Introduction to Mathematical Modeling

MTH 351/651

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Office: Manchester 388

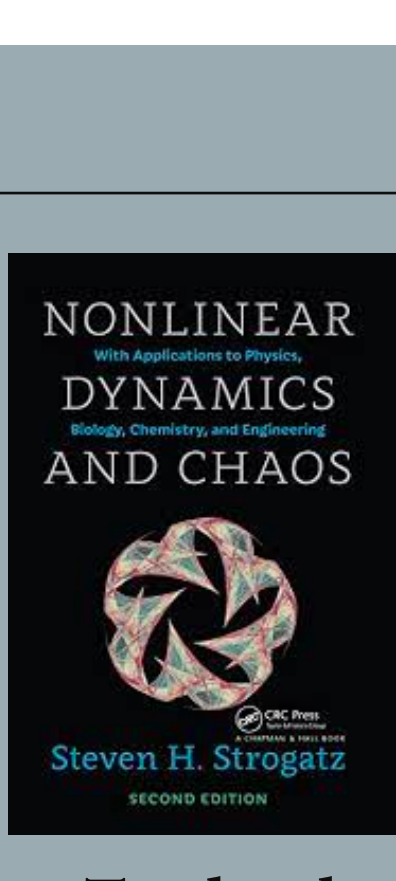
Course Website: http://users.wfu.edu/gemmerj/math351-651F22.html
Canvas: The course syllabus and grades will be posted on Canvas
Office Hours: T 10:00-11:00, W 12:00-2:00, Th 1:00-3:00
Class Meeting Times: MWF 9:00-9:50
Class Location: Kirby 103

COURSE DESCRIPTION

An introduction to mathematical modeling and modern techniques in the nonlinear analysis of ordinary and or partial differential equations. Specific mathematical topics covered include: dimensional analysis, one-dimensional flows, phase plane analysis, limit cycles, bifurcations, and stability analysis. Additional topics covered at the discretion of the instructor can include, but are not limited to: hyperbolic conservation laws, reaction diffusion equations, Fourier analysis, traveling wave solutions to partial differential equations, chaotic dynamics, perturbation methods, calculus of variations. The emphasis of the course will be equal parts theory, mathematical modeling, and computational explorations. The theory will be presented within the context of applications drawn from areas such as population modeling, spread of infectious diseases, chemical kinetics, traffic modeling, collective behavior, as well as other topics from biology, chemistry and physics.

REQUIREMENTS

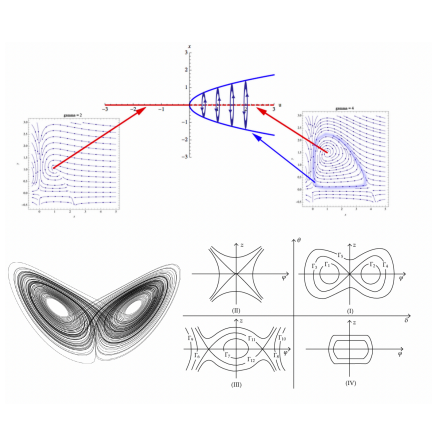
Prerequisites:
Linear Algebra, Differenital Equations



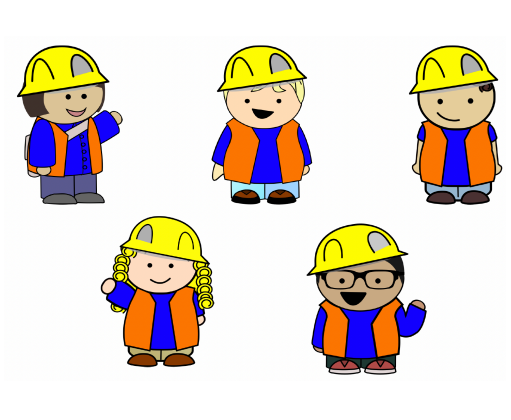
Textbook:
Nonlinear Dynamics and Chaos, Strogatz

Software:
Matlab, Mathematica: WFU Software Link

OBJECTIVES

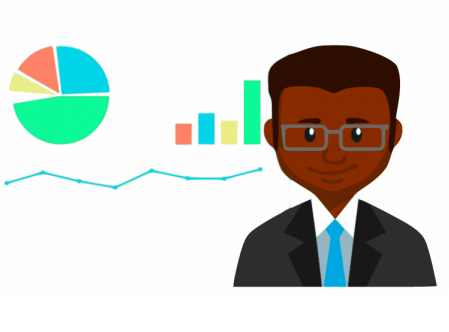


Master Analysis of ODES



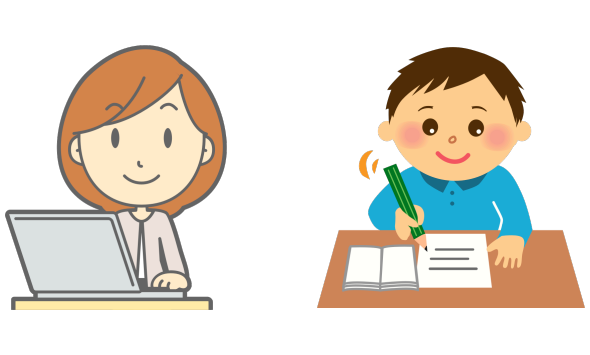
Build Mathematical Models

Develop Programming Skills



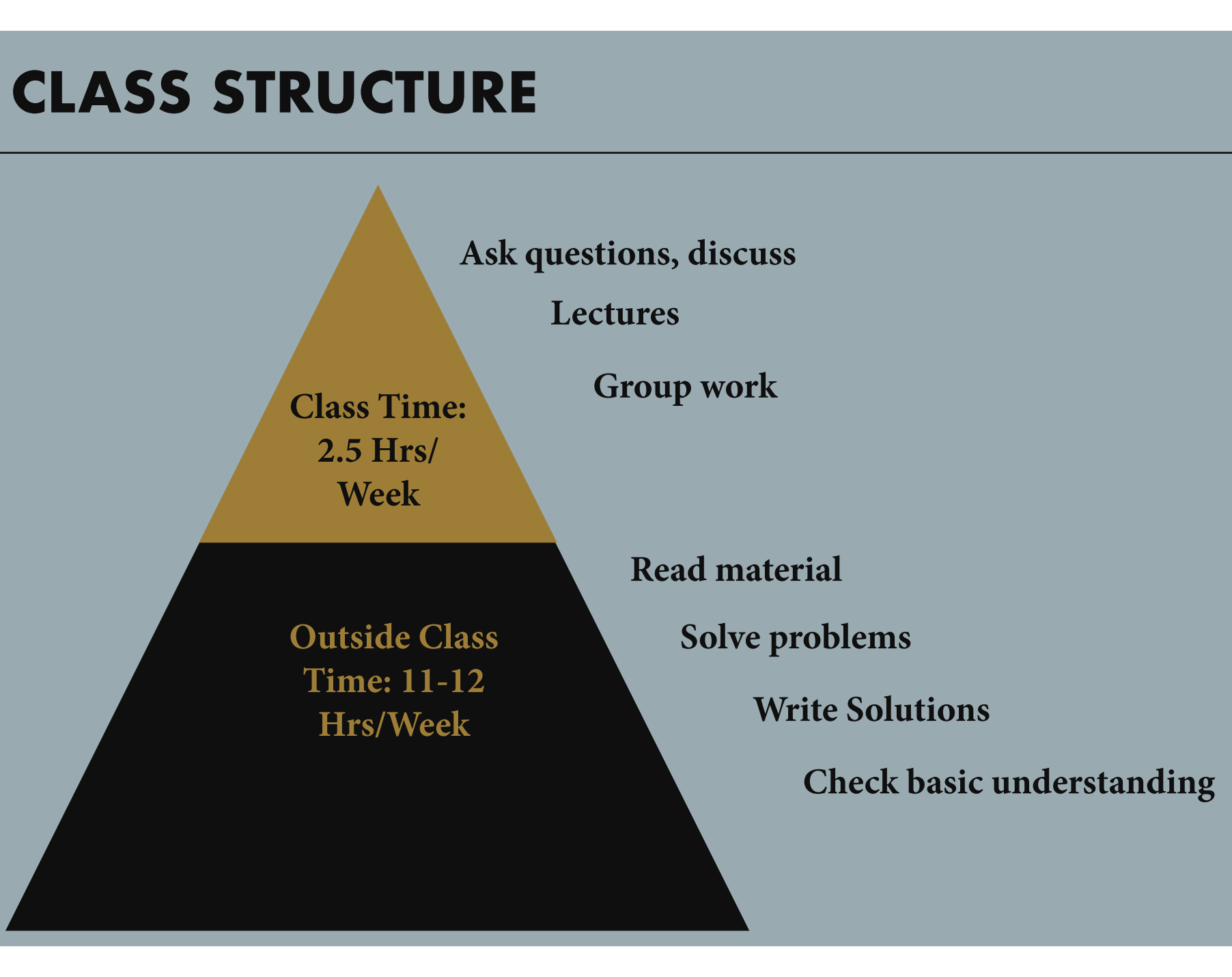
Communicate Effectively

Learning to collaborate



Write Effectively

CLASS STRUCTURE



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+

Classworks (5%)
Structured in class group assignments
Grades based on attendance

Term paper proposal (5%)
Brief essay on the project you would like to study (one page max)

Quizzes (5%), at least 1 dropped
5-10 minutes
In class on Fridays

Weekly Homework (10%), at least 1 dropped
Open book, collaboration allowed with citation
Homework is due on Friday in class

Term paper presentation (10%)
Presentations should be done on computer
Final presentations will occur during the last week of class

Term paper (15%)
Term paper should be written in LaTeX
The term paper is due on the assigned date of the final exam

Two summative assessments (25%)
In class, closed notes

Final Exam (25%)
Comprehensive
In class, closed notes

Classworks: Throughout the course there will be several announced and unannounced class works. These consist of structured group assignments that will be completed during class time. These assignments will generally be exploratory allowing students to synthesize concepts through a "hands on" approach. Classworks will be graded based on attendance.

Quizzes: On most Fridays there will be a short 5-10 minute in-class quizzes. These quizzes will consist of a very short problem that will test your knowledge of the prior lectures and homework. These quizzes are to help both the students and the instructor understand concepts that students may be struggling with. All quizzes will be announced in class. There will be no "pop" quizzes. There are no retakes for missed quizzes, however I will drop the lowest quiz score from your final grade.

Weekly Homework: Homework will be assigned most weeks on Thursday and will be due Friday 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.

Term Paper: A significant portion of the student's progress towards completion of the course goals will be evaluated through the completion of a term paper. Potential topics will be posted on the course website. The student will select a topic to study in detail, reproduce the results in the reference and complete some assigned problems on the topic. The complete assessment of the term paper consists of submission of a brief project proposal (1 page max), a final term paper and a final presentation. The final version of the term paper should be written in an expository form with all mathematical details fully written out including the solutions to the assigned problems. The term paper should be written using a professional typesetting program such as LaTeX and the final presentation should done on a computer. The final presentations will occur during the last week of class. Undergraduates can work in groups of 2-3 and are encouraged to do so. Graduate students must work individually.

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

Late Work Policy: Except in very extreme circumstances, I do not accept late assignments or reschedule exams. If you have a situation in which you cannot make an exam for personal reasons, you must arrange accommodations with the instructor to schedule the exam **before the scheduled exam date.** If you have a legitimate emergency situation, I will make sure that all students in the course will have access to the same exception to this policy.

If you need to miss class due to a university sponsored activity, such as athletics. Please contact the faculty member as soon as possible to reschedule due dates.

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. Wake Forest University provides reasonable accommodations to students with disabilities. If you are in need of an accommodation, then please contact me privately as early in the term as possible. Retroactive accommodations may not be provided. Students requiring accommodations must also consult the Center for Learning, Access, and Student Success(118 Reynolda Hall, 336-758-5929, http://class.wfu.edu). 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/.

Emergency Fund

You **deserve** a learning environment in which all of your physiological and safety needs are met. If you are experiencing situations in which these needs are not met, e.g. you do not have adequate housing or sufficient food security, the Chaplain's Office has an emergency fund which can provide support: https://chaplain.wfu.edu/care-support/chaplains-emergency-fund/. In situations in which you need immediate assistance there is emergency funding available through the Department of Mathematics and Statistics. If you are in need of emergency help you are encouraged to reach out to a faculty member in the Department of Mathematics and Statistics who will work with the chair of the department to address your needs.

Course Resources

The department has a limited amount of funding for class materials. If you cannot afford class materials, you are encouraged to contact the chair of the department privately as early in the term as possible. Due to the limited amount of funds, students must exhaust all other sources of funding before applying to the department for assistance.

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

One Dimensional Flows

Week 1:
1. 8/22: Going over the syllabus
2. 8/24: Introduction to flows and a geometric way of thinking, **Section 2.0-Section 2.1**
3. 8/26: Fixed points and stability, application to population growth, **Section 2.2-Section 2.3**

Week 2:
1. 8/29: Linear stability analysis, existence and uniqueness, **Section 2.4-2.5**
2. 8/31: Impossibility of oscillations and potentials, **Section 2.6-2.7**
3. 9/02: **Classwork #1, Homework #1 Due**

Week 3:
1. 9/05: Solving equations on the computer, **Section 2.8**
2. 9/07: **Classwork #2**
3. 9/09: Saddle node bifurcations, **Sections 3.0-3.1, Quiz #1, Homework #2 Due**

Week 4:
1. 9/12: Transcritical bifurcations and applications to lasers, **Section 3.2-3.3**
2. 9/14: Pitchfork bifurcation and bead on a rotating hoop, **Section 3.4-3.5**
3. 9/16: Application to harvesting fish in a lake**, Section 3.7, Quiz #2, Homework #3 Due**

Week 5:
1. 9/19: Introduction to flows on a circle, **Sections 4.0-4.3**
2. 9/21: Application to fireflies **Section 4.4**
3. 9/23: **Summative Assessment #1 on Sections 2.0-3.5**

Two Dimensional Flows

Week 6:
1. 9/26: Linear systems and phase portraits, **Section 5.1**
2. 9/28: Classification of linear systems part I, **Section 5.2**
3. 9/30: Classification of linear systems part II, **Sections 5.2, Quiz #3, Homework #4 Due**

Week 7:
1. 10/03: Application to love and war, **Section 5.3**
2. 10/05: Phase portraits, existence and uniqueness **Section 6.1-6.2**
3. 10/07: **Classwork #3, Quiz #4, Homework #5 Due, Term paper proposal due**

Week 8:
1. 10/10: Fixed points and linearization, **Section 6.3**
2. 10/12: Lotka-Volterra systems **Section 6.4, Homework #6 Due**
3. 10/14: **Fall break**

Week 9:
1. 10/17: Conservative systems, **Section 6.5,**
2. 10/19: Reversible systems and the pendulum, **Section 6.6-6.7**
3. 10/21: Index theory, **Section 6.8, Quiz #5, Homework #7 Due**

Week 10:
1. 10/24: Catch up day
2. 10/26: **Classwork #4**
3. 10/28: **Summative Assessment #2 (Sections 4.0-6.5)**

Limit Cycles and Bifurcations in Two Dimensions

Week 11:
1. 10/31: Examples of limit cycles, **Sections 7.0-7.1**
2. 11/02: Ruling out limit cycles, **Section 7.2**
3. 11/04: Poincare-Bendixon Theorem, **Section 7.3, Quiz #6, Homework #8 Due**

Week 12:
1. 11/07: Lienard systems and relaxation oscillations, **Sections 7.4-7.5**
2. 11/09: **Classwork #5**
3. 11/11: Co-dimension one bifurcations**, Section 8.1, Quiz #7, Homework #9 Due**

Week 13:
1. 11/14: Hopf bifurcations, **Section 8.2**
2. 11/16: Application to chemical reactions, **Section 8.3**
3. 11/18: Global bifurcations of cycles, **Section 8.4, Quiz #8, Homework #10 Due**

Week 14:
1. 11/21: Coupled oscillators and quasiperiodicity, **Section 8.5**
2. 11/23: **Thanksgiving break**
3. 11/25: **Thanksgiving break**

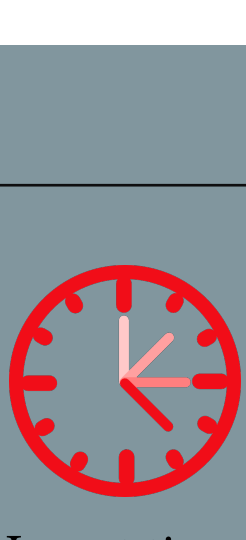
Week 15:
1. 11/28: Presentations day 1
2. 11/30: Presentations day 2
3. 12/02: Presentations day 3, **Quiz #9, Homework #11 Due**

Final Exam: 12/08, 9:00 AM (Final paper due).

SUCCESS

Attend class

Participate constantly



Invest time

Concentrate on concepts in addition to calculations

Seek help when needed

Eliminate Virtual Distractions