INTRODUCTION TO FLUID MECHANICS

Department of Chemical Engineering

CHEM ENG 2O04 COURSE OUTLINE

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Office hours: **TBD**

TEACHING ASSISTANTS:

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SCHEDULE: Look on "Avenue to Learn"

OFFICIAL DESCRIPTION: Properties of fluids; Instruments for measuring and controlling fluid flow; Macroscopic balances for mass, momentum, and energy; Basic principles and design procedures for turbomachinery; Introduction to software tools for fluid flow design and analysis; Application of Navier-Stokes equations for unidirectional flow systems; Boundary layer theory applied to internal and external flows.

COURSE OBJECTIVE: The objective is to show how the equations of conservation of mass and momentum can be used to solve problems in fluid mechanics. What sort of equations should one derive for determination of forces, velocities, streamlines, shear rates, shear stresses and pressure. What kinds of approximations are appropriate for internal and external laminar and turbulent flows? How do the calculations relate to experimental observations and how the results can be used for design purposes involving tubes, ducts, pipelines and pumps?

LECTURE RECORDINGS: I strongly recommend that you attend the lectures in person, however I am keenly aware that due to many factors (e.g. COVID, job interviews) that it is not always possible. Thus, all the lectures will be recorded (but not livestreamed) via ECHO360 lecture capture (no guarantees on quality or reliability).

REQUIRED TEXT: P.J. Pritchard Fox and McDonald's Introduction to Fluid Mechanics 10th ed., Wiley & Sons. It is available in a paperback format (ISBN: 9781119721024) from the campus bookstore; here is the link to the course materials listing. The same edition was used for the past three years and so there may be used copies available on campus (at campus bookstore or elsewhere).

Also, you are welcome to use the 9th edition of the 'Fox & McDonald' textbook (ISBN 9781118912652) if you can find it.

I would not recommend having any other editions of the textbook for this course.

We will use “Avenue to Learn” (AVENUE) extensively in this course including:

- Posting of course materials (e.g. lecture notes, assignments)
- Posting of ECHO360 recorded lectures
- Submitting your homework assignments and tutorial activities
- Grading activities

Thus you are expected to check the course Avenue page quite regularly.

OUTLINE:

1. FUNDAMENTAL CONCEPTS
Viscosity, surface tension, vapour pressure, Newtonian and non-Newtonian fluids, the no-slip condition, laminar vs turbulent flow

2. MEASUREMENTS
Viscosity, pressure, velocity, flow rate

3. FLUID STATICS
Pressure distribution, manometers, Young-Laplace equation

4. GENERAL TRANSPORT PHENOMENA APPROACH
Conservations laws, constitutive equations

5. CONSERVATION OF MASS
Differential and integral balances, special emphasis on transient processes

6. MECHANICAL ENERGY BALANCES (aka THE BERNOULLI EQUATION)
Problem solving with the Bernoulli equation, frictional losses. Moody chart, pipelines with pumps and turbines

7. TURBOMACHINERY
Positive displacement, centrifugal pumps, turbines

8. CONSERVATION OF MOMENTUM
Linear momentum balance, Navier-Stokes equations

9. UNIDIRECTIONAL FLOWS
Pressure driven, gravity and drag flows, several examples involving solution of ordinary and partial differential equations, interpretation of the solutions and results.

10. LAMINAR AND TURBULENT BOUNDARY LAYERS
Basic concepts, turbulent flow in tubes and over flat plates

11. EXTERNAL FLOWS AND DRAG
Friction and form drag, creeping flow, lift on airfoils

12. SPECIAL TOPICS IN FLUID MECHANICS (if time permits)
e.g. Design and performance of wind turbines, microfluidics/nanofluidics,

GRADING:
The following shows the contribution of components to the final grade:

Component	Weight	Notes
Final Exam	35%	2.5 hours; the date, time, and location will be scheduled by the Registrar's office.
Midterm #1	20%	Date, time, and location to be determined.
Midterm #2	20%	Date, time, and location to be determined.
Assignments	15%	There will be 5 assignments; each one can be completed individually, or in groups of two (see notes below about my recommendations for working in a group of two). For each assignment, you are to include a one-page cover letter that gives a concise summary of the work that was done. It should contain sufficient information to convince the reader that it is worthwhile to go ahead and examine the rest of the assignment. The quality of the cover letter will be worth a significant portion of the assignment grade. A template for you to use will be posted on AVENUE.
Tutorial Participation	10%	There will be 10 tutorials. For each tutorial, there will be a component that you will have to upload to Avenue in order to receive the corresponding participation grade.

Policies regarding grading:

- The value of any work that is missed with a valid McMaster Student Absence Form (as per the University's policy on "Requests for Relief for Missed Academic Term Work') will be moved to the Final Exam Grade.
- The final percentage grades will be converted to letter grades using the Registrar's recommended procedure; grade adjustments may be done at the discretion of the instructor.

Midterms & Final Exam

- You are allowed to bring in a laptop or tablet (but no cell phones) provided that it is in "airplane mode" (so no internet access or communicating with others) with only a document reader (e.g. Adobe Acrobat, Microsoft OneNote) open to review the course materials.
- You are allowed to bring in the Fox and McDonald's Introduction to Fluid Mechanics textbook (any edition and any version)
- You are allowed to bring in any printed or hand-written notes.
- Only the McMaster Standard Calculator (Casio FX-991MS/MS+) may be brought into the testing room.

Assignments

- You must sign and upload a signed copy of the 'ChE 2O04 Student Contract on Plagiarism'. **Students who do not submit this contract will NOT have their assignments graded.**
- We encourage you to complete the assignments in groups of no more than 2 members. You and your partner will receive the greatest benefit if you each do all the questions yourselves. Arrange to meet and review your solutions, discussing various approaches. You are defeating the purpose of the group-based assignment if you simply divide the assignment into sections, one for each group member. This is definitely not recommended, because you are losing out on the learning opportunity of seeing your mistakes and the group member's mistakes, and

learning from them. The grade assigned for each submission will be given to both members of the group.

- Assemble and post to AVENUE **a single submission (in PDF format)** with name(s) & student number(s) clearly identified at the top of the first page.
- **No sharing of any work may be done for the assignments; this includes handwritten documents and any electronic files (e.g. Excel worksheets, PIPE-FLO files). Also, reusing solutions from previous years will be considered plagiarism.** Please ensure that you have read the University's academic integrity policy (part of which is reproduced below). Incidents of academic dishonesty will be penalized (usually zero grade and the infraction will, without any reservations, be reported to the Academic Integrity Office).
- Assignments must be handed in by 7:00pm on the scheduled due date. *Late assignments will be penalized in an incremental fashion as follows:*
    - *5-mark deduction if submitted after 7:00pm on the scheduled due date but before 7:00pm on the next day*
    - *10-mark deduction if submitted after 7:00pm on the next day*

  Late assignments may be accepted without penalty at the discretion of the instructor but only if a request is made no later than 12:00pm on the scheduled due date.
- Each assignment question will be graded as follows:

  4 marks: Complete and neatly done. All correct solutions. All work is logically presented and demonstrates a strong understanding of the subject material.

  3 marks: Complete and neatly done. Most solutions are correct. Most work is logically presented and demonstrates a sound understanding of the subject material.

  2 marks: Complete and legible. Some solutions are correct. Work occasionally lacks logic but demonstrates a developing understanding of subject material.

  1 mark: Handed in but is incomplete and/or illegible. Work is poorly presented and does not demonstrate an understanding of the subject material.

  0 marks: Not completed.
- For any assignment questions based on the PIPE-FLO software, you must show the FLO-SHEET letter (by going to File → Print) which includes the filename and print date details; it is NOT acceptable to show a simple screenshot/screen capture of your system.

PIPE-FLO:

PIPE-FLO (from Revalize) is a leading fluid flow design and modeling software which is used in various industries to simulate and analyze complex fluid transport systems. For this course we will be using the 'student edition' of the software which can be installed on any Windows device via this link: http://downloads.pipe-flo.com/media/V19/PIPE-FLO-Advantage-Student-Edition-Setup-v19.0.zip

After successfully downloading and installing the software, you will need to activate it by doing the following:

1. Enter 9650-1604-0053-033e as the product key
2. Enter your name
3. Enter 'McMaster University' for the company name/division
4. Enter 999 for the phone number (no need to share your real phone number!)
5. Enter your McMaster email address

For those with a Mac device, PIPE-FLO has been installed on the computers in the campus computer labs which you can access via the Remote Desktop app; a video is posted on Avenue on how exactly to do this.

We have developed a very nice courseware package for you to learn how to use the software. These tutorials are meant to be self-guided and thus no lecture or tutorial times will be allocated to them.

LEARNING OBJECTIVES

After completing this course, the student should be able to:

L.1 Apply the control volume approach to solve transient mass balance problems for both liquid & ideal gas systems

L.2 Employ the hydrostatic equation to calculate the pressure and resulting buoyancy forces acting on submerged objects

L.3 Employ the mechanical energy balance (aka Bernoulli equation) to calculate design parameters (pressure drops, flow rates, pipe sizes) for specific piping configurations that contain various types of fittings, connections, and valves.

L.4 Use a hydraulic analysis software package to calculate design parameters (pressure drops, flow rates, pipe sizes) for specific piping configurations that contain various types of fittings, connections, and valves.

L.5 Describe the characteristics of centrifugal and positive displacement pumps, and use pump performance curves to select an appropriate centrifugal pump for a given piping system

L.6 Apply the visual solution method (VSM) to solve the linear momentum equation for problems with both stationary and moving control volumes

L.7 Simplify the Navier-Stokes equations for unidirectional, laminar flow problems to determine the governing transport equation and then solve for the correct velocity profile in a given system

L.8 Calculate the drag forces on objects in a flow field using analytical expressions and/or drag coefficient correlations

L.9 Write a one-page cover letter that clearly and succinctly summarizes the key content of an academic assignment using appropriate and professional organization and formatting.

COURSE OUTCOMES AND CEAB INDICATORS

Certain courses in the chemical engineering curriculum collect indicator data related to the development of the attributes deemed critical for engineers according to the Canadian Engineering Accreditation Board (CEAB). These indicators will be assessed throughout the course and redacted samples of student work may be collected for submission to the CEAB during McMaster Engineering's accreditation cycle. The indicators assessed in ChE 2O04 are as follows:

1.3 Competence in Engineering Fundamentals

3.2 Synthesizes the results of an investigation to reach valid conclusions

5.2 Successfully uses engineering tools

7.2 Composes an effective written document for the intended audience

8.2 Integrates appropriate standards, codes, legal, and regulatory factors into decision making.

The CEAB indicators listed above are mapped to the course learning outcomes as shown in the table below:

Indicator	Learning Outcomes
1.3	L.1, L.2, L.3, L.5, L.6, L.7
3.2	L.3, L.4, L.6
5.2	L.4
7.2	L.9
8.2	L.3, L.4, L.5

The above outcomes and indicators are for your information. Graduating from an accredited institution has many advantages which you can read about here:
https://engineerscanada.ca/accreditation/about-accreditation

The P.R.O.C.E.S.S.
The department of Chemical Engineering has a storied history of education. In addition to teaching and learning, the department is proud of our graduates not only for their academic success, but their more intrinsic traits that make them respected members of the engineering community.
Recently, several high-ranking graduates from the McMaster Chemical Engineering Program employed in various industries (oil/gas, financials, etc.) were interviewed to ask what traits they look for when hiring for engineering positions. Using this information, the department would like to present to you the PROCESS: a code of conduct that we hope will guide our students throughout this program and their careers to come.

- Professionalism
- Responsibility
- Ownership
- Curiosity
- Empathy
- Selflessness
- Service

It is up to YOU to interpret these traits and apply them to your time at McMaster and your career as you see fit. These traits will not be assessed for grades but will be strongly encouraged throughout your time at McMaster. We hope that you identify with these character traits and what they mean to you, and that you trust the process.

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/

The following illustrates only three forms of academic dishonesty:
•plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
•improper collaboration in group work.
•copying or using unauthorized aids in tests and examinations.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's Academic Accommodation of Students with Disabilities policy.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors. The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email