ME 320, *Fluid Flow*

Syllabus for Fall Semester 2024

John M. Cimbala, Penn State University. Latest update: 29 July 2024

Lectures: **Lesson videos, notes, quizzes, and homeworks on Canvas. In-person class time used for review, additional examples, and Q&A. M, W, [F if necessary] 11:15-12:05 in 129 Waring Hall.**

Videos: See https://www.me.psu.edu/cimbala/Cengel_Cimbala_book/Supplements/List_Fluid_Mechanics_Lesson_Videos_for_CC_Book.xlsx

Text: ***Fluid Mechanics: Fundamentals and Applications***, Y. A. Çengel and J. M. Cimbala, McGraw-Hill, New York - ***required***. Any edition is acceptable, print or e-book.

Prerequisites: E MCH212, MATH 251; M E 201 or M E 300; MATH 230 or MATH 231 or equivalent.

Instructor:
- **John M. Cimbala**, jmc6@psu.edu. Professor of Mechanical Engineering, 234 Reber Building, **814-863-2739**, www.me.psu.edu/cimbala. ←Weekly schedule is posted on this website.
- Office hours: **Wednesday 3:00-5:00 pm** [Subject to change – will notify.]

TAs/Grader: **Baha El-Khader** (bte5086) and **TBA** (xxx1234) – The TAs/Graders will grade all homeworks.

Course Description: This course is an introduction to fluid mechanics; it emphasizes fundamental concepts and problem-solving techniques. Topics to be covered include fluid properties, fluid statics, fluid kinematics, control volume analysis, dimensional analysis, internal flows (pipe flows), differential analysis (including approximations such as creeping flow, potential flow, and boundary layers), and external flows (lift and drag). Brief introductions to computational fluid dynamics (CFD), compressible flow, and turbomachinery (pumps and turbines) will also be provided. ***Students are expected to read the assigned portions of the text***! Students are also expected to be proficient in applying mathematics (e.g., integration, differentiation, and application of differential equations), statics and dynamics (e.g., free body diagrams), and thermodynamics (e.g., first law, systems, and control volumes).

Web Pages: The main website for this course is on Penn State's Canvas site at **https://psu.instructure.com/**. Professor Cimbala also maintains a second website at **http://www.me.psu.edu/cimbala/me320** where he will post lesson videos, etc. in the event that Canvas is down. Use this website only if you have trouble connecting or finding something on Canvas. Students are expected to check Canvas regularly for lesson notes and videos, homework assignments, quizzes, and other information. Hardcopies (handouts) of homework assignments will *not* be provided.

Grading: All quizzes, exams, and homework assignments are *comprehensive*, making use of previous material. Automatic late penalties are given in Canvas for late submissions of homework and quizzes.

Homework	**21%**	Highest 14 scores counted out of 15 total; due the **next** Wednesday each week at midnight
Lesson Quizzes	**65%**	Typically one quiz per lesson; due the **next** Wednesday each week at midnight; highest 65 scores counted out of approximately 75 total
Final Exam	**14%**	**3 hours online during finals week; 12:01 am December 16 to 11:59 pm December 18**

Course Objectives: Upon completion of this course, students should be able to:

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.
2. Interpret and distinguish various kinematic descriptions of fluid flows (scalar and vector fields, streamlines, streaklines, pathlines, timelines, acceleration).
3. Analyze and solve problems involving fluids at rest, including pressure variation, forces and moments on surfaces, buoyancy and stability.
4. Interpret and apply the various differential and integral forms of the conservation laws of mass, momentum, and energy, and their various approximate forms, to engineering analysis and design.
5. Apply dimensional analysis and similarity and scaling principles to the design and analysis of experiments, nondimensionalized equations, and interpretation of nondimensional parameters (Reynolds number, drag coefficient, power coefficient).
6. Evaluate head loss and power requirements in piping systems by applying conservation laws to laminar and turbulent internal (pipe and duct) flows.
7. Solve fluid flow problems by identifying appropriate assumptions and approximations (creeping flow, potential flow, Bernoulli, boundary layers)
8. Calculate lift and drag on bodies using integral methods and boundary layer analysis.
9. Solve compressible flow problems including flow through converging-diverging nozzles, choked flow, and normal shock waves, emphasizing differences between compressible and incompressible flow.

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Schedule: We plan to follow the schedule below, ***subject to change***. Note that the **Modules** on Canvas correspond to typical semester **Calendar Weeks** since there are 15 modules and 15 weeks in the semester.

Week #	Module (Week) Number and Name and Topics to be Covered	Textbook Chapter(s)
1	**MODULE 01: Introduction and Fluid Properties**: fluids and their applications, no-slip condition, classification of fluid flows; density, viscosity, vapor pressure, surface tension	**1, 2**
2	**MODULE 02: Pressure and Fluid Statics**: hydrostatic equation, hydraulic jacks, barometers, and manometers	**3**
3	**MODULE 03: Pressure and Fluid Statics (continued)**: hydrostatic forces on submerged surfaces, buoyancy and stability, fluids in rigid body motion	**3**
4	**MODULE 04**: **Fluid Kinematics**: Lagrangian and Eulerian descriptions, flow visualization, vorticity, Reynolds transport theorem	**4**
5	**MODULE 05**: **Conservation Laws:** mass and energy control volume equations; irreversible losses; turbomachinery efficiencies; grade lines	**5**
6	**MODULE 06**: **Conservation Laws (continued)**: Bernoulli equation; linear momentum equation	**6**
7	**MODULE 07**: **Dimensional Analysis and Modeling**: dimensional homogeneity, dimensional analysis, experimental testing, similarity	**7**
8	**MODULE 08**: **Flow in Pipes**: laminar versus turbulent flow, major and minor losses	**8**
9	**MODULE 09**: **Flow in Pipes (continued)**: major and minor losses, piping networks and pump selection, pumps and turbines, flow rate and velocity measurement instruments	**8, parts of 14**
10	**MODULE 10**: **Differential Analysis**: stream function, continuity, Navier-Stokes equation	**9**
11	**MODULE 11**: **Differential Analysis (continued)**: analytical solutions; introduction to computational fluid dynamics (CFD)	**9, parts of 15**
12	**MODULE 12**: **Approximate Solutions**: creeping flow, inviscid regions, irrotational regions	**10**
13	**MODULE 13**: **Approximate Solutions (continued)**: boundary layers	**10**
14	**MODULE 14**: **External Flows**: drag and lift, friction and pressure drag	**11**
15	**MODULE 15**: **Introduction to Compressible Flow**: isentropic flow, shock waves	**12**

Grading Scale:
The following are minimum cutoffs for each grade:

- 90.00% = A
- 86.66% = A-
- 83.33% = B+
- 80.00% = B
- 76.66% = B-
- 73.33% = C+
- 70.00% = C
- 60.00% = D
- less than 60.00% = F

Grade Disputes: If a student feels that an exam or homework was graded unfairly, or if there is an error in the grading, it should be brought to the attention of the grader (TA: homework, Professor: quizzes and exams) within one week after the material is graded except under extenuating circumstances.

Cheating Policy: Cheating is not tolerated in this course. You should refer to the Academic Integrity website at http://www.engr.psu.edu/faculty-staff/academic-integrity.aspx which explains what behaviors are in violation of academic integrity, and the review process for such violations. On the next page is a summary of the policy. Specifically for this course:

- First offense: Zero score for the item in question, and infraction reported to the College.
- Second offense: Failure of the course, and infraction reported to the College.

Summary of Penn State's Academic Dishonesty Policy: The University defines academic integrity as the pursuit of scholarly activity in an open, honest and responsible manner. All students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts (refer to Senate Policy 49-20. Dishonesty of any kind will not be tolerated in this course. Dishonesty includes, but is not limited to, cheating, plagiarizing, fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the instructor, or tampering with the academic work of other students. Students who are found to be dishonest will receive academic sanctions and will be reported to the University's Office of Student Conduct for possible further disciplinary sanctions (refer to Senate Policy G-9).

Definition and expectations: Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. Academic integrity is a basic guiding principle for all academic activity at The Pennsylvania State University, and all members of the University community are expected to act in accordance with this principle.

Accommodating Disabilities and Disability Access Statement:

Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Office for Disability Services (ODS) 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 Office for Disability Services Web site : http://equity.psu.edu/ods .

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: For further information, please visit the Student Disability Resources Web site: **http://equity.psu.edu/student-disability-resources.** In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation. See **http://equity.psu.edu/student-disability-resources/applying-for-services.** If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

Counseling & Psychological Services (CAPS) Statement:

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. You can contact CAPS by calling the Main CAPS number/Appointment Scheduling: 814-863-0395 (Please call between the hours of 8am and 5pm, Monday-Friday to schedule an appointment) or visit us at our office location, 5th Floor Student Health Center.

Sexual Assault and Relationship Violence Hotline:

A hotline has been established for victims and observers of sexual assault and relationship violence. Trained counselors on the hotline will help students access appropriate resources. Penn State students from any campus can call 1 (800) 560-1637 to access the 24 hour a day, seven day a week hotline.

Library Resources:

Many of Penn State's library resources can be utilized from a distance. Through the University Libraries website, you can

- access magazine, journal, and newspaper articles online using library databases;
- borrow materials and have them delivered to your doorstep...or even your desktop;
- get research help via e-mail, chat, or phone using the Ask a Librarian service (Links to an external site.)Links to an external site.; and much more.

You must have an active Penn State Access Account to take full advantage of the University Libraries' resources and services. Once you have a Penn State account, you will automatically be registered with the library within 24–48 hours. If you would like to check that your registration has been completed, visit the Libraries home page (Links to an external site.)Links to an external site., click on **Library Accounts**, and then click on **My Library Account**.

Academic Integrity:

Academic integrity—scholarship free of fraud and deception—is an important educational objective of Penn State. Academic dishonesty can lead to a failing grade or referral to the Office of Student Conduct (Links to an external site.)Links to an external site. Academic dishonesty includes but is not limited to

- cheating,
- plagiarism,
- fabrication of information or citations,
- facilitating acts of academic dishonesty by others,
- unauthorized prior possession of examinations,
- submitting the work of another person or work previously used without informing the instructor and securing written approval, and
- tampering with the academic work of other students.

The University defines academic integrity as the pursuit of scholarly activity in an open, honest and responsible manner. All students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts (refer to Senate Policy 49-20). Dishonesty of any kind will not be tolerated in this course. Dishonesty includes, but is not limited to, cheating, plagiarizing, fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of

another person or work previously used without informing the instructor, or tampering with the academic work of other students. Students who are found to be dishonest will receive academic sanctions and will be reported to the University's Office of Student Conduct for possible further disciplinary sanctions (refer to Senate Policy G-9).

How Academic Integrity Violations Are Handled:

In cases where academic integrity is questioned, the Policy on Academic Integrity (Links to an external site.)Links to an external site. indicates that procedure requires an instructor to notify a student of suspected dishonesty before filing a charge and recommended sanction with the college. Procedures allow a student to accept or contest a charge. If a student chooses to contest a charge, the case will then be managed by the respective college or campus Academic Integrity Committee. If a disciplinary sanction also is recommended, the case will be referred to the Office of Student Conduct (Links to an external site.)Links to an external site.. All Penn State colleges abide by this Penn State policy, but review procedures may vary by college when academic dishonesty is suspected. Information about Penn State's academic integrity policy and college review procedures is included in the information that students receive upon enrolling in a course. To obtain that information in advance of enrolling in a course, please contact us by going to the Contacts & Help page (Links to an external site.)Links to an external site..

Additionally, World Campus students are expected to act with civility and personal integrity; respect other students' dignity, rights, and property; and help create and maintain an environment in which all can succeed through the fruits of their own efforts. An environment of academic integrity is requisite to respect for oneself and others, as well as a civil community.

For More Information on Academic Integrity at Penn State:

Please see the Academic Integrity Chart (Links to an external site.)Links to an external site. for specific college contact information or visit one of the following sites:

- Penn State Senate Policy on Academic Integrity (Links to an external site.)Links to an external site.
- iStudy for Success! (Links to an external site.)Links to an external site. (education module about plagiarism, copyright, and academic integrity)
- Turnitin (Links to an external site.)Links to an external site. (a web-based plagiarism detection and prevention system)