ME527/CE527 ADVANCED FLUID MECHANICS
FALL 2025

INSTRUCTOR: Goodarz Ahmadi, Room 267 CAMP
(315-268-2322)
gahmadi@clarkson.edu
Office Hours: Monday and Wednesday, 12:30 - 3:30 pm.
TEXT: None. Lecture notes are available on the web.
Recommended Book: Incompressible Flow, by Ronald L. Panton, 4th ed. John Wiley (2013).
TA: Roy King (CAMP 292) Office hours: Friday 3:00-5:00 pm.

Course Description

Review of engineering mathematics, kinematics of fluid motion, conservation laws, continuity and momentum equations, Navier-Stokes equation, viscous flow theory, simple flows, and low Reynolds number flows. Introduction to computational fluid dynamics. Asymptotic methods, perturbation methods, singular perturbation, and matched asymptotic expansion. Boundary layer theory, similarity solutions, and integral method. Review of the instability of viscous flows. Origin of turbulence. Phenomenological theories of turbulence. Reynolds' equation, energy, and vorticity transport in turbulence. Introduction to turbulence modeling.

Delivery Method

The course is offered in blended mode, both in-person in the class as well as online (synchronous). The lectures are captured by Echo 360 and made available to students in Moodle.

COURSE WEB SITE:

https://webspace.clarkson.edu/projects/fluidflow/public_html/courses/me527/index.html
https://sites.clarkson.edu/gahmadi/courses/me527/

Course Objectives

1. To provide a fundamental understanding of fluid flows in the laminar regime.
2. To provide a fundamental understanding of boundary layer flow.
3. To provide an understanding of the computational modeling of fluid flows.
4. To provide an understanding of the industrial applications of fluid flows.

Course Learning Outcomes

Objective 1:

- Students will be able to formulate and solve fluid flows under the laminar regime.

Objective 2:

- Students will be able to use perturbation and asymptotic methods and analyze boundary layer flows.

Objective 3:

- Students will demonstrate a fundamental understanding of computational fluid mechanics.
- Students will demonstrate the use of the ANSYS-Fluent Code for solving laminar flows.
- Students will demonstrate the use of the CFD code for solving turbulent flows.

Objective 4:

- Students will understand the concept of the stability of fluid motion.
- Students will understand the basics of turbulent flows.
- Students will understand the industrial applications of fluid flows.

COURSE OUTLINE

Course Schedule & Graded Activities

Dates	Module Title	Learning Materials (readings, videos, etc.)	Activities
Week 1	**I. REVIEW OF ENGINEERING MATHEMATICS**	• Review of differential equations • Review Partial Differential Equations • Indicial notation	Homework
Week 2	**II. CONTINUUM FLUID MECHANICS**	• Kinematics • Conservation Laws • Review of Continuum Thermodynamics • Constitutive Equations	Homework
Week 3	**III. NAVIER- STOKE EQUATION**	• Exact Solutions • Viscous Flows	Homework
Week 4-5	**IV. LOW REYNOLDS NUMBER FLOWS**	• Creeping Flows • Lubrication Theory • Squeeze Film • Flow around a Sphere	Homework
Weeks 6-14	**V. COMPUTATIONAL FLUID MECHANICS**	• Finite Difference and Finite Volume Methods • Introduction to CFD • ANSYS-Fluent Code	Exam- 1
Weeks 7-10	**VI. ASYMPTOTIC METHODS**	• Perturbation Theory • Singular Perturbation Theory • Matched Asymptotic Expansion	Homework
Weeks 11-14	**VII. BOUNDARY LAYER THEORY**	• Boundary Layer Theory • Self-Similar Solutions • Integral methods • Jets and Wake Flows	Homework
Week 15	**VIII. STABILITY OF FLUID MOTION**	• Theory of Small Perturbation • The Orr-Sommerfeld Equation	Computer Projects Homework
Week 16	**IX. TURBULENT FLOWS**	• Reynolds Equation and Turbulence Stresses • Phenomenological Theories	Homework Final Exam

COURSE TOPICS

I. REVIEW OF ENGINEERING MATHEMATICS

- Review of differential equations
- Review Partial Differential Equations
- Indicial notation

II. CONTINUUM FLUID MECHANICS

- Kinematics
- Conservation Laws
- Review of Continuum Thermodynamics
- Constitutive Equations

III. THE NAVIER-STOKE EQUATION

- Exact Solutions
- Viscous Flows

IV. LOW REYNOLDS NUMBER FLOWS

- Creeping Flows
- Lubrication Theory
- Squeeze Film
- Flow around a Sphere

V. COMPUTATIONAL FLUID MECHANICS

- Finite Difference and Finite Volume Methods
- Introduction to CFD
- ANSYS-Fluent Code

VI. ASYMPTOTIC METHODS

- Perturbation Theory
- Singular Perturbation Theory
- Matched Asymptotic Expansion

VII. BOUNDARY LAYER THEORY

- Boundary Layer Theory
- Self-Similar Solutions
- Integral methods
- Jets and Wake Flows

VIII. STABILITY OF FLUID MOTION

- Theory of Small Perturbation
- The Orr-Sommerfeld Equation

IX. TURBULENT FLOWS

- Reynolds Equation and Turbulence Stresses
- Phenomenological Theories

EVALUATION METHOD

Midterm (October 24, 2025, CAMP 184, 3:00-4:15 pm) 25%
Final Exam (Final Exam week) 35%
Projects (Due December 2, 2025) 30%
Homework 10%

Grading

Grade Ranges

Graduate Letter Grades

Course Average	Grade	Quality Points
97+	A+	4.0
93-96	A	4.0
90-92	A-	3.667
87-89	B+	3.334
84-86	B	3.0
80-83	B-	2.667
76-79	C+	2.334
70-75	C	2.0
<70	F	0

Course Policies

Etiquette Expectations & Learner Interaction

Educational institutions promote the advancement of knowledge through positive and constructive debate--both inside and outside the classroom. Please visit and follow: Netiquette and Electronic Learner Interaction Guidelines.

Institutional Policies & Regulations

Academic Integrity

Students are expected to abide by the standards of academic honesty, as described in the Clarkson Regulations. In addition, the work or words of others must be appropriately cited. Please refer to Clarkson Library's Guide to Plagiarism and Citing Sources.

Students with Disabilities Policy

Clarkson University welcomes inquiries and applications from individuals who have disabilities. Information relating to disabling conditions is not a determining factor in admission decisions. The University strives to make all facilities and programs accessible to students with disabilities by providing appropriate academic adjustments and other appropriate modifications (accommodations) as necessary. Timely notification of any need for accommodations due to a disability is encouraged so that the Office of Accommodative Services (OAS) may provide for students in an efficient manner.

For more information or other appropriate campus referrals, contact:

Director of Accommodative Services
Clarkson University
PO Box 5645
Potsdam, NY 13699-5635
Phone: 315-268-7643
Fax: 315-268-2400
Email: oas@clarkson.edu
Office of Accessibility Services Website

Instructor Participation

During this course, as your instructor, you can expect me to

- Respond to emails and voicemails within 1 day
- Grade activities and assessments within 3 days
- Be an active participant on the discussion board

Lecture Capture Policy

The lectures are captured and will be available on Moodle.

Academic Freedom

The fundamental aspects of academic freedom at Clarkson University include both the freedom to teach and the freedom to learn. Students are encouraged to exercise this freedom responsibly, embracing opportunities for open discussion, inquiry, and expression in the classroom. Professors evaluate student performance based solely on academic criteria, fostering a fair and supportive learning environment. To maintain a respectful and safe community, the University prohibits actions that violate the law, defame individuals, pose genuine threats, infringe on privacy or confidentiality, contravene the Equal Opportunity, Harassment, and Nondiscrimination Policy, or involve unwelcome activity in the classroom. The professor determines if classroom behavior is inappropriate and may address the issue directly or refer it to the appropriate official with authority to address the issue.

REFERENCES

1. J. Y. Tu, K. Inthavong, and G. Ahmadi, "Computational Fluid and Particle Dynamics in the Human Respiratory System," Springer, New York (2013). https://www.springer.com/gp/book/9789400744875
2. F. White, Viscous Flow, McGraw-Hill (1974). https://www.amazon.com/Viscous-Fluid-MCGRAW-MECHANICAL-ENGINEERING/dp/0072402318
3. Happel and H. Brenner, Low Reynolds Number Hydrodynamics, Martinus Nijhoff (1983) https://www.springer.com/gp/book/9789024728770
4. H. Schlichting, Boundary Layer Theory, McGraw-Hill (1979). https://link.springer.com/book/10.1007%2F978-3-662-52919-5
5. J.O. Hinze, Turbulence, McGraw-Hill (1975). https://www.amazon.com/Turbulence-McGraw-Hill-mechanical-engineering-Hinze/dp/0070290377
6. H. Tennekes and J.L. Lumley, A First Course in Turbulence, MIT Press (1981). https://mitpress.mit.edu/books/first-course-turbulence