APMA 930–4
Computational Fluid Dynamics (CFD)
Spring 2019

Instructor.

John Stockie
Department of Mathematics, SFU
Office: K 10518
Tel: +1 778 782 3553
stockie@math.sfu.ca

Course web page. http://www.math.sfu.ca/~stockie/apma930

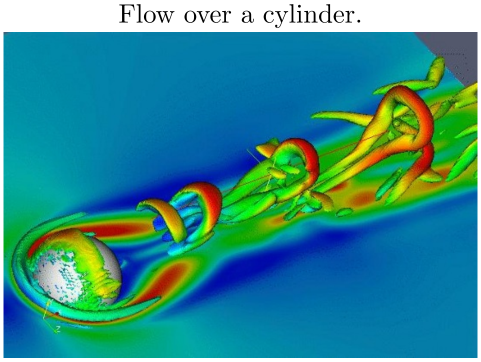
Classes.

Time:	Tuesdays & Thursdays 2:30-4:20
Location:	AQ 5008

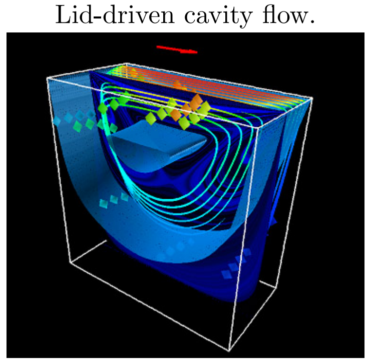
Description. This course will introduce students to a variety of computational approaches for solving the partial differential equations governing fluid dynamics, focusing on finite difference and finite volume techniques. Theoretical background material will be introduced as necessary, but the emphasis of the course will be on the numerical methods, their accuracy and stability, and applying them in practical calculations of real fluid flows. Students will gain experience writing their own codes, as well as employing existing open-source software packages. Applications will be drawn from a wide variety of problems arising in wave propagation, incompressible fluids, compressible gas dynamics, and porous media flow. In contrast with the common engineering approaches to teaching CFD, I will not emphasize the study of complex flows in sophisticated geometries using commercial codes, but will focus instead on the design of the underlying algorithms, and carefully assessing their correctness, accuracy, efficiency and robustness.

Prerequisites. Previous courses in ordinary and partial differential equations (such as MATH 310 or MATH 314) are required, as is some experience in computer programming (any language is fine although knowledge of MATLAB would be helpful). A previous course in fluid dynamics (such as MATH 462) would be an advantage, but is not required.

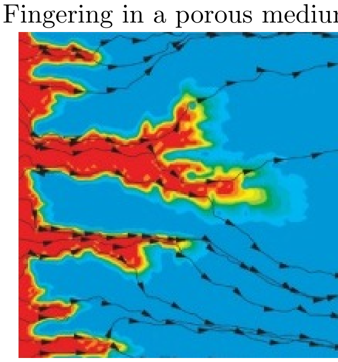
Flow over a cylinder.



Lid-driven cavity flow.



Fingering in a porous medium.



Grading. The grade for this course will be made up of homework assignments (60%) and a project (40%). There will be no final examination.

Textbook. There is no textbook for this course. Material will be drawn from a number of texts, some of which are held on reserve in the library:

- P. Colella and E.G. Puckett, *Modern Numerical Methods for Fluid Flow*, course notes, 1994. **[distributed as PDF]**
- C. Pozrikidis, *Introduction to Theoretical and Computational Fluid Dynamics* (Oxford University Press), 1997. **[hardcopy on reserve]**
  Alternately: C. Pozrikidis, *Fluid Dynamics: Theory, Computation, and Numerical Simulation* (Springer), 2009. **[online reserve]**
- R.J. LeVeque, *Finite Volume Methods for Hyperbolic Problems* (Cambridge University Press), 2002. **[online reserve]**
- K.W. Morton and D.F. Mayers, *Numerical Solution of Partial Differential Equations: An Introduction* first or second ed. (Cambridge University Press), 1994 or 2005. **[hardcopy on reserve]**
- D.A. Nield and A. Bejan, *Convection in Porous Media*, 3rd ed. (Springer), 2006. **[online reserve]**

Outline.

1. Background and Governing Equations *(1 week)*:
Navier-Stokes equations; boundary conditions; simplifications and extensions; analytical solutions.

2. Finite Difference and Finite Volume Methods for Linear Problems *(2 weeks)*:
Consistency, stability and convergence; CFL condition; Lax Equivalence Theorem; von Neuman stability analysis; common upwind and centered schemes; finite volume approach; time-stepping.
Applications: scalar advection; heat equation; wave equation.

3. Incompressible Fluid Flow *(3 weeks)*:
Stokes equations; pressure-Poisson equation; Navier-Stokes equations; projection methods.
Applications: creeping flow; potential flow; driven cavity flow.

4. Porous Media Flow *(3 weeks)*:
Darcy's Law; capillarity; porous medium equation and nonlinear diffusion; IMPES method; Brinkman-Forchheimer extension.
Applications: oil reservoir simulation; groundwater transport; porous channels.

5. Nonlinear Wave Propagation and Compressible Flows *(3 weeks)*:
Hyperbolic conservation laws; nonlinear systems; Riemann solvers; CLAWPACK code.
Applications: gas dynamics; shallow water waves; traffic and pedestrian flow; atmospheric transport.

Additional Topics:
Interspersed throughout the course, I will introduce additional material related to fluid mechanics, scientific computing, reproducible research, and validated numerics.