18.385j/2.036j Nonlinear Dynamics and Chaos.

Tue and Thu 11:00-12:30 PM [technically in room 2-147].

Covid-19: This course will *very likely* be fully virtual, with (live) online lectures, which will be recorded and accesible through canvas. The course will have two web pages: one public in the Math. site, and another in canvas [used to upload problem set answers, access class recordings, announcements, etc.] Because the situation is somewhat unpredictable, *this syllabus may have to be updated later in the semester.*

Textbook: S. Strogatz, *Nonlinear Dynamics and Chaos*, Westview press [paperback].
Most of the theory here will be covered. The lectures follow the book only partially, and some topics are not in the book (e.g. Floquet Theory).

MatLab: I **urge you to become proficient in MatLab.** MatLab course scripts may be used in the lectures, and you should use them to reinforce the course materiel. MatLab will also be needed for some of the problem sets. See the course web page for more MatLab information.

D-software: Athena used to give access to "dstool" and "xphased", not sure if it still does. The first is a very powerful (but tricky to use) Dynamical Systems software package, while the second is more limited, but user friendly.

Team work: I encourage you to form study groups. This will be hard while virtual, but it helpful for learning. We will talk about this during the first lecture.

References:

S. Wiggins, *Introduction to Applied Nonlinear Dynamical Systems and Chaos*, Springer-Verlag. More "mathy" than Strogatz. Used for some topics.

P. G. Drazin, *Nonlinear Systems*, Cambridge U. P.

H-O Peitgen, H. Jurgens and D. Saupe, *Chaos and Fractals. New frontiers of science*, Springer-Verlag.

T. S. Parker and L. O. Chua, *Practical numerical algorithms for chaotic systems*, Springer-Verlag.

D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations*, Oxford U. P.

P. Berge, Y. Pomeau and C. Vidal, *Order Within Chaos*, Wiley.

S.W. McCuskey, *Introduction to Celestial Mechanics*, Addison Wesley.

J. Guckenheimer and P. Holmes, *Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields*, Springer Verlag. Requires mathematical sophistication. Subject covered at a rigorous level, with proofs requiring knowledge beyond course pre-requisites (say, at the level of **Coddington & Levinson,** *Theory of Ordinary Differential Equations*, McGraw-Hill or Krieger).

A. J. Lichtenberg and M. A. Lieberman, *Regular and stochastic motion*, Applied Math. Sciences #38, Springer. New title: *Regular and chaotic dynamics.*

R. S. MacKay and J. D. Meiss, *Hamiltonian Dynamical Systems; a reprint selection*, CRC Press.

Instructor:	R. Rosales, rrr@math.mit.edu [Useful only in case of non-virtual: room 2-337, x3-2784]. Off. Hours: TBA, **check the News UPDATES link in the web page.**
TA:	TBA, **check the News UPDATES link in the web page.**
Exams:	None. Neither midterm, nor final. See **GRADING** below.
Problem sets:	8 (± 1) problem sets (one every ≈ 1.5 wk). **Do them all:** *you need them to learn the material.* Also: see **GRADING** below. **You will need a computer, and MatLab.** Complete answers will be posted after their due date.
Term paper:	One is needed. See **GRADING** below.
WEB page:	http://math.mit.edu/classes/18.385/index.html (as well as the canvas web page).

GRADING: Each problem set will contain a buried mini-quiz within it (1-3 problems). Only the quiz will be graded, but you need to do all the problems, since the quiz problems will not be identified. The course grade will be based on the cumulative quiz-grade, and a binary-grade term paper.
Term paper grading: If you hand in an acceptable term paper, then the grade is quiz-based, as explained above. Else the grade is F. The term paper can be handed any time before the last day of lectures, and *please, do not wait till the last week to do it,* it is assigned the first day of classes.

Term paper. On any topic relevant to the course materiel (instructor pre-approval required). It does not have to be original research, but it must be original work [e.g.: review the literature in some topic, and summarize the results in your own words, giving proper credit to the sources]. *The explanations must be clear, and accessible by someone with the level of an average student in the class.* You can use materiel from your own research, but "recycling" (e.g.: handing a piece of your thesis) is not allowed. You must process it to follow the guidelines here. Further requirements:

- Must be typed (font size 11-12) and submitted electronically in **pdf format**.
- Length should not exceed about 15 pages, using standard page formatting. You can use more if you have many figures, but use judgement here!

Failure to follow all these guidelines may result in a paper being classified as "not acceptable".

OUTLINE of the Course: A rough idea follows. Some things may be covered in more detail than this implies, or the reverse. This is just to give you an idea of the "flavor".

- One-dimensional systems and elementary bifurcations.
- Two-dimensional systems; phase plane analysis, limit cycles, Poincaré-Bendixson theory.
- Nonlinear Oscillators, qualitative and approximate asymptotic techniques, Hopf bifurcations.
- Lorenz and Rossler equations, chaos, strange attractors and fractals.
- Iterated mappings, period-doubling, chaos, renormalization, universality.
- Hamiltonian systems; complete integrability and ergodicity.
- Area preserving mappings, KAM theory.
- Other: Floquet theory, Infinite Dimensional Hamiltonians, On-Off Dissipative Systems, Dynamic Mode Decomposition, etc.

The End