MATH528
Mathematical methods for the physical sciences I

Course syllabus

Times	MWF 12:20-1:10PM, Phillips 332
Office hours	Tu 1:00-2:30PM Th 10:00-11:30AM, and by email appointment, Chapman 451
Instructor	Sorin Mitran
TAs	Colin Thomson (Th 10:00-12:00 Ph376), Katie Slyman (Mo 2:30-3:30 Ph407)

This course introduces mathematical methods useful for quantitative modeling. Historically, such methods have been developed within research in the physical sciences, but now find applicability across many fields including medical, biological and social sciences. The course concentrates on:

- Formulating corect mathematical models
- Analysis of mathematical models
- Solving mathematical models

Within the vast range of mathematical models, this course discusses models in which the current state of a system is known and a hypothesis is made on the way the system may change. The mathematical transcription of such a model is one or more differential equations (DEs). Assuming that students have had a first exposure to ODEs through the MATH383 prerequisite, more advanced analysis and solution methods will be discussed.

The instructor reserves the right to make changes to the syllabus. Any changes will be announced as early as possible.

Course goals

Students will acquire proficiency in the formulation, theory and solution of physical models expressed as ODEs or systems of ODEs.

Honor Code

Unless explicitly stated otherwise, all work is individual. You may discuss various approaches to homework problems with students, instructors, but must draft your answers by yourself. In joint projects, each student will clearly identify which portions of the work they contributed.

Grading

Required work

- Homework - Best 12 of 14 assignments x 5 = 60 points
- Midterm examination = 12 points
- Final examination = 28 points
- Extra credit - additional two homework assignments, 2 x 5 = 10 points

Mapping of point scores to letter grades

Grade	Points	Grade	Points	Grade	Points	Grade	Points
H+,A *cum laude*	101-110	H-,B+	86-90	P-,C+	71-75	L-,D+	56-60
H+,A	96-100	P+,B	81-85	L+,C	66-70	L–,D-	50-55
H,A-	91-95	P,B-	76-80	L,C-	61-65	F	0-49

Course policies

- Students are free to establish their own schedule; there is no need to inform instructor of absences. Course attendance is highly recommended to gain insight into course topics
- Late homework is not accepted.
- Homework is to be submitted electronically through Sakai

Examinations

- The midterm examination during normal class meeting time before Fall Break will consist of 3 questions, 4 points each.
- The final examination, Fr. Dec. 14, 12:00PM, will consist of 7 questions, 4 points each.

Course materials

Course topics

- Ordinary differential equations (ODE): first-order, classification, theory, second-order, initial and boundary value problems
- Numerical methods for ODEs (NUM): theory, software, applications (introduced throughout course)
- ODE systems (SYS): linear systems, nonlinear systems
- Laplace transforms (LT): theory, applications to solving ODEs
- Series solutions (SS): theory, special functions
- Fourier series (FS): theory, applications
- Advanced applications (AA): application of course material to solve realistically complex problems

Textbook

Advanced Engineering Mathematics, E. Kreyszig, 10^{th} edition.

Class slides

Slides summarizing the main topics of each lecture or mini-lab are generally posted 48 hours prior to class time. Work through the slides while reading the associated textbook material (indicated by section numbers, e.g., §1.1-3 in the table below) before class to gain a first exposure to lecture material. Lessons contain theoretical concepts and present instructor-solved examples. In-class lab sessions are focused on active student learning of course material through problem formulation and solution. Homework extends lab topics.

Week	Dates	Monday	Wednesday	Friday
01	08/20-24	-	Lesson01 ODE §1.1-3	mLab01 Intro
02	08/27-31	Lesson02 ODE §1.4	Lesson03 ODE §1.5	mLab02 ODE
03	09/03-07	(Labor Day)	Lesson04 ODE §1.7, §2.1	mLab03 ODE lab03.nb
04	09/10-14	Lesson05 ODE §2.2-4	(Hurricane Florence)	(Hurricane Florence)
05	09/17-21	Lesson06 ODE §2.5-7	Lesson07 ODE §2.8-9	mLab04 ODE §2.10
06	09/24-28	Lesson08 ODE §3.1-3	Lesson09 SYS §4.1-2	mLab05 SYS §4.3
07	10/01-05	Lesson10 SYS §4.4	Lesson11 SYS §4.5	mLab06 SYS §4.6
08	10/08-12	Lesson12 SS §5.1-2	Lesson13 SS §5.3	Midterm prep
09	10/15-19	Midterm prep	Midterm exam §1-§5	(Fall Break)
10	10/22-26	Lesson15 LTR §6.1	Lesson16 LTR §6.2	mLab07 LTR §6.3
11	10/29-02	Lesson20 LTR §6.4	Lesson21 LTR §6.5	mLab09 LTR §6.6-7
12	11/05-09	Lesson22 FS §11.1	Lesson23 FS §11.2	mLab10 FS §11.3
13	11/12-16	Lesson24 FS §11.4	Lesson25 FS §11.5	mLab11 FS §11.6
14	11/19-23	Lesson26 FS §11.7-8	(Thanksgiving)	(Thanksgiving)
15	11/26-30	Lesson27 AA §11.9	Lesson28 AA §12.4	mLab12 AA §12.6-7
16	12/03-07	AA §12.10	Review	-

Homework

Homework questions are classified as:

- Exercises, 0.25 points, 5 minutes
- Problems, 0.50 points, 10 minutes
- Projects, 1 point, 20 minutes

The above list shows the grade points awarded for correct solution of each question type and the time needed to draft a solution, assuming theoretical course concepts are well understood. Note that true understanding of course topics requires solution of additional questions, typically 2 to 4 times the number of those drafted as formally submitted homework. It is assumed students will do so in preparation for each homework.

Students may freely choose what questions to solve according to the rules:

- If Project questions are specified, at least one must be solved
- If Problem questions are specified, at least two must be solved
- If Exercise questions are specified, at least four must be solved
- Solution to questions totaling 5 grade points must be presented for full credit
- Questions solved in class may not be included in submitted homework. In particular, the Homework01 model solution will be worked out in first week of class.

Questions are taken from textbook, with PS1.1.1-8(p18) indicating questions 1 to 8 from Problem Set 1.1 on page 18.

Homework drafting instructions:

1. If you choose to install TeXmacs and Mathematica on your Windows of macOS laptop submit:
   - A TeXmacs file hwXX.tm (XX$\in\{01, 02, ..., 14\}$) containing your calculations, with labeled answers as exemplified by Ex(PS1.1.4) for a solution to the exercise given as question 4 in Problem Set 1.1. Modify XX to indicate homework being submitted.
   - A Mathematica notebook XX.nb containing computer calculations and graphics, with answers labeled as above. Modify XX to indicate homework being submitted.

2. If you work within the SciComp@UNC environment submit a single file HWXX.tm (note capitalization, XX$\in\{01, 02, ..., 14\}$) containing your calculations along with embedded computer calculations and graphics, with labeled answers as exemplified by Ex(PS1.1.4) for a solution to the exercise given as question 4 in Problem Set 1.1. Modify XX to indicate homework being submitted.

Homework Templates: hwXX.tm XX.nb HWXX.tm. Solutions are posted only in HWXX form.

Nr.	Issue Date	Due Date	Topic	Exercises	Problems	Projects	Solutions
01	08/22	08/29	ODE	PS1.1.2-7(p8) PS1.3.2-17(p18)	PS1.1.16-20(p8) PS1.2.1-8(p11) PS2.1.15(p11) PS1.3.22-27(p19)	PS2.1.16(p12) PS2.1.17-20(p12) PS1.3.33-35(p19)	HW01.pdf
02	08/29	09/05	ODE	PS1.4.1-12(p26) PS1.5.3-12(p34)	PS1.5.14(p34) PS1.5.31-40(p35)	PS1.4.16,18(p27) PS1.5.20(p35)	HW02.pdf
03	09/06	09/20 (Hurricane Florence)	ODE	RQ1 (p43) 22-26 PS2.1.3-10, 15-19 (p53) PS2.2.1-15 (p59)	PS1.7.2,8,10 (p42) RQ1(27-30) PS2.1.11-14	PS1.7.6 (p43) with f(x,y) from 1.5.22,23 (p35) PS2.1.20 (p53)	HW03.pdf
04	09/20	09/27	ODE	PS2.2.16-30 (p59) PS2.8.3-20 (p91)	PS2.2.31-36 (p60) PS2.4.5-9 (p69) PS2.4.14-19 (p69)	PS2.2.37 (p60) PS2.4.10 (p69) PS2.8.24-25 (p92)	HW04.pdf
05	09/27	10/4	SYS	PS4.3.1-15 PS4.4.1-10	PS4.1.10-11	PS4.1.14-15 PS4.3.18-20	HW05.pdf
06	10/4	10/11	SYS	PS4.5.4-7 PS4.6.2-7	PS4.5.9-13 PS4.6.10-15	PS4.5.14-15 PS4.6.17-20	
07	10/11	10/18	SS	Skipped due to	hurricane	cancellations	
08	10/22	10/29	LTR	PS6.1.1-16 PS6.1.25-32	PS6.2.8-15	PS6.2.22,30	
09	10/29	11/05	LTR				
10	10/29	11/05	LTR				
11	11/05	11/12	FS				
12	11/12	11/19	FS				
13	11/19	11/26	AA				
14	11/26	12/05	AA				

Software

Modern software systems allow efficient, productive formulation and solution of mathematical models. A key goal of the course is to familiarize students with these capabilities, adopting one of two options:

1. Use of TeXmacs mathematics editor and Mathematica computational package under Windows or macOS. This is suitable for students with interest mainly in an application domain such as physics or biology.

2. Installation of the SciComp@UNC environment that contains TeXmacs, Mathematica, and many additional software packages. This is a virtual Linux machine typically hosted on Windows or macOS. A key feature of the environment is that the applications all work together. This is suitable for students interested in general scientific computation or intending to pursue graduate studies.

All coursework can be carried out in either environment, and examples will be presented in both. The SciComp@UNC environment requires 60GB free disk space and a laptop that conforms to CCI minimal standards.

Installing Mathematica, TeXmacs, svn, course materials in Windows 10 or macOS

- Install Mathematica for which UNC has a site license. Go to Undergraduate Library Help center if you encounter problems
- Install TeXmacs
- Install TortoiseSVN on Windows 10 or SmartSVN on macOS
- Checkout course materials:
  - → In Windows explorer, navigate to c:\
  - → Right-click and select SVN checkout
  - → In URL of repository field type: svn://mitran-lab.amath.unc.edu/courses/MATH528
  - → Similar procedure for macOS

SciComp@UNC Linux environment

Follow instructions at SciComp@UNC.

Tutorials

Software usage is introduced gradually in each class and miniLab session, so the first resource students should use is careful, active reading of the material posted in class. In particular, carry out small tasks until it becomes clear what the software commands accomplish. Some additional resources:

- Mathematica
  - http://www.wolfram.com/language/fast-introduction-for-math-students/en/
  - http://www.wolfram.com/wolfram-u/catalog/gen005/
  - http://www.wolfram.com/language/fast-introduction-for-programmers/en/
- TeXmacs:
  - http://www.texmacs.org/tmweb/help/tutorial.en.html
  - https://www.youtube.com/watch?v=mlcqGRv7xhc

Course material repository

Course materials (lecture notes, workbooks, homework, examination examples) are stored in a repository that is accessed through the subversion utility, available on all major operating systems. The URL of the material is http://mitran-lab.amath.unc.edu/courses/MATH528

Windows procedure

In Explorer right-click on course directory, select TortoiseSVN update.

Linux, OSX procedure

The above address is needed for an initial checkout using commands such as:

```
mkdir ~/courses
cd ~/courses
svn co svn://mitran-lab.amath.unc.edu/courses/MATH528/
```

In the SciComp@UNC virtual machine the initial checkout can be carried out through the terminal commands

```
cd ~/courses
make MATH528
```

Update the course materials before each lecture by:

```
cd ~/courses
svn update
```

Links to course materials will also be posted to this site, but the most up-to-date version is that from the subversion repository, so carry out the svn update procedure prior to each lecture.