Materials Science:
School of Graduate Studies
Trent University

MTSC 6270H: Topics in Materials Science II
Finite Element Method for Problems in Physics
FA2018
Peterborough

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Campus: Peterborough	Office Location: SC213	Office Hours: Th 12:00-13:50

Dates of Course	**Start:** Sep 17, 2018	**Finish:** Dec 17, 2018

Course Description:

This reading course certifies and overviews an ongoing online learning course (**Coursera; *Finite Element Method for Problems in Physics***) which introduces and uses the finite element method to solve problems in physics. The emphasis is on coding up the formulations in a modern, open-source environment that can be expanded to other applications.

Course Structure:

The course includes about 45 hours of online lectures covering the material from an introductory graduate class at University of Michigan. The treatment is mathematical, which is natural for a topic whose roots lie deep in functional analysis and variational calculus. Much of the success of the Finite Element Method as a computational framework lies in the rigor of its mathematical foundation, and this needs to be appreciated, even if only in the elementary manner presented here. A background in PDEs and, more importantly, linear algebra, is assumed.

The development itself focuses on the classical forms of partial differential equations (PDEs): elliptic, parabolic and hyperbolic. At each stage, however, we make numerous connections to the physical phenomena represented by the PDEs. For clarity we begin with elliptic PDEs in one dimension (linearized elasticity, steady state heat conduction and mass diffusion). We then move on to three dimensional elliptic PDEs in scalar unknowns (heat conduction and mass diffusion), before ending the treatment of elliptic PDEs with three dimensional problems in vector unknowns (linearized elasticity). Parabolic PDEs in three dimensions come next (unsteady heat conduction and mass diffusion), and the lectures end with hyperbolic PDEs in three dimensions (linear elastodynamics). Interspersed among the lectures are responses to questions that arose from a small group of graduate students and post-doctoral scholars who followed the lectures live. At suitable points in the lectures, we interrupt the mathematical development to lay out the code framework, which is entirely open source, and C++ based.

Course Schedule:

The schedule is broken down into twelve units, with unit summary meetings taking place every week.

1. Introduction to a simple one-dimensional problem that can be solved by the finite element method.
Graded: Unit 1 Quiz

2. The approximate, or finite-dimensional, weak form for the one-dimensional problem.
Graded: Unit 2 Quiz

3. Writing the finite-dimensional weak form in a matrix-vector form and introduction to coding in the deal.ii framework.
Graded: Unit 3 Quiz
Graded: Coding Assignment 1

4. Further details on boundary conditions, higher-order basis functions, and numerical quadrature.
Graded: Unit 4 Quiz

5. The mathematical analysis of the finite element method.
Graded: Unit 5 Quiz

6. An alternate derivation of the weak form, which is applicable to certain physical problems.
Graded: Unit 6 Quiz

7. Three-dimensional scalar problems, such as the heat conduction or mass diffusion problems.
Graded: Unit 7 Quiz

8. Choice of basis functions, and second coding assignment
Graded: Unit 8 Quiz
Graded: Coding Assignment 2

9. Two-dimensional formulation for scalar problems, such as the steady state heat or diffusion equations.
Graded: Unit 9 Quiz

10. Three-dimensional, linearized elasticity at steady state
Graded: Unit 10 Quiz
Graded: Coding Assignment 3

11. Unsteady heat conduction, or mass diffusion, problem, and its finite element formulation.
Graded: Unit 11 Quiz
Graded: Coding Assignment 4

12. Elastodynamics, and its finite element formulation.
Graded: Unit 12 Quiz

Learning Outcomes/Objectives/Goals/Expectations:

By the end of the course a successful student should be able to:

- Demonstrate significant experience with programming in C++
- Identify the differential equation underpinning problems of elasticity, heat conduction, and diffusion

- Demonstrates a working knowledge of solving linear differential equations using the finite element method
- Analyse and communicate the results from finite element modelling of the problems in physics listed above

Evaluation and Explanation:

This is a **pass/fail course**. Each student's progress on each of the 12 specified units listed above will be assessed by the instructor to determine whether this constitutes sufficient progress towards a satisfactory passing grade. Achievement in the course will be discussed at each weekly meeting.

Suggested readings and resources:

Books: There are many books on finite element methods. This class does not have a required textbook. However, the following books are recommended by Coursera

The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, T.J.R. Hughes, Dover Publications, 2000.

The Finite Element Method: Its Basis and Fundamentals, O.C. Zienkiewicz, R.L. Taylor and J.Z. Zhu, Butterworth-Heinemann, 2005.

A First Course in Finite Elements, J. Fish and T. Belytschko, Wiley, 2007.

The deal.ii library for writing the computer code can be found at dealii.org.

Academic Policies

As stated in the Graduate Student Academic Integrity Policy,
"All members of the University community share the responsibility for the academic standards and reputation of the University. When students submit work for academic evaluation and credit, they imply that they are the sole authors of the work. Clear and careful attribution of the words and ideas of others is an essential part of academic scholarship. Academic honesty is a cornerstone of the development and acquisition of knowledge and is a condition of continued membership in the University community."
Furthermore,
"Academic dishonesty, including plagiarism and cheating, is ultimately destructive of the values of the University. Scholarly integrity is required of all members of the University. Engaging in any form of academic dishonesty or misconduct in order to obtain academic credit or advantage of any kind is an offence under this policy."
Please review the Graduate Student Academic Integrity Policy section of the Graduate Calendar for definitions, penalties, and procedures for dealing with academic dishonesty.

As described in the Graduate Student Appeals Procedure, students may appeal grade on "assignments and examinations associated with graded courses that are part of the requirements of a degree" and other "examinations or evaluations associated with major degree requirements such as comprehensive or candidacy examinations, evaluation of major research or internship papers and theses defences." Students should first attempt to resolve a matter informally with the initial decision-maker(s). Where informal resolution is not possible, a student has the right to make a formal appeal. The appeal process is described in the Graduate Student Appeals Procedure section of the Graduate Calendar.

Access to Instruction statement: It is Trent University's intent to create an inclusive learning environment. If a student has a disability and/or health considerations and feels that he/she may need accommodations to succeed in this course, the student should contact the Student Accessibility Services Office (SAS) at the respective campus as soon as possible. Email: sas@trentu.ca Phone: 705-748-1281 Location: BH Suite 132.

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