ME 3414 Fluid Dynamics

Spring 2022
CRN 17244
last modified April 24, 2022

Instructor	Emad Masroor	
Lectures	MW 2:30 — 3:45	125 Goodwin Hall
Recitations	T 3:30 — 4:20	115 Goodwin Hall
Instructor Office hours	MW 4:00 — 5:30 & by appt.	114-I Randolph Hall
TA Office Hours	R 4:30 PM — 7:30 PM & F 9:30 AM — 12:30 PM via Zoom 707 896 9201	
E-mail communication	`emad@vt.edu` — Please include 'ME3414' in the subject line.	
Textbook	Munson, Young and Okiishi's Fundamentals of Fluid Mechanics 9th edition, Gerhart, Hochstein & Gerhart	
Pre-/Co- Requisites	See the online Timetable of Classes	
Major requirement	You must be a ME major in order to take this class	
Lab	You must be concurrently enrolled in ME 3414 Lab	
Lab Instructor	Clinton Dancey `cld@vt.edu`	
Website	`https://canvas.vt.edu`	
Final Exam	Monday, May 09, 2022, 2:05 PM — 4:05 PM	

Catalog description Comprehensive first course in fluid dynamics. Fluid properties. Hydrostatics. Mass, momentum,and energy conservation in control volumes. Elementary dynamics and Bernoullis equation.Dimensional analysis and similitude. Laminar and turbulent flows. Introduction to Eulers and Navier-Stokes equations. Pipe flows. External flows and boundary layers. Introduction to compressible flows. Includes laboratory experiments.

Learning objectives Upon successfully completing this course, you will be able to:

1. Predict the forces and moments applied to surfaces under hydrostatic conditions.
2. Implement the concept of the control volume and apply conservation of mass and linear momentum principles in modeling and analyzing steady open systems.
3. Model and analyze steady, one-dimensional inviscid flows through the application of Bernoulli?s equation; including the prediction of static and dynamic pressure variations throughout a flowing system.
4. Perform dimensional analyses on general fluid flow systems and apply the concepts of similitude to such systems, including the application of similitude to laboratory modeling, and scale effects, as well as the correlation of experimental data.
5. Model and analyze the flow of viscous fluids through pipes and simple piping systems for both laminar and turbulent flows, including minor losses.
6. Model the effects of flow on immersed bodies including the application of the concepts of boundary layers, and lift and drag.

Course evaluation Your grade in this course will be made up of the following four components.

Homework	10%
Quizzes	5%
Lab	15%
Mid-term exams	20% $\times 2$
Final exam	30 %

The assignment of letter grades will be at the discretion of the Instructor, but will generally adhere to the standard Virginia Tech grade distribution: A- 90+, B- 80+, C- 70+, D- 60+, F <60

Honor code The Undergraduate Honor Code pledge that each member of the university community agrees to abide by states:

"As a Hokie, I will conduct myself with honor and integrity at all times. I will not lie, cheat, or steal, nor will I accept the actions of those who do."

Students enrolled in this course are responsible for abiding by the Honor Code. A student who has doubts about how the Honor Code applies to any assignment is responsible for obtaining specific guidance from the course instructor before submitting the assignment for evaluation. Ignorance of the rules does not exclude any member of the University community from the requirements and expectations of the Honor Code. The normal sanction I will recommend for a violation of the Honor Code is an F* sanction as your final course grade. The F represents failure in the course. The "*" is intended to identify a student who has failed to uphold the values of academic integrity at Virginia Tech. For additional information about the honor code, please see `https://www.honorsystem.vt.edu/`

Lectures & Recitations The meeting times for this course consist of two types of classes: *Lectures*, consisting of 1:15 blocks of time, and *Recitations*, consisting of 50-minute blocks of time. Both are mandatory. During the recitation times, the Instructor will solve example problems in class which will help you develop the skills necessary for solving the kinds of problems which will appear in homework and on exams.

Quizzes At the beginning of some class meetings, there will be a multiple-choice quiz, conducted via Canvas, to test your knowledge of the material most recently covered in class. These questions will be conceptual, and won't require detailed calculations; instead, they will test rudimentary knowledge of the principles of fluid dynamics. Your score on the quizzes should be a barometer for you to gauge how well you are doing in this course.

Classroom expectations Students are expected to attend every class meeting and take notes. The instructor will make available the lecture slides/notes developed in class, but these do not replace the need for students to actively engage with the material, ideally by taking their own notes. Please be respectful of everyone else's time by being punctual. You must not use cell phones or laptop computers during class, but you are permitted to take notes on a tablet or tablet-like device. If you must use a communications device such as a cell phone during class, you may excuse yourself from the classroom.

Laboratory This course has an accompanying lab section. You must be enrolled in one of the lab sections. The lab is run independently , and all questions regarding lab should be directed to the lab instructor. At the end of the semester, the Instructor will ask for your lab grades from the lab instructor and incorporate them into your final grade.

Exams There will be two mid-term exams and one final exam. The material covered in each mid-term will be specified in advance, and will generally include the material covered up to and including the week prior to the mid-term. The final exam will be 'comprehensive', meaning that it will cover all of the material taught in the course. All exams will be closed-book and closed-notes; you are permitted to bring one $8\frac{1}{2} \times 11$ sheet of paper with equations. Fluid properties and necessary constants will be provided with the exams. The mid-term exams will be conducted in class on the dates/times noted in the class schedule, whereas the final exam will be conducted at the time and location determined by the registrar.

Homework assignments

Purpose One of the objectives of this course is to enhance your ability to solve technical problems and to communicate the *results* as well as the *process* you used to arrive at the result. The purpose of homework assignments is therefore to evaluate not just your ability to arrive at the correct solution to an engineering problem, but also your process for working through it.

Policies Homework will be assigned each week, and will be due on **Fridays at 5:00 PM** unless noted otherwise. You must turn in your homework on Canvas in PDF format by taking *clear*, *legible* scans of handwritten work. You may use your phone to make these scans, but it is recommended that you use a scanner to improve legibility. In general, late homework will not be graded, but each student can request up to two extensions, of one week's duration, with no penalty. However, you **must** specifically request for such extensions by sending an e-mail to the instructor before the 5 PM deadline. You are encouraged to discuss solution strategies with other students in the class, but your submissions must be your own work. You are encouraged to note, on the first page of each assignment, which other students you worked with, but this does not permit you to simply copy solutions from another student.

Format Adherence to the following format is expected for all assignments.

- Use A4 or Letter size paper.
- Write/draw clearly and legibly. Always err on the side of using more rather than less space to draw or write. If your handwriting is not legible, your work will not be graded.
- Start each problem on a new page.
- Each solution should be preceded by 'Given:' and 'Find:', with the appropriate information repeated from the problem statement.
- Clearly define all symbols you have used. e.g., 'm: mass, g: acceleration due to gravity', etc, even if these are the same as the problem statement.
- Draw a large, clear diagram or schematic, including a free-body diagram or control-volume diagram, if appropriate.
- Explicitly state the physical laws or principles (e.g., Newton's second law, conservation of energy, etc.) which you have used in your solution.
- Perform calculations symbolically without substituting values until the last step. This will help the grader follow along with your argument, and will help minimize arithmetic mistakes.
- Box your final answers.
- Unless a quantity is dimensionless, you *must* include units with all of your numerical answers. It is recommended that you also include units in all intermediate steps.
- At this stage in your engineering education, it is assumed that you are familiar with the concept of signficant figures. Use sound judgement when deciding how many significant figures you use in your answers; an inordinately high number of significant figures is just as bad as a low one. You *will* be penalized for egregious mistakes of this kind.

Grading Each problem assigned on homework will have an equal number of points, and will be equally weighted regardless of how many problems were assigned in a certain week. In general, to receive a perfect score on a homework problem, you must adhere to the formatting guidelines above. Grades will be reported via Canvas. You may request a regrade for a homework problem by e-mailing the instructor within one week of the grade being reported.

Week	No.	Type	Date	Topic	Textbook
1	1	Rec	T 1/18	Intro, Logistics, Fluid Properties	1.1-1.4
	2	Lec	W 1/19	Fluid Properties	1.5-1.10
2	3	Lec	M 1/24	Intro Hydrostatics	2.1-2.3
	4	Rec	T 1/25	Hydrostatics: manometry	2.4-2.6
	5	Lec	W 1/26	Hydrostatics: buoyancy	2.7-2.11
3	6	Lec	M 1/31	Hydrostatics: forces on surfaces	2.7-2.11
		Rec	T 2/1	No class	
	7	Lec	W 2/2	Fluid Kinematics: streamlines etc.	4.1
4	8	Lec	M 2/7	Acceleration & material derivative	4.2
	9	Rec	T 2/8	F = ma along & across streamline	3.2, 3.3
	10	Lec	W 2/9	Bernoulli's Equation	3.1-3.4
5	11	Lec	M 2/14	Bernoulli's Equation	3.1-3.5
	12	Rec	T 2/15	Bernoulli's Equation	3.6-3.7
	13	Lec	W 2/16	Reynold's Transport Theorem Control Volumes (CV)	4.3, 4.4
6	14	Lec	M 2/21	CV: Mass Conservation	4.4,5.1
	15	Rec	T 2/22	Review session for Midterm 1	
			W 2/23	**Midterm 1**	
7	16	Lec	M 2/28	CV: Mass & Momentum Conservation	5.1,5.2
	17	Rec	T 3/1	Control Volumes	5
	18	Lec	W 3/2	CV: Momentum Conservation	5.2
8				Spring Break	
9	19	Lec	M 3/14	CV: Energy Conservation	5.3
		Rec	T 3/15	No class	
	20	Lec	W 3/16	Differential analysis of flows	6.4-6.5
10	21	Lec	M 3/21	Euler's and Navier-Stokes equations	6.8-6.9
	22	Rec	T 3/22	Intro to Reynolds number	7
	23	Lec	W 3/23	Buckingham Pi Theorem	7
11	24	Lec	M 3/28	Dimensional Analysis	7
	25	Rec	T 3/29	Modeling and Similitude	7
	26	Lec	W 3/30	Fully developed laminar flow in pipes	8
12	27	Lec	M 4/4	Internal Flows in pipes & ducts	8
	28	Rec	T 4/5	Internal Flows	8
			W 4/6	No class	
13	29	Lec	M 4/11	Intro to External Flows	9
	30	Rec	T 4/12	Review session for Midterm 2	
			W 4/13	**Midterm 2**	
14	31	Lec	M 4/18	Boundary Layers	9
	32	Rec	T 4/19	External flows & boundary layers	9
	33	Lec	W 4/20	Turbulent boundary layers; Drag	9
15	34	Lec	M 4/25	Drag & Lift forces	9
	35	Rec	T 4/26	Forces on bodies	9
	36	Lec	W 4/27	Intro to Compressible flows	11
16		Lec	M 5/2	No class	
	37	Rec	T 5/3	Compressible flows	11
	38	Lec	W 5/4	Review session	