UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
DEPARTMENT OF PHYSICS AND ASTRONOMY
COURSE OUTLINE

1. **Course:** Physics 619, Statistical Physics II

   Lecture Sections:

   L01: MW, 14:00-15:15, SA 121
   Instructor: Dr. J. Davidsen

Office:	SB505
Phone:	403 2107964
Email:	davidsen@phas.ucalgary.ca
Office Hours:	M 11:00-12:00 & by appointment

   Desire 2 Learn (D2L): Phys 619 L01 – (Winter 2015) – Statistical Physics II
   Departmental Office: SB 605, 403-220-5385, phasugrd@ucalgary.ca

2. **Prerequisites:** Physics 611. It is expected that a student's background will include Physics 481 or its equivalent.

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:

Assignments (3)	45%
Class participation	5%
Topic presentation	20%
Topic paper	30%

   Percentage to letter grade conversion scale:

> = 90 %	A +	> = 75 %	B +	> = 61 %	C +	> = 50 %	D +
> = 85 %	A	> = 70 %	B	> = 57 %	C	> = 47 %	D
> = 80 %	A -	> = 65 %	B -	> = 53 %	C -	< 47 %	F

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. It is the student's responsibility to familiarize himself/herself with these regulations. See also Section E.6 of the University Calendar

5. **Course Materials:** *There is no official textbook for this course.* Assignments, and supporting lecture material will be posted on the course D2L website.

6. **Examination Policy**: Midterm test is closed book. No calculators or laptops will be allowed. Students should also read the Calendar, Section G, on Examinations.

7. **Writing across the curriculum statement:** In this course, the quality of the student's writing in the topic paper will be a factor in the evaluation of this paper. See also Section E.2 of the University Calendar.

8. OTHER IMPORTANT INFORMATION FOR STUDENTS:

(a) **Misconduct:** 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 Section K. Student Misconduct 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 on assembly points.

(c) **Academic Accommodation Policy:** Students with documentable disabilities are referred to the following links: Students with Disabilities: http://www.ucalgary.ca/pubs/calendar/current/b-1.html B.1 and Student Accessibility Services: http://www.ucalgary.ca/access/.

(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 is 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; Student Ombudsman

(g) **Internet and Electronic Device Information:** You can assume that in all classes that you attend, your cell phone should be turned off unless instructed otherwise. 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.

(h) **U.S.R.I.:** At the University of Calgary, feedback provided by students through the Universal Student Ratings of Instruction (USRI) survey provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses (www.ucalgary.ca/usri). Your responses make a difference - please participate in USRI Surveys.

The following signature lines should be added to the course outline as appropriate

Department Approval____Date__________________________

Associate Dean's Approval for
Alternate final examination arrangements: ___________________________Date:___________________________

Course Syllabus

This class gives an introduction to equilibrium and nonequilibrium critical phenomena corresponding to phase transitions and methods to study fluctuating systems. While there is a well-established framework to study critical phenomena in equilibrium systems, this is not the case for non-equilibrium systems. One of the central scientific challenges 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 observations and simulations. The goal of this course is to develop specific conceptual, mathematical, and numerical skills for understanding and analyzing critical phenomena and associated fluctuations in different settings as well as complex systems and their dynamics in general.

Course outline:

1. Random walks and emergent properties (universality, scale invariance)
2. Percolation (order and control parameters, phase transition, scaling functions, scaling relations, self-similarity and fractals, finite size scaling)
3. Phase transitions in equilibrium (examples, critical exponents, spontaneous symmetry breaking, first order and continuous phase transitions)
4. Ising model (existence of phase transitions and how they occur, mean-field theory, Monte Carlo simulations)
5. Real-space renormalization & renormalization group theory (percolation, Ising model)
6. Avalanches and self-organized criticality (crackling noise, earthquakes & rock fracture, solar flares, neuronal avalanches, branching processes)
7. Extreme events & records (point processes, generating functions)
8. Complex networks (small worlds, topology, dynamics on and of networks)
9. Causality & information theory (mutual information, transfer entropy, Granger causality, partial measures, applications: fMRI, nerve cell cultures, climate, earthquakes)

Selection of reference books:

- K. Christensen & N.R. Moloney: **C**omplexity And Criticality (Imperial College Press Advanced Physics Texts)
- J. Sethna: Statistical Mechanics: Entropy, Order Parameters and Complexity (Oxford Master Series in Physics)
- J. Cardy: Scaling and Renormalization in Statistical Physics (Cambridge Lecture Notes in Physics
- N. Goldenfeld: Lectures On Phase Transitions And The Renormalization Group (Frontiers in Physics)
- M. Newman: Networks: An Introduction (Oxford University Press)

Further references and all course relevant material can be found on **D2L**.

General course information

- Textbook & lecture notes:

  As none of the currently available textbooks satisfactorily covers all aspects of the course, we do not follow a specific book. On our course D2L website, I have listed a number of books and other reference material that might be helpful for you to follow up on specific aspects covered in class. I strongly encourage you to look at other books on the course topics as well since some of you might find the presentation in a given book (more) accessible while other might not. Being able to identify suitable, reliable and understandable reference sources on a given topic (if necessary) is one of the keys to success in this class and beyond.

  While some students learn best in class by taking detailed notes, for others this is more a distraction from following and understanding the key concepts – and identifying my mistakes – in class. It is important to figure out which approach works best for you and act accordingly. It also might be helpful to team up with other students to share class notes and discuss specific topics.

- Grading philosophy:

  Because I try to encourage participation as much as possible, I have put a heavier accent on assignments than is maybe customary.

- 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.

  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 three homework assignments over the term, which will typically be posted on **D2L** on Wednesdays and are due the second following Wednesday **before** class. 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:

  - Your main two goals in writing up your homework are **to be clear** (so that it is understandable 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 we 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.
- 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.
- 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.
- 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 .
- If you use using Mathematica or any other software package in a homework assignment, please do not hand in the output of your entire session. Instead, just give us enough output to convince us that you have answered the question correctly. You should also include any code that you write so that we can try to understand how you obtained your answers.

❖ Topic presentation and topic paper

Instead of a final exam, each member of the class will give a 20-minute oral presentation to the class and write a summary paper about some topic related to the themes of this course that he or she is especially interested in. As a first step to prepare for your talk and paper, 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 but it cannot be related to ongoing or previous research or for a previous course, for which you have already worked out the details of a talk and/or paper.

- Grading of the presentation 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 during regular class hours in two or three sessions at the end of the term.
- 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. If the paper is based on reading some research article, on carrying out some simple experiment, or on simulating or analyzing some mathematical model, the paper should include a comprehensive background to the topic. The paper will be due at the end of the term.