SIO 214a, Fluid Mechanics, Fall Quarter 2014

Myrl C. Hendershott and Sarah N. Giddings, October 2 - December 12, 2014

Schedule

Class: Tuesday 9:30-11:00, Friday 15:30-17:00

Problem session: Tuesday 11:00-12:00 (immediately following class)

Week 1-2: Introduction, mathematics refresher, kinematics

Week 2-3: Conservation laws

Week 4: Vorticity, Reynolds experiment

Week 5 - 10: Problem vignettes (Bernoulli, Blazius boundary layer, Plane-Couette flow, wind driven flow on a lie, lubrication problem, gravity current, horizontal convection, Raleigh Bernard, lift/drag, instability, etc.)

Week 11: turbulence, course review

Expectations

Participation in class and problem sessions is critical as we expect you to become proficient at problem solving and intuitive reasoning. While many of the assignments, mini-labs, and participation are not directly graded, a lack of engagement and understanding will be evident during the final exam. Grades will be based on homework (not graded but must participate in problem sessions, turn in homework, and make your own corrections, roughly 20%), mid-term (big graded homework, roughly 20%), and an written and oral final exam (roughly 60%).

References

The text for this class is the fourth edition of Kundu's Fluid mechanics, now significantly broadened in scope by co-author Cohen. A fifth edition,with one more coauthor Dowling is now available online at

http://www.sciencedirect.com/science/book/9780123821003

References will be provided to both fourth and fifth editions. This book is notable for its breadth and also for the vignette-like nature of the exposition; you can pick it up and start nearly anywhere, and you've learned something interesting in just a few pages. But it is not overly discursive. Batchelor *is* discursive, with detailed and informative discussion, but the range of topics is not as great. The macho book to use would be Landau and Lifschitz, the discussion is terse and dense, but the overall level of mathematical sophistication apparently attained by students during the heroic days of Soviet physics is not yet widespread. Some most consulted fluids books are (with the author's initials as they will be referenced)

• Fluid Mechanics, Pijush K. Kundu and Ira M Cohen (KC4), Fourth edition, 2008, Academic Press.

• Introduction to Fluid Mechanics, G. K. Batchelor (GKB), Cambridge University Press

• Fluid Mechanics, Lev D. Landau and Evgeny M. Lifschitz (LL), 1959, Pergamon Press.

• Lectures on Geophysical Fluid Dynamics, R. Salmon (RS), 1998, Oxford University Press.

Some classical texts are very valuable for specific topics.

• Boundary-Layer Theory, H. Schlichting (HS), 1968. McGraw-Hill (IMCH does not prefer later editions).

• Physical Fluid Dynamics, D. J. Tritton (DJT), 1988. Oxford Science (harder than it looks).

• Fundamentals of Ocean Dynamics, V. M. Kamenkovich, 1977, Elsevier Scientific Publishing Company (www.sciencedirect.com/science/bookseries/04229894/16), the first two chapters emphasize thermodynamic considerations needed in arriving at equations of motion)

• Elementary Fluid Mechanics, R. L. Street, G. Z Watters, J. K. Vennard (SWV), seventh edition, 1996, John Wiley and Sons (many intriguing problems).

Perhaps the best bang for the buck would be a combination of KC and GKB.

Given such books, another is not required and what notes are distributed are not a book draft. They are rather intended as a guide to selective reading so that you are not overwhelmed by the length and detail in any of the texts. For mathematical details MCH finds the most useful single reference to be the two volume set

Methods of Mathematical Physics, P. M. Morse and H. Feshbach (MF I, MF II), 1953 McGraw-Hill.

Readers may find its occasional use of stereoscopic sketches an amusing early prelude to todays supergraphics, but they will be hard pressed to find its later equal for the material it covers.

Exhortatory Material

The fun of this material is the interplay, at every level from setting up a problem to getting the answer, between sometimes complicated mathematical manipulation and the most direct kind of physical intuition. In this sense the study of fluid mechanics gives you skills and a powerful viewpoint that reach far beyond the material of the course.

Fluid mechanics is complicated. We could spend the entire course simply stating the fundamental principles in a clear and correct manner. At the other extreme, we could simply consider all the fluid problems that are unified by the principle "this is one I can solve." We want to steer a middle course, stating the fundamentals we will need as quickly as is possible without serious misrepresentation, and then applying them to a wide variety of problems as time - and the primary restriction to incompressibility - permit.

One approach to the mechanics of fluids is to acknowledge their molecular structure from the beginning and so to start with the motions of individual molecules. This is the approach taken in RS. In this class we shall follow the more traditional route of idealizing the fluid as a continuum from the outset. By dealing primarily with incompressible fluids, most thermodynamic subtleties are deferred for subsequent courses. Even with the restriction to incompressible fluids, there is not time to carry out all manipulations during lectures. Be glad about this, because if we did all the manipulations you?d be so bored you wouldn't learn anything.

For the most part we will state the problem to be solved, outline the manipulations, and assert the solution. Learning to do more with this kind of presentation - the kind of presentation employed in most scientific talks and seminars - than to uncritically say "yes, I see" or (far worse) "they write equations without deriving them, therefore nobody can understand anything, and furthermore I am not going one step further until this is fixed" - is a very important skill. It requires discerning the difference between manipulations which may be complicated but are fundamentally straightforward, and manipulations that immediately raise more fundamental questions than "I didn't follow that" in your mind. Dirac is reputed to have said that one really understands an equation when one does not need to solve it to understand the solution; having a repertoire of standard problems that you understand at this Diracian level is the key to critically listening to/reading presentations that necessarily skim over lots of manipulations. We hope to help you develop that repertoire in this class.

The way to organize this material mentally is to break it up into a series of short and self-contained vignettes, each one a little lecture that you can give, without notes, to yourself or to a colleague ... or to an examining committee. We will try to organize the material into those vignettes, and encourage you to recite them to yourself in odd moments without reference to notes. In this way you will soon develop a reputation for talking to yourself, and will be well on the way to becoming an academic.

Notes provided will sometimes be very good, sometimes very sketchy. This is partly because MCH always has to rethink the lecture the night before giving it, and partly because you need to take your own notes rather than having a briefing book version in front of you to doze over as the lecturer drones on.

We also want to make the material accessible to a wide variety of students, and not only to those with very firm foundations in math and physics. That broader class of students may find themselves learning mathematical methods (as opposed to pure mathematics) along with the physics; our advice to them is not to lose courage and say ”Oh I'd better do a remedial math course first” but rather to just learn the new material as it comes along - as indeed one always has to do when entering a new field. This may initially involve some rote learning without full immediate understanding. Do not despise that. Rather, with D'Alembert, ”allez en avant, et la foi vous viendra.”

Do not ever hesitate to ask us questions in/out of class. Email is the best way to get our attention;

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