

# ME527/CE527 ADVANCED FLUID MECHANICS FALL 2022



**INSTRUCTOR:** Goodarz Ahmadi, Room 267 CAMP/ Room 304 SC  
(315-268-2322)

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Office Hours: Tuesday and Thursdays 12:30 - 3:30 pm  
(Some meetings by appointment on Zoom)

**TEXT:** None. Lectures notes are available on the web.

**Recommended Book:** Incompressible Flow, by Ronald L. Panton, 4th ed. John Wiley (2013)

**TA:**

## 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 (asynchronous). The lectures are captured by Echo 360 and will be available to students in Moodle.

## COURSE WEB SITE:

[https://webspace.clarkson.edu/projects/fluidflow/public\\_html/courses/me527/index.html](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 using the ANSYS-Fluent Code for solving laminar flows.
- Students will demonstrate using the CFD code for solving turbulent flows.

#### Objective 4:

- Students will understand the concept of 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	<b>I. REVIEW OF ENGINEERING MATHEMATICS</b>	<ul style="list-style-type: none"><li>• Review of differential equations</li><li>• Review Partial Differential Equations</li><li>• Indicial notation</li></ul>	Homework
Week 2	<b>II. CONTINUUM FLUID MECHANICS</b>	<ul style="list-style-type: none"><li>• Kinematics</li><li>• Conservation Laws</li><li>• Review of Continuum Thermodynamics</li><li>• Constitutive Equations</li></ul>	Homework
Week 3	<b>III. NAVIER- STOKE EQUATION</b>	<ul style="list-style-type: none"><li>• Exact Solutions</li><li>• Viscous Flows</li></ul>	Homework
Week 4-5	<b>IV. LOW REYNOLDS NUMBER FLOWS</b>	<ul style="list-style-type: none"><li>• Creeping Flows</li><li>• Lubrication Theory</li><li>• Squeeze Film</li><li>• Flow around a Sphere</li></ul>	Homework
Weeks 6-14	<b>V. COMPUTATIONAL FLUID MECHANICS</b>	<ul style="list-style-type: none"><li>• Finite Difference and Finite Volume Methods</li><li>• Introduction to CFD</li><li>• ANSYS-Fluent Code</li></ul>	Exam- 1
Weeks 7-10	<b>VI. ASYMPTOTIC METHODS</b>	<ul style="list-style-type: none"><li>• Perturbation Theory</li><li>• Singular Perturbation Theory</li><li>• Matched Asymptotic Expansion</li></ul>	Homework
Weeks 11-14	<b>VII. BOUNDARY LAYER THEORY</b>	<ul style="list-style-type: none"><li>• Boundary Layer Theory</li><li>• Self-Similar Solutions</li><li>• Integral methods</li><li>• Jets and Wake Flows</li></ul>	Homework
Week 15	<b>VIII. STABILITY OF FLUID MOTION</b>	<ul style="list-style-type: none"><li>• Theory of Small Perturbation</li><li>• The Orr-Sommerfeld Equation</li></ul>	Computer Projects Homework
Week 16	<b>IX. TURBULENT FLOWS</b>	<ul style="list-style-type: none"><li>• Reynolds Equation and Turbulence Stresses</li><li>• Phenomenological Theories</li></ul>	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 21, 2022, CAMP 178, 3:00-4:20 pm) 25%

Final Exam (Final Exam week) 35%

Computer Projects 30%

Homework 10%

## Grading

### Grade Ranges

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

### 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 properly 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](mailto: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

## COVID Policy

If the number of COVID infections St Lawrence County increases, please a mask  
If feeling sick, please do not come to class. The lectures are captured and will be available on Moodle

## 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>