ME 320: Fluid Flow

Summer 2021, Online University Park

May 17 to August 13, 2021

Instructor: Dr. Laura L. Pauley
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Most weeks the class and office hours will be on Friday at 10AM-noon EDT. On weeks when there is an exam, the class and office hours will be on Thursday at 10AM-noon EDT
Zoom Live Class at 10 AM EDT at https://psu.zoom.us/j/93822957772 You will need to log into psu.zoom.us before entering the Zoom session. Class attendance is optional and the class will be recorded and posted on Canvas.
Zoom Office Hours will be immediately after class at https://psu.zoom.us/j/2440712508 .

Text: Fluid Mechanics, Fundamentals and Applications, 4th Edition, Cengel and Cimbala. For this section of ME 320, you can use an earlier edition of the text. The last pages of this syllabus give the reading assignments for earlier editions. I will not use textbook problems for homeworks.

References: An Album of Fluid Motion, Van Dyke TA357.V35 An copyright-approved pdf of this book is available online at https://sites.google.com/site/parabolicpress/home
Illustrated Experiments in Fluid Mechanics QC145.2.N37
Visualized Flow, The Japan Society of Mechanical Engineers, TA357.V53
Introduction to Fluid Mechanics, Fox & McDonald TA357.F69
Fundamentals of Fluid Mechanics, Munson, Young & Okiishi TA357.M86

Prerequisites: Previously passed: EMCH 212, ME 300, MATH 251 or MATH 250, MATH 230 or 231. No exceptions will be given unless you have taken a similar course at a different institution.

Grading:

Homework**	20%
Exam 1	25%
Exam 2	25%
Final	30%

** The lowest homework grade will be dropped before the average is determined.

The final course grade will be assigned using the following cutoffs:

Final Course Average	Grade
<65.00	F
65.00≤ avg <70.00	D
70.00≤ avg <77.00	C
77.00≤ avg <80.00	C+
80.00≤ avg <83.00	B-
83.00≤ avg <87.00	B
87.00≤ avg <90.00	B+
90.00≤ avg <93.00	A-
93.00≤ avg	A

Homework: Homework will be due for every module. Homework is submitted to the Canvas assignment dropbox. Late homework can be submitted up to 48 hours after the due date and time. Late homework is penalized by 15%. No late homework will be accepted after 48 hours. Homework solutions will be posted on Canvas within 72 hours of the due date.

Grade Appeal: For two weeks after a homework or exam is returned, the grade may be appealed by returning it with a short note to Dr. Pauley. After two weeks have passed, no grade will be changed.

Missed Exams: No make-up exams will be given except as required by University Policy 42-27. You must contact Dr. Pauley prior to any anticipated exam absence to arrange a makeup exam. If you are sick, notify Dr. Pauley by email or phone call. Do not come to Reber Building if you are ill.

Canvas: This course has a Canvas site. Included on the site are the lecture notes, homework assignments, homework solutions, exam solutions, and sample exam problems. It is suggested that you work on the sample exam problems when preparing for an exam.

Exams: Exams will be proctored using Examity at no additional expense to the student. Each exam will be open during an 11 hour period and you must schedule a time for your exam to be proctored by Examity.

"This course will require you to take exams using certain proctoring software that uses your computer's webcam or other technology to monitor and/or record your activity during exams. The proctoring software will be listening to you, monitoring your computer screen, viewing you and your surroundings, recording and storing any and all activity (including visual and audio recordings) during the proctoring process. By enrolling in this course, you consent to the use of the proctoring software selected by your instructor, including but not limited to any audio and/or visual monitoring which may be recorded. ***Please contact your instructor with any questions****."*

Computer Requirements: At this time, review Examity System Requirements < https://examity.psu.edu/support-technical-help/> to make sure your computer meets the minimum standards. In addition, be sure to access the Examity Computer Readiness Check <https://prod.examity.com/systemcheck/check.aspx>

In addition to the Examity requirements, this online course will require:

- Access to graphics-capable printer
- Ready access to a document scanner that allows for the creation of PDF files, which will enable students to submit handwritten homework and exams. You must have access to the scanner during your proctored exam session. Students can use a computer scanner or Camscanner on their cell phone. Submitted scanned work must be in one pdf file. Photos of your work are not accepted.

Disability Access: Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Student Disability Resources Web site provides contact information for every Penn State campus: **http://equity.psu.edu/student-disability-resources/disability-coordinator .** For further information, please visit the Student Disability Resources Web site: **http://equity.psu.edu/student-disability-resources.**

Counseling and Psychological Services: CAPS can help students resolve personal concerns that may interfere with their academic progress, social development, and satisfaction at Penn State. Some of the more common concerns include anxiety, depression, difficulties in relationships (friends, roommates, or family); sexual identity; lack of motivation or difficulty relaxing, concentrating or studying; eating disorders; sexual assault and sexual abuse recovery; and uncertainties about personal values and beliefs.

Accommodations for Military Personnel: Veterans and currently serving military personnel and/or spouses with unique circumstances (e.g., upcoming deployments, drill/duty requirements, disabilities, VA appointments, etc.) are welcome and encouraged to communicate these, in advance if possible, to the instructor in the case that special arrangements need to be made. We value and respect our military students and your families as well as the unique challenges you face. We want you to be successful students at Penn State, whether you reside in State College or anywhere in the world.

Academic Integrity Policy

Academic integrity is the pursuit of scholarly activity free from fraud and deception and is an educational objective of this institution. All University policies regarding academic integrity apply to this course. All submitted work for this class (homeworks and exams) must be your individual effort. Evidence to the contrary will result in failure of the course. This same policy applies to any other deliberately dishonest action.

The University and the College of Engineering consider academic dishonesty, including cheating and plagiarism, to be a serious offense. The University Policy 49-20 describes the general university policy on academic dishonesty. For Engineering, the academic integrity web site is at https://advising.engr.psu.edu/student-resources/academic-integrity.aspx . Dishonest incidents should be reported to the course instructor or to the Department Head who will refer it to the College Committee on Academic Dishonesty.

Academic dishonesty includes, but is not limited to,

- cheating, including using solutions posted online
- plagiarizing
- fabricating of information or citations
- facilitating acts of academic dishonesty by others, including uploading solutions to an online site or sharing your work with others.
- having unauthorized possession of examinations
- submitting the work of another person or work previously used without informing the instructor
- tampering with or modifying the academic work of other students

Examples: Any sharing of assignment solutions or answer keys via personal communication or websites other than those communications or web-based applications used as part of the course is not allowed. Copying from other students, copying from answer keys or solution sets, or having tutors complete assignments for students is unacceptable. All of these are examples of academic dishonesty. Instructors regularly monitor the web for inappropriate posting of instructional materials.

It is expected that any work submitted is your own. Students in this class are expected to write up their problem sets or assignments individually. Students are expected to work on exams on their own. All exam answers must be your own, and you must not provide any assistance to other students, nor accept assistance from others during exams.

Consequences: Students who present other people's work as their own, post their own work for others to copy, or post answer keys will receive, at minimum, a 0 on the assignment. They may also receive an F or XF in the course and be recommended for academic or disciplinary sanctions.

For any material or ideas obtained from other sources, such as fluid properties or other information you find on the web, in the library, etc., a source reference must be given.

ME 320 Fluid Flow, Summer Session 2021
Syllabus
Readings from 4th Edition of Text

	Topics	Reading
Topic A	Introduction to Fluids and Fluid Properties	Chapter 1& 2
	Homework 1 due Monday May 24 by 11 PM	
Topic B	Hydrostatic Pressure, Manometry	3-1 to 3-3
	Hydrostatic Forces on Submerged Plane Surfaces	3-4
	Homework 2 due Tuesday June 1 by 11 PM	
Topic C	Buoyancy	3-6 pages 100-104 only
	Fluid Kinematics	4-1 to 4-5
	Homework 3 due Monday June 7 by 11 PM	
Topic D	Reynolds Transport Theorem	4-6, 5-1
	Integral Conservation of Mass Equation	5-2
	Homework 4 due Monday June 14 by 11 PM	
Topic E	Bernoulli Equation	5-4
	Homework 5 due Monday June 21 by 11 PM	

EXAM 1, 60 minutes, available Friday June 25 from noon to 11 PM EDT

Topic F	Integral Linear Momentum Equation	6-1 to 6-4
	Homework 6 due Monday July 5 by 11 PM	
Topic G	Internal Flows	5-6, Chapter 8
	Homework 7 due Monday July 12 by 11 PM	
Topic H	Dimensional Analysis	Chapter 7 and 11-1 to 11-4, 11-6
	Homework 8 due Monday July 19 by 11 PM	

EXAM 2, 60 minutes, available Friday July 23 from noon to 11 PM EDT

Topic I	Differential Equation for Mass (Continuity)	9-2
	Differential Equation for Momentum (Navier-Stokes)	middle of page 469 to 475
	Examples	9-6
	Homework 9 due Monday August 2 by 11 PM	
Topic J	Boundary Layers	10-6 (pages 559-576 only) and 11-5 to 11-6
	Homework 10 due Monday August 9 by 11 PM	

Final Exam, 120 minutes, available Friday August 13 from noon to 11 PM EDT

Homework Solution Format

In engineering, a clear organized solution of a problem can be more important than the final numerical answer. On the job, coworkers will often review your work and an organized solution allows others to quickly understand what you have done. For a clear presentation, all important steps and assumptions must be included in the solution. A statement about the method of solution may also be included for clarity.

Engineering quality solutions will be required for some homework problems. Both the solution presentation and the final results will be graded for these problems. All important steps in the solutions must be included and must be easily understood. The following guidelines should be followed when using the Homework Solution Format. **Use the bold word titles (not the step numbers) below as headings in your solutions.** You will also find these steps outlines in Section 1-8 of the text on page 24.

Begin each problem on a new piece of paper. You can use the back side of the page to continue the problem solution if necessary.

Step 1: **Problem Statement.** In your own words briefly state the problem and what will be found. Do not repeat the given problem statement.

Step 2: **Schematic.** Draw a sketch when possible showing dimensions and labeling fluids.

- For a control volume analysis, indicate the control volume being used, the direction of forces applied, and the coordinate system being used.
- For an analysis along a streamline, draw the streamline and label locations 1 and 2.

Step 3: **Assumptions and Approximations.** List all assumptions and approximations.

Step 4: **Physical Laws.** State the basic governing equations used to solve the problem. These equations will be found from the textbook or lecture notes. State the equation number beside any equation from the text. State the lesson number and slide number (for example LB2S6) for any equation from the lesson slides.

Step 5: **Properties.** List the properties to be used and reference the table in which the values were found. In this section, list only fluid and solid properties found from tables; problem dimensions are included in the schematic. Properties can only be used from the textbook and the Properties Handout found on Canvas. If the properties handout was used, reference “Properties Handout”. Do not use properties found online. Points will be taken off if the reference is not included with the properties. As an example

Water at 20°C:	ρ=998 kg/m^3	Properties Handout
Gold:	SG=19.2	Table 2-1

Conversion factors can also be listed in the Properties section.

Step 6: **Calculations.** Problems should be solved using variables. As a last step, numbers are substituted and the final numerical result is obtained. The equation with numerical values substituted must be written before the final numerical result is found. Points will be taken off on each problem if this step is omitted.

- Include units in the final result.
- Box the final result given to three significant digits. Intermediate values should be carried to four digits so that the final answer is accurate to three digits.

Step 7: **Discussion.** Discuss the results. Are the results expected? What does the solution in variable form tell you? For example, if the pressure drop is doubled in a pipe flow problem, how does the flow velocity change? When the problem includes a velocity, compare that velocity to the speeds you found in Problem 5 of Homework 1.

Course Objectives and Outcomes

Course Objectives (Broad Goals):

A. Develop appreciation for the beauty of fluid phenomena and understanding of the relationship between the mathematics, the physics and the modeling of fluid mechanics.
B. Develop proficiency in the analysis of fluids systems with mathematical modeling, measurement tools, and computer technologies.
C. Understand the application of fluid mechanics to engineering, technology, biology, the environment, and other fluid phenomena.
D. Advance proficiency in professional communications and interactions.

Course Outcomes (Graded student work): (Mapping to Course Objectives shown in brackets)

1. Articulate the properties that distinguish fluids from other forms of matter, and the broad range of engineering applications and natural phenomena that involve fluid mechanics. [A]
2. Apply concepts of vector fields (velocity and streamlines, force and acceleration), scalar fields (pressure, density, temperature), and vector differential and integral calculus to engineering analysis of fluids systems, and to the interpretation of flow physics through the conservation laws and flow visualization. [A,B]
3. Apply Newton's second law to analysis and design involving fluids at rest using integral and differential calculus, including pressure variation, forces and moments on plane surfaces, and buoyancy. [A,B,C]
4. Apply systems and control volume methods based on mass, momentum, and energy conservation, as appropriate, to the analysis and design of engineering fluid systems. [B,C]
5. Interpret and apply the various differential forms of the conservation laws, particularly Newton's second law and its various approximate forms, to engineering analysis and design. [B, C]
6. Apply mass, momentum, and energy conservation to steady internal (pipe and duct) flows, correctly interpret and apply laminar and turbulent flow models, and estimate head loss and power requirements in piping systems. [B, C]
7. Develop mathematical models through justifiable approximations; for example, correctly interpret and apply the boundary layer approximation, the “inviscid” approximation and the Bernoulli relationships to analysis of fluid systems, and estimate levels of approximation in engineering models. [A, B, C]
8. Apply basic principles of dimensional homogeneity to engineering analysis, and apply dimensional analysis and similitude to the design of experiments, and to the representation and interpretation of data. Properly interpret the Reynolds number and other fundamental nondimensional parameters, and their roles in defining regimes of fluid flows. [B]
9. Apply integral methods, and basic empirical and theoretical models, to the analysis of boundary layer flows, and to the estimation of lift and drag on bodies. [A, B]
10. Apply fundamental knowledge of fluid mechanics to the analysis of specific sensors and instruments used in fluid-flow experiments. [B]
11. Apply basic software tools (e.g., spreadsheets and mathematical solving software) to the analysis of experimental data and mathematical models. [B, D]
12. Demonstrate the ability to solve problems in a clear step-by-step manner and follow policies and instruction as outlined in the syllabus and other course materials. [D]
13. Demonstrate professionalism in oral and written communications with course instructors and fellow students. [D]

ME 320 Fluid Flow, Summer Session 2021
Syllabus
Readings from 3rd Edition of Text

	Topics	Reading
Topic A	Introduction to Fluids and Fluid Properties	Chapter 1& 2
	Homework 1 due Monday May 24 by 11 PM	
Topic B	Hydrostatic Pressure, Manometry	3-1 to 3-3
	Hydrostatic Forces on Submerged Plane Surfaces	3-4
	Homework 2 due Tuesday June 1 by 11 PM	
Topic C	Buoyancy	3-6 pages 98-101 only
	Fluid Kinematics	4-1 to 4-5
	Homework 3 due Monday June 7 by 11 PM	
Topic D	Reynolds Transport Theorem	4-6, 5-1
	Integral Conservation of Mass Equation	5-2
	Homework 4 due Monday June 14 by 11 PM	
Topic E	Bernoulli Equation	5-4
	Homework 5 due Monday June 21 by 11 PM	

EXAM 1, 60 minutes, available Friday June 25 from noon to 11 PM EDT

Topic F	Integral Linear Momentum Equation	6-1 to 6-4
	Homework 6 due Monday July 5 by 11 PM	
Topic G	Internal Flows	5-6, Chapter 8
	Homework 7 due Monday July 12 by 11 PM	
Topic H	Dimensional Analysis	Chapter 7 and 11-1 to 11-4, 11-6
	Homework 8 due Monday July 19 by 11 PM	

EXAM 2, 60 minutes, available Friday July 23 from noon to 11 PM EDT

Topic I	Differential Equation for Mass (Continuity)	9-2
	Differential Equation for Momentum (Navier-Stokes)	middle of page 463 to 469
	Examples	9-6
	Homework 9 due Monday August 2 by 11 PM	
Topic J	Boundary Layers	10-6 (pages 555-572 only) and 11-5 to 11-6
	Homework 10 due Monday August 9 by 11 PM	

Final Exam, 120 minutes, available Friday August 13 from noon to 11 PM EDT

ME 320 Fluid Flow, Summer Session 2021
Syllabus
Readings from 2nd Edition of Text

	Topics	Reading
Topic A	Introduction to Fluids and Fluid Properties	Chapter 1& 2
	Homework 1 due Monday May 24 by 11 PM	
Topic B	Hydrostatic Pressure, Manometry	3-1 to 3-3
	Hydrostatic Forces on Submerged Plane Surfaces	3-4
	Homework 2 due Tuesday June 1 by 11 PM	
Topic C	Buoyancy	3-6 pages 97-100 only
	Fluid Kinematics	4-1 to 4-5
	Homework 3 due Monday June 7 by 11 PM	
Topic D	Reynolds Transport Theorem	4-6, 5-1
	Integral Conservation of Mass Equation	5-2
	Homework 4 due Monday June 14 by 11 PM	
Topic E	Bernoulli Equation	5-4
	Homework 5 due Monday June 21 by 11 PM	

EXAM 1, 60 minutes, available Friday June 25 from noon to 11 PM EDT

Topic F	Integral Linear Momentum Equation	6-1 to 6-4
	Homework 6 due Monday July 5 by 11 PM	
Topic G	Internal Flows	5-6, Chapter 8
	Homework 7 due Monday July 12 by 11 PM	
Topic H	Dimensional Analysis	Chapter 7 and 11-1 to 11-4, 11-6
	Homework 8 due Monday July 19 by 11 PM	

EXAM 2, 60 minutes, available Friday July 23 from noon to 11 PM EDT

Topic I	Differential Equation for Mass (Continuity)	9-2
	Differential Equation for Momentum (Navier-Stokes)	middle of page 445 to 451
	Examples	9-6
	Homework 9 due Monday August 2 by 11 PM	
Topic J	Boundary Layers	10-6 (pages 531-548 only) and 11-5 to 11-6
	Homework 10 due Monday August 9 by 11 PM	

Final Exam, 120 minutes, available Friday August 13 from noon to 11 PM EDT

ME 320 Fluid Flow, Summer Session 2021
Syllabus
Readings from 1st Edition of Text

	Topics	Reading
Topic A	Introduction to Fluids and Fluid Properties	Chapter 1& 2
	Homework 1 due Monday May 24 by 11 PM	
Topic B	Hydrostatic Pressure, Manometry	3-1 to 3-3
	Hydrostatic Forces on Submerged Plane Surfaces	3-4 to 3-5
	Homework 2 due Tuesday June 1 by 11 PM	
Topic C	Buoyancy	3-7 pages 89-92 only
	Fluid Kinematics	4-1 to 4-4
	Homework 3 due Monday June 7 by 11 PM	
Topic D	Reynolds Transport Theorem	4-5, 5-1
	Integral Conservation of Mass Equation	5-2
	Homework 4 due Monday June 14 by 11 PM	
Topic E	Bernoulli Equation	5-4 and 5-5
	Homework 5 due Monday June 21 by 11 PM	

EXAM 1, 60 minutes, available Friday June 25 from noon to 11 PM EDT

Topic F	Integral Linear Momentum Equation	6-1 to 6-4
	Homework 6 due Monday July 5 by 11 PM	
Topic G	Internal Flows	5-7, Chapter 8
	Homework 7 due Monday July 12 by 11 PM	
Topic H	Dimensional Analysis	Chapter 7 and 11-1 to 11-4, 11-6
	Homework 8 due Monday July 19 by 11 PM	

EXAM 2, 60 minutes, available Friday July 23 from noon to 11 PM EDT

Topic I	Differential Equation for Mass (Continuity)	9-2
	Differential Equation for Momentum (Navier-Stokes)	middle of page 425 to 431
	Examples	9-6
	Homework 9 due Monday August 2 by 11 PM	
Topic J	Boundary Layers	10-6 (pages 511-528 only) and 11-5 to 11-6
	Homework 10 due Monday August 9 by 11 PM	

Final Exam, 120 minutes, available Friday August 13 from noon to 11 PM EDT