جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

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	2016/2017
Semester Start Date	01/22/2017
Semester End Date	05/18/2017
Class Schedule (Days & Time)	02:30 PM - 04:00 PM | Sun Wed

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Sigurdur T Thoroddsen	Sigurdur.Thoroddsen@kaust.edu.sa	+966128082160		By appointment.

Teaching Assistant(s)

Name	Email
None	None

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	**40.00**% - Written report **30.00**% - Presentation **30.00**% - Midterm exam

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	Sun 01/22/2017 Wed 01/25/2017	**Basics**: Overview of experimental methods in fluid mechanics
2	Sun 01/29/2017 Wed 02/01/2017	Fundamental concepts of measurement uncertainty; precision; errors; significan digits; bias error; central limit theorem ***(Students need to take Safety classes online!)***
3	Sun 02/05/2017 Wed 02/08/2017	Statistical treatment of experimental data: time and ensamble averages; Probability density functions; Correlation coefficient; Spectrum and Flourier Transform
4	Sun 02/12/2017 Wed 02/15/2017	Fundamentals of optics: Lenses; Chromatic aberrations; Filters; Depth of field; Aperture; Diffraction; Airy disc; Scheimpflug condition; Light-field imaging
5	Sun 02/19/2017 Wed 02/22/2017	Image sensors: CCD; CMOS; color sensors; Bayer filter; pixel resolution
6	Sun 02/26/2017 Wed 03/01/2017	Flow visualization: Flowlines; dye visualization; fossil turbulence; smoke wire; hydrogen bubbles; shadowgraph; Schlieren imaging; Coherent structures
7	Sun 03/05/2017 Wed 03/08/2017	Interferometry: Theory of thin film intereferometry; Monochromatic vs Two-color interferometry; Drop impact example
8	Sun 03/12/2017 Wed 03/15/2017	High-Speed imaging: Rotating drup cameras; Streak cameras; Framing cameras; Image-converter cameras; In-Situ Image Sensors; Current cameras
9	Sun 03/19/2017 Wed 03/22/2017	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	Sun 03/26/2017 Wed 03/29/2017	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	Sun 04/02/2017 Wed 04/05/2017	Laser-Induced Fluorescence (LIF): Beer-Lambert law; Quenching; Laser cavitation
12	Sun 04/09/2017 Wed 04/12/2017	Laser-Doppler Velocimetry (LED); Fringe setup; Direction ambiguity; Two component setup
13	Sun 04/16/2017 Wed 04/19/2017	Particle Velocimetry: Streak Velocimetry; Pulse-tagging; Particle tracking velocimetry (PTV)
14	Sun 04/23/2017 Wed 04/26/2017	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	Sun 04/30/2017 Wed 05/03/2017	Stereoscopic PIV; Scanning laser sheet PIV: Micro-PIV Holographic PIV: Optical setup
16	Sun 05/07/2017 Wed 05/10/2017	Tomographic PIV: Camera optimized setup; MART algorithm; Self Calibration; Reconstruction; 3-D correlation; PPP; Scanning Tomo-PIV
17	Sun 05/14/2017 Wed 05/17/2017	Using Matlab for Image and Video processing Using Davis (LaVision) for calculating velocity fields from PIV images
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Note

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