King Abdullah University of Science and Technology KAUST

# Numerical Analysis of Differential Equations - Course Syllabus

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**Course Number:** AMCS 252

**Course Title:** Numerical Analysis of Differential Equations

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| **Academic Semester:** | Spring | **Academic Year:** | 2015/ 2016 |
| **Semester Start Date:** | Jan, 24, 2016 | **Semester End Date:** | May, 19, 2016 |

**Class Schedule:** Sundays and Wednesdays; from 14:30 to 16:00

**Classroom Number:**

**Instructor(s) Name(s):** Matteo Parsani
**Email:** matteo.parsani@kaust.edu.sa

**Teaching Assistant name:** TBD
**Email:**

**Office Location:** Bldg. 1; level 3; Office #3204
**Office Hours:** By appointment (e-mail or ask before or after the class)

## COURSE DESCRIPTION FROM PROGRAM GUIDE

Theory and technique for the numerical analysis of ODEs and of PDEs of parabolic, hyperbolic, and elliptic type: accuracy, stability,convergence and qualitative properties. Runge-Kutta and linear multistep methods, zero-stability, absolute stability,stiffness, and order conditions. Finite difference methods, multigrid, dimensional and perator splitting, and the CFL condition.

## COMPREHENSIVE COURSE DESCRIPTION

This course will introduce you to numerical methods for solving ordinary differential equations (ODEs) and partial differential equations (PDEs). We will concentrate on finite difference methods and their application to standard model problems. This will allow the methods to be taught in simple terms while at the same time treating such concepts as accuracy and stability with a reasonable degree of mathematical rigour.

Similarities and differences between algorithm and stability analysis for different types of equations will be presented. We will begin with finite difference solution of steady state problems followed by boundary value problems. Next we will focus on the solution of initial value ODEs, and finally initial value PDEs. Emphasis will be given to two simple but very important equations, i.e., the heat equation and the advection equation.

## GOALS AND OBJECTIVES

General concepts such as accuracy, stability, boundary conditions, verifications, and validation are presented. Your main goal should be to gain understanding of the methods through analysis of their accuracy and stability, and also by implementing and experimenting with the methods. Investigate, through computations, the behavior of the numerical methods, analyze the results, discuss alternative algorithms, and draw critical conclusions helps invaluably to assimilate theoretical notions; it challenges you to excel at tasks beyond the basic expectation of a course; it encourages confidence in your abilities.

Depending on the performance of the students, we could spend some time looking at new tools. For instance, for group collaboration and code development, we could start using a modern version control system such as one would encounter when interacting with real software projects.

## REQUIRED KNOWLEDGE

You should possess knowledge of linear algebra, differential equations, and some notions of advanced calculus such as Taylor series. Some programming experience with high level languages such as python and matlab (or octave) is required. Knowledge of numerical analys is welcome but is not strictly required.

## REFERENCE TEXTS

***Main textbook*** :

Finite Difference Methods for Ordinary and Partial Differential Equations, by Randall J. LeVeque.

**Additional resources**:

Alfio Quarteroni Riccardo Sacco Fausto Saleri, Numerical Mathematics, Second Edition, Springer.

Strikwerda, John. 2007. Finite Difference Schemes and Partial Differential Equations. Society for Industrial and Applied Mathematics.

## METHOD OF EVALUATION

| Percentages % | Graded content |
|---|---|
| 20%<br>40%<br>40% | **Homework**<br>**Mid-term**<br>**Course project**<br><br>**One written exam will be given, approximately one-half (depending on the performance of the students) of the way through the semester. A list of exam topics will be provided prior to the exam.**<br><br>**After the exam, students will be evaluated through a project. Students will choose a topic of interest related to the course. The project will involve reading some papers on a research topic and perfoming an implementation or analysisd of a numerical method.** |

## COURSE REQUIREMENTS

### Assignments

For each class session, you will be given a reading assignment and 1 (or 2) homework problems. It is essential that you devote substantial time to the reading, since I will not cover all topics in class. Instead, you should come to class prepared to ask questions. You may also email me before the lecture with questions or requests so that we could use part of the class time to discuss in greater detail an important topic, a specific problem, or an explanation that seems not clear.
During each class, one student will be asked to present a homework solution. Homework can be solved in group of people. Presenting a perfect solution the first time is excellent, but you will not be penalized for minor mistakes. The point is to demonstrate that you understand the concepts (or to improve your understanding) and can communicate them clearly to the class (like you would do, for instance, during a conference ow workshop presentation).

### Course Policies

If you have a personal activity, family, or religious conflict with the course schedule, you can expect to be heard sympathetically. Please contact me by the end of the second week of the term to discuss appropriate accommodations for any conflicts that can be foreseen. For illness-related absences, there are standard procedures to follow.
Late work in this course will receive no credit. You should always turn in what you have completed by the deadline. If there are extenuating circumstances, come talk to me before the deadline.

**NOTE**
The instructor reserves the right to make changes to this syllabus as necessary.