UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

**Department of Physics & Astronomy**
Science B 605
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# REVISED COURSE OUTLINE FOR REMOTE LEARNING

To account for the necessary transition to remote learning from March 13 onward, adjustments have been made to assessment deadlines and requirements so that all coursework tasks are in line with the necessary and evolving health precautions for all involved (students and staff). If you are unable to meet the deadlines or requirements specified, please connect with your course instructor to work out alternative dates/assessments.

1. **Course:** PHYS 619, Statistical Physics II - Winter 2020

   Lecture 01: TR 11:00 - 12:15 - Remote Learning (check with your instructor or coordinator for details)

| Instructor | Email | Phone | Office | Hours |
|---|---|---|---|---|
| Dr Joern Davidsen | davidsen@phas.ucalgary.ca | 403 210-7964 | SB 505 | By email and remotely via skype or zoom. In person meetings by appointment only. |

**Course Site:**

D2L: PHYS 619 L01-(Winter 2020)-Statistical Physics II

**Note:** Students must use their U of C account for all course correspondence.

2. **Requisites:**

See section 3.5.C in the Faculty of Science section of the online Calendar.

**Prerequisite(s):**
Physics 611.

3. **Grading:**

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

| Component(s) | Weighting % |
|---|---|
| Assignments (3) | 45% |
| Class participation | 5% |
| Topic presentation - done remotely last week of classes (April 8 to April 15) | 20% |
| Topic paper (April 23, 2020) | 30% |

Each piece of work (reports, assignments, quizzes, midterm exam(s) or final examination) submitted by the student will be assigned a grade. The student's grade for each component listed above will be combined with the indicated weights to produce an overall percentage for the course, which will be used to determine the course letter grade.

The conversion between a percentage grade and letter grade is as follows.

| | A+ | A | A- | B+ | B | B- | C+ | C | C- | D+ | D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Minimum % Required** | 90 % | 85 % | 80 % | 75% | 70% | 65 % | 61 % | 57% | 53% | 50 % | 47 % |

4. **Missed Components Of Term Work:**

The University has suspended requirements for students to provide evidence for reasons for absences so please do not attend medical clinics for medical notes or Commissioners for Oaths for statutory declarations. Please let your instructor know immediately if you are ill and cannot meet the deadlines specified.

5. **Scheduled Out-of-Class Activities:**

There are no scheduled out of class activities for this course.

6. **Course Materials:**

**There is no official textbook for this course.**

Selection of reference books:
• K. Christensen & N.R. Moloney: Complexity 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 including assignments, and supporting lecture material will be posted on the course D2L website.

7. **Examination Policy:**

No aids are allowed on tests or examinations.

Students should also read the Calendar, Section G, on Examinations.

8. **Approved Mandatory And Optional Course Supplemental Fees:**

There are no mandatory or optional course supplemental fees for this course.

9. **Writing Across The Curriculum Statement:**

For all components of the course, in any written work, the quality of the student's writing (language, spelling, grammar, presentation etc.) can be a factor in the evaluation of the work. See also Section E.2 of the University Calendar.

10. **Human Studies Statement:**

Students will not participate as subjects or researchers in human studies.

See also Section E.5 of the University Calendar.

11. **Reappraisal Of Grades:**

A student wishing a reappraisal, should first attempt to review the graded work with the Course coordinator/instructor or department offering the course. Students with sufficient academic grounds may request a reappraisal. Non-academic grounds are not relevant for grade reappraisals. Students should be aware that the grade being reappraised may be raised, lowered or remain the same. See Section I.3 of the University Calendar.

a. **Term Work:** The student should present their rationale as effectively and as fully as possible to the Course coordinator/instructor within **ten business days** of either being notified about the mark, or of the item's return to the class. If the student is not satisfied with the outcome, the student shall submit the Reappraisal of Graded Term work form to the department in which the course is offered within 2 business days of receiving the decision from the instructor. The Department will arrange for a reappraisal of the work within the next ten business days. The reappraisal will only be considered if the student provides a detailed rationale that outlines where and for what reason an error is suspected. See sections I.1 and I.2 of the University Calendar

b. **Final Exam:** The student shall submit the request to Enrolment Services. See Section I.3 of the University Calendar.

12. **Other Important Information For Students:**

a. **Mental Health** The University of Calgary recognizes the pivotal role that student mental health plays in physical health, social connectedness and academic success, and aspires to create a caring and supportive campus community where individuals can freely talk about mental health and receive supports when needed. We encourage you to explore the mental health resources available throughout the university community, such as counselling, self-help resources, peer support or skills-building available through the SU Wellness Centre (Room 370, MacEwan Student Centre, Mental Health Services Website) and the Campus Mental Health Strategy website (Mental Health).

b. **SU Wellness Center:** The Students Union Wellness Centre provides health and wellness support for students including information and counselling on physical health, mental health and nutrition. For more information, see www.ucalgary.ca/wellnesscentre or call 403-210-9355.

c. **Sexual Violence:** The University of Calgary is committed to fostering a safe, productive learning environment. The Sexual Violence Policy (https://www.ucalgary.ca/policies/files/policies/sexual-violence-policy.pdf) is a fundamental element in creating and sustaining a safer campus environment for all community members. We understand that sexual violence can undermine students' academic success and we encourage students who have experienced some form of sexual misconduct to talk to someone about their experience, so they can get the support they need. The Sexual Violence Support Advocate, Carla Bertsch, can provide confidential support and information regarding sexual violence to all members of the university community. Carla can be reached by email (svsa@ucalgary.ca) or phone at 403-220-2208 .

d. **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. Examples of academic misconduct may include: submitting or presenting work as if it were the student's own work when it is not; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; collaborating in whole or in part without prior agreement of the instructor; borrowing experimental values from others without the instructor's approval; falsification/ fabrication of experimental values in a report. **These are only examples**.

e. **Assembly Points:** In case of emergency during class time, be sure to FAMILIARIZE YOURSELF with the information on assembly points.

f. **Academic Accommodation Policy:** Students needing an accommodation because of a disability or medical condition should contact Student Accessibility Services in accordance with the procedure for accommodations for students with disabilities available at procedure-for-accommodations-for-students-with-disabilities.pdf.

   Students needing an accommodation in relation to their coursework or to fulfill requirements for a graduate degree, based on a protected ground other than disability, should communicate this need, preferably in writing, to the Associate Head of the Department of Physics & Astronomy, Dr. David Feder by email phas.ahugrd@ucalgary.ca or phone 403-220-8127. Religious accommodation requests relating to class, test or exam scheduling or absences must be submitted no later than **14 days** prior to the date in question. See Section E.4 of the University Calendar.

g. **Safewalk:** Campus Security will escort individuals day or night (See the Campus Safewalk website). Call 403-220-5333 for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

h. **Freedom of Information and Privacy:** This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). 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 Legal Services website.

i. **Student Union Information:** VP Academic, Phone: 403-220-3911 Email: suvpaca@ucalgary.ca. SU Faculty Rep., Phone: 403-220-3913 Email: sciencerep@su.ucalgary.ca. Student Ombudsman, Email: ombuds@ucalgary.ca.

j. **Internet and Electronic Device Information:** Unless instructed otherwise, cell phones should be turned off during class. All communication with other individuals via laptop, tablet, smart phone or other device is prohibited during class unless specifically permitted by the instructor. Students that violate this policy may be asked to leave the classroom. Repeated violations may result in a charge of misconduct.

k. **Surveys:** At the University of Calgary, feedback through the Universal Student Ratings of Instruction (USRI) survey and the Faculty of Science Teaching Feedback form provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses. Your responses make a difference - please participate in these surveys.

l. **Copyright of Course Materials:** All course materials (including those posted on the course D2L site, a course website, or used in any teaching activity such as (but not limited to) examinations, quizzes, assignments, laboratory manuals, lecture slides or lecture materials and other course notes) are protected by law. These materials are for the sole use of students registered in this course and must not be redistributed. Sharing these materials with anyone else would be a breach of the terms and conditions governing student access to D2L, as well as a violation of the copyright in these materials, and may be pursued as a case of student academic or non-academic misconduct, in addition to any other remedies available at law.

**Course description**

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.

**Syllabus**

1. Random walks and emergent properties
1.1. Random walks & Brownian motion: universality, scale invariance, polymers
1.2. The diffusion equation
2. Percolation
2.1. Percolation in 1D: cluster number density, average cluster size, correlation function, phase transition
2.2. Percolation on the Bethe lattice/Cayley tree
2.3. Percolation in 2D: scaling ansatz, scaling function
2.4. Scaling relations
2.5. Geometric properties of clusters: fractals
2.6. Finite size scaling (time permitting)
3. Phase transitions in physical equilibrium systems: examples, critical exponents, spontaneous symmetry breaking, first order and continuous phase transitions
4. Ising model
4.1. Existence of phase transitions: energy-entropy argument
4.2. How phase transitions occur in practice: transfer matrix
4.3. Mean-field theory: critical exponents
5. Renormalization
5.1. Coarse graining & renormalization group procedure
5.2. Real-space renormalization of percolation
5.3. Real-space renormalization of the Ising model
5.4. Wilson's renormalization group (RG) theory
5.5. Perturbation theory for the RG recursion relation: cumulant expansion
6. Avalanches and criticality
6.1. Crackling noise: Plasticity, Barkhausen noise, seismicity & rock fracture, space weather & solar flares, neuronal avalanches
6.2. Branching processes: Generating function approach, epidemic-type aftershock sequence model
7. Extreme events & records
7.1. Stable extreme value distributions: Gnedenko's extreme value theorem
7.2. Record statistics (time permitting)
8. Complex systems & complex networks
8.1. Mathematics of networks: graph representation, basic definitions
8.2. Erdös-Renyi graphs
8.3. Small-world networks: transitivity, clustering
8.4. Phase transitions in networks: giant component
8.5. Scale-free networks: centrality measures
8.6. General random graph models: degree assortativity
8.7. Emergence of network structure from dynamics: preferential attachment models, copying models, triadic closure, multiplex networks
9. Causality & network inference
9.1. Seismicity and aftershocks
9.2. Neuronal cultures & brain activity
9.3. Causal network inference problem: functional/effective networks, Granger causality
9.4. Information theoretic approaches: entropies, mutual information, Venn diagram, conditional entropies
9.5. Transfer entropy & causality: time series graphs

**General course information**

i) *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.

ii) *Grading philosophy:*
Because I try to encourage participation as much as possible, I have put a heavier accent on assignments than is maybe customary.

iii) *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 to me outside of lecture is also one way to participate in class. I want to see evidence of you actively trying to learn about the course material.

iv) *Homework assignments:*
There will be three homework assignments over the term, which will typically be posted on D2L on Thursdays and are due the second following Thursday 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 mu=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.

v) *Topic presentation and topic paper*
Instead of a final exam, each member of the class will give an oral presentation in the last week of the term (remotely via skype or zoom, length to be determined, not more than 30 minutes) to the class during regular class times 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 in mid-February 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.

**Course Learning Incomes**
Students are expected to have working knowledge of concepts and methods to describe many-particle systems from a classical mechanical point of view as covered in Phys 611 and summarized in the Course Learning Outcomes of Phys 611.

**Course Learning Outcomes**
The aims of the course are that, upon completion of the course, the student is expected to have acquired the following knowledge and skills:
- The student can explain the concept of phase transitions, give examples, derive scaling relations between different critical exponents based on a suitable scaling ansatz and calculate the critical exponents in the mean-field limit for models such as percolation and the Ising model.
- The student can summarize the basic ideas of renormalization and apply real-space renormalization to simple models such as the Ising model and percolation to calculate scaling functions and critical exponents.
- The student can define branching process, apply it to describe avalanche processes and calculate the scaling functions and critical exponents using generating functions.
- The student can motivate and summarize Gnedenko’s extreme value theorem.
- The student can give a detailed overview of complex networks, highlight the main scientific questions and challenges and derive the properties of simple network models such as Erdös-Renyi graphs.
- The student can precisely define the notion of causality and explain the differences between causality and transfer entropy and other related information theoretic measures.
- The student is able to identify suitable, reliable and understandable reference material and critique original peer-reviewed literature on critical phenomena, complex networks and causality.
- The student can solve problems individually and communicate his/her own understanding of a given topic clearly in written and oral form.

Electronically Approved - Mar 17 2020 20:46

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**Department Approval**

Electronically Approved - Mar 18 2020 17:30

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**Associate Dean's Approval for alternate final examination arrangements or remote learning**