UNIVERSITY OF CALGARY
DEPARTMENT OF PHYSICS and ASTRONOMY
COURSE OUTLINE

1. Course: **Physics 621, Nonlinear Dynamics and Pattern Formation**

   Lecture Sections: **L01:** TuTh, 11:00-12:15, ST 057

Instructor: Dr. Jörn Davidsen
Office: SB505
Telephone: 403 210 7964
E-mail: davidsen@phas.ucalgary.ca
Office hours: Tuesdays & Thursdays 12:15-12:45 or by appointment

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

2. **PREREQUISITES:** It is expected that a student's background will include Physics 451 (Statistical Mechanics II), 481 (Computational Physics II) and 521 (Nonlinear Dynamics & Chaos) or equivalents. Specifically, students should have a working knowledge of the following concepts: multivariable Taylor series, phase space, maps, flows, dissipation, attractors (including limit cycles, tori, and strange attractors), basins of attraction, fixed points, linear stability of a fixed point, Fourier analysis, power spectra, Lyapunov exponents, fractal dimensions, and the elementary bifurcations (Hopf, saddle-node, transcritical, pitchfork, supercritical, and subcritical). Although some of these concepts will be reviewed in class as needed, the review will usually be brief.

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	40%
Midterm test	30%
Topic presentation	20%
Class participation	10%

   Percentage grades will be given for all elements of term work and examinations in Physics 621. A weighted course percentage will be calculated for each student after all topic presentations have been given. A table of conversion from final course percentage to final course letter grade will be published on the Phys 621 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.

5. The **midterm** will take place during the last three weeks of the term. The **topic presentations** will take place during the final exam period. Both activities will be scheduled during the term to avoid any conflicts with other classes.

   REGULARLY SCHEDULED CLASSES HAVE PRECEDENCE OVER ANY OUT-OF-CLASS-TIME-ACTIVITY. If you have a clash with this out-of-class-time-activity, please inform your instructor as soon as possible so that alternative arrangements may be made for you.

6. **TEXTBOOK**: ***"Pattern formation and dynamics in nonequilibrium systems "***, Michael Cross and Henry Greenside, Cambridge

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 pattern formation and self-organization in nature. The central scientific challenge is to identify and to explain the similarities of different non-equilibrium systems, to discover unifying themes, and, if possible, to develop a quantitative understanding of experiments and simulations. The goal of this course is to develop specific conceptual, mathematical, and numerical skills for understanding complex phenomena and the spatiotemporal structure of non-equilibrium systems. We will discuss experiments on fluid systems, chemical reaction-diffusion systems and excitable media such as heart tissue.

Key topics to be discussed include: Reaction-diffusion systems, hydrodynamical systems, bistable media, excitable and oscillatory media, stability analysis, bifurcations, pattern selection, amplitude equations and normal forms, fronts, traveling waves, topological defects, spiral waves, spatiotemporal chaos, defect-mediated turbulence, spatiotemporal point processes.

Course outline:

1. Linear stability and Turing patterns
2. Nonlinear states
3. Derivation of mathematical models of spatiotemporal dynamics
4. Amplitude equations
5. Fronts
6. Oscillatory patterns
7. Excitable media
8. Spatiotemporal chaos and turbulence

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

R. C. Desai and R. Kapral, *Dynamics of self-organized and self-assembled structures* (Cambridge 2009)
P. Ball, *The self-made tapestry – Pattern formation in nature* (Oxford 2004)

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

Class participation
The emphasis in this course will be on discussion and critical thinking. Given this, your active class participation throughout the semester will be essential. You will occasionally be asked to go to the blackboard to sketch or to work out some argument, you will be challenged in class to defend your thinking by appropriate reasoning or by references to material covered in the lectures and reading.
I expect all members of the class to read and to think about the material before lecture and to come prepared to ask questions and to discuss the material in class. If you don't understand something during lecture or from the assigned reading, please don't be shy, ask questions! If something catches your interest and you want to learn more, ask questions. Talking with me outside of lecture is also one way to participate in class. I want to see evidence of your actively trying to learn about the course material.

Homework assignments
There will be continuous homework assignments over 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 a two-hour closed-book exam during the last three weeks of the term. It will be scheduled during the term.

Topic presentation
Instead of a final exam, each member of the class will give a 20-minute oral presentation to the class about some topic related to pattern formation that he or she is especially interested in. Depending on the number of students in the class, this could be done in pairs. As a first step to prepare for your talk, please make an appointment to meet with me the week after spring break so that I can help you to identify a suitable topic and to make sure that the topic will not take too much time for you to investigate. Your presentation can be on any topic related to the themes of this course (e.g., theory, experiment, or simulation of some pattern-forming system) but it can not be related to ongoing or previous research or for a previous course, for which you have already worked out the details of a talk.
Grading will be equally based on content (including introduction that motivates why your topic is interesting, 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). The presentations will be scheduled as a block session during the final exam period.

Important dates for Winter 2012

M 09-01	Lectures begin.
F 20-01	Drop date deadline
Mo 23-01	Add/swap date deadline
F 27-01	Fee payment deadline
Su 19-02 to Su 26-02	Reading week (no lectures)
F 06-04	Good Friday (no lectures)
F 13-04	Lectures end.
M 16-04 to We 25-04	Final Exam period.