Department of Civil and Environmental Engineering

CIVE 604 Fluid Turbulence and Modeling **(Spring 2018)**

Instructor
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Office hours: MW 1.30-2.30 PM in A207E – Engr. Building, or by appointment.

Lectures: MWF 12.00 -12.50 PM, E106 (Engineering)

Class website: https://colostate.instructure.com/

Textbook: Class will be taught primarily using lecture notes prepared by instructor and the prescribed text book **Turbulent Flows"** by Stephen B. Pope, Cambridge University Press.

Some useful reference textbooks that maybe available in the library include:

- Fluid Mechanics by Pijush K. Kundu and Ira M. Cohen, Academic Press, 2004.
- Statistical Theory and Modeling for Turbulent Flows – Durbin, 2011, Wiley.
- Chen, Ching-Jen and Jaw, Sheng-Yuh, Fundamentals of Turbulence Modeling, 1997, Taylor & Francis
- Tennekes & Lumley (1972), A first course in turbulence.

Course Prerequisite: CIVE 300 and CIVE502 (or equivalent) – An undergraduate course in fluid mechanics is a must and a graduate level course in fluid mechanics is highly recommended.

Overview: Turbulence is a ubiquitous phenomenon in fluid flows (both natural and engineered) e.g. in rivers, estuaries, oceans and the atmosphere. Over the course of the semester, the student will be required to study both the theory of turbulent flows and on how to model such flows. This course will expose the student through a lecture and discussion style format to the state of the art in turbulence modeling and discuss cutting edge research findings in the classroom.

Course Objectives: The thrust of this introductory course on turbulence modeling is equip the student to build the physical and mathematical tools necessary to tackle turbulent flows encountered in engineering. Successful students will be able to:

- Explain the formulation and limitations of turbulence models in the context of the closure problem.
- Identify, formulate and apply appropriate turbulence models in CFD problems
- Awareness of approximations and limitations of different categories of turbulence models.

- Demonstrate a basic understanding of turbulence modeling for hydraulic, environmental and wind engineering flows.

You should also expect to:

- Take responsibility for your learning
  - Read textbooks/journal papers on your own
  - Ask questions from me, your classmates and yourself
  - Turn in excellent assignments demonstrating your knowledge of the solution
- Tap into your existing intuition, strengths, and passion to learn fluid dynamics
- Become an active participant in your computational fluid dynamics education, taking full advantage of lectures, texts, homework, office hours and everyday life!

COURSE LOGISTICS

Course website https://colostate.instructure.com/ The Canvas website will be used to post homework assignments and solutions, practice exams, lecture notes, announcements etc. You can also check your grades online.

Homework: Assignments will be posted bi-weekly (depending on the extent of work involved) on the Canvas class webpage. Written reports of basic chapter readings as well as journal articles will form part of homework assignments. Please note that reading assignments may be examined via pop-up quizzes. While you are encouraged to discuss assignments with each other, you may not look or copy anyone else's written work.

Your solution to homework problems should:

- Formulate/define the problem
- Indicate the solution procedure clearly
- Draw your conclusions by highlighting the answers with correct units!
- Must be submitted using Engineering paper or letter size white paper.
- Homework assignments should be stapled, with **Fluid Turbulence and modeling CIVE604– Spring 18, Assignment No., Name and CSUID** written on top of first page. Please write your name on top of all other pages in case bindings get loose. Note homework assignments

You are expected to arrange your work in a neat and orderly manner. This will not only help others to understand your work but will aid your thought process.

Exams: There will be one midterm exam and a final project. Material in the exams will be drawn from lectures and homework assignments. Collaboration or copying from others during an exam will not be tolerated and may result in zero credit and referral to Student Conduct Services. All exams are closed book. However, I will allow each student to bring in one single-sided letter size paper with his/her handwritten notes and formulae. No other resources will be allowed during the exams.

Course Evaluation: Students will be evaluated as follows:

- Bi-weekly homework assignments focusing on basic theory, canonical turbulent flow problems and turbulence modeling exercises - 45%
- Quizzes, other assignments & attendance - 5%
- Midterm examination - 25%
- Final Project – 25%

Term grades for this course will use the +/- grading system as described in the CSU catalog. Grading will be assigned according to a traditional grade scale at a minimum, i.e. A=90-100%, B=80-89%, C=70-79%, D=60-69, F <60%.

Makeup exam policy: For folks who can not attend regular exams due to university business duty, serious illness, or family emergency (all with written proof or statement), a makeup exam may be arranged AFTER the regular exam. Please inform the instructor as soon as possible. No exceptions will be made without a legitimate reason and a timely arrangement. There are no make-ups for pop-up quizzes.

Academic Integrity: Academic dishonesty is a serious issue. University rules including academic penalty and further investigation by the university authorities will be strictly enforced in this course. Please review the student handbook for details regarding these rules.

The following honor pledge (not compulsory) shall be included in all exams and assignments in this course:

***I pledge on my honor that I have not received or given any unauthorized assistance in this exam (replace with assignment as required)*, followed by your signature.**

How to survive and thrive in this course: Find a study group! Take advantage of office hours! If you have a question, ask it. Enjoy the subject and its numerous applications in engineering and the natural environment!

TENTATIVE COURSE SCHEDULE:

Jan. 17	First lecture
April 4	Midterm Exam
May 4 –	Last lecture

Week	Topics
1- Jan. 15	Introduction to turbulence - scales of fluid motion and what is turbulence - role of the third dimension, equations of motion. cartesian tensors
2 - Jan. 22	Introduction to turbulence - scales of fluid motion and what is turbulence - role of the third dimension, equations of motion. Cartesian tensors
3 – Jan. 29	Statistical description of turbulence - random processes and fields, probability and averaging
4– Feb. 5	Vorticity and vortical structures
5- Feb. 12	Mean flow equations, Reynolds stresses, gradient-diffusion and turbulent-viscosity hypothesis
6- Feb. 19	Free shear flows: round jets, mixing layers, grid turbulence
7– Feb. 26	The scales of turbulent motion, Energy cascade, Kolmogorov hypotheses, Velocity spectra
8- Mar. 5	Wall flows: Channel flows, Pipe flows, Boundary layers
9 - Mar 12	**SPRING BREAK – NO CLASSES**
10- Mar 19	Wall flows: Channel flows, Pipe flows, Boundary layers
11- Mar. 26	Introduction to modeling and simulation: challenges and appraisal of different models.
12- April 2	Reynold-averaged Navier-Stokes (RANS) models, turbulent viscosity models: the k-ε model and k-ω model. **Midterm Evening Exam April 4th.**
13 - April 9	Direct numerical simulations, large-eddy simulations: introduction, filtering, the Smagorinsky model
14 - April 16	Journal clubs – reading of state of art turbulence journal articles.
15 - April 23	Applications – riverine and estuarine flows, water quality modeling, flow through vegetation, dispersion modeling, and invited lectures.
16 – April 30	**Final thoughts – summary/project presentations**