UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

Department of Physics & Astronomy
Science B 605
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COURSE OUTLINE

1. **Course:** PHYS 451, Statistical Mechanics II - Winter 2024

   Lecture 01 : TR 15:30 - 16:45 in MS 431

Instructor	Email	Phone	Office	Hours
Dr Javier Orlandi	javier.orlandi@ucalgary.ca	403 210-6548	SB 505	Wednesdays 14:00-15:00 (may be adjusted to fit students schedules)

To account for any necessary transition to remote learning for the current semester, courses with in-person lectures, labs, or tutorials may be shifted to remote delivery for a certain period of time. In addition, adjustments may be made to the modality and format of assessments and deadlines, as well as to other course components and/or requirements, so that all coursework tasks are in line with the necessary and evolving health precautions for all involved (students and staff).

In Person Delivery Details:

Lectures will be delivered in-person in a classroom setting. In addition to the recommended text books, learning materials will be posted on D2L for self-study. While attendance of the lectures is not mandatory, it is an important learning opportunity and it provides direct feedback on the individual learning progression.

Course Site:

D2L: PHYS 451 L01-(Winter 2023)-Statistical Mechanics II

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

Equity Diversity & Inclusion:

The University of Calgary is committed to creating an equitable, diverse and inclusive campus, and condemns harm and discrimination of any form. We value all persons regardless of their race, gender, ethnicity, age, LGBTQIA2S+ identity and expression, disability, religion, spirituality, and socioeconomic status. The Faculty of Science strives to extend these values in every aspect of our courses, research, and teachings to better promote academic excellence and foster belonging for all.

The Physics and Astronomy EDI Committee acknowledges there are persistent barriers that prevent such accessibility and hinder our progress towards EDI. Our representatives (faculty, postdocs, graduate and undergraduate students) are committed to addressing any concerns and work towards proactive solutions that enact necessary change within the department. To submit anonymous questions, comments or concerns regarding EDI related issues, please reach out to our Associate Head EDI, Claudia Gomes da Rocha (claudia.gomesdarocha@ucalgary.ca)

2. **Requisites:**

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

   Prerequisite(s):
   Physics 449.

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:

Course Component	Weight	Due Date (duration for exams)	Modality for exams	Location for exams
Assignments (5)	35%	Ongoing		
Term project[1]	30%	Ongoing		
Final oral examination[2]	20%	Ongoing		
Midterm	15%	Mar 05 2024 at 03:30 pm (75 Minutes)	in-person	In Class

[1] Term project will be graded based on 3 components. 1 - An In Class presentation (10%) (March 12, 14, or 19). 2 - A written report (15%, Due on April 2). 3 - Participation and feedback (5%)
[2] Will take place during exam week (Apr 15 to Apr 23). The actual date will be scheduled in consultation with the students (3 possible dates will be available to each student)

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 %	60 %	55%	50%	45 %	40 %

The University of Calgary offers a flexible grade option, Credit Granted (CG) to support student's breadth of learning and student wellness. Faculty units may have additional requirements or restrictions for the use of the CG grade at the faculty, degree or program level. To see the full list of Faculty of Science courses where CG is not eligible, please visit the following website: https://science.ucalgary.ca/current-students/undergraduate/program-advising/flexible-grading-option-cg-grade

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

In the event that a student legitimately fails to submit any online or in-person assessment on time (e.g. due to illness, domestic affliction, etc...), please contact the course coordinator, or the course instructor if this course does not have a coordinator to arrange for a re-adjustment of a submission date, or possible exemption and reweighing of components. Absences not reported within 48 hours will not be accommodated. Students may be asked to provide supporting documentation (Section M.1) for an excused absence, See FAQ.

If an excused absence is approved, options for how the missed assessment is dealt with is at the discretion of the coordinator or course instructor. Some options such as an exemption and pro-rating among the components of the course may not be a viable option based on the design of this course.

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

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

6. **Course Materials:**

Recommended Textbook(s):

H. Gould , J. Tobochnik, *Statistical and thermal physics*: Princeton University Press.
W. Greiner, L. Neise, H. Stoecker, *Thermodynamics and Statistical Mechanics*: Springer.

In order to successfully engage in their learning experiences at the University of Calgary, students taking online, remote and blended courses are required to have reliable access to the following technology:

- A computer with a supported operating system, as well as the latest security, and malware updates;
- A current and updated web browser;
- Webcam/Camera (built-in or external);
- Microphone and speaker (built-in or external), or headset with microphone;
- Current antivirus and/or firewall software enabled;
- Stable internet connection.

For more information please refer to the UofC ELearning online 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 a s 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 t o 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 Services:** For more information, see their website or call 403-210-9355.

c. **Sexual Violence:** 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. The complete University of Calgary policy on sexual violence can be viewed here.

d. **Student Ombuds Office:** A safe place for all students of the University of Calgary to discuss student related issues, interpersonal conflict, academic and non-academic concerns, and many other problems.

e. **Student Union Information:** SU contact, Email your SU Science Reps: science1@su.ucalgary.ca, science2@su.ucalgary.ca, science3@su.ucalgary.ca,

f. **Academic Accommodation Policy:**

It is the student's responsibility to request academic accommodations according to the University policies and procedures listed below. The student accommodation policy can be found at: https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Student-Accommodation-Policy.pdf

Students needing an accommodation because of a disability or medical condition should communicate this need to Student Accessibility Services in accordance with the Procedure for Accommodations for Students with Disabilities: https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Accommodation-for-Students-with-Disabilities-Procedure.pdf.

Students needing an accommodation in relation to their coursework or to fulfil requirements for a graduate degree, based on a Protected Ground other than Disability, should communicate this need, by filling out the Request for Academic Accommodation Form and sending it to Dr. David Feder by email phas.ahugrd@ucalgary.ca preferably 10 business days before the due date of an assessment or scheduled absence.

g. **Misconduct:** Academic integrity is the foundation of the development and acquisition of knowledge and is based on values of honesty, trust, responsibility, and respect. We expect members of our community to act with integrity. Research integrity, ethics, and principles of conduct are key to academic integrity. Members of our campus community are required to abide by our institutional Code of Conduct and promote academic integrity in upholding the University of Calgary's reputation of excellence. Some examples of academic misconduct include but are not limited to: posting course material to online platforms or file sharing without the course instructor's consent; submitting or presenting work as if it were the student's own work; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; borrowing experimental values from others without the instructor's approval; falsification/fabrication of experimental values in a report. Please read the following to inform yourself more on academic integrity:

Student Handbook on Academic Integrity
Student Academic Misconduct Policy and Procedure
Faculty of Science Academic Misconduct Process
Research Integrity Policy

Additional information is available on the Student Success Centre Academic Integrity page

h. **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.

i. **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.

j. **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.

Syllabus

1. Phase transitions & critical phenomena

1.1. Ising model

1.2. Existence of phase transitions: energy-entropy argument

1.3. How phase transitions occur in practice: transfer matrix

1.4. Mean-field theory: critical exponents

1.5. Real-space renormalization: coarse-graining, renormalization group procedure, block spin transformation, Wilson's renormalization group theory

2. Complexity

2.1 Complex systems and network theory

2.2 Percolation and avalanche dynamics

3. Classical statistical mechanics wrap-up

3.1 Grand canonical ensemble

4. Breakdown of classical statistical mechanics

4.1. Dilute polyatomic gases: small oscillations, linear stability, normal modes, equipartition of energy, symmetries, vibrational modes, rotational modes

4.2. Condensed matter & solid-state physics: crystal lattices, vibrations of a solid, normal modes of a crystal, Brillouin zone, Einstein model, Debye model, phonons

4.3. Black body radiation: ultraviolet catastrophe, Casimir force, Stefan-Boltzmann law

5. Quantum statistical mechanics

5.1. Quantum microstates: observables, time evolution

5.2. Quantum macrostates: density matrix, equilibrium condition

5.3. Quantum ensembles: microcanonical ensemble, canonical ensemble, grand canonical ensemble

5.4. Quantum statistical entropy & extremal properties of thermodynamic potentials: 2nd law of thermodynamics

5.5. 3rd law of thermodynamics

6. Ideal quantum gas

6.1. Indistinguishable particles: fermions, bosons, anyons

6.2. Hilbert space of indistinguishable particles

6.3. Ideal quantum gas in the canonical ensemble: bosons & fermions

6.4. Ideal quantum gas in the grand canonical ensemble: degenerate Fermi gas, Fermi energy, Sommerfeld expansion, degenerate Bose gas, Bose-Einstein condensation

General course information

1. Textbook & lecture notes

As none of the currently available textbooks satisfactorily covers all aspects of the course, there are two textbooks listed under course material. For more information on the two textbooks and their supporting online material including free downloads, please see our course D2L website. On D2L, there are a number of additional books and other reference material that might be helpful for you to follow up on specific aspects covered in class. It is strongly encouraged for 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.

2. Midterm

The in-class midterm (75 min long) will focus on the material covered up to that point, including all homework assignments.

3. Class participation

Your active class participation throughout the semester is essential. 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.

4. Homework assignments

There will be continuous homework assignments over the term, which will typically be posted on D2L on Thursdays and due in approximately 10 days. 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. 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 typically require a mixture of analytical, numerical, and graphical approaches. The mathematical derivations or analyses for the analytical problems should be fully written out. Numerical and graphical answers involve output that is best attached in vector format. 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 use it to assess how you obtained your answers.

5. Term project

Each member of the class will have to explore some topic related to the themes of this course that they are especially interested in. A list of possible topics will be available in D2L, but students are encouraged to choose topics outside of the list (with the instructor's approval). Students will be able to work alone or in groups (up to 3 students), hereinafter called teams. No two teams will be allowed to work on the same topic, and topics will be assigned on a first-come first-serve basis.

The term project will have two major components:

- 5.1. A short **In-class presentation** (3 min per team member). The style of the presentation will be up to the teams (with supervisor's approval): slides, chalk, alternative media, performance, etc... The presentation will have to introduce the selected topic to fellow classmates and clearly state the motivation behind the chosen topic and its connection with statistical mechanics and the coursework. The presentation will be graded based on content, clarity of presentation, delivery, time-management, and citation standards. Presentations will be scheduled between March 12 and March 19. All teams will be required to attend at least a full day of presentations from their peers. Presentations will be recorded for grading purposes. Only the teaching team will have access to the recordings and they will be deleted within one year.
- 5.2. A **project report.** The report should be written in prose (no bullet points or numbered lists), and be pitched at the level of fellow students. The reports will have to be written individually (one per team member) but can reference each other. Different reports from the same team can have overlapping information in the introduction and background section, but each report should explore a different aspect of the chosen topic. 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 5-7 pages in length, in 10-12 point font including tables, figures, and bibliography. The paper will be graded on presentation (including equations, figures, tables, and captions), content, logical flow, discussion, 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. Students are required to write the report by themselves and adhere to the tenets of academic integrity. Students might be asked to clarify or comment in person on the report's contents. Reports will have to be submitted by April 12. The reports will be uploaded to D2L and available to the other students.
- 5.3 **Class Feedback**. Each student will be required to provide feedback on the presentations and reports of 5 other teams and rank them (1 to 5). All feedback will have to be submitted by April 9. It will be compiled and curated by the instructor and the TAs and delivered to the teams soon after. The top 5 class-ranked projects will have up to an extra 5% bonus points for the final exam (5% for the best project, 4% for the second, etc.). That is, the final exam for the best team will be worth 25% instead of 20% of the total mark (one could end up with a final grade exceeding 100%).

As a first step to preparing for your project, please make an appointment to meet with the instructor no later than one month after the start of classes so that we can help you identify a suitable topic and make sure that the topic will not take too much time for you to investigate. Your project can be on any topic related to the themes of this course but it cannot be related to ongoing or previous research or from a previous course.

6. Final exam

The final will be an oral exam scheduled between Apr 15 and Apr 23. Several dates will be available to avoid conflict with other scheduled exams. The exam will consist of a short presentation followed by a Q&A session with the instructor at their office or alternative meeting room (a TA might also be present). The exam will be recorded for grading purposes. Only the teaching team will have access to the recordings and they will be deleted within one year.

By April 1st, each student will be assigned 3 topics from those covered in class at random that they will have to study and prepare. At the beginning of the exam, one of the topics will be chosen at random and will have to be presented (free format, but without supporting material). The presentation should last no more than 8 minutes. The presentation will be followed by a Q&A session where the intructor will query the student mainly about the presented material **and the term project.** The instructor might also ask about the other 2 chosen topics if necessary. The oral exam is expected to last 15 minutes. Students are encouraged to contact the instructor for any accommodation they might need for the exam.

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 449 and summarized in the Course Learning Outcomes of PHYS 449.

Course Outcomes:

- The student is able to solve problems in statistical mechanics with the help of computers, such as coding in python or using symbolic computation programs such as Maple or Mathematica
- The student can describe continuous phase transitions, give examples and explain the concepts of a critical point and universality.
- The student can give an overview of experimental findings that are in disagreement with classical statistical mechanics and explain how this can be resolved by quantum statistical mechanics.

- The student can explain the basic concepts of ensemble theory in quantum statistical mechanics including the differences between bosons and fermions.
- The student is able to identify suitable, reliable and understandable reference material and critique original peer-reviewed literature on statistical mechanics.
- The student can solve problems individually or in teams and communicate his/her own understanding of a given topic clearly in written and oral form.

Electronically Approved - Jan 05 2024 10:47

Department Approval