UNIVERSITY OF CALGARY
DEPARTMENT OF PHYSICS and ASTRONOMY
COURSE OUTLINE

1. Course: **Physics 521, Nonlinear Dynamics**

Lecture Sections: **L01:** MoWeFr, 11:00-11:50, SS 117

Instructor: Dr. Jörn Davidsen
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Office hours: Wednesdays 14:00-15:00 or by appointment

Main Physics and Astronomy Office: SB 605, 220-5385

2. **PREREQUISITES:** Applied Mathematics 433; Physics 381; and Physics 499; or consent of the Department.

3. **GRADING**: The University policy on grading and related matters is described sections F.1 and F.2 of the online University Calendar. In determining the overall grade in the course the following weights will be used:

Homework assignments	25%	
Midterm test	25%	(In-class: Wednesday, November 2nd)
Topic presentation	25%	
Topic paper	25%	

Percentage grades will be given for all elements of term work and examinations in Physics 521. A weighted course percentage will be calculated for each student after the topic papers have been handed in. A table of conversion from final course percentage to final course letter grade will be published on the Phys 521 Blackboard site later in the term.

4. **Missed Components of Term Work**. The regulations of the Faculty of Science pertaining to this matter are found in the Faculty of Science area of the Calendar in section 3.6: **http://www.ucalgary.ca/pubs/calendar/current/sc-3-6.html**. It is the student's responsibility to familiarize himself/herself with these regulations. See also **http://www.ucalgary.ca/pubs/calendar/current/e-3.html**.

Assignments: Assignments must be handed in on time. Late assignments will not be marked, unless circumstances such as illness prevent a student from meeting the deadline.

6. TEXTBOOK: ***"Nonlinear Dynamics and Chaos "***, Steven H. Strogatz, Westview Press / Perseus Books

7. EXAMINATION POLICY: All exams are closed book exams, no calculators are permitted. Students are encouraged to read the Calendar, Section G, on Examinations: **http://www.ucalgary.ca/pubs/calendar/current/g.html**.

Department Approval_____ **Date**_____

Associate Dean's Approval for
out of regular class-time activity: _____ **Date:**_____

11. OTHER IMPORTANT INFORMATION FOR STUDENTS:

(a) ACADEMIC MISCONDUCT (cheating, plagiarism, or any other form) is a very serious offence that will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under K. Student Misconduct (**http://www.ucalgary.ca/pubs/calendar/current/k.html**) to inform yourself of definitions, processes and penalties

(b) ASSEMBLY POINTS in case of emergency during class time. Be sure to FAMILIARIZE YOURSELF with the information at **http://www.ucalgary.ca/emergencyplan/assemblypoints**.

(c) ACADEMIC ACCOMMODATION POLICY. Students with documentable disabilities are referred to the following links:
Calendar entry on students with disabilities: **http://www.ucalgary.ca/pubs/calendar/current/b-1.html**
Disability Resource Centre: **http://www.ucalgary.ca/drc/**

(d) SAFEWALK: Campus Security will escort individuals day or night (**http://www.ucalgary.ca/security/safewalk/**). Call **220-5333** for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

(e) **FREEDOM OF INFORMATION AND PRIVACY:** This course will be conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). As one consequence**, students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page**. For more information see also **http://www.ucalgary.ca/secretariat/privacy.**

(f) **STUDENT UNION INFORMATION:** VP Academic **Phone**: 220-3911 **Email**: suvpaca@ucagary.ca.
SU Faculty Rep. **Phone:** 220-3913 **Email:** sciencerep@su.ucalgary.ca Website **http://www.su.ucalgary.ca/home/contact.html**.
Student Ombudsman: **http://www.su.ucalgary.ca/services/student-services/student-rights.html**

(i) **INTERNET and ELECTRONIC COMMUNICATION DEVICE Information.** You can assume that in all classes that you attend, **your cell phone should be turned off**. Also, communication with other individuals, via laptop computers, Blackberries or other devices connectable to the Internet is not allowed in class time unless specifically permitted by the instructor. If you violate this policy you may be asked to leave the classroom. Repeated abuse may result in a charge of misconduct.

Course Syllabus

This class gives an introduction to nonlinear dynamical systems as they arise in a wide range of areas of science and engineering. While the main goal of the class is to present the mathematical concepts and techniques, lectures and problems will also make contact with physical systems wherever possible.

Key topics to be discussed include: Phase space representation, nonlinear oscillators, bifurcations, normal forms, deterministic chaos, attractors, fractals, and synchronization.

Course outline:

1. Vector fields and flows in one dimension: flow on the line, existence and uniqueness theorem, bifurcations, flow on a circle
2. Two-dimensional systems: classification of linear systems, stability, phase plane analysis, Poincare-Bendixson theorem, limit cycles, relaxation oscillators, weakly nonlinear oscillators, bifurcations & center-manifold theorem
3. Chaos: Lorenz model, Poincare maps, one-dimensional iterated maps, Lyapunov exponents, strange attractors, invariant measure, routes to chaos, universality & renormalization, two-dimensional maps, Arnold tongues, fractals & fractal dimensions, Kolmogorov-Sinai entropy

In addition to our textbook, the following are useful reference books:

K.T. Alligood, T.D. Sauer and J.A. Yorke, *Chaos, an Introduction to Dynamical Systems* (Springer, New York 1996)
H.G. Schuster: Deterministic Chaos - an introduction (VCH, Weinheim 1994)
T. Tel and M. Gruiz: Chaotic dynamics - An introduction based on classical mechanics (Cambridge 2006)

Further references and all course relevant material can be found on **Blackboard**.

Homework assignments
There will be about five homework assignments during the first half of the term. These are the backbone of the course in that it is through these assignments that you will build up and apply your understanding of the various concepts and techniques. Please keep the following in mind as you work on and write up your assignments:

1. Your main two goals in writing up your homework are **to be clear** (so that I can understand what you have written) and **to demonstrate insight**. Writing clearly means using readable handwriting. You should avoid tiny script and avoid trying to cram many sentences and equations onto a single page. Leave plenty of space between symbols and between successive lines of equations. Leave plenty of space between the ending of one homework problem and the beginning of the next. Spread your answers out over many pages if necessary. (Paper is cheap compared to the time needed for you to complete the assignments and for me to grade your assignments.) If I cannot read and understand your assignments easily, you will get little or no credit.

   Demonstrating insight means *using complete sentences* that explain what you are doing and why. Cryptic brief answers like "yes", "no", "24", or "*f(x)*" will not be given credit. Instead, explain what you are doing and why, e.g., as if to a friend who is not familiar with this course. Your homework must show that you understand how you got your answer and that you appreciate the significance of your answer. A well-written complete answer is one that you will be able to understand yourself a month after you have written the answer, even if you don't remember the original question.

2. You are allowed to collaborate on the homework assignments (this is realistic, scientists collaborate all the time in research) but as much as possible you should attempt the assignments on your own since you will learn the most that way. Whether or not you collaborate, **you must write up your homework on your own, in your own words, and with your own understanding. You must also acknowledge explicitly at the beginning of your homework anyone who gave you substantial help, e.g., classmates, myself, or other people.** (Again, scientists usually acknowledge in their published articles colleagues that helped to carry out the research.) Failure to write your homework in your own words and failure to acknowledge help when given can lead to severe academic penalties so please play by the rules.
3. The assignments will require typically a mixture of analytical, numerical, and graphical approaches. The mathematical derivations or analyses for the analytical problems should be written out by hand on paper. Please use ink, not pencil. Numerical and graphical answers involve output that are best printed out on a laser printer, then stapled to your handwritten sheets. A hand-sketch of a graphical plot with essential features described is also acceptable.

4. Please pay attention to details as you write your assignments. All symbols should be given names the first time you introduce them, e.g., say "the momentum *p*" or "the flux *F*" instead of just using the symbols *p* and *F*. Physical units should be given for any answer that is a physical quantity, e.g., say "the angular momentum was *A*=0.02 J-sec" or "the angle was μ=0.32 radians." Numerical answers should have the minimum number of significant digits that is consistent with the given data. For example, if you have a product or ratio of numbers of which the least accurate number has two significant digits, the final answer should have only two significant digits. Graphs should have their axes clearly labeled by the corresponding variables and by the variables' physical units. Each graph should have a title that explains the graph's purpose. A good way to learn how to write effectively is to imitate the style of published articles, e.g., those published in Physical Review Letters .
5. If you use using Mathematica or any other software package in a homework assignment, please do not give me the output of your entire session. Instead, just give me enough output to convince me that you have answered the question correctly. You should also include any code that you write so that I can try to understand how you obtained your answers.

Midterm exam
This will be an in-class closed-book exam on November 2nd.

Topic presentation and topic paper
Instead of a final exam, each member of the class will write a paper on some topic related to nonlinear dynamics that he or she is especially interested in. I will provide a list of suggestions after the midterm. The paper can also be based on reading some research article, on carrying out some simple experiment, or by simulating or analyzing some mathematical model. In that case, the paper should include a comprehensive background to the topic. The paper should be clearly written in prose (no bullet points or numbered lists), and be pitched at the level of fellow students. Referencing must be provided similar to the referencing typical in published scientific papers. The references must be in the style of some journal: identify a preferred journal and strictly follow that journal's style guide. The paper should be 15 to 20 pages in length double space in 12 point font including tables, figures, and bibliography. The paper will be graded on presentation (including equations, figures, tables, and captions), logical flow, discussion, and referencing and bibliography.

Each student will give a 20-minute oral presentation to the class about the chosen topic. Grading will be equally based on content (including logical flow and discussion of material) and on delivery (clear slides that are fully readable at a distance, use of props, eye contact with the audience, pace and volume of speaking, enthusiasm, avoidance of fillers such as "um", confidence, effectiveness at answering questions).

Important dates for Fall 2011

M 12-09	Lectures begin.
F 23-09	Drop date deadline
Mo 26-09	Add/swap date deadline
F 30-09	Fee payment deadline
Mo 10-10	Thanksgiving (no lectures)
Th 10-11 to Su 13-11	Reading days (no lectures)
F 09-12	Lectures end.
M 12-12 to We 21-12	Final Exam period.