University of Colorado Boulder **MCEN 5021/ASEN 5051; Fall 2019**
Department of Mechanical Engineering **Introduction To Fluid Dynamics**

Syllabus

1. Course specifics:

Instructor: Prof. Debanjan Mukherjee **Email:** debanjan@Colorado.Edu
Grader/TA: Srinath Karmungi **Email:** Srinath.Karmungi@Colorado.Edu

Class timings: Mon-Wed-Fri: 02:00 pm – 02:50 pm
Classroom: ECCR 105

Office hours: Mondays 03:00 pm – 04:30 pm. ECME 275
Wednesdays 10:00 am – 12:00 pm. ECME 275
Additional meetings/office hours: by appointment.
In case of any missed office hours, make up office hours of equivalent time will be posted.

Course website: All materials, assignments, and communications will be handled through the course website on Canvas (canvas.colorado.edu).

2. Course description:

This course serves to provide a graduate level introduction to the foundational concepts in fluid mechanics. Students will learn about the fundamental fluid forces; kinematics in fluids; balance laws for mass, momentum, and energy; and use mathematical formulations based on these to analyze classical flow problems. The course will explore concepts of incompressibility vs compressibility; vortices and vorticity; laminar vs turbulent flows; potential flows; boundary layers; and dimensional analysis.

3. Textbooks and references:

The primary text we will follow for this course is: ***Fluid Mechanics, 6th Edition – Pijush Kundu, Ira Cohen, David Dowling, Elsevier***. The library at CU Boulder has an electronic copy for all students to download, when logged in from university proxied networks.

Other texts that you may find helpful as reference from time to time (and for future studies in fluid mechanics) include the following:

- *Viscous fluid flow – Frank M. White; Mcgraw Hill, Inc.*
- *Continuum mechanics: concise theory and problems – P. Chadwick; Dover Publications.*

4. Learning goals:

The broad learning outcomes of this class comprise building a strong foundation in:

(a) identifying and understanding fundamental concepts in fluid mechanics;
(b) describing fluid flow in a variety of scenarios physically and analytically; and
(c) communicating these physical and mathematical aspects in a technically proficient manner.

The overarching technical learning goals for this class have been listed below, wherein at the end of this course, students will be able to:

- ✓ Recognize the wide spectrum of physics and applications underlying the subject of fluid mechanics.
- ✓ List the fundamental similarities and differences between behavior of fluids and solids.
- ✓ Recall the basic definitions of fundamental physical and thermodynamical parameters.
- ✓ List the fundamental mathematical definitions and operations for Cartesian vectors and tensors.
- ✓ Recognize that flow comprises deformation driven by external forces.
- ✓ List the basic descriptors of deformation in continuous media using vector/tensor machinery.
- ✓ Analyze common flow kinematics using continuum deformation and kinematics measures.
- ✓ Recall basic balance laws for mass, momentum, and energy for bulk material.
- ✓ Develop governing equations for balance laws in continuous media using vector/tensor machinery.
- ✓ Explain the definition and importance of material constitutive laws.
- ✓ Identify the common boundary conditions required for flow analysis.
- ✓ Analyze common fluid flow dynamics problems using continuum balance laws.
- ✓ Explain basic concepts pertaining to vortex and vorticity.
- ✓ State the basic theorems on vortex and vorticity.
- ✓ Derive vorticity theorems and results using fundamental continuum equations/definitions.
- ✓ Describe analytically how vortices interact and influence flow velocities.
- ✓ State the definition of, and common mathematical conditions in, ideal flow.
- ✓ Recognize the formulation and limitations of ideal flow theory.
- ✓ Illustrate the use of stream function and velocity potential in two/three dimensional flows.
- ✓ Derive classical ideal flow results for flows past simple objects.
- ✓ State the definition of, and common mathematical conditions in, laminar flow.
- ✓ Outline typical steps in obtaining flow solutions from fundamental balance equations.
- ✓ Develop exact and approximate solutions for viscous flows in confined and unconfined geometries.
- ✓ State the definition of, and associated mathematical simplifications for, boundary layers.
- ✓ Outline the equations of fluid motion for attached laminar boundary layers.
- ✓ Develop exact and approximate solutions for steady laminar boundary-layer flow.
- ✓ Describe the basic phenomenology of boundary layer transition and separation.

Week by week logistical and topical breakdown will also be available on Canvas in form of modules, and will be updated as and when any changes occur.

This course serves only as a graduate level introduction to fluid mechanics, focusing more on the fundamental concepts than a deep dive into a set of topical areas. In view of that scope, it is also important to make note of topics that we will NOT be covering in-depth within the scope of this course:

- Detailed mathematical and physical treatment of turbulent flows.
- Detailed mathematical and physical treatment of compressible flows.
- Detailed discussion on concepts pertaining to flow instabilities.
- Special topics like: environmental flows, geophysical flows, biological flows, multiphase flows etc.

The mechanical and aerospace engineering departments (and other departments within the college) offer several specialized courses on each of these topics which would be suitable next steps to pursue your interests in these directions after our graduate level introduction. Please consult with your instructor if you have interests in any of these other topical areas.

5. Grading and evaluation policies:

5.1. Grade breakdown:

Course grading will be based on a combination of homeworks, a midterm examination, and a final project. Final grades will equal ***50% of all homeworks + 25% examination + 25% final project***.

5.2. Homework submissions:

All homework submissions will be handled electronically, and submissions will be accepted only via the submissions webpage on Canvas. Students are required to type out problem solutions using a software tool of their choice (Word/Powerpoint/TeX etc.). Students are encouraged to work with their peers on the homeworks. However, each student ***must submit their own version of the homework*** for the final homework submissions.
Note: For students choosing to use TeX for their work, the online tool Overleaf is highly recommended.

5.3. Practice and zero-grade assignments:

From time to time, assignments that have 0 grades associated with it will be posted. These will be extra practice material, and activity based exercises etc. to help students learn. It is NOT MANDATORY to complete and submit these assignments. However, students will have an option of reporting completion of these activities, and submitting them. If a student has completed all of these, he/she/they will receive an option of extra credit based on this work.

5.4. Late submission policy:

Late submissions for homeworks will receive a penalty (i.e. docked points). Any late submission will get 20% points docked + 1% for each day of delay thereafter. Thus, if a student submits a homework 2 days after the due date – 22% of that homework score will be docked. If a student knows in advance that he/she/they must miss a homework due date – no later than the date of issue of corresponding homework – the student must send the instructor an email to schedule alternate submission arrangements. Any such requests sent beyond the date of issue of homework will not be considered.

5.5. Regrading requests:

Regrading requests must be addressed to both the TA as well as the instructor – with a clear and reasonable explanation of the reason for the request for change of grades. It is NOT guaranteed that the request will be considered and lead to change of grades. In addition, if during regrading, the instructor/TA finds sufficient reasons for reducing grades which were originally not accounted for – they MAY reduce grades accordingly. These rules are in place to make students ***treat their regrading requests seriously***, and ***look through their graded work very carefully prior to submitting a request***.

5.5. Examination:

The course will comprise a midterm examination which will be conducted towards the later quarter of the semester. Exact examination date will be confirmed after the first half of the semester. Unless otherwise stated during the course of the semester – the examination will be take-home. The examination will have to be turned in as hard-copy by the deadline mentioned on the examination at the time of administration. No late submissions will be accepted. In addition, the examination will ***not be preponed or postponed for any student***. If you have a major scheduling conflict with the exam date (when decided) you ***MUST IMMEDIATELY*** inform your instructor.

5.6. Course project:

In lieu of a course final examination, there will be a course final project, which is designed after mimicking the creation of a journal issue.

Students will form teams of 3 – and each student will conduct a literature review on a topic in fluid mechanics. Topics can be independently chosen, or students can ask instructor to recommend topics. Topics must represent a broad enough domain area in fluid mechanics and not a specific individual project. Students are required to conduct a review of peer-reviewed journal articles on this chosen topic. A minimum of 8 and a maximum of 12 papers must be included in the review (assuming groups of 3). Students are required to write a review article – formatted as a journal manuscript – based on their literature review. The review articles will then undergo single-blind peer review. Each paper will have 2 reviewers + reviewed by instructor. Students will get the chance to revise their manuscript based on this review and submit the final version. Deadline to submit the revised version of the manuscripts is the last day of scheduled final examinations. The final mock journal issue will be emailed to all students at the end of the class.

Combined grades for this activity will depend upon:
(a) quality of the manuscript;
(b) quality of the peer-review comments by the student reviewer; and
(c) quality of the student-author response to reviews.

The design of this course project targets a key learning objective for this class. We want students from this class to not only learn basic concepts in fluid mechanics, but also to: (a) use their learning to comprehend state of the art research/technical articles, (b) synthesize their interpretation of these articles, and (c) communicate this effectively to a technically knowledgeable peer-audience.

5.7. Privacy of graded work and submissions:

Grades for all graded work will always be communicated privately, via your account on Canvas. All requests for regrades will also always be handled in a private manner. At any point of time, the instructor will only reveal to all students class averages, and related statistical trends.

6. Communications:

Outside of office hours and scheduled meetings, emails are the best way to communicate with your instructor. Students can expect a response in a 24 hour time window – and should feel free to send a reminder email (on sufficiently urgent matters) if they do not hear within 24 hours. Note that practices like sending homework emails the day before submissions at 2:00 am will not be tolerated, and ***students are encouraged to always communicate in a timely manner***. Policies of respectful and professional communication as outlined in Section 10-12 will apply to all such communications. Additionally, students are encouraged to make good use of the peer-to-peer discussion forum on Canvas which will be set-up (see Section 9). Students can post *"Can someone help me with …"* type questions on the forum – and any of their peers who may have a solution will be able to quickly pitch in.

7. Honor code:

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

8. Course expectations - Academic integrity and dishonesty:

Students are expected to follow the University honor code, and uphold the highest levels of academic integrity and honesty at all times. ***Homework submissions must be individually submitted, and no plagiarism of any form will be tolerated***. Examples of plagiarism in our context will include: copying homework from a solution manual, copying directly from an online resource, copying directly from classmates etc. Additionally, ***any existing material used – both in homeworks and in project – must be duly cited***. Especially for the course project, copying text from the papers to be reviewed will not be tolerated. Lastly, the examination will be administered as a take-home examination, and any attempts to discuss the examination with peers, or copying/cheating, will lead to zero grades on the examination. Any ***complaint for plagiarism or academic dishonesty will be dealt with seriously***, which may include penalties on homework/project/exam scores, and an entry in your departmental file/record.

9. Collaboration and peer-learning emphasis:

Collaborative work and peer-to-peer learning comprises a major focus of this course. To facilitate this, there will be a peer-learning discussion forum that will be activated on Canvas. Students are encouraged to post questions, help fellow students, and answer questions etc. Helpful and active students may receive ``Good Citizen Brownie Points''! Instructor and TA will try and ensure this is as much peer-driven as possible, and will only moderate from time to time on this forum as and when deemed necessary (or appropriate). Furthermore, as mentioned earlier, students are encouraged to work together on homeworks and assignments (but students MUST submit thier own work). Copying and submitting duplicate assignments of each other will NOT be tolerated. ***Working together does not mean plagiarizing each other's work.***

10. Classroom behavior:

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Class rosters are provided to the instructor with the student's legal name. Instructor will gladly honor your request to address you by an alternate name or gender pronoun. Please advise us of this preference early in the semester so that Instructor may make appropriate changes to my records. For more information, see the policies on classroom behavior and the Student Code of Conduct.

11. Sexual misconduct, discrimination, harassment and/or related retaliation:

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct intimate partner abuse (including dating or domestic violence), stalking, protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

12. Course expectations – Academic climate and in-class/out-of-class behavior:

Students will be held to the highest standards of respectful, collegial, non-discriminatory, and non-disruptive behavior both inside and outside of the classroom. Complementing the standard University policy on conduct and behavior, we will also expect students in this class to create a professional atmosphere in the classroom by: (a) silencing mobile phones, muting laptops, and reducing their usage

to the utmost minimum during the class; (b) refraining from disrupting others in the class if student needs to arrive late or leave early on some day owing to reasonable circumstances; (c) treating each other with respect in the classroom as well as non-classroom interactions (emails, discussion forums, group meetings for homework/project); (d) never using hateful or offensive language that disrupts the inclusive nature of our classroom. In addition, time is of value to everyone – hence it is expected that students will be respectful of everyone's time. This means respecting office hour schedules, keeping extra office hour requests for reasonable situations only, and being mindful of your peer's time for group work (homeworks or projects). Finally, most communications and scheduling happens over email. Hence, it is of utmost importance that students communicate using respectful and professional emails. Any unprofessional language in emails will not be tolerated.

13. Other specific course policies:

During the semester, in case instructor is traveling for a certain date, the class for that date will be administered as a ``flipped classroom". Specifically, video recorded lecture material will be sent out via Canvas, and students will be required to work with the video, following which they attend regular class hours with the TA to address any specific questions or clarifications they may have. In addition, for each class missed due to travel, the instructor will hold extra office hours equivalent of class time.

14. Accommodation for disabilities:

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website.

15. Accommodation for religious holidays:

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, standard campus practices and policies will be followed.

16. Tentative course schedule:

A tentative weekly topical schedule has been listed below, along with coordinated assignment submission timelines. Please note that this may change during the course, and the latest version will always be available on Canvas.

Week	Day	Classes	Assignments	Notes	Details/Remarks
Aug. 26 - Aug. 30	Mon	Lec 1	HW 1 Issued Friday	Course Overview and Syllabus	
Aug. 26 - Aug. 30	Wed	Lec 2		Introductory Concepts I	
Aug. 26 - Aug. 30	Fri	Lec 3		Introductory Concepts II	
Sep. 02 - Sep. 06	Mon				Labor Day Holiday
Sep. 02 - Sep. 06	Wed	Lec 4		Vectors and Tensors I	Project topic decision + advising: starts
Sep. 02 - Sep. 06	Fri	Lec 5		Vectors and Tensors II	
Sep. 09 - Sep. 13	Mon	Lec 6	HW 1 due Friday; HW 2 issued Friday	Fluid kinematics I	
Sep. 09 - Sep. 13	Wed	Lec 7		Fluid Kinematics II	
Sep. 09 - Sep. 13	Fri	Lec 8		Fluid Kinematics III	
Sep. 16 - Sep. 20	Mon	Lec 9		Fluid Kinematics IV	Project topic decision + advising: ends
Sep. 16 - Sep. 20	Wed	Lec 10		Fluid Kinematics V	
Sep. 16 - Sep. 20	Fri	Lec 11		Fluid Kinematics VI	
Sep. 23 - Sep. 27	Mon	Lec 12	HW 2 due Friday; HW 3 issued Friday	Conservation Laws I	
Sep. 23 - Sep. 27	Wed	Lec 13		Conservation Laws II	
Sep. 23 - Sep. 27	Fri	Lec 14		Conservation Laws III	
Sep. 30 - Oct. 04	Mon	Lec 15		Conservation Laws IV	
Sep. 30 - Oct. 04	Wed	Lec 16		Conservation Laws V	
Sep. 30 - Oct. 04	Fri	Lec 17		Conservation Laws VI	
Oct. 07 - Oct. 11	Mon	Lec 18	HW 3 due Friday; HW 4 issued Friday	Vorticity I	
Oct. 07 - Oct. 11	Wed	Lec 19		Vorticity II	
Oct. 07 - Oct. 11	Fri	Lec 20		Vorticity III	
Oct. 14 - Oct. 18	Mon	Lec 21		Vorticity IV	Final list of papers for review due Friday
Oct. 14 - Oct. 18	Wed	Lec 22		Vorticity V	
Oct. 14 - Oct. 18	Fri	Lec 23		Potential Flow I	
Oct. 21 - Oct. 25	Mon	Lec 24	HW 4 due Friday; HW 5 issued Friday	Potential Flow II	
Oct. 21 - Oct. 25	Wed	Lec 25		Potential Flow III	
Oct. 21 - Oct. 25	Fri	Lec 26		Potential Flow IV	
Oct. 28 - Nov. 01	Mon	Lec 27		Potential Flow V	DM is away on travel all week
Oct. 28 - Nov. 01	Wed	Lec 28		Dimensional Analysis I	
Oct. 28 - Nov. 01	Fri	Lec 29		Dimensional Analysis II	
Nov. 04 - Nov. 08	Mon	Lec 30	HW 5 due Friday; HW 6 issued Friday	Laminar Flow I	
Nov. 04 - Nov. 08	Wed	Lec 31		Laminar Flow II	
Nov. 04 - Nov. 08	Fri	Lec 32		Laminar Flow III	
Nov. 11 - Nov. 15	Mon	Lec 33		Laminar Flow IV	
Nov. 11 - Nov. 15	Wed	Lec 34		Laminar Flow V	
Nov. 11 - Nov. 15	Fri	Lec 35		Boundary Layers I	
Nov. 18 - Nov. 22	Mon	Lec 36	HW 6 due Friday; HW 7 issued Friday	Boundary Layers II	Review paper submission + review assignment opens
Nov. 18 - Nov. 22	Wed	Lec 37		Boundary Layers III	
Nov. 18 - Nov. 22	Fri	Lec 38		Boundary Layers IV	
Nov. 25 - Nov. 29	Mon				Fall Break and Thanksgiving
Nov. 25 - Nov. 29	Wed				
Nov. 25 - Nov. 29	Fri				
Dec. 02 - Dec. 06	Mon	Lec 39	HW 7 due Friday	Boundary Layers V	Review paper submission closes
Dec. 02 - Dec. 06	Wed	Lec 40		Additional Concepts I	
Dec. 02 - Dec. 06	Fri	Lec 41		Additional Concepts II	
Dec. 09 - Dec. 13	Mon	Lec 42		Special Topics & Outlook I	Final submission opens + Reviews close
Dec. 09 - Dec. 13	Wed	Lec 43		Special Topics & Outlook II	
Dec. 09 - Dec. 13	Fri				Semester Ends