

**Faculty of Engineering Course Syllabus
Department of Engineering Mathematics
Directed Studies Course
ENGM 6000 Numerical Methods for Engineers and Scientists
Winter 2021**

INSTRUCTOR: Wendy Gentleman, wendy.gentleman@dal.ca,

LECTURES: material corresponding to 3 in-person hrs/wk that is a combination of lecture and coding. Classes will be delivered live, with recordings posted online so you can re-watch at your convenience.

HELP SESSION: 1 hr/week live (recorded)

COURSE DESCRIPTION

This class introduces Numerical Methods that are used to solve common mathematical problems encountered by engineers and scientists. The course is designed to complement to a standard undergraduate numerical methods course, although no previous exposure is necessary. We will cover methods for (i) solving algebraic equations, including optimization, (ii) data fitting, including interpolation and goodness of fit, (iii) numerical calculus, and (iv) differential equations. Specific topics will be based on students' interest. Students will learn different approaches, how to implement suitable solution algorithms, and how to assess errors. They will also conduct an independent project which can be related to their thesis research.

COURSE PREREQUISITES

Single variable calculus, multivariate calculus, linear algebra, differential equations, or permission of instructor

COURSE OBJECTIVES

- Develop students' understanding of the theory underlying common numerical methods
- Train students how to design efficient and accurate solution algorithms, and illustrate ways to implement those algorithms as code in, for example, MATLAB
- Demonstrate competence in use of computational tools
- Train students in ways to analyze and evaluate the accuracy of different methods.
- Introduce practical applications using this knowledge and these skills.

LEARNING OUTCOMES:

Demonstrated understanding of numerical methods used for (1) Solving systems of linear and nonlinear algebraic equations including optimization, (2) Fitting functions to data and assessing goodness of fit, (3) Using calculus to estimate practical quantities and associated error, (4) Solving differential equations, and, (5) gaining experience with mathematical software, such as MATLAB.

COURSE ASSESSMENT

Assignments (Approximately weekly, total weight 50%)

Project (Proposal 5%, Oral Presentation 20%, Written Report 25%)

DRAFT COURSE SCHEDULE (topics and timing to be finalized by professor based on students' experience and interest. This will be decided during first week of term)

Category	
Course introduction + MATLAB introduction	
1: Solution of algebraic equations	
1.1. Linear systems Applications: Chemical reactors	a) Naive Elimination (Gauss-Jordan + Gaussian with Back Substitution) b) Wise Elimination (Tri-Diagonal, LU decomposition + Partial Pivoting) c) Iterative Methods (Gauss Jacobi + Gauss-Seidel) d) Relaxation
1.2 Nonlinear equations Applications: Electric charge, water tanks	a) Brute force b) Bracketing methods (Bisection + Regula Falsi) c) Open methods (Newton + Secant)
1.3. Nonlinear systems Application: Heated surfaces	a) Newton b) Steepest Descent
2: Curve fitting	
2.1 Data fitting (Data Exact) Applications: Vertical diffusion in oceans and thermistors	a) Standard polynomials b) Lagrange polynomials c) Runge phenomena d) Fourier fits e) Splines (Linear + Quadratic + Cubic + Hermite)
2.2. Data fitting (Data Approx) Applications: Machine precision, polymer degradation	a) Least squares concepts + vector formulae b) Lines of best fit c) Goodness of fit and vector formulae d) Nonlinear fits that are linear combinations (multivariate and transformations) e) Weighted least squares (maximum likelihood)
Study Break	
3: Numerical Calculus	
3.1. Numerical differentiation Applications: Motion in space, oil spill	a) Finite difference approximations (forward, backward, centered and different orders of error)
3.2. Numerical integration Applications: Thermal pollution	a) Reimann b) Midpoint c) Trapezoidal d) Simpsons 1/3 e) Romberg f) Gauss-Legendre

Category	
4: ODEs	
4.1. IVPs Applications: Pendulums, population dynamics, skydiving	a) (Forward) Euler b) Backward Euler c) Crank-Nicholson d) Runge-Kutta e) Higher Order Taylor Methods f) Adams-Bashforth g) Adams-Moulton h) Stiffness
4.2. BVPs Application: Cooling fins	a) Shooting b) Finite Difference c) Boundary Conditions
5: PDEs	
5.1 FD Parabolic PDEs Application: Diffusion, chemical reactors	a) Discretization + BCs b) Explicit (Euler) c) Implicit d) Crank-Nicholson
5.2 FD Elliptic PDEs Application: Electric fields, temperature distributions on heated plates	a) Discretization b) Boundary conditions
5.3 FD Hyperbolic PDEs Applications Wave equation	a) Discretization + BCs b) Explicit (Euler) c) Implicit
Introduction to FEM	a) Concepts of FEM
Project presentations	

DALHOUSIE ENGINEERING STUDENT OATH

I, as one who is preparing to enter the profession of engineering, promise to conduct myself in an honorable and ethical manner, and, as such, I will not cheat, plagiarize or be involved in any other academically dishonest activities. I shall uphold the values of truth, honesty and trustworthiness. I shall study diligently so that I will be able to safeguard human life, to protect the welfare of society and the environment, and to uphold the reputation of the profession. In all this I shall be concerned for the well-being of others, and not just myself.

UNIVERSITY POLICIES, STATEMENTS, GUIDELINES AND RESOURCES FOR SUPPORT

This course is governed by the academic rules and regulations set forth in the University Calendar and the Senate. For details see <https://academicalendar.dal.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog>.

UNIVERSITY STATEMENTS

ACADEMIC INTEGRITY

At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect (The Center for Academic Integrity, Duke University, 1999). As a student, you are required to demonstrate these values in all of the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. For details visit https://www.dal.ca/dept/university_secretariat/academic-integrity.html

ACCESSIBILITY

The Advising and Access Centre and the Student Success Centre (Agricultural Campus) serve as Dalhousie's centres for expertise on student accessibility and accommodation. Our work is governed by Dalhousie's Student Accommodation Policy to best support the needs of Dalhousie students. Our team works with students who request accommodation as a result of: disability, religious obligation, an experienced barrier related to any other characteristic protected under Canadian Human Rights legislation. For details visit https://www.dal.ca/campus_life/academic-support/accessibility.html

STUDENT CODE OF CONDUCT

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. For details visit https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/student-life-policies/code-of-student-conduct.html

ACCOMMODATION POLICY FOR STUDENTS

Students may request accommodation as a result of barriers related to disability, religious obligation, or any characteristic protected under Canadian Human Rights legislation. The full text of Dalhousie's Student Accommodation Policy can be accessed here:

http://www.dal.ca/dept/university_secretariat/policies/academic/student-accommodation-policy-wef-sep-1-2014.html

Students who require accommodation for classroom participation or the writing of tests and exams should make their request to the **Advising and Access Services Centre (AASC)** prior to or at the outset of the regular academic year. More information and the *Request for Accommodation* form are available at www.dal.ca/access.

DIVERSITY AND INCLUSION CULTURE OF RESPECT

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported. For details visit <https://www.dal.ca/cultureofrespect.html>

RECOGNITION OF MIKMAQ TERRITORY

Dalhousie University acknowledges that the University is located on Traditional Mikmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel and support. Visit the office in the McCain Building (room 3037) contact the programs at elders@dal.ca or 902-494-6803.

UNIVERSITY POLICIES AND PROGRAMS

- Important Dates in the Academic Year (including add/drop dates) can be found at https://www.dal.ca/academics/important_dates.html
- University Grading Practices: Statement of Principles and Procedures. For details visit https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html
- Scent-Free Program. For details visit <https://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html>
- Faculty Information: Student Self-Declaration of Absence. For details visit https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/academic-policies/student-absence/student-absence---for-faculty.html

LEARNING AND SUPPORT RESOURCES

- General Academic Support Advising
Halifax: Visit https://www.dal.ca/campus_life/academic-support/advising.html
Truro: Visit <https://www.dal.ca/about-dal/agricultural-campus/ssc/academic-support.html>.
- Fair Dealing Guidelines. For details visit <https://libraries.dal.ca/services/copyright-office/guidelines/fair-dealing-guidelines.html>.
- Black Students. For details visit https://www.dal.ca/campus_life/communities/black-student-advising.html
- International Students. For details visit https://www.dal.ca/campus_life/international-centre.html
- Indigenous Students. For details visit https://www.dal.ca/campus_life/communities/indigenous.html.
- Library. For details visit <https://libraries.dal.ca>
- Copyright Office. For details visit <https://libraries.dal.ca/services/copyright-office.html>.
- E-Learning website <https://www.dal.ca/dept/elearning.html>.
- Writing Centre. https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html.
- Faculty or Departmental Advising Support: Studying for Success Program For details visit https://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html
- Student Finance page: Visit https://www.dal.ca/admissions/money_matters.html.

STUDENT HEALTH AND WELLNESS RESOURCES

- Student Health and Wellness. Visit https://www.dal.ca/campus_life/health-and-wellness/services-support.html.
- Student Services @ Sexton. Visit https://www.dal.ca/campus_life/academic-support/student-services-sexton.html.
- Online Resources for Students. For details visit https://www.dal.ca/campus_life/health-and-wellness/online-resources.html.

SAFETY

- Biosafety. Visit <https://www.dal.ca/dept/safety/programs-services/biosafety.html>.
- Research Laboratory Safety Policy Manual. Visit <https://www.dal.ca/dept/safety/documents-policies-procedures.html>
- Laboratory Chemical Safety Manual. Visit <https://www.dal.ca/dept/safety/programs-services/chemical-safety.html>.
- Radiation Safety Manual. Visit <https://www.dal.ca/dept/safety/programs-services/radiation-safety.html>