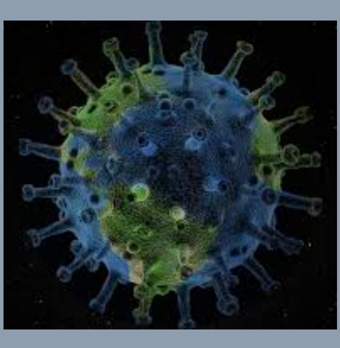
Introduction to Mathematical Epidemiology



MST 383/683

Dr. John Gemmer: gemmerj@wfu.edu
Office: Manchester 388
Course Website: http://users.wfu.edu/gemmerj/math383-683F21.html
Canvas: The course syllabus and grades will be posted on Canvas
Office Hours: M 3:00-4:00, T 12:00-1:00, T 2:00-3:00 W 12:00-2:00
Class Meeting Times: TTh 3:30-4:45
Class Location: Kirby 108

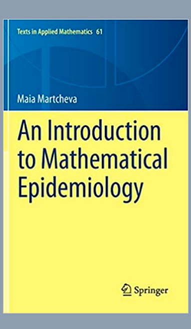
COURSE DESCRIPTION

The COVID-19 pandemic has had a profound impact on society. In response, the mathematics and broader scientific community has focused considerable research efforts to understand the spread of the virus and its impact not only on physical health, but on mental health, the economy, climate, distribution networks, equitable distribution of vaccines, and racial disparities to name but a few. Despite a tremendous volume of research in this area, there is still considerable effort devoted to developing and analyzing improved mathematical models that address aspects of the above issues. In particular, there is a clear demand for epidemiological models that incorporate human behavior. In this course we will study some of the tools used by mathematical epidemiologists with an eye towards understanding what strategies can be used to mitigate the spread of a disease. This is an exciting area of modern mathematics that lies at the intersection of nonlinear dynamical systems, statistics, network science and control theory. The specific mathematical topics we will learn will include qualitative analysis of differential equations, graph theory, Markov chains on networks, moment closure approximations, model fitting, and Pontryagin's maximum principle. In addition to these mathematical topics you will also learn to simulate and analyze mathematical models in Matlab and Mathematica.

In partnership with Elon University, this course is supported by a Center for Undergraduate Research in Mathematics (CURM) mini-grant which is supported by the National Science Foundation (NSF) DMS awards #0636648, #1148695, and #1722563.

REQUIREMENTS

Prerequisites:
Vector Calculus, ODES, Linear Algebra

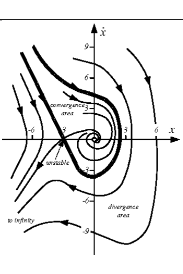


Textbook
Maia Martcheva

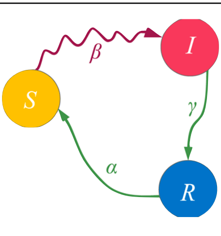
Computer Access:
Laptop/Desktop

Software:
Matlab, Mathematica, Overleaf: WFU Software Link

OBJECTIVES

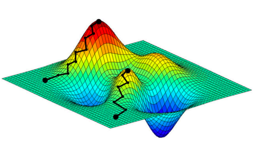


Master qualitative analysis of ODEs

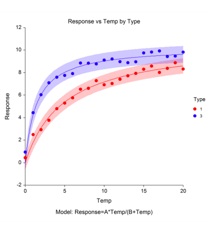


Master modeling of epidemics

Develop Mathematical Computational Skills



Master elementary optimal control theory



Master elementary model fitting

Write Effectively

CLASS STRUCTURE

Class Time: 2.5 Hrs/ Week

- **Ask questions, discuss**
- **Lectures**
- **Coding of models**
- **Analyzing data and fitting models**

Asynchronous Time: 11-12 Hrs/Week

- **Read material**
- **Solve problems**
- **Write numerical solutions**
- **Check basic understanding**

EVALUATION

We focus on learning and mastery. You are guaranteed the following grades if your final percentage lies within the following ranges:

90-92.9: A-	93-100: A	
80-82.9: B-	83-86.9: B	87-89.9: B+
70-72.9: C-	73-76.9: C	77-79.9: C+
60-62.9: D-	63-66.9: D	67-69.9: D+

Weekly Homework (20%), at least 1 dropped
Open book, collaboration allowed with citation
Homework is due on Thursday in class

Computational Assignments and Term Paper (20%)
In class collaboration
Term paper for graduate students (5% bonus for undergraduates)

Two summative assessments (30%)
In class, closed notes

Final Exam (30%)
Comprehensive
In class, closed notes

Weekly Homework: Homework will be assigned most weeks on Friday and will be due Thursday in class the following week. Late homework will not be accepted under any circumstances. However, I will drop at least one homework assignment from your grade. While you are allowed to collaborate with your colleagues, homework must consist of solutions that show all steps, be your own work and be written clearly using complete sentences as appropriate (see homework policy). All homework will be submitted in class on paper. I will not accept digital versions of your homework.

Computational Assignments: During the course there will be several computational assignments. These assignments will consist of in class group work in which students will use Matlab or Mathematica to simulate numerical models, analyze data, and fit models to data. The students will then complete an out of class component which will be due within at least a week. The numerical assignments will be submitted on Canvas in the form of a Mathematica file, Matlab script, whatever R uses, or other code you used, e.g. Python.

Term Paper: Every graduate student is required to write a term paper on a chapter from the text that is not covered in the course. The paper must be written in LaTeX. Your textbook is written for a two semester course and has a wealth of interesting topics to pick from. In addition to writing an expository paper, you will be required to work through some of the problems from the text. You can work in groups of up to two people for the term paper. Undergraduate students can write a term paper for a possible 5% bonus.

Summative Assessments: There will be two in class summative assessments in the course and a cumulative final exam.

COURSE ENVIRONMENT

Names/Pronouns

You deserve to be addressed in the manner you prefer. To guarantee that I address you properly, you are welcome to tell me your pronoun(s) and/or preferred name at any time, either in person or via email.

Diversity

We embrace diversity of age, background, beliefs, ethnicity, gender, gender identity, gender expression, national origin, religious affiliation, sexual orientation, and other visible and non-visible categories. **I do not tolerate discrimination.**

Accessibility

I want you to succeed in this course and all of your courses. See lac.wfu.edu/ for learning accommodations. For personal issues, stress, health problems or life circumstances see shs.wfu.edu/. Contact me if you have other special circumstances. **I will find resources for you.**

Title IX

You deserve a community free from discrimination, sexual harassment, a hostile environment, sexual assault, domestic violence, dating violence, and stalking. If you experience or know of a Title IX violation, you have many options for support and/or reporting; see titleix.wfu.edu/.

The Honor Code

At Wake Forest, we expect you to behave as honorable citizens of the class, the university, and the world as a whole. When you complete an assignment with your name on it, you are representing that everything you are turning in is your own work. That means that you do not copy from other students, textbooks, or websites. If at any time I become aware of cheating or plagiarism in this course, I will submit the information to the honor council.

TENTATIVE COURSE CALENDAR

SIR/SIS Models and Qualitative Analysis

Week 1:
1. 8/24: SIR model, **Section 2.1**
2. 8/26: Estimating parameters in SIR Model, SIS model, **Sections 2.2-2.3.1**

Week 2:
1. 8/31: Qualitative analysis of nonlinear first order ODEs, **Sections 2.3.2-2.3.3**
2. 9/2: SIS model with saturating treatment, **Section 2.4**

Week 3:
1. 9/7: SIR model with population growth, **Sections 3.1-3.2**
2. 9/9: Introduction to the phase plane, **Section 3.3.1**

Week 4:
1. 9/14: Linearization and asymptotic stability, **Sections 3.3.2-3.3.3**
2. 9/16: Analysis of the dimensionless SIR model, **Section 3.4**

Week 5:
1. 9/21: Global Stability, **Section 3.5**
2. 9/23: **Summative Assessment on Weeks 1-4**

Network Dynamics and Computing R_0

Week 6:
1. 9/28: Introduction to epidemics on static networks, **External Reading**
2. 9/30: Epidemics on adaptive networks, **External Reading**

Week 7:
1. 10/5: Moment closure approximations, **External Reading**
2. 10/7: **Fall Break**

Week 8:
1. 10/12: Building complex epidemiological models, **Section 5.1**
2. 10/14: Jacobian approach to computing R_0, **Section 5.2**

Week 9:
1. 10/19: Next generation approach part I, **Section 5.3**
2. 10/21: Next generation approach part II, **Section 5.3**

Week 10:
1. 10/26: Examples of fitting epidemic models to data, **Sections 6.1-6.3**
2. 10/28: **Summative Assessment on Weeks 5-9**

Model Selection and Control of Epidemics

Week 11:
1. 11/2: Model selection, **Section 6.4**
2. 11/4: Exploring sensitivity, **Section 6.5**

Week 12:
1. 11/9: SEIR model, **Section 7.1-7.2**
2. 11/11: Lyapunov functions, **Section 7.3**

Week 13:
1. 11/16: Vaccination: single-strain diseases, **Section 9.1-9.2**
2. 11/18: Modeling quarantine and isolations, **Section 9.4**

Week 14:
1. 11/23: Optimal Control part I, **Section 9.5**
2. 11/25: **Thanksgiving**

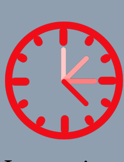
Week 15:
1. 11/30: Optimal Control part II, **Section 9.5**
2. 12/2: Optimal Control part III, **Section 9.5**

12/07: Final Exam at 2:00

SUCCESS

Attend class

Participate constantly



Invest time

Concentrate on concepts in addition to calculations

Seek help when needed

Eliminate Virtual Distractions