MIE1210 HS - Computational Fluid Mechanics & Heat Transfer
INSTRUCTOR:

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Course Outline

MIE1210 is an introductory course that will teach a Finite Volume (FV) and Finite Difference (FD) approaches to Computational Fluid Dynamics (CFD) and Heat Transfer. Since the advent of commercially available computers, CFD has been an important engineering research domain as it gave researchers the ability to solve analytically intractable problems of industrial relevance. In the last two decades, the immense demand for CFD research and expertise has spawned the commercialization of software packages such as Fluent/CFX and FEMlab. Despite these readily available software packages, there is a recognized importance to user expertise, fundamental knowledge, and critical understanding of their inner workings. In addition, home spun research codes are still prominent in academia and industry. This is due in large part to the fact that commercial software packages are geared toward a broad range of research topics, and may not function as efficiently as a code designed with a specific problem in mind, and to the fact that developments in CFD are typically achieved in research before they are adopted by software companies.

This course is appropriate both for students who wish to become knowledgeable users of commercial CFD programs, and students who plan to create, develop, or enhance research codes. Therefore, the overreaching goals of this course are threefold: **1.** To give you an introduction to fundamental discretization and solution techniques for heat transfer and fluid dynamics problems; **2.** To give you an understanding of solution methodologies, advantages, downfalls, considerations (stability, accuracy, efficiency), and the inner workings of CFD software; and **3.** To have you gain experience writing programs and solving 1D and 2D problems, and in using these programs to demonstrate and reinforce 1 and 2.

Course Topics

(i) Introduction and toolkit review
(ii) Model problem (the heat conduction equation)
(iii) 2D problems (the convection/diffusion equations)
(iv) 2D Navier-Stokes equations, and
(v) Advanced topics in Computational Fluid Dynamics.

Evaluation

100% of your course grade will be based on assignments and projects, which will cover topics (i) through (iv). **In this course, there will be *no graded assignments or tests/less than 5% of the evaluation for the course* returned before the last date to drop courses. Students should be aware of this in making any decision whether or not to remain in the course past the drop date. No requests for late withdrawal will be supported on the grounds that insufficient feedback was available before the drop date.**

Textbooks

A classical textbook for this course is

Patankar, Numerical Heat Transfer and Fluid Flow (1980)

However, it is somewhat dated, and therefore it will be supplemented by the others, mainly:

H. K. Versteeg, W. Malalasekera, Introduction to Computational Fluid Dynamics: the finite volume method, Second Edition (2007)

There will be parts of the course which be taught from the latest CFD developments not being yet found in text books. Some other important text books and resources are:

Computational fluid dynamics: an introduction, John F. Wendt, John David Anderson (2009)
Lomax, Pulliam, & Zingg, Fundamentals of Computational Fluid Dynamics (1999)
Ferziger, Computational Methods for Fluid Dynamics (2002)
Roache, Fundamentals of Computational Fluid Dynamics (1998)
Hirsch, Numerical Computation of Internal and External Flows (2007)
Chapra and Canale Numerical Methods for Engineers (2006)
Online resources (e.g. http://www.cfd-online.com/ ; http://www.stanford.edu/class/cme324/saad.pdf)

Course Policies

General:

All students must have a utoronto account registered with ROSI so that you can receive course related emails. This course maintains a Blackboard web space, which archives a variety of course-related information including: class announcements, lecture slides, homework assignments, contact information, and the gradebook.

Plagiarism:

Assignments will be done individually. If you are having trouble with a problem, you may consult with other students in the class. You may not examine someone else's work without them present. You may not copy and paste code from anyone else's work. You may not use parts of your own codes that were written before this course, without permission from the instructor. If you obtain information from a book or website to help you solve a problem, you must cite that book or website. **An electronic copy in text or ascii format of all sourcecodes must be submitted through Blackboard with each assignment.** The codes will be databased and scanned for consistency with those from the rest of the class and from previous years. Cases of suspected plagiarism will be dealt with according to Section B of the University of Toronto's Code of Behavior on Academic Matters, http://www.governingcouncil.utoronto.ca/policies/behaveac.htm, which all students are expected to know.

Private meetings will be arranged for each student to examine students' works. Students will be examined by the course TA or instructor in the meetings to ensure the source codes and reports have been prepared by the student. Any suspicious work will be reported to MIE associate chair of graduate studies for further review.

Late Assignments:

Late assignments will be docked 10% per day. I am, however, willing to grant extensions if assignment due dates coincide with tests or projects from other courses. This will have to be arranged with me at least 3 days prior to the assignment due date.

Legitimate Excuses:

If you need more time to complete an assignment for any valid reason, you must immediately report it to the instructor. If the reason is medical, you must download a medical note and have it completed by your doctor. Please make sure that your medical note includes the date it was written and a statement from the doctor that you are unable to complete an assignment by its due date.

Grading Adjustments:
If you are unable to complete an assignment due to a legitimate excuse, your other assignments will be worth a larger portion of the course grade. However, assigned problems will often ask you to build upon or enhance codes that you wrote for previous problems. Therefore, if you do not complete an assignment, you may be responsible for writing codes that you will need to complete future assignments.

Grades:
Individual grades will be posted on Blackboard as they become available. Please check these periodically to make sure that the posted grades match your own records. Any discrepancy should be reported immediately to the instructor.

Assignment Preparation:
For programming questions:
1. All programs can be written in your preferred language such as Python, FORTRAN, C/C++ and etc.
2. Submit a print out of the code *and* upload the source code into Blackboard.
3. Specify the programming language used.
4. Hand in your code output. It should be formatted and easily readable.
5. Each program should be **well-commented** and should have a header describing the purpose of the code, and should contain your full name as registered at the university, student number, assignment number, and question number.

Course Content
Part 1: Introduction and toolkit review
- Conservation equations (mass, momentum, energy)
- Taylor series expansion and manipulation
- Linear system solution (using commercial packages and freeware) **[Project 1]**
- Introduction to Finite Difference Discretization
- Introduction to Finite Volumes Discretization

Part 2: Model problem
- Finite volume discretization of Heat Conduction equation
  - Solving 2D Heat Equation with Dirichlet and Neumann boundary conditions **[Project 2]**
  - Finite volume discretization of Convection/diffusion equations
  - Solving 2D energy equation with prescribed velocity field **[Project 3]**
- Finite volume discretization of 2D Navier-Stokes equations
  - Temporal discretization
  - Staggered versus Collocated discretization
  - Pressure velocity coupling techniques
  - Solving 2D Navier-Stokes and energy equations for a lid-driven cavity problem **[Project 4]**

Part 3: Advanced Topics
- Spectral analysis (stability, accuracy, efficiency of different numerical schemes)
- Advanced methods in mesh generation