# ADVANCED FLUID MECHANICS, ME/CHE/EID440, FALL 2021

Instructor: David Wootton, PhD
Expertise: biomedical fluid mechanics and bioengineering

Lectures: Wed. 12:00 – 12:50, 101 Astor Place rm 205, Friday 10:00 – 11:50, 41CS rm427

Following are the requirements for the successful completion of this course:

1. **Class Meetings**
   a. Attend the class meetings given each week and take careful notes.
   b. Discussion, progress reports, and presentations of projects.
   c. Communicating with the other class members is critical to success in this course. The instructor welcomes questions and verbal feedback during class, especially if a point is not clear, speed is too high, or an instructor error is identified.
2. **Supplementary Materials**
   a. Homework and exam solutions will be posted to the class Moodle site.
   b. There is supplemental material for the textbook available on the book CD, and online from the publisher, as noted in the preface (p. vii) of the text.
   c. Several resources are available to illustrate fluid flow phenomena. These include
      i. Online videos of films by the National Committee for Fluid Mechanics Films and University of Iowa instructional videos:

         http://web.mit.edu/hml/ncfmf.html

         http://css.engineering.uiowa.edu/fluidslab/referenc/instructional.html

      ii. Multimedia Fluid Mechanics, a CD ROM with films and interactive material to illustrate key concepts in fluid mechanics. One CD (2nd edition) will be on reserve in the library.

3. **Homework Problem Assignments**
   a. Homework assignments, about 1/week, will be due in class for a completion grade. The problems are puzzles and exercises related to the lecture material, and final exam. Timely homework completion is <u>required</u> to get full credit (worth 10%).
   b. **FORMAT** Use the following format for your solutions. (1) Sketch the Problem. (2) List and define known and unknown variables. (3) Briefly (1-3 sentences) explain the principles used to solve the problem. (4) Solve the problem symbolically. (5) Plug in numbers with units to solve numerically. (6) Check your solution (units, magnitude, and direction). (7) Briefly discuss the value of and insight imparted by the solution. If you don't believe in your solution, explain why; if your solution has limitations, discuss these briefly.
   c. Include your name, date, homework assignment number, and time spent solving homework.
   d. The homework will be logged (but not graded).
   e. Homework solutions will be posted/emailed on Moodle. **Please check your homework** and bring any questions to office hours or class meetings.

f. No late submission of homework assignments will be accepted without prior arrangement.

4. **Testing**
   a. A comprehensive take-home examination will be due during the final class meeting. Each student will schedule a short oral exam during the final exam period to discuss the take-home exam and other course concepts.

5. **Research Project**
   a. Each student or pair of students will conduct a research project during the term. The topic will be of your choosing with approval of the instructor. Several general types of projects may be developed, for example:
      i. Analytical modeling of flow in a device of interest, such as a wave energy generator, flow reactor, pressure regulator, etc.
      ii. Validation of a CFD model using an analytical model solution
      iii. Research and present to the class a novel flow field, flow phenomena, or fluid mechanism not covered in the regular class material.
      iv. Measure and present to the class a flow field or fluid phenomena.

6. **Planning Time Spent**
   a. As a rule of thumb, you should expect to spend 3 hours per credit hour, outside of class time, for any college course.
   b. This means expect to spend 9 hours per week on reading, homework, and preparation for exams. Note the time spent on your homework assignments, and let the instructor know if the course takes significantly more or less outside time.

7. **Grading**
   a. **Homework** on-time completion will weigh **20%** of overall grade. (Homework is checked for completion during Monday class break. Students are responsible for checking their own homework.
   b. **Project** report and presentation will weigh **40%** of your overall grade.
   c. The **final examination** covers all Chapters and weighs **40%** of your overall term grade.
   d. Any student who first identifies a substantive instructor **mistake** during lecture, or a mistake in the textbook/solutions (not already found in the published errata or by the instructor or a classmate) will receive **1% extra credit**. Pay attention and be critical.
   e. The **final grade** follows the established policy of: $A \geq 90\%$; $B \geq 80\%$; $C \geq 70\%$; $D \geq 60\%$, and a lower grade will require the student to retake the course.

8. **Enrichment Opportunities**

   Dr. Wootton's lab carries out **biomedical fluid mechanics** research on obstructive sleep apnea, in collaboration with researchers at Albert Einstein Medical College, the Children's Hospital at

Montefiore, and the University of Pennsylvania. Contact Dr. Wootton for current opportunities to join the research project.

9. **Makeup classes for religious holidays, professional development, or illness**
   Please let the instructor know if there are religious holidays which prevent you from attending class. It is possible to arrange a makeup class if enough students need to miss a class due to a religious holiday. At this point, I expect to excuse students for Yom Kippur, Monday Sept 28 at their request. Since we are a small class, we may simply reschedule the class meeting, or I can schedule a makeup meeting for affected students.

   I am not aware of other religious holiday conflicts with the course schedule. Students occasionally have professional development opportunities that conflict with a class. Please notify the instructor within one week of any planned absence.

   In case you must miss class due to illness, please contact the instructor to arrange a makeup meeting if needed.

10. **Diversity and Inclusion**
    "We are committed to Peter Cooper's radical commitment to diversity and value, living and working in a diverse community. We value, encourage, and promote all aspects of human differences, fostering a culture that embraces a broad variety of personal circumstances, experiences, perspectives, and opinions." (Cooper Union Engineering Core Values).

    Treat your colleagues in this course with respect, even if you have a disagreement with their opinion or perspective, or a criticism of their work. If you find the design, instruction, or specific experiences within the course that result in barriers to your inclusion or accurate assessment of achievement, please notify the instructor or department chair (Professor Baglione) as soon as possible, and/or contact the Title IX officer.

# ADVANCED FLUID MECHANICS, ME/CHE/EID 440

**Course Schedule** **Fall 2021**

Text: White, Frank M., Viscous Fluid Flow, 3rd Edition, McGraw Hill. ISBN 0072402318. Buy early to find a good used copy.

Secondary Text: RW Fox, AT McDonald, PJ Pritchard, Introduction to Fluid Mechanics, 6th or later Edition, John Wiley and Sons. Other similar texts can be substituted, e.g. Munson et al Fundamentals of Fluid Mechanics, FM White's Fluid Mechanics, Wilcox's Basic Fluid Mechanics.

| Mtg | Date | Reading | Topic | Assignment Due (Fri) |
|---|---|---|---|---|
| 1<br>2 | | **1 – 2** | Properties and Conservation Laws; | |
| 3 | | **Fox 4** | Finite Control Volumes | HW 1. |
| 4<br>5 | | **2-3 to 2-5; 3.1-3.3; Fox 5** | Navier-Stokes equations derived.<br>Couette and duct flows. | |
| 6<br>7 | | **2.9, Class Notes** | Scaling and Nondimensionalization | HW 2 (Control Volume) |
| 8<br>9 | | **3-9.8** | Lubrication flow | Project Topic Proposal |
| 10<br>11 | | **3.4 - 3.5** | Unsteady flow. Inviscid flow intro. | HW 3 (Scaling, Navier-Stokes equations) |
| 12<br>13 | | **Fox 6, class notes** | Bernoulli equations | HW 4 (Unsteady Flow) |
| 14<br>15 | | **4.1 – 4.3.1** | External flow and boundary layers;<br>"Exact" (Blasius) solution | HW 5 (inviscid Flow) |
| 16<br>17 | | **4.3.3 – 4.6** | Boundary Layers: Pressure Gradient, separation, Thwaite's method | |
| 18<br>19 | | **Ch. 5** | Transition & Stability. | HW 6 (Boundary Layers)<br>Project Topic Presentations |
| 20<br>21 | | **6.1 – 6.4** | Turbulence: Governing Equations, Wall-Bounded Turbulent Flow Structure. | Fluid Mechanics Films (flow stability and turbulence) |
| 22<br>23 | | **6.5** | Internal Turbulent Flows 1 | |
| 24 | | **6.6** | Internal Turbulent Flows 2<br>No class Wednesday (Friday Schedule) | HW 7 (Turbulence 1) |
| 25<br>26 | | **6.9** | Free Turbulent Flows | |
| 27<br>28 | | | Project Presentations | HW 8 (Turbulence 2) |
| 29<br>30 | | | Final Exam (comprehensive)<br>Summary, Review, Looking Ahead | Project Reports |

Optional: Compressible ideal gas flow: 1D models and phenomena
Not covered in detail, but of interest: Potential flow (Aero, ME322), CFD (ME407), rarified gas flow, non-Newtonian flow, hydrodynamic stability, magnetohydro-dynamics, plasma flow, flow in collapsible conduits, acoustics, acoustic streaming, …

## Helpful advice

- **TAKE NOTES DURING LECTURE!** Get a three-ring notebook (preferably D-ring) and a three-hole punch to keep course syllabus, lecture notes, quizzes and exams organized to facilitate studying for the final. Use a compass or a circle template to draw figures.

- I encourage you to work on homework and some additional problems in teams and divide the problems amongst team members. Discuss your solutions to become conversant and literate in fluid mechanics.

- If you get stuck on a particular problem, move on to another for a time. Your brain is a multiprocessor. Typically, it is easier to see a solution the second or third time you look at a problem.

- Try to describe in one or two statements how you are approaching the problem, even before you solve it (you can always change your approach later if it doesn't work). There are 3 reasons to do this: (1) psychologists tell us that this approach ("metacognition") helps you learn, because you start organizing your knowledge at a higher level, (2) you can communicate more efficiently with fellow students and colleagues, and (3) you will get better grades.

- Although most problems in the text involve numerical solutions, solve problems symbolically prior to substituting values. Carry units in your numerical solutions and check your work and your units. I will grade harshly if you disregard units; it is unprofessional and has led to historic engineering failures.

- Write neatly. If your method of solution is not neat or if you are unsure of your answer, redo the problem and put a box around your answer at the end.

- Use office hours to get hints on problem solving or to give hints to the instructor. Use email for pressing questions when office hours are not available. And work with several classmates to share some information; just be sure that you can do similar work and talk about it with other students and the instructor.