ME 331: Advanced Fluid Mechanics

Fall 2013 - Prof. Arindam Banerjee

Schedule: **MW : 8.45– 10.00 AM**

Location: **To be decided**

Levels: **Graduate, Undergraduate (Juniors & Seniors)**

TOPICS TO BE COVERED:

- ❑ Kinematics of fluid flow
- ❑ Conservation Equations: Integral & Differential Forms and their solution techniques
- ❑ Boundary Layer Theory –with Introduction to free shear layers. Stability & Separation.
- ❑ 2D potential flow theory of incompressible fluids
- ❑ Intro to Turbo-machinery – Systems Design
- ❑ Numerical solutions to governing equations: preliminary CFD techniques
- ❑ **Pre-requisite:** **ME 231 or equivalent**. Must have some exposure to PDEs.

Text Book: Basic Fluid Mechanics – D.C. Wilcox – 4th Edition.
(In addition we will also use the ME231 text book)

Questions? Contact - Prof. Banerjee (Packard 562) – E-mail: arb612@Lehigh.edu

LEHIGH UNIVERSITY

ME331 Advanced Fluid Mechanics - Fall 2012

Department of Mechanical Engineering & Mechanics

Instructor: Prof. Arindam Banerjee (Email: arb612@lehigh.edu ; Phone: 610-758-4099)
Office: 562 Packard Laboratory
Class schedule: **MWF 9.10 am - 10.00 am**
Class Location: **Packard 503**
Office hours : **TTh 4.00 – 5.00 pm** (or by appointment)
Grading Outline: Homework – 15%, 2 mid-term exams: 20% each, CFD Project: 15%, Final Exam: 30% (comprehensive exam).
Grading Policy: **FINAL GRADES** will be curved. Tentative breakdown: A: Above 2 standard deviations from mean, B: Above 1 standard deviation from mean, C: Class mean score, D: Below 1 standard deviation from mean, F: Below 2 standard deviations from mean. Intermediate (+/-) letter grades will be calculated likewise. Letter grade will be given only after each exam.
Prerequisites: **ME 231 or 1 undergraduate fluid mechanics class.**
Course objectives: This course is designed to follow ME 231 and give the students an overview of various aspects of incompressible fluid flow that is beyond the scope of the first fluids course. In particular, derivation and solutions to the conservation equations, laminar boundary layers and viscous flows will be discussed. The course will introduce advanced topics of incompressible flows that include analytical and numerical methods for solving PDEs governing fluid flows. Students will also obtain hands-on experience using Anys CFX (a commercial CFD package).
Textbook: **Wilcox, David C., Basic Fluid Mechanics. Fourth Ed., DCW Industries, 2010** (ISBN-13: 978-1-928729-44-0)
Software: **Companion software (by Wilcox) + Ansys CFX software**
Course Site: All course related materials (not including class notes) will be on Course Site

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Topics to be covered: (all chapter #s are from Wilcox)

- ❑ Chapter 1: Introduction: Dimensions/Units, Definition, Continuum Approximation, Fluid properties and Fluid Flow regimes
- ❑ Chapter 4: Kinematics: Descriptions of flow, vorticity, circulation, flow viz. metrics, fluxes, extensive and intensive properties, RTT and review of vector calculus
- ❑ Chapter 5: Mass and Momentum Principles: Governing Equations in Integral and Differential forms, mass principle, Euler's and Bernoulli's Equation, Navier Stokes Equation (Chapter 12)
- ❑ *Chapter 6: Control Volume Techniques: Quick review of methods in 231 (fixed/moving CV); accelerating CV.
- ❑ *Chapter 9: Turbo-machines: Angular momentum principles (Lawn Sprinklers), Euler Turbo-machine Equation, Dimensional Analysis (concept of specific speed) and common turbo-machines (pumps, compressors, turbines)
- ❑ Chapter 11: Potential Flow: Equations of motion, Mathematical foundation, Bernoulli's equation (revisited), Fundamental solutions (vortex, source/sink, doublet), flow past a cylinder, airfoil flow, Intro to CFD – discretization, stability, convergence, grid sensitivity, relaxation methods
- ❑ Chapter 12: Viscous Flows: Kinematics of Fluid particle, Navier-Stokes Equation (derivation); CFD techniques for viscous flows
- ❑ Chapter 13: Solutions to Navier Stokes Equations: Couette-Poiseuille Flow, Lubrication theory
- ❑ Chapter 14: Boundary Layers : BL equations, solutions, effect of pressure gradient, turbulence

(Topics in * will be covered towards the end of the semester)

Policies:

Home-Work/Projects:

- ➢ Home-works (typically 2-3 problems) will be assigned at the end of every class and will be due at the **start** of next class – no late home-works will be accepted. You are expected to work on your own. If you have questions about the Home-Work, make every effort to come and see me. If that is not possible, send me an email with clear and concise question(s). A scanned copy of your work typically helps me to identify the problem faster. Home-Work solutions will be posted on Course-Site.

- In order to standardize the problem solution and presentation process for ME 331, it is expected that all homework will conform to certain standards. These are:
  a. Start each problem on a new sheet of paper. Your name should appear at the top right corner of the first page. All problem solutions are to be placed in numerical order in one packet and stapled (no paper clips) in the upper left corner only.
  b. Each problem solution should be organized and easy to follow. Start with a brief problem statement in the form:
     Given: A clear statement of given information, showing appropriate schematics.
     Find: A clear statement of what is required
  c. Solutions must include:
     i. Basic equations employed
     ii. A clear list of simplifying assumptions
     iii. Organized solution procedure with clearly indicated results, and,
     iv. Consistent use and listing of proper units.
  d. If the problem demands a graphical presentation, this should appear on separate pages, and should be done using a computational printing program (e.g. Excel, MatLab, Maple, etc.). Make sure that all axes are clearly titled, labeled, and that a legend is provided if more than one plot is presented on each graph.
- For the project, a discussion of each figure presented in the report is required. Figures should be identified by figure numbers and should include a figure caption. Formatting will be based on ASME paper writing standards (check out: http://www.asme.org/kb/proceedings/proceedings/formatting-the-paper).

Exams:

- Exams are open (text) book only. No class notes are allowed. No electronic devices are allowed during exams.
- A review session will be provided before each exam. Students are encouraged to make every effort to attend them. Times will be announced before the exam.
- The final exam is comprehensive (i.e. it will contain all topics covered in class).

Accommodation for Students with Disabilities: If you are requesting accommodations, please contact the Office of Academic Support Services at University Center (Phone: 610-758-4152) as early as possible during the semester. You need to bring in proper documentation for Academic Support Service Office before any request can be granted.

Academic Integrity: The work you submit with your name on it must be your own. The Lehigh community considers the promotion of academic integrity a fundamental responsibility. Statements issued by Undergraduate and Graduate Student Senates articulate the understanding of the importance of this responsibility by the student community. Academic integrity violations will be referred to the Office of Student Conduct. Some useful resources can be found at: http://www.lehigh.edu/~infdli/AcademicIntegrity.htm

Welcome to ME331! Please do not hesitate to contact me if you have concerns. I wish you all the best for a successful semester.