# Syllabus for 4193/5093, Intro Math Modeling/Math Models, Spring 2020

**Lectures:** TR 1:30-2:45 p.m. in 122 PHSC

**Instructor:** Prof. Nikola Petrov, `npetrov@ou.edu`, 1101 PHSC

**Class web page:** `https://math.ou.edu/~npetrov/math4193_5103_s20.html`

**Office Hours:** Mon 2:30–3:30 p.m., Tue 10:30-11:30 a.m., or by appointment, in 1101 PHSC.

**Course description:** The class will study basic theory of nonlinear dynamics. Since a nonlinear system of ODEs does not satisfy the Superposition Principle, finding the general solution of such a system is very complicated and often impossible. Because of this, one can instead try to describe the qualitative behavior of the solutions of the system. In this class we will derive nonlinear (systems of) ODEs occurring in some simple mechanical problems, and will analyze the behavior of their solutions. We will discuss briefly questions of existence and uniqueness of solutions, and will develop some methods for studying their bifurcations, i.e., situations in which the solutions of the system change their qualitative behavior dramatically for a small change of some parameter. We will study the phase portraits of autonomous linear systems, some bifurcations occurring in such systems (saddle-node, transcritical, pitchfork, Hopf), presence or absence of certain types of asymptotic behavior of the solutions, relaxation oscillations, limit cycles, hysteresis, Poincaré maps, etc. We will discuss the famous Lorenz system and similar systems exhibiting highly irregular behavior ("chaos"). We will also study some concepts related to highly iterated maps, i.e., the behavior of $f \circ f \circ \cdots \circ f$, where the function ("map") $f$ is composed with itself $n$ times, for $n \to \infty$. We will study bifurcations in some maps, their periodic orbits, Lyapunov exponents, and the universal behavior of such maps. If time permits, we will touch on different concepts of dimension that are important in the context of nonlinear dynamics.

**Texts:** Your lecture notes will be enough most of the time, but sometimes we may use parts of the following books, all freely available for OU students:

1. M. W. Hirsch, S. Smale, R. L. Devaney, *Differential Equations, Dynamical Systems, and an Introduction to Chaos*, 3rd edition, Academic Press, 2012.
2. A. C. King, J. Billingham, S. R. Otto, *Differential Equations: Linear, Nonlinear, Ordinary, Partial*, Cambridge University Press, 2003.
3. S. Wiggins, *Introduction to Applied Nonlinear Dynamics and Chaos*, 2nd edition, Springer, 2003.
4. C. Kuehn, *Multiple Time Scale Dynamics*, Springer, 2015.
5. F. Brauer, C. Castillo-Chavez, *Mathematical Models in Population Biology and Epidemiology*, 2nd edition, Springer, 2012.
6. J. D. Murray, *Mathematical Biology*, Vols. 1 and 2, 3rd edition, Springer, 2002, 2003.
7. T. Witelski, *Methods of Mathematical Modelling: Continuous Systems and Differential Equations*, Springer, 2015.
8. C. Chicone, *Ordinary Differential Equations with Applications*, 2nd edition, Springer, 2006.
9. R. Haberman, *Mathematical Models: Mechanical Vibrations, Population Dynamics, and Traffic Flow*, SIAM, 1998.
10. R. H. Enns, *It's a Nonlinear World*, Springer, 2011.
11. G. S. Layek, *An Introduction to Dynamical Systems and Chaos*, Springer, 2015.
12. R. Seydel, *Practical Bifurcation and Stability Analysis*, 3rd edition, Springer, 2010.

**Grading:** Your grade will be based on the following:

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| Homework (lowest grade dropped) | 45 % |
| An in-class midterm exam | 20 % |
| A take-home final exam | 35 % |

Students who are taking the class for a graduate credit (i.e, as MATH 5103) will have some additional homework problems and will have to complete a final project.

**Attendance:** You are expected to attend all lectures, and you are responsible for all information given out during them. All electronic equipment should be turned off before the start of every lecture, and should remain off until the class is dismissed. Since learning calculus requires your full attention, activities such as *conversing with other students, eating, sleeping, reading a newspaper, listening to headsets, using computers, cell phones, or other electronic devices, are not allowed!*

**Homework:** The homework assignments will be given on the class web site. Your homework solutions must be turned in at the beginning of class on the due date. Giving just an answer to a problem is not worthy any credit – you have to write a complete solution which gives your step-by-step reasoning and is written in grammatically correct English. Your lowest homework grade will be dropped. You are encouraged to discuss the homework problems with others, but you should write up the solutions in your own words.

**Policy on *W/I* grades:** Through the end of the sixth week of the semester, students can withdraw from the course with an automatic $W$. Between the seventh and tenth weeks of the semester, undergraduate students can continue to withdraw with an automatic $W$, but graduate students must obtain the instructor's signature on the University's "drop form" to withdraw from the course, and along with the signature the instructor must indicate whether the student is passing or failing at the time of the withdrawal. After the tenth week of the semester, all students can only withdraw via petition to the Dean of their college. The petition process also requires the instructor's signature with a passing-failing indication at the time the petition is filed. Note that a "failing" indication on the petition means that even if the petition is approved the grade in the course will be weighted in the GPA as an $F$.

The grade of $I$ is not intended to serve as a benign substitute for the grade of $F$, and is only given if a student has completed the majority of the work in the course at a passing level (for example everything except the final exam), the course work cannot be completed because of compelling and verifiable problem beyond the student's control, and the student expresses a clear intention of making up the missed work as soon as possible. Moreover, current OU policies require that instructors and the affected students execute a written "Incomplete Contract" before a grade of $I$ can be given. The contract makes clear: (1) what work is to be made up; (2) when the make-up work must be completed (which cannot be more than one calendar year from the assignment of the $I$); and (3) *what alternative grade will be assigned if the make-up work is not completed*. If the make-up work specified in the contract is not made up within one calendar year, then the alternative grade specified in the contract will be entered on the student's transcript.

**Academic Misconduct:** All cases of suspected academic misconduct will be reported to the Office of Academic Integrity Programs as possible violations of University's Academic Integrity Code. If the violation is confirmed by the Academic Integrity Program's Office, the penalties can be quite severe, so the best advice is **Don't do it!** For more details on the University's policies concerning academic misconduct consult

`http://www.ou.edu/integrity`

This link also has information about admonitions (essentially warnings about potential misconduct for fairly minor infractions) and your rights to appeal charges of academic misconduct.

Students are also bound by the provisions of the *OU Student Code*, available at

`https://www.ou.edu/content/dam/studentlife/documents/AllCampusStudentCode.pdf`

**Students with disabilities:** The University of Oklahoma is committed to providing reasonable accommodation for all students with disabilities. Students with disabilities who require accommodations in this course are requested to speak with the instructor as early in the semester as possible. Prior to receiving accommodations in this course, students with disabilities must be registered with the Disability Resource Center, 730 College Avenue, phone 405–325–3852.

**Religious holidays:** It is the policy of the University to excuse the absences of students that result from religious observances and to provide without penalty for the rescheduling of examinations and additional required class work that may fall on religious holidays. Please let me know as soon as possible if you are going to miss a class due to this reason.