PHYD37: Fall 2022
Introduction to Fluid Mechanics

Community Agreement

This course aims to offer a joyful and meaningful learning experience to every participant. We will build that rich experience together by devoting our strongest effort to the class. You will be challenged and supported. Please be prepared to take an active, engaged, patient, and generous role in your own learning and that of your classmates.

Course Description:

This course is an introduction to the analysis of motion of fluids such as water, air, magma, as well as an introduction to transport phenomena such as heat and mass transfer. We will cover the topics of mass, momentum and energy conservation. We will derive and discuss several important dimensionless numbers that can help us understand the type of flow and study in more detail two types of regimes: inviscid and highly-viscous flow. We will also cover the theory of waves and instabilities.

Our Class Meetings: Wednesdays & Thursdays 10am-12:00m EV140
Location: **EV 140**

Instructor: Prof. Diana Valencia (she/her/hers)
diana.valencia@utoronto.ca
416 208 2986

Office Hours Location: SW 504B
Office Hours: Wednesday from Noon to 1pm, or by appointment

Marker: Nathan Winsor
winsor@mail.utoronto.ca

Prerequisites

It is expected that the student is familiar with vector calculus and basic solutions to ordinary and partial differential equations. Some knowledge of thermal physics may be helpful.

Student Learning Outcomes:

By the end of this course, students should be able to:

1. Non-dimensionalise physical problems and extract the relevant non-dimensional governing parameters (e.g. Reynolds number)

2. Derive and solve transport equations pertaining to mass and heat transfer

3. Follow the derivation of the equations governing fluid motions: conservation of mass, momentum and energy (including identifying the Eulerian and Lagrangian derivatives, tensor calculus, etc)

4. Identify the regime in which the fluid moves according to the Reynolds number to simplify and solve the equations analytically in simple cases

5. Be familiarized with how fluid dynamic current problems are solved

Course Readings and Materials

Course Readings:

There is no required textbook. I will provide you with notes through out the term, and coming to class and taking notes will be essential to ensure your success.
Here is a list of recommended books:
- Fluid Mechanics by Pijush K. Kundu and Ira M. Cohen (recommended)
- Fluid Mechanics by Frank White
- An Introduction to Fluid Dynamics by G.K Batchelor

Course Overview

Unit 1: Introduction
- ➢ Dimensional Analysis
- ➢ Tensor Notation

Unit 2: Heat and Mass Transfer
- ➢ Word statements
- ➢ Solving equations with different boundary conditions

Unit 3: Fluid Mechanics Derivation
- ➢ Derivation of governing equations: mass conservation, material derivative
- ➢ Derivation of momentum and energy equations, constitutive equations

Unit 4: Exact Solutions to Navier-Stokes Equations
- ➢ Solutions to simple problems with three different boundary conditions

Unit 5: Low Reynolds number flows
- ➢ Simplification to low Reynolds number flow regime and implications
- ➢ Solution to simple geometry problems

Unit 6: High Reynolds number flows
- ➢ Simplification to high Reynolds number flow regime and implications
- ➢ Boundary layers
- ➢ Flight dynamics

If time permits:
1. Numerical solutions to N-S equations
2. Waves and instabilities
3. Rayleigh-Bernard Convection

Course Policies and Expectations

1. **Communication Policies**

Email Policy: Email is a great way to communicate with me.

- Please email me ("Prof. Diana" or "Prof. Valencia", or if you know or want to know Spanish "Profe Diana") directly at diana.valencia@utoronto.ca
- **Include "PHYD37" in your email's subject line and your name in the body of your email.**
- I will respond to all email inquires within 24 hours from Monday 9am to Friday 5pm. I will respond to emails sent after Friday at 5pm by 11 am Monday morning.
- Please check your official university email address daily (Mondays through Fridays) during our academic term.

2. **Classroom Participation and Engagement:**

- Attendance: Although attendance is not mandatory, I strongly encourage you to come to class and be on time. There are many things I teach in class that you will not find on the notes and the experience of learning together is invaluable. The expectation is that you are in your seat and ready to begin by 10:10am. Please do not start packing up before the end of class, it is disruptive to others around you and to myself.

- Discussions/Questions: I welcome questions, please raise your hand at anytime during the class. As much as I appreciate multilingualism, to be inclusive to all, we will use English as the ONLY language in class. During group class work, please be inclusive to others, ask questions, share your knowledge.

- Electronic Devices: Research shows that longhand note taking is more effective (Muller and Oppenheimer, 2015) than laptop note taking. Despite this, you are permitted to take notes in your laptop or tablet. However, you are not allowed to use your phone, tablet, computer for anything else. I understand that staying connected to family and friends is fun, but it distracts you from the learning experience (Grinols and Rajesh, 2014) and it is disruptive and disrespectful to others and myself.

3. **Grading Policies:**
   a. **Grading System:** The grading scale for this course is based on a points system. Therefore, grades will NOT be rounded up or down. **If you have concerns about your grade on an assignment, you have 5 days after the grade is posted in quercus to email me.** Therefore, do NOT wait until the end of the academic term if you have questions about your grade. In general, grades are only changed due to a miscalculation.

   b. **Late Work Policy**: No late work will be graded. If you miss a deadline for the homework or poster presentation the corresponding percentage lost will be added to your final exam.

4. **Academic Honesty**

Students in this course are obligated to understand what constitutes plagiarism. UTSC demands high standards of integrity and ethical conduct. We will follow a strict adherence to the University's Code of Behaviour for Academic Matters. You can find it in https://www.utsc.utoronto.ca/vpdean/academic-integrity-matters

5. Accessibility Services, Accommodations, and Safety:

If you are with the AccessAbility office, please let me know as soon as possible, I will make every effort to accommodate your learning needs.

6. Flexibility Clause:

As this course's professor, I reserve the right to modify the course requirements, mode of delivery, and other related policies as circumstances may dictate with sufficient notification to all students. Given the COVID-19 crisis, I recognize that unanticipated emergencies may arise that require modifications to our class schedule and/or requirements. *I do not expect to invoke this clause*, but if I need to, you will be notified as soon as possible. Any change will be posted on our course quercus website and sent to your university email address.

7. I am here to help

Your educational growth and success are important to me. I want to see each student perform well in this class. Therefore, please know that I am here to support your learning and success! You are welcome to stop by my office hours or email me if you have any questions.

Course Requirements and Methods of Assessment

1. Course Requirement #1: Problem Sets

There will be homework assigned on a regular basis. The only ground rule is that you may not consult solutions on the Internet and that the work you turn in must be your own. You are encouraged to discuss ideas with other students. If you have worked with another student, make sure you write her/his name as collaborator on the first page of the work you hand in.

If you chose to not hand in a problem set, the percentage of the problem set will be added to the final exam.

2. Course Requirement #2: Midterm

We will have one midterm. This is the opportunity for you to show all that you have learned up to that point and also get detailed feedback so you can prepare for the final exam. If you don't show up to the midterm, the percentage will be added to the final.

3. Course Requirement #3: Final Exam

At the end of the term you will have the opportunity to showcase all that you have learned in this course by solving problems that are similar to those you have solved throughout the course.

4. Course Requirement #4: Final Presentation

At the end of the term there will be one final presentation where you and a partner will showcase a fluid mechanics research article of your choice and present it to the class. You will be required to videotape the presentation (10 minutes) and send the video in. We will show it the last day of classes to everyone and your peers and I will have the opportunity to ask questions. Please make sure to run it by your instructor at least 4 weeks in advance to make sure the level and emphasis of the article is adequate. The two most widely read journals describing current research in fluid dynamics are the *Journal of Fluid Mechanics* and *Physics of Fluids,* with *Annual Review of Fluid Mechanics* a great source for students to get an overview picture.

Showing your work: On your problem sets, make sure you show all the work that went into solving each question. This will allow the grader to follow your method, to know if you understand the material and where you are having difficulties. Don't be afraid to explain what you are doing. Your solution should look like an explanation to someone about how you solve the problem. It is not the grader's job to decipher your work, so make sure your work is neat, legible, complete and organized. A concluding statement is generally a good idea.

Assessments

1. Problem Sets 20%
2. Midterm 25%
3. Final Exam 35%
4. Final Presentation 15%

5% to what ever best grade you get between PS or Midterm

Our Grading Scale For Each Problem

Points	Meaning
3	Problem is solved correctly and final solution is expressed without errors.
2.5	Student has made a minor mistake (sign, factor, etc)
2	Student has mostly solved the problem but has missed a few final steps
1	Student has solved part of the problem
0	Student has not attempted the problem or has written gibberish

Semester Schedule

Date	Topic(s)
week 1 Sept 6	Introduction: Examples, Dimensional Analysis, Bucking-Pi Theorem, Tensor Notation
week 2 Sept 13	Heat and mass transfer
week 3 Sept 20	Heat and mass transfer
week 4 Sept 27	Fluid Mechanics: Derivation of mass conservation and material derivative
week 4 Oct 3	Derivation of moment and energy equations, constitutive equations
week 5 Oct 10	Reading Week

week 6 Oct 17	Exact solutions to Navier-Stokes equations
week 7 Oct 24	High Reynolds number flows
week 8 Oct 31	Low Reynolds number flows
week 9 Nov 7	Low Reynolds number flows
week 10 Nov 14	Waves and Instabilities
week 11 Nov 21	Rayleigh-Bernard Convection
week 12 Nov 28	Numerical solutions to N-S equations Final Presentation