 ME326 ‑ INTERMEDIATE FLUID MECHANICS

**Spring 2022**

**Instructor:** Goodarz Ahmadi, Room 267 CAMP (315-268-2322)

[gahmadi@clarkson.edu](mailto:gahmadi@clarkson.edu)

Office Hours: Tuesday and Thursday 12:30 - 3:30 pm by appointment.

(Due to COVID-19, all meetings by appointment on Zoom

[https://clarkson.zoom.us/j/761986404](https://www.google.com/url?q=https://clarkson.zoom.us/j/761986404&sa=D&source=calendar&ust=1610466600844000&usg=AOvVaw0AY6wLi4wCY5vVM5llbltr))

**Text:** Fluid Mechanics, Fundamentals and Applications, 3/e or 4/e,

by Cengel and Cimbala (ISBN-978-0-07-338032-2)

**TA:** Mohsen Motie Shirazi**,** [motiesm@clarkson.edu](mailto:motiesm@clarkson.edu)

Office Hours: Wednesday 1:00-2:00 pm CAMP 175

Jannatul Ferdausi, [ferdaum@clarkson.edu](mailto:ferdaum@clarkson.edu) Office Hours: Monday 1:00-2:00 pm

**Course Site:** <http://webspace.clarkson.edu/projects/fluidflow/courses/me326/index.html>

<https://sites.clarkson.edu/gahmadi/courses/me326/>

**Prerequisites:** ES330, ES340, MA232

**Class Time:** TT4:30-5:45 pm, Lectures will be posted on Moodle

Computer Lab, F 3:00-4:30, CAMP 163/172

(CAMP 177 for Lectures on ANSYS-FLUENT)

**Course Description**

A continuation of ES 330. Topics include: deformation and stress in fluids; basic conservation laws; kinematics of fluid flow; theory of potential flow; introduction to compressible flows; isentropic flows and shock waves; compressible flows with friction and heat transfer; Navier-Stokes equation and theory of viscous flow; low Reynolds number flows with applications to hydrodynamic lubrication; laminar boundary layer theory and von Karman momentum integral method; introduction to computational fluid dynamics; applications of fluid mechanics to engineering problems including turbomachinery.  Introduction to design concepts.

**Delivery Method**

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

**Course Web Site:**

<http://webspace.clarkson.edu/projects/fluidflow/courses/me326/index.html>

<https://sites.clarkson.edu/gahmadi/courses/me-326-intermediate-fluid-mechanics/>

# Course Objectives

1. Students to learn the fundamentals of viscous incompressible flows.
2. Students to learn the basics of non-viscous potential flows.
3. Students to learn the fundamentals of computational fluid mechanics.
4. Students to learn the fundamentals of compressible flows.

**Course Learning Outcomes**

**Objective 1** a) Students will be able to formulate and solve incompressible laminar parallel flows in Cartesian and polar coordinates. (1)1

b) Students will be able to analyze boundary layer flows over a flat plate. (1)

c) Students will be able to evaluate drag forces in laminar and turbulent flows for different immersed bodies. (1)

**Objective 2** a) Students will be able to use the stream and potential functions and solve elementary potential flows. (1)

b) Students will be able to analyze simple potential flows by the method of superposition. (1)

**Objective 3**  a) Students will use the basic computational fluid mechanics. (1)

b) Students will demonstrate using the ANSYS-FLUENT Code for solving two-dimensional laminar and turbulent flows. (1, 6)

**Objective 4**  a) Students will be able to analyze 1-D isentropic compressible flows. (1)

b) Students will be able to analyze 1-D flows with shock waves. (1)

c) Students will be able to analyze 1-D compressible flows with friction. (1)

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1 Numbers in parentheses refer to the course outcomes consistent with ABET Criterion 3.

**COURSE OUTLINE**

## Course Schedule & Graded Activities

|  |  |  |  |
| --- | --- | --- | --- |
| **Dates** | **Text Section** | **Learning Materials/Topics** | **Activities** |
| Week 1  Jan. 13‑14 | 4.1 | • Applications Fluid Mechanics  • Review of ES330 | ---- |
| Week 2  Jan. 17-21 | 9.1,2,4 | • Review of Differential Equations  • Conservation Laws  • Viscous Flow | Homework-1  4.19, 9.28, 30, 31, 34, 36, 38  Due date: Jan. 27 (Thursday) |
| Week 3  Jan. 24-28 | 9.4,5,6 | • Viscous Flows  • Naiver-Stokes Equation  • Viscous Parallel Flows | Homework-2  9.86, 87, 89, 91, 95  Due date: Feb. 3 (Thursday) |
| Week 4  Jan. 31-Feb. 4 | 9.6 | • Exact Solutions,  • Approximate Solutions  • CFD | Homework-3  9. 96, 101, 102, 103, 104  Due date: Feb. 10 (Thursday) |
| Week 5  Feb. 7-11 | 10.6 | • Boundary layer Flows  • CFD, ANSYS-Fluent Code | Homework-4  10.99, 100, 102, 114, 115, 116  Due date: Feb. 22 (Tuesday) |
| Week 6  Feb. 14-18 | 10.6, 11.1-4 | • Boundary layer Flows  • Drag Force  • CFD, ANSYS-Fluent Code | Homework-5  11.51,65,99,106  Due date: Mar. 8 (Tuesday) |
| Week 7  Feb. 21-23 | 11.1-4 | • Drag Force  • Immersed Bodies | ---- |
| **Feb. 24-25** |  | **February Break** |  |
| Week 8  Feb. 28-  Mar. 4 | 9.3, 10.2-4 | • Stream Function  • Inviscid Flows | Homework-6  10.56,59, 60, 66, 71  Due date: Mar. 10 (Thursday)  **Exam 1, March 4, CAMP 177** |
| **Mar. 4 Friday** | **3:00-4:15** | **Exam 1, CAMP 177** |  |
| Week 9  Mar. 7-11 | 10.5 | • Inviscid Irrotational Flows | Homework-7  Assigned Problems are posted.  Due date: Mar. 24 (Thursday)  Project 1 due date: March 10 |
| **Week10**  **Mar. 14-18** |  | **Spring Break** |  |
| Week 11  Mar. 21-25 | 12.1‑3 | • Acoustic Waves  • Isentropic Flow | Homework-8  12.7, 9, 25, 26, 27  Due date: Apr. 3 (Tuesday) |
| Week 12  Mar 28-Apr. 1 | 12.3 | • Isentropic flow | Homework-9  12.38, 40, 45, 48, 50  Due date: Apr. 7 (Thursday)  **Exam 2, April 1, CAMP 177** |
| **Apr. 1**  **Friday** | **3:00-4:15** | **Exam 2, CAMP 177** |  |
| Week 13  Apr. 4-8 | 12.4 | • Normal Shocks  • Nozzles and Diffusers | Homework-10  12.62, 63, 65, 66, 69, 70  Due date: Apr. 14 (Thursday) |
| Week 14  Apr. 11-15 | 12.5,6 | • Flows with heat transfer  • Flows with friction | Homework-11  12.87, 88, 93, 95  Due date: Apr. 21 (Thursday)  Project 2 due date: April 14 |
| Weeks 15  Apr. 18-22 | 12.6 | • Flows with friction | Homework-12  12.105,106,107,109,114  Due date: Apr. 26 (Tuesday) |
| Week 16  Apr. 25-29 |  | • Review | Bonus project due date: Apr. 26 |
| **Final Exam week** |  | **Final Exam** | **Final Exam** |

**Evaluation Methods**

1. Homework and quizzes 10%

2. Exam-1 25% **Friday, March 4, CAMP 177 (3:00-4:15)**

3. Exam-2 20% **Friday, April 1, CAMP 177 (3:30-4:15)**

4. Final Exam 30% **Final Week**

5. Projects 15%

**Exam Policy**

Hourly exams will be closed book and closed notes. A formula sheet will be provided for the hourly exams. The final exam will be open book. The students are permitted to bring their textbooks to the final exam. Notes and homework solutions are not allowed.

## **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 |
| 83-86 | B | 3.0 |
| 80-82 | B- | 2.667 |
| 77-79 | C+ | 2.334 |
| 73-76 | C | 2.0 |
| 70-72 | C- | 1.7 |
| 67-69 | D+ | 1.3 |
| 63-66 | D | 1 |
| 60-62 | D- | 0.7 |
| <60 | 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](https://intranet.clarkson.edu/administrative/tlc/learner-support/netiquette-and-electronic-learner-interaction-guidelines/).

## **Institutional Policies**

### [Institutional Policies & Regulations](https://www.clarkson.edu/student-administrative-services-sas/clarkson-regulations)

### Academic Integrity

Students are expected to abide by the standards of academic honesty, as described in the [Clarkson Regulations](https://www.clarkson.edu/student-administrative-services-sas/clarkson-regulations).  The work or words of others must be properly cited.  Please refer to Clarkson Library's [Guide to Plagiarism](http://libguides.library.clarkson.edu/plagiarism) and [Citing Sources](http://libguides.library.clarkson.edu/citations/home).https://ssl.gstatic.com/ui/v1/icons/mail/images/cleardot.gif

### [Students with Disabilities Policy](https://www.clarkson.edu/policies-and-laws)

**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](https://www.clarkson.edu/accessability-services)

## **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

**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>

1. F. White, Viscous Flow, McGraw‑Hill (1974).

<https://www.amazon.com/Viscous-Fluid-MCGRAW-MECHANICAL-ENGINEERING/dp/0072402318>

1. H. Schlichting, Boundary Layer Theory, McGraw Hill (1979).

<https://link.springer.com/book/10.1007%2F978-3-662-52919-5>