grading to credit only (S/U) grading is subject to university deadlines. Refer to the Registration and Records calendar for deadlines related to grading. For more details refer to <http://policies.ncsu.edu/regulation/reg-02-20-15>.

Requirements for Auditors (AU)

Information about and requirements for auditing a course can be found at <http://policies.ncsu.edu/regulation/reg-02-20-04>.

Policies on Incomplete Grades

If an extended deadline is not authorized by the instructor or department, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at <http://policies.ncsu.edu/regulation/reg-02-50-3>.

Late Assignments

- If a student has a university approved excused reason for turning in an assignment late, they will not be penalized if the assignment is turned in within one week of receiving the assignment (or another negotiated time). Students wishing to take advantage of this must contact their instructor.
- If the late assignment is unexcused, automatic extensions can be requested in WebAssign for a 24-hour period up to 5 days after an assignment is due with a 40% reduction in points earned during the extension period.

Attendance Policy

For complete attendance and excused absence policies, please see <http://policies.ncsu.edu/regulation/reg-02-20-03>.

Attendance in all classes is required and will be taken during each class meeting.

Students with a University approved excused absence will not be penalized.

Test Makeup Policy

All anticipated absences must be excused in advance of the test date. These include university duties or trips (certified by an appropriate faculty or staff member), required court attendance (certified by the Clerk of Court), or religious observances (certified by the Department of Parent and Family Services 515-2441). Emergency absences must be reported as soon as possible once returning to class and must be appropriately documented (illness by an attending physician or family emergencies by Parent and Family Services). If you are sick on a project presentation day and decide not to give your presentation, go to the health center or other medical facility. Students who miss presenting a project and have a university approved excuse must submit appropriate documentation.

Additional Excuses Policy

None.

Academic Integrity

Students are required to comply with the university policy on academic integrity found in the Code of Student Conduct found at <http://policies.ncsu.edu/policy/pol-11-35-01>.

Both faculty and students at North Carolina State University have a responsibility to maintain academic integrity. An informational brochure about academic integrity is available from the university and students are encouraged to obtain a copy.

Academic Honesty

See <http://policies.ncsu.edu/policy/pol-11-35-01> for a detailed explanation of academic honesty.

"Cheating is the giving, taking, or presenting of information or material by a student that unethically or fraudulently aids oneself or another person on any work which is to be considered in the determination of a grade or the completion of academic requirements or the enhancement of that student's record or academic career." (NCSU Code of Student Conduct)

Scholarly activity is marked by honesty, fairness and rigor. A scholar does not take credit for the work of others, does not take unfair advantage of others, and does not perform acts that frustrate the scholarly efforts of others. The violation of any of these principles is academic dishonesty. Penalties for a violation: For the first violation, you will receive a zero for your work and be put on academic integrity probation for the remainder of your stay at NCSU. The second violation may result in your suspension from NCSU. Both situations will involve the Office of Student Conduct. See the website for a full explanation:

http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php

Honor Pledge

Your signature on any test or assignment indicates "I have neither given nor received unauthorized aid on this test or assignment."

Electronically Hosted Course Components

Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include classroom recordings from zoom, online discussions of class topics and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

Electronically hosted Components: Class videos, notes, and other materials; homework assignments; forum discussions.

For more information see the [syllabus regulation](#) the student privacy section of the Keep Teaching FAQ: <https://provost.ncsu.edu/faculty-resources/keep-teaching/faqs/>.

Accommodations for Disabilities

Reasonable accommodations will be made for students with verifiable disabilities. To take advantage of available accommodations, students must register with the [Disability Resource Office](#) at Holmes Hall, Suite 304, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the [Academic Accommodations for Students with Disabilities Regulation \(REG02.20.01\)](#)

Students with disabilities should additionally contact their instructor about accommodations.

Non-Discrimination Policy

NC State University provides equality of opportunity in education and employment for all students and employees. Accordingly, NC State affirms its commitment to maintain a work environment for all employees and an academic environment for all students that is free from all forms of discrimination. Discrimination based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation is a violation of state and federal law and/or NC State University policy and will not be tolerated. Harassment of any person (either in the form of quid pro quo or creation of a hostile environment) based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation also is a violation of state and federal law and/or NC State University policy and will not be tolerated. Retaliation against any person who complains about discrimination is also prohibited. NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at <http://policies.ncsu.edu/policy/pol-04-25-05> or http://www.ncsu.edu/equal_op/. Any person who feels that he or she has been the subject of prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 919-515-3148.

Course Schedule

Lecture TuTh 3:00 - 4:15 pm — Semester Schedule — 08/16/2021 to 11/29/2021 (last day of classes)

COVID-19 Policy

First of all, remember before you come to class

- Wash your hands frequently with soap and water for at least 20 seconds.
- Follow proper hand-washing techniques, here is one example:
<https://www.youtube.com/watch?v=bQCP7waTRWU>
- If soap and water are not immediately available, use an alcohol-based hand-sanitizer containing ≥60% alcohol.

Due to the COVID-19 pandemic, public health measures continue to be implemented across campus. Students should stay current with these practices and expectations through the [Protect the Pack](#) website (<https://www.ncsu.edu/coronavirus/>). The sections below provide expectations and conduct related to COVID-19 issues.

Health and Participation in Class

We are most concerned about your health and the health of your classmates and instructors/TAs.

- If you test positive for COVID-19, or are told by a healthcare provider that you are presumed positive for the virus, you should not attend any hybrid or face-to-face (F2F) classes and work with your instructor on any adjustments necessary; also follow other university guidelines, including self-reporting ([Coronavirus Self Reporting](#)): Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
- If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to a F2F class or activity.
- If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to make alternative plans, as necessary.
- If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor.

Health and Well-Being Resources

These are difficult times, and academic and personal stress are natural results. Everyone is encouraged to [take care of themselves](#) and their peers. If you need additional support, there are many resources on campus to help you:

- Counseling Center ([NCSU Counseling Center](#))
- Student Health Services ([Health Services | Student](#))
- If the personal behavior of a classmate concerns or worries you, either for the classmate's well-being or yours, we encourage you to report this behavior to the NC State CARES team: ([Share a Concern](#)).
- If you or someone you know are experiencing food, housing, or financial insecurity, please see the Pack Essentials Program ([Pack Essentials](#)).

Community Standards related to COVID-19

We are all responsible for protecting ourselves and our community. Please see the [community standards](#) (which have been updated for 2021) and Rule 04.21.01 regarding Personal Safety Requirements Related to COVID-19 [RUL 04.21.01 – Personal Safety Requirements Related to COVID-19 – Policies, Regulations & Rules](#)

Course Expectations Related to COVID-19

- **Face Coverings:** All members of the NC State academic community are expected to follow all university policies and guidelines, including the [Personal Safety Rule](#) and [community standards](#), for the use of face coverings. Face coverings are required in instructional spaces. Face coverings should be worn to cover the nose and mouth and be close fitting to the face with minimal gaps on the sides.
- **Course Attendance:** NC State attendance policies can be found at: [REG 02.20.03 – Attendance Regulations – Policies, Regulations & Rules](#). Please refer to the course's attendance, absence, and deadline policies for additional details. If you are quarantined or otherwise need to miss class because you have been advised that you may have been exposed to COVID-19, you should not be penalized regarding attendance or class participation. However, you will be expected to develop a plan to keep up with your coursework during any such absences. If you become ill with COVID-19,

you should follow the steps outlined in the health and participation section above. COVID 19-related absences will be considered excused; documentation need only involve communication with your instructor.

- **Technology Requirements:** This course may require particular technologies to complete course-work. Be sure to review the syllabus for these expectations, and see the [syllabus technical requirements](#) for your course. If you need access to additional technological support, please contact the Libraries' Technology Lending Service: ([Technology Lending](#)).

Course Changes Related to COVID-19

NO LONGER AVAILABLE - Grading/Scheduling Changing Options Related to COVID-19

Two policies, enhanced S/U Grading Option and Late Drop, put in place at the beginning of the COVID-19 pandemic have been discontinued. In some cases, an option may be to request an "incomplete" in the course. If you are experiencing difficult or extenuating circumstances, you should discuss possible options with your instructor and your academic advisor.

Compliance

If a student refuses to comply with the Community Standards in a classroom or laboratory setting, in addition to possible disciplinary action, the student may be required to leave the class or lab setting. In such a circumstance, the absence may be treated as an unexcused absence. Failure to follow these community standards or any other university policy or guidance related to COVID-19 health and safety may lead to administrative and/or disciplinary action. Violations of state or local laws, ordinances or executive orders are also subject to criminal citations or penalties. See the Office of Student Conduct COVID-19 page for more information about requirements and sanctions for violating Community Standards. See also RUL 04.21.01 (Personal Safety Requirements Related to COVID-19)

Need Help?

If you find yourself in a place where you need help, academically or otherwise, please review these Step-by-Step Help Topics. (Insert information or links for college or departmental level support programs, if available.)

Other Important Resources

- **Keep Learning:** [Keep Learning](#)
 - **Protect the Pack FAQs:** [Frequently Asked Questions](#) | [Protect the Pack](#)
 - **NC State Protect the Pack Resources for Students:** [Resources for Students](#) | [Protect the Pack](#)
 - **Academic Success Center** (tutoring, drop in advising, career and wellness advising): [Academic Success Center](#).
 - **NC State Keep Learning, tips for students opting to take courses remotely:** [Keep Learning Tips for Remote Learning](#)
 - **Introduction to Zoom for students:** <https://youtu.be/5LbPzzPbYEw>
 - **Learning with Moodle, a student's guide to using Moodle:** <https://moodle-projects.wolfware.ncsu.edu/course/view.php?id=226>
 - **NC State Libraries** [Technology Lending Program](#)
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