



COURSE OUTLINE

1. **Course:** PHYS 451, Statistical Mechanics II - Winter 2023

Lecture 01 : TR 15:30 - 16:45 in SA 124

Instructor	Email	Phone	Office	Hours
Dr Javier Orlandi	javier.orlandi@ucalgary.ca	403 210-6548	SB 505	Wednesdays 15:30-16:30

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.

Re-Entry Protocol for Labs and Classrooms:

To limit the spread of COVID-19 on campus, the University of Calgary has implemented safety measures to ensure the campus is a safe and welcoming space for students, faculty and staff. The most current safety information for campus can be found [here](#).

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 (6)	42%	Ongoing		
Midterm	23%	Mar 21 2023 at 03:30 pm (60 Minutes)	in-person	In Class
Final topic paper	35%	Apr 12 2023		

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:**

The university has suspended the requirement for students to provide evidence for absences. Please do not attend medical clinics for medical notes or Commissioners for Oaths for statutory declarations.

In the event that a student legitimately fails to submit any online assessment on time (e.g. due to illness 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. Absences not reported within 48 hours will not be accommodated. If an excused absence is approved, one possible arrangement is that the percentage weight of the legitimately missed assignment could also be pro-rated among the components of the course. This option is at the discretion of the coordinator and 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 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 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 (syasa@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. Grand canonical ensemble
 - 1.1 Ideal gas: chemical potential
 - 1.2 Surfactant adsorption
2. Phase transitions & critical phenomena
 - 2.1. Ising model
 - 2.2. Existence of phase transitions: energy-entropy argument
 - 2.3. How phase transitions occur in practice: transfer matrix
 - 2.4. Mean-field theory: critical exponents
 - 2.5. Real-space renormalization: coarse graining, renormalization group procedure, block spin transformation, Wilson's renormalization group theory
3. Crackling noise, avalanches & complex systems
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

4.4. Black-hole thermodynamics (time permitting)

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 (60 min long) will focus on the material covered up to that point, including all homework assignments.

3. 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 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 (about 6), which will typically be posted on D2L on Thursdays and are due the 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 $A=0.02 \text{ J}\cdot\text{sec}$ " or "the angle was $\mu=0.32 \text{ radians}$." 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. Topic paper

Instead of a final exam, each member of the class will write a summary paper about some topic related to the themes of this course that they are especially interested in. As a first step to prepare for your paper, please make an appointment to meet with me no later than one month before the end of classes 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 paper 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. 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.

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 03 2023 17:29

Department Approval