189-579B Numerical Differential Equations

Martin J. Gander

Time: Monday evening, 18:00-21:00 in Burnside Hall 1205

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Textbook: There is no single textbook which covers the material. I use for the ordinary differential equations part *Solving Ordinary Differential Equations* by E. Hairer, S.P. Nørsett and G. Wanner, and for the partial differential equations part *Numerical Solution of Partial Differential Equations by the Finite Element Method* by Claes Johnson, *Finite Difference Schemes and Partial Differential Equations* by John C. Strikwerda and *Spectral Methods in Matlab* by Lloyd N. Trefethen.

Handouts: On the Web at http://www.math.mcgill.ca/mgander/teaching/189-579B/

Course Summary: Many physical phenomena can be formulated as differential equations, for example the flow of a fluid or the temperature in your apartment. The solution of these equations is however challenging and analytical methods rarely suffice to obtain the desired results. Only numerical methods can solve the problems of interest in applications. This course introduces you to the theory of modern numerical methods for solving ordinary differential equations (ODEs) and partial differential equations (PDEs). We use throughout the course Matlab to develop prototype codes and we use Maple to avoid tedious hand calculations. This is the ideal course for you if you are an applied mathematician or engineer who needs to solve ODEs and PDEs in your application area. After the course you will be able to make an informed choice when solving your problems numerically.

Topics:

- Numerical methods for ordinary differential equations (Linear multistep and Runge-Kutta methods, consistency, stability and convergence, adaptive integration).
- Hamiltonian problems, symplectic integration.
- Shooting methods for boundary value problems.
- Numerical methods for elliptic partial differential equations, including finite difference, finite element, finite volume and spectral methods.
- The method of lines for hyperbolic and parabolic partial differential equations, implicit and explicit time integration.
- Multi-grid methods and domain decomposition if time permits.

Prerequisites: The main prerequisite for the course is that you understand the continuous problems for which numerical methods are developed. So you need to know ODEs and PDEs at the level taught in a 'methods of mathematical physics' course and basic numerical analysis including programming.

Grading: The final grade is based on the homeworks, the final and class participation. There is a homework assignment about every two weeks and the final is a take-home exam. The overall grade is computed according to the following table:

Homeworks	40%
Class participation	10%
Final	50%