MECH ENG 3F04
Modeling and Numerical Solutions

Undergraduate Studies
Winter 2025
Course Outline

CALENDAR/COURSE DESCRIPTION

This course provides the fundamental numerical methods used in computational engineering and physics using MATLAB including: Root Finding Methods, Solving a System of Linear or Non-linear Algebraic Equations, Unconstrained Optimization techniques, Curve-fitting and Interpolation, Numerical integration and differentiation, Solution of Ordinary and Partial Differential Equations.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): Registration in any Mechanical Engineering Program
Antirequisite(s): ENG PHYS 2CE4, ENG PHYS 3NM4

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Chris Morton
JHE 308A
mortoc5@mcmaster.ca

Office Hours:
Tuesday – 12:30 pm
Friday – 12:30 pm
Or by appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Rangarajan, Shreenivas	rangas6@mcmaster.ca
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Office Hours: By Appointment

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

http://avenue.mcmaster.ca/

- All course material: supplementary lecture materials, lecture recordings, tutorials, projects, and assignments + solutions will be available on A2L.
- Lectures will be delivered in person and recorded (Tuesday/Thursday, ITB AB102), lectures will be delivered online and recorded (Friday).
- Tutorials will be held in person (ITB AB102) with recorded or hand-written solutions/notes made available on A2L.

COURSE INTENDED LEARNING OUTCOMES

By the end of this course, students should be able to:

- Determine the roots of non-linear equations using bracketing and non-bracketing numerical methods.
- Solve a large system of linear algebraic equations using direct and iterative numerical methods.
- Solve nonlinear equations and systems of non-linear equations using a variety of methods, understanding differences in the methods in terms of convergence and speed
- Perform one- and multi-dimensional unconstrained optimizations using a variety of methods, understanding differences in the methods in terms of convergence and speed
- Perform polynomial and spline Interpolations while understanding the limitations/benefits of the various approaches
- Perform regressions on data sets using least-squares methods including linearization of non-linear data sets.
- Calculate the numerical derivative or numerical integral of a set of discrete and continuous data and assess the accuracy of the result.
- Solve ordinary differential equations that occur in many branches of engineering using Euler's and high order numerical methods subjected to appropriate boundary and/or initial conditions and understand the discretization error for each method.
- Solve boundary value problems using finite difference methods and solving the resulting linear equation set.
- Develop numerical algorithms for modelling physical problems; implement and test these in a computing environment (MatLab).

MATERIALS AND FEES

Required Texts:

The main textbook for the course:
Chandra & Canale, Numerical Methods for Engineers, 8th Ed. (**Note:** While any edition of the book is acceptable it is the responsibility of the student to ensure questions/topics/tables and formulas are consistent with this edition).

Additional Texts (not required):

- Numerical Recipes: The Art of Scientific Computing, William H. Press, Saul A. Teukolsky, William T. Vetterling & Brian P. Flannery

Calculator:
Only the McMaster Standard Calculator will be permitted in tests and examinations. This is available at the Campus Store.

Other Materials:
MATLAB programing is a mandatory component in this class. Students must obtain a valid program and license for MATLAB in the 1st week of classes.

COURSE FORMAT AND EXPECTATIONS

The course is organized as follows:

- 2 x 50-min lectures per week in-person (theory development, Tues/Thurs)
- 1 x 50-min lectures per week online (problem solving and MATLAB implementation, Fri)
- 2 x 50-min per week office hours following to Tuesday & Friday Lectures

- 1 x 50-min tutorial per week
- 2 projects (marked for 10% each – total 20%)
- 2 scheduled Tests during class time (5% each – total 10%)
- 1 Midterm Exam (30%)
- 1 Final Exam (40%)

COURSE SCHEDULE

Week/Date	Topic	Readings
1/Jan 06	▪ Review of mathematical models for mechanical systems, ODEs	Chapter 1
2/Jan 13	▪ Numerical Analysis: Approximating functions, derivatives, integrals, partial derivatives	Chapter 3, 21.1-3, 23
3/Jan 20	▪ Numerical Analysis: Truncation Errors, error analysis, roots of equations	Chapter 4, 5
4/Jan 27	▪ Numerical Analysis: Direct solution of systems of linear algebraic equations	Chapter 9
5/Feb 03	▪ Numerical Analysis: Iterative solution of systems of linear algebraic equations ▪ Numerical Analysis: Solutions to systems of non-linear algebraic equations	Chapter 11 Chapter 6.6
6/Feb 10	▪ Numerical Solution of ODEs (1st order IVP, nth order IVP)	Chapter 25
7/Feb 17	**Term Recess**	
8/Feb 24	▪ Numerical solution of ODEs (sets of ODEs, BVP)	Chapter 27
9/Mar 3	▪ Numerical solution of PDEs (Laplace/Poisson equation)	Chapter 29-30
10/Mar 10	▪ Numerical solution of PDEs (Diffusion, Wave equation)	Chapter 31-32
11/Mar 17	▪ Optimization and Least Square Regression	Chapter 13-14,17
12/Mar 24	▪ Least Squares Regression and Interpolation	Chapter 17,18
13/Mar 31	▪ Interpolation and Fourier Approximation	Chapter 19

ASSESSMENT

Component	Due Date	Weight
Projects (x2)	Jan 31, Mar. 28	20%
Midterm Exam	Feb. 27	30%
Tests (x2)	Jan. 24, Mar. 14	10%
Final Exam	TBD	40%
Total		100%

ACCREDITATION LEARNING OUTCOMES

The Learning Outcomes defined in this section are measured for Accreditation purposes only and will not be directly taken into consideration in determining a student's grade in the course.

Outcomes	Indicators
Numerically solve ordinary and partial differential equations that occur in many branches of mathematics and engineering	1.1

Develop numerical algorithms for modelling physical problems; implement and test these in a computing environment (MATLAB).	5.1
Create finite difference methods to first and second order ordinary and partial differential equations such as the Wave, Laplace and Heat Equations.	5.2

For more information on Accreditation, please visit: https://www.engineerscanada.ca

EQUITY, DIVERSITY, AND INCLUSION

Every registered student belongs in this course. Diversity of backgrounds and experiences is expected and welcome. You can expect your Instructor to be respectful of this diversity in all aspects of the course, and the same is expected of you.

The Department of Engineering Physics is committed to creating an environment in which students of all genders, cultures, ethnicities, races, sexual orientations, abilities, and socioeconomic backgrounds have equal access to education and are welcomed and treated fairly. If you have any concerns regarding inclusion in our Department, in particular if you or one of your peers is experiencing harassment or discrimination, you are encouraged to contact the Chair, Associate Undergraduate Chair, Academic Advisor or to contact the Equity and Inclusion Office.

MENTAL HEALTH & WELLNESS

For a list of McMaster University's resources, please refer to the Student Wellness Centre.
Talkspot is a non-crisis mental health resource specifically for students in the Faculty of Engineering.

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:
1. plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. improper collaboration in group work.
3. copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

McMaster is committed to an inclusive and respectful community. These principles and expectations extend to online activities including electronic chat groups, video calls and other learning platforms.

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.

COURSE POLICY ON MISSED WORK, EXTENSIONS, AND LATE PENALTIES

1. It is the students' responsibility to regularly check the course webpage (ex. Avenue to Learn) for updates and announcements.
2. Project submissions overdue by less than 24 hours from the deadline will be marked out of 75%. The dropbox on A2L will not accept assignment submissions later than 24 hours.
3. Any MSAF applied to a Test will require the Test to be rescheduled for the following week during the same timeslot.
4. Any MSAF applied to a project will result in an automatic three business days extension to the project deadline.

5. Any MSAF specially approved for a Midterm Exam will require the Midterm Exam to be rescheduled to a suitable timeslot the following week.

SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

1. **Relief for missed academic work worth less than 25% of the final grade resulting from medical or personal situations lasting up to three calendar days:**

    - Use the McMaster Student Absence Form (MSAF) on-line self-reporting tool. No further documentation is required.
    - Students may submit requests for relief using the MSAF once per term.
    - An automated email will be sent to the course instructor, who will determine the appropriate relief. Students must immediately follow up with their instructors. Failure to do so may negate the opportunity for relief.
    - The MSAF cannot be used to meet a religious obligation or to celebrate an important religious holiday.
    - The MSAF cannot be used for academic work that has already been completed attempted.
    - An MSAF applies only to work that is due within the period for which the MSAF applies, i.e. the 3-day period that is specified in the MSAF; however, all work due in that period can be covered by one MSAF.
    - The MSAF cannot be used to apply for relief for any final examination or its equivalent. See *Petitions for Special Consideration* above.

2. **For medical or personal situations lasting more than three calendar days, and/or for missed academic work worth 25% or more of the final grade, and/or for any request for relief in a term where the MSAF has been used previously in that term:**

    - Students must report to their Faculty Office to discuss their situation and will be required to provide appropriate **supporting documentation**.
    - If warranted, the Faculty Office will approve the absence, and the instructor will determine appropriate relief.

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.