Experimental Fluid Mechanics
ASEN-6519-002
Fall Semester 2018

Syllabus

Time: Tue. & Thurs. 2:00pm-3:15pm

Location: DUAN G2B21 and CU Research Wind Tunnel Laboratory (East Campus)

Instructor:

Assistant Professor John Farnsworth
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Office Hours: Wed. 1pm - 3:00pm

Website:

Canvas (https://canvas.colorado.edu)

Objective: To establish a fundamental understanding of the theory and practice of performing experimental measurements in fluid mechanics.

Description: This course presents an intermediate level introduction into the theory and practice of performing experimental measurements in fluid mechanics. The fundamental principles and definitions associated with instrumentation, measurement procedures, data analysis, and uncertainty quantification will be discussed. A specific focus will be placed on the application of a variety of measurement techniques in low-speed aerodynamic environments. A selection of measurement techniques will be extensively studied and applied including: classical pressure and temperature measurements, thermal (hot-wire) anemometry, laser doppler anemometry, particle image velocimetry, surface and field flow visualization techniques, schlieren and shadowgraph photography techniques.

Prerequisites: Undergraduate level courses dedicated to the fundamentals of fluid mechanics, thermodynamics, and aerodynamics are recommended for this course. A basic background in optics, simple electronics, system dynamics, and signal processing will also be beneficial.

Required Text:

S. Tavoularis, *Measurements in Fluid Mechanics*. Cambridge University Press, 1st ed., 2005.

Supplemental References:

1. C. Tropea, A. Yarin, J.F. Foss, *Springer Handbook of Experimental Fluid Mechanics*. Springer, 1st ed., 2007. http://www.springer.com/us/book/9783540251415
Note: *An electronic copy of this book can be downloaded through the publisher webpage (above) while you are connected to the CU Campus Network as a part of the CU Library subscriptions.*

2. R. J. Goldstein, *Fluid Mechanics Measurements*. Taylor & Francis, 2nd ed., 1996.
3. E. Rathakrishnan, *Instrumentation, Measurements, and Experiments in Fluids*. CRC Press, 1st ed., 2007.
4. H. W. Coleman and W. G. Steele, *Experimentation, Validation, and Uncertainty Analysis for Engineers*. Wiley, 3rd ed., 2009.
5. J. R. Taylor, *An Introduction to Error Analysis*. University Science Books, 2nd ed., 1997.
6. J. B. Barlow, W. H. Rae, A. Pope, *Low-Speed Wind Tunnel Testing*. Wiley, 3rd ed. 1999.
7. M. Raffel, C. Willert, S. Wereley, J. Kompenhans, *Particle Image Velocimetry*. Springer, 2nd ed., 2007.
8. R. J. Adrian and J. Westerweel, *Particle Image Velocimetry*. Cambridge University Press, 1st ed., 2010.
9. G. S. Settles, *Schlieren and Shadowgraph Techniques*. Springer, 1st. ed., 2001.

Grading: The following presents the planned grading structure for the course. Be aware, that this is subject to change, however the class will be thoroughly notified and polled for agreement.

40% Homework Assignments ($\sim$ 4 during first half of semester)
50% Lab Assignments($\sim$ 4 during second half of semester)
10% Participation

-Grades are posted to the class website (Canvas).

Class Format: The class meets twice a week for an hour and fifteen minutes of formal lecture and discussion. Select class meetings will be held in the Experimental Aerodynamics Laboratory which is part of the Sustainability Energy and Environment Complex (SEEC) on the CU Boulder East Campus. During these class periods hands-on experimental laboratory experiments will be conducted.

Laboratory Assignments: A selection laboratory assignments (four or five) are planned to provide a practical application of the measurement techniques discussed in lecture. Each of these exercises will be formally assigned at least one week prior to the scheduled laboratory period. During each laboratory period students will work in groups to collect data as outlined in the assignments, however individual laboratory reports will be submitted. These reports will be limited to a three page single spaced document with a minimum 1 in margin and 10 pt font. This page limit is inclusive of all discussion, figures, and references. The lab reports will be due one week after the completion of the in laboratory assignment and should be uploaded as a pdf document to the drop-box folder on the course website.

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.

Classroom and On-Campus 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. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the Student Code of Conduct.

Discrimination and Harassment: 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 (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and 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.

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.

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, you must let the instructors know of any such conflicts within the first two weeks of the semester so that we can work with you to make reasonable arrangements. For full details see the campus policy regarding religious observances.

Schedule (Tentative)

Week	*Dates*	*Tuesday*	*Thursday*	*Assignments*
1	Aug. 28 & 30	Syllabus and Introductory Thoughts	Basic Principles and Fluid Properties	**Reading:** Chap. 1
2	Sep. 4 & 6	Similarity	Measurement Systems (Static Response)	**R:** Chap. 2
3	Sep. 11 & 13	Measurement Systems (Dynamic Response)	Electronics and Signal Conditioning	**R:** Chap. 4
4	Sep. 18 & 20	Statistical Analysis	Uncertainty Analysis	**R:** Chap. 4 & 3
5	Sep. 25 & 27	Light, Optics, and Illumination	Light Scattering and Measurement	**R:** Chap. 5
6	Oct. 2 & 4	Static, Dynamic, & Total Conditions	Test Apparatus & Procedures	**R:** Chap. 6 & 7
7	Oct. 9 & 11	Temperature Measurements	Pressure Measurements	**R:** Chap. 12 & 8
8	Oct. 16 & 18	Flow Rate Measurements	Velocity Measurements: Overview	**R:** Chap. 9 & 11
9	Oct. 23 & 25	Velocity Measurements: Thermal Anemometry	**Lab Assignment # 1** (Hot-Wire Cal. & Meas.)	
10	Oct. 30 & Nov. 1	Velocity Measurements: Laser Doppler Anemometry	Velocity Measurements: Laser Doppler Anemometry	
11	Nov. 6 & 8	Velocity Measurements Particle Image Velocimetry	**Lab Assignment # 2** (PIV Image Processing)	**Due:** Lab # 1
12	Nov. 13 & 15	Velocity Measurements Particle Image Velocimetry	**Lab Assignment # 3** (PIV Meas. & Analysis)	
13	Nov. 20 & 22	**No Class** (Fall Break)	**No Class** (Fall Break)	
14	Nov. 27 & 29	Flow Visualization Schlieren Photography	**Lab Assignment # 4** (Schlieren Photography)	**R:** Chap. 10 **Due:** Lab # 2
15	Dec. 4 & 6	Flow Visualization: Other Techniques	Wall Shear Measurements	**R:** Chap. 14 **Due:** Lab # 3
16	Dec. 11 & 13	Measurement of Composition: PLIF	**Lab Demonstration** (PLIF)	**R:** Chap. 14 **Due:** Lab # 4