Course Syllabus: Experimental Methods in Fluid Mechanics - ME 304

Division	Physical Science and Engineering Division
Course Number	ME 304
Course Title	Experimental Methods in Fluid Mechanics
Academic Semester	Spring
Academic Year	2018/2019
Semester Start Date	01/27/2019
Semester End Date	05/23/2019
Class Schedule (Days & Time)	02:30 PM - 04:00 PM | Mon Thu

Instructor(s)

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Course Information

Comprehensive Course Description	The main focus of this course is to teach the student how to use the most common modern technique to measure fluid flows, i.e. Particle Image Velocimetry (**PIV**). This will include both the underlying theory, as well as experiments in the laboratory and finally how to use commercial programs to extract the velocity fields from the images. Students are required to take **two safety classes** before ettending laboratory sessions. This includes the general satety class and specifically, laser safety. The professor will be on hand during all laser-experiments to further reduce possible injuries to the students. Thoroddsen's laboratory has the required safety equipment, such as laser goggles and laser-curtains to prevent stray laser-beams traveling around the laboratory. The official topics for this class are the following: Basic sampling theory. Spectral decomposition, aliasing, Nyquist criterion and dynamic range. *Basic optics*, *lasers*, diffraction limit. *Particle tracking* and streak photography. Point measurements of velocity, pitot static tube, *hot wires*, laser-doppler velocimetry (LDV). Measurements of velocity ?elds in planes and volumes, using *particle image velocimetry (PIV)*. Micro-PIV. Measurement of scalar fields (*LIF)*. Holographic PIV. *High-speed video* technology. This course has a significant laboratory component. In more detail, I will cover the following specific topics, in approximately the following sequence: 1. Overview of experimental methods in current use. 2. Fundamental concepts of measurement uncertainty; precision; errors; significan digits; bias error; central limit theorem 3. Statistical treatment of experimental data: time and ensamble averages; Probability density functions; Correlation coefficient; Spectrum and Flourier Transform 4. Fundamentals of optics: Lenses; Chromatic aberrations; Filters; Depth of field; Aperture; Diffraction; Airy disc; Scheimpflug condition; Light-field imaging 5. Image sensors: CCD; CMOS; color sensors; Bayer filter; pixel resolution; 6. Flow visualization: Flowlines; dye visualization; fossil turbulence; smoke wire; hydrogen bubbles; shadowgraph; Schlieren imaging; Coherent structures 7. Interferometry: Theory of thin film intereferometry; Monochromatic vs Two-color interferometry; Drop impact example 8. High-Speed imaging: Rotating drup cameras; Streak cameras; Framing cameras; Image-converter cameras; In-Situ Image Sensors; Current cameras 9. Velocity measurements: Orifice meters; Floats; Pitot-tube; Magnetic flowmeters; Acoustic flowmeters; Hot-wires, constant current vs constant temperature; X-wires; Cold-wires for temperature measurements 10. Basics of lasers: laser types, gas, solid, dye lasers; Continuous wave vs pulsed lasers; Flash-lamps and Q-switch; Ruby; Helium-Neon; Argon-Ion; NdYag; Frequency doublers; Beam profiles; LEDs 11. Laser-Induced Fluorescence (LIF): Beer-Lambert law; Quenching; Laser cavitation 12. Laser-Doppler Velocimetry (LED); Fringe setup; Direction ambiguity; Two component setup 13. Particle Velocimetry: Streak Velocimetry; Pulse-tagging; Particle tracking velocimetry (PTV); 14. Basic theory underlying PIV: Particle density; Interrogation window size; Sub-pixel correlation peaks; Optimum displacement; Sources of error; Bad vector corrections; Bias error; Window offset and deformation; Pixel-locking 15. Stereoscopic PIV; Scanning laser sheet PIV: Micro-PIV 16. Holographic PIV: Optical setup 17. Tomographic PIV: Camera optimized setup; MART algorithm; Self Calibration; Reconstruction; 3-D correlation; PPP; Scanning Tomo-PIV 18. Using Matlab for Image and Video processing 19. Using Davis (LaVision) for calculating velocity fields from PIV images These lecture classes will be interspersed with **4 Laboratory assignments:** **I. Fundamentals:** Oscilloscopes; Time-Delay circuits; Diffraction; Color CCD & CMOS **II. Laser-Induced Fluorescence:** Continuous wave laser cutting a turbulent water jet containing fluorescent dye **III. Particle-Image-Velocimetry:** Using pulsed NdYag lasers to obtain dual-pulse images; also continuous wave laser to get high-speed video images of the above jet. **IV. Laser-Induce Cavitation**, or **Tomo-PIV**, dependent on class progress
Course Description from Program Guide	
Goals and Objectives	Student will become familiar with the functioning of methods used to measure fluid flow, temperature, velocity, dye concentrations etc. Will know how to perform state of the art velocity measurements using PIV.
Required Knowledge	Basic undergraduate knowledge of fluid mechanics. Basic familiarity with statistics. Basic familiarity with photography is helpful. Basic programming using Matlab.
Reference Texts	"Particle Image Velocimetry" by Ronals J. Adrian & Jerry Westerweel, Cambridge University Press (2011) "Fluids Mechanics Measurements" Edited by Richard J. Goldstein, Second Edition, Taylor & Francis (1996)
Method of evaluation	**30.00**% - Midterm exam **30.00**% - Presentation **40.00**% - Written report

Nature of the assignments	Experiments in the laboratory in groups. Individual writing of lab reports answering specific questions from the laboratory assignment. Final presentation will be in a group, of a larger project.
Course Policies	Students should attend all classes and laboratory sessions alike.
Additional Information	

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Mon 01/28/2019	**Basics**: Overview of experimental methods in fluid mechanics
1	Thu 01/31/2019	**Fundamental Concepts:** uncertainty, precision, errors, bias, sampling theory. ***(Students need to take Safety classes online!)***
2	Mon 02/04/2019	Statistical treatment of experimental data; averages, probability density functions, Correlation tensor, Spectrum
2	Thu 02/07/2019	Fundamentals of Optics, Image sensors; streak photography
3	Mon 02/11/2019	High-Speed imaging; Flow Visualization: Shadowgraphs, Schlieren imaging
3	Thu 02/14/2019	**Laboratory Experiment 1: Oscilloscopes; Time-Delay circuits; Optics; Color CCD & CMOS, Airy-disc intensity pattern**
4	Mon 02/18/2019	Airy disc and diffraction
4	Thu 02/21/2019	Basics of lasers: **Laser-safety class**
5	Mon 02/25/2019	Laser Induced Fluorescence (***LIF***)
5	Thu 02/28/2019	Laser-Doppler Velocimetry (***LDV***)
6	Mon 03/04/2019	**Laboratory Experiment 2: Laser-Induced Fluorescence (LIF)**
6	Thu 03/07/2019	Basics of *Particle Image Velocimetry* (**PIV**)
7	Mon 03/11/2019	Sources of error in PIV
7	Thu 03/14/2019	Particle Tracking, Shake-the-box method
8	Mon 03/18/2019	Planar PIV. Particle density. Speckle effects.
8	Thu 03/21/2019	Stereo PIV and Micro-PIV
9	Mon 03/25/2019	Spring Break
9	Thu 03/28/2019	Midterm, In class, closed notes and closed book
10	Mon 04/01/2019	Single-camera 3-D Particle Tacking
10	Thu 04/04/2019	Holographic PIV
11	Mon 04/08/2019	**Laboratory Experiment 3: Particle Image Velocimetry (PIV)**
11	Thu 04/11/2019	Mulit-camera particle tracking velocimetry (PTV)
12	Mon 04/15/2019	Tomographic PIV
12	Thu 04/18/2019	Rainbow PIV, Shadow PTV
13	Mon 04/22/2019	**Laboratory Experiment 4: Tomographic PIV**
13	Thu 04/25/2019	MART algorithm, Self-calibration, Shake-The-Box
14	Mon 04/29/2019	Interferometry measurements
14	Thu 05/02/2019	Thermal measurements
15	Mon 05/06/2019	Using Matlab for Image and Video processing
15	Thu 05/09/2019	Final Presentations for PIV experiments
16	Mon 05/13/2019	Final Presentations of group 2
16	Thu 05/16/2019	Final class if needed
17	Mon 05/20/2019	Final Exam Week
17	Thu 05/23/2019	Final Exam Week

Note

The instructor reserves the right to make changes to this syllabus as necessary.