PHYS 316: Thermodynamics and Statistical Mechanics

Units: 4

Term—Day—Time:

- **Spring 2023**
- **Monday, Wednesday, and Friday from 8.30 am to 9.50 am**
- **Three 80 minutes classes per week, 15 weeks**

Location:

- **In-Person: ZHS 360 (Zumberge Hall)**
- **And Online (live session): https://usc.zoom.us/j/99538269593 (check our Blackboard page for the passcode) (remember to sign-in using the SSO method)**

Instructor:

- **Dr. Marcin Abram**
- **e-mail: mjabram@usc.edu**

Teaching Assistant:

- **Chunyu Tan**
- **e-mail: chunyuta@usc.edu**

Students Hours (also known as Office Hours):

- **Wednesday, from 12 (noon) to 1 pm**
- **Online: https://usc.zoom.us/j/8934576028 (check the meeting passcode in the "Contacts" section of the Blackboard page of our class)**
- **Everybody is welcome!**
- **Drop-in, drop-out style. It means you don't have to make an appointment. Just join the session and ask your questions.**

Piazza:

- **https://piazza.com/usc/spring2023/phys316**

Crearted in January 2023

Course Description

Physics 316 is an intermediate-level course in thermodynamics and statistical mechanics. In this class, we will learn how to describe the physics of a large number of interacting objects, which number can exceed the value of the Avogadro number. This class can also be seen as the second course in the canon of theoretical physics. As such, it will be your gateway to studying quantum mechanics (PHYS 438), soft matter physics, condensed matter physics, and many other specialized classes. In this class, we'll make heavy use of concepts from single-variable and multivariable calculus, linear algebra, and statistics. We will also use some concepts from the field of discrete mathematics (we will introduce the relevant topics during the class). The auxiliary goal of this class is to build on ideas from the introductory mechanics and thermodynamics while developing a range of new math skills. The topics include classical thermal physics (energy, enthalpy, entropy, models of diluted gas, thermodynamical laws, and their consequences), statistical physics (microstates, statistical ensembles, partition functions, quantum statistics, etc.), and modern applications of statistical physics (Ising model, phase transitions, critical phenomena, mean-field theory, superfluidity, etc.).

Learning Objectives

At the end of this course, you will be able to:

1. Describe (quantitatively and qualitatively) systems that consist of a large number of elements.
2. Provide microscopic interpretation of classical thermal physics.
3. Apply various methods to solve systems of interacting particles (classical and quantum).
4. Discuss a range of modern applications of statistical physics (e.g., universality and critical phenomena, superfluidity, etc.).
5. Create a scientific poster featuring modern applications of statistical physics.
6. Prepare peer-review reports.
7. Present your findings in the form of a short academic presentation.

Prerequisite(s)

I have constructed the course with the understanding that you have completed (or you are familiar with the content of):

- ★ Either PHYS 152 (Fundamentals of Physics II) or PHYS 161 (Advanced Principles of Physics I), and
- ★ MATH 226 (Calculus III).

Co-Requisite(s) or Concurrent Enrollment

None.

Recommended Preparation

To succeed with this class, review the information from:

- ★ Introduction to Physics (mostly the sections devoted to mechanics and thermodynamics).
- ★ Calculus (you should be able to solve simple integrals and multivariable equations).
- ★ Algebra (you should be fluent in matrix calculus; you should know how to calculate eigenvalues and eigenvectors).
- ★ Statistics (probability, ability to work with probability distributions of one or many random variables)
- ★ Quantum Mechanics (a general overview)

Course Elements

This course will be comprised of:

- ★ lectures,
- ★ weekly problem sets (short conceptual and longer quantitative questions),
- ★ a student project (discussed below), and
- ★ a final exam.

The course will ordinarily be taken for a letter grade. All information regarding the class will be communicated with you via Blackboard (larger announcements) and Piazza (more informal communication).

Description and Assessment of Assignments

Weekly Problem Sets

Each week, I will publish a problem set. Those are take-home assignments that require you to write down solutions to various quantitative physical problems. A portion of each problem set can be also dedicated to some conceptual questions. Each problem set will be worth 20 points. There will be 11 problem sets in total. You will all have approximately 6 days to complete each problem set. The solutions should be uploaded on our Blackboard site in a form of a single pdf file (you can either write the solutions in LaTeX or you can write them by hand, scan the papers, and create a pdf). As long as the problem set is open, you will be able to send multiple answers (only the latest submitted answer will matter). The closing time for the problem set is always the following Friday at 8 am PT (Pacific Time). Specifically,

- ★ The deadline for the *first* problem set is on Friday, January 20, 2023, at 8 am PST
- ★ The deadline for the *second* problem set is on Friday, January 27, 2023, at 8 am PST.
- ★ …
- ★ The deadline for the *eleventh* problem set is on Friday, April 14, 2023, at 8 am PDT.

You can find the full schedule in the “Course Schedule: A Weekly Breakdown” section on page 14.

Note, that in those written assignments, the completeness and the clarity of your solution (your calculations or derivations) will matter as much as the final correct answer. Writing down just a single final value (even if correct) is not enough. See the table below:

Grade Component	Meets Expectations (75%-100%) For Problem Sets: 15-20 points	Approaches Expectations (50%-75%) For Problem Sets: 10-15 points	Needs Improvement (0%-50%) For Problem Sets: 0-10 points
Completeness (25%) 5 points in total	All questions are answered. All cases are considered.	Most questions are answered. The most obvious cases are considered (for example non-zero forces are examined, but the student didn't consider a special case when T=0).	The main question is not addressed. The answer is irrelevant to the task. The analysis of the issues and events is either vague or incomplete.
Clarity (25%) 5 points in total	A non-expert (e.g., a fellow student) can understand the solutions. All concepts and used techniques are defined and explained. Whenever it is applicable, the solution is accompanied by illustrative plots. The plots are explained and interpreted. There are references to sources.	The teacher (or another professional physicist) can understand the solution but a non-expert might have some trouble doing so. The solution has some minor shortcuts or some non-explained assumptions. Not every step of the analysis is explained, but it is still possible to follow the author's logic. Some references are missing.	It is hard to follow the solutions. The solution has some major shortcuts or hidden assumptions. There are no references in the texts. The analysis or evaluations of the issues and events are vague. It is either hard or impossible to understand or verify the correctness of the calculations.
Validity (50%) 10 points in total	All calculations are correct. The final values (or plots) are correct and the final interpretation or conclusions are probable.	Small mistakes in the answers and/or calculations (e.g., a wrong sign, a missing constant). The final answer is close to the correct value (e.g., it differs by a small factor - twice too large or twice too small; however, the general trend is correct).	Major mistakes in the calculations and/or in the analysis. The final values and/or conclusions are incorrect.

Student Project

Your task is to:

- ★ Prepare a scientific poster on one of the topics below.
- ★ Peer-review two posters prepared by your colleagues.
- ★ Address the comments that you received from your peers.
- ★ Present your work (4-5 minutes long presentation) in class.

The objective of this assignment is to a) explore literature regarding modern topics in the fields of thermal and statistical physics, b) synthesize the acquired knowledge in the form of a scientific poster, c) prepare peer-review reports, d) respond to the comments of your reviewers, e) summarize the main points of your work in a form of a short presentation.

Projects Propositions (choose one):

- ❏ *(For those who like Physics)* Model and characterize different types of phase transitions. Some possible starting points: Read about order parameters. Read about the critical phenomenon, critical points, and universality of systems undergoing phase transitions. Characterize different types of phase transition. Since you want to create a scientific poster, you might think about different ways to visualize that phenomenon. You can also present the underlying theory of phase transitions (cf. work of Landau). You can also present examples of different systems that undergo a phase transition. Another direction would be to focus less on systems, and more on methods, e.g., by comparing different methods of finding and/or characterizing phase transitions.
- ❏ *(For those who like math)* Compare different probability distributions. Possible ways of approaching this topic: Describe different classes of probability distributions. Link them to some physical (or biological) systems (see an example of how a biological system can motivate a new class of distributions, cf. https://www.jstor.org/stable/2235986, or access the article via our library). Another angle in this topic would be to focus on the differences and consequences of different types of statistical distributions. In your description, you can include a comparison of different types of physical particles, namely classical particles, fermions, or bosons. If you are doing this, you could discuss both the origin of those differences and the consequences (e.g., superconductivity, superfluidity, the existence of fermion stars and boson stars, etc.).
- ❏ *(For those who like programming)* Simulate a system of many interacting particles. Possible ways of approaching this topic: find some relevant papers. Try to replicate the results. Think about a good way to visualize the evolution of the system (after all, you are making a poster, you are not writing a classical article). If you are using a fancy numerical method, compare your results with a naive (brute-force) approach. Alternatively, you can focus on comparing different approximations, to show the tradeoffs: e.g., some methods are faster but might be less precise, other methods can work well but only for some specific classes of systems, etc.
- ❏ *(For those who like applied math)* Compare different diffusion models. Possible ways of approaching this topic: you can focus either on theory or applications. There are many interesting applications of diffusion models, that explain e.g., the advantageous genes spreading, dispersions of biological populations, epidemic evolutions, particle aggregation, etc.
- ❏ *(For those who like astronomy)* Compare different approximation methods used to model systems of a large number of elements (e.g., models describing the formation or evolution of galaxies, etc.).
- ❏ *(For those who like reading)* Discuss some modern applications of statistical physics. For example, show some non-trivial connections with different fields, or discuss elements of another field from the perspective of statistical physics. Some examples include (but are not limited to): a) Connections between machine learning and statistical physics. There

are some machine learning models that are inspired by some physical systems, e.g., Hopfield networks or restricted Boltzmann machines, just to mention a few. b) Another direction could be to discuss emergent behavior that appears when we increase the number of elements in the system. Here, a good start would be the essay "More is Different" by P. W. Anderson, https://doi.org/10.1126/science.177.4047.393. c) There are sometimes interesting synergies between fields that usually appear quite distant from each other. For example, there is an article from the fields of statistical physics and archeology (just to give you one example of what is possible), c.f., Joaquim Fort and Vicenç Méndez, "Time-Delayed Theory of the Neolithic Transition in Europe", Phys. Rev. Lett. **82**, 867 (1999), https://doi.org/10.1103/PhysRevLett.82.867.

- ❏ *(For those who don't like the above projects)* Modify the above propositions or propose your own project. Discuss your choice with the instructor (I'm usually happy to allow you to work on your own projects - but I want to know what those topics are in advance).

Structure and Formatting:

We encourage you to use the LaTeX template https://www.overleaf.com/read/sxnnphvgdzkr that I prepared for you in Overleaf. If you also use alternative programs or editors (if this is your choice), as long as the overall style of your poster approximates (to some reasonable extent) the style of the provided template. Please remember to submit your poster in PDF format (not as a docx, rtf, odt, jpg, eps, or any other type of file). If any numerical methods were used to visualize or calculate anything, provide a link to a GitHub repository with relevant code, scripts, or notebooks. When programming, you are free to use any language of your choice - as long as the code is clear and well-commented (to give me a chance to understand what you did). Regarding the overall structure of your poster, you are expected to follow either the APS Physical Review or the Nature style guidelines (those guidelines are originally written for scientific articles, not posters, but some points can be still applicable - e.g., the parts regarding the notation, affiliation format, table format, figure caption style, etc.), see:

- https://cdn.journals.aps.org/files/styleguide-pr.pdf (APS Physical Review).
- https://www.nature.com/articles/nphys724 (Nature Physics).

Steps:

1. Prepare and share your work plan by **Monday, January 23, by 8 am PST**. You don't have to know your topic yet. However, you should have a plan for how long your "exploration" phase should last. You should plan: when you should have your topic, when you should start creating your poster, etc. Make sure that your plan is consistent with all the deadlines described in this syllabus.
2. Choose your topic.
3. Find relevant literature. Read about your topic. Prepare a literature review **by Monday, February 13, by 8 am PST**.
4. Make a plan for your poster. Decide which aspects you are going to illustrate and which aspects you will describe using text. After all, you have limited space (only one

large-format page, you can reasonably show only a few figures and you have only space to have about 1000 words). Thus, you have to be creative about the space you have. Submit your project outline **by Monday, February 27, by 8 am PST**.

5. Complete the necessary calculations (depending on your topic, you might have some numerical or analytical calculations). Prepare plots and figures.
6. Prepare the first version of your poster. You should have an early draft by March 10 (you can still have missing pieces, but at least you should try the template and you should start putting things together). You do not have to upload it yet - it is your internal deadline.
7. Proofread your poster. Make sure that all key terms are defined. Make sure that the poster has the right structure, style, and format. Remember, that the list of references at the end of your poster is not enough - your sources must be cited in the main text of your poster (see the template that I prepared for you).
8. Prepare a pdf of your poster. Make sure that you do not exceed the available space and that everything is in the right order. Make sure that your name, affiliation, abstract and paper title are visible. Submit the pdf using Blackboard **by Monday, March 20, not later than 8 am PDT (note the change of the time from PST to PDT)**.
9. Choose two posters prepared by your peers (I will coordinate this process, to make sure that each poster gets an equal number of reviewers). Read the poster. Using the Blackboard forum, give each author suggestions on how they can improve their work (you can also assess, whether everything is accessible and understandable - the problem with posters is that sometimes they look impressive, but they are incomprehensible - you should be able to understand the topic by reading the poster and by looking at the figures and tables without any help from the author - if you don't understand something, this means that probably the poster can be improved). You should complete this action **by Monday, April 3, by 8 am PDT**.
10. Read the suggestions you received from your peers. Address them (either incorporate the suggested changes or challenge them, describing in a separate post why you think those changes would not improve the quality of your poster).
11. Submit your final poster **by Monday, April 17, by 8 am PDT**.
12. Present a short summary of your work (4-5 minutes) **either on Monday, April 24, or Wednesday, April 26**.
13. Write an academic reflection, summarizing your experience. Submit it **by Monday, April 24, by 8 am PDT**.

Additional Notes:

You are free to use any sources. However, you must cite all sources that you used (if not, you will violate the academic integrity standards). It might happen that you will cite non-peer-reviewed sources, like technical documentation of certain libraries or technical blog posts. This is acceptable as long as the non-peer-reviewed sources do not constitute the majority of your bibliography. If you decided to use quotes, remember to use them correctly. Plagiarism (or using sources without proper citations) is a major violation of the university academic integrity standards and will be

reported to the Office of Student Judicial Affairs and Community Standards at USC, see details at https://policy.usc.edu/wp-content/uploads/2022/09/USC_StudentCode_August2022.pdf and to review the possible sanctions and penalties, check the Appendix A: Academic Dishonesty Sanction Guidelines. Finally, when you write your poster, think about your audience. Your main audience is not the instructor, but rather your peers. Write in a way that your colleagues can understand. You can assume certain fluency in math and physics in your readers, but do not assume that your audience has any specific prior familiarity with the topic of your poster.

Poster Grading Criteria:

Grade Component	Meets Expectations (90%-100%)	Approaches Expectations (75%-90%)	Needs Improvement (50%-75%)	Inadequate (0%-50%)
Content	The content matches the topic. The overall quality of the work is high. The topic is challenging. The analysis and the discussion are comprehensive.	The content matches the topic. The overall quality of the work is high - however, there are some minor problems. For example, the discussion part doesn't cover all the important aspects.	The content matches the topic. However, there are some major issues. For example, the analysis, and the discussion are far from comprehensive.	The content does not match the topic; There are major factual mistakes. We detected that *any* part of the text was not written independently (plagiarism).
Support	All claims are supported by relevant citations. Citations are high quality (mostly peer-reviewed sources).	All claims are supported by relevant citations. Citations are low quality (mostly non-peer-reviewed sources).	Not all claims are supported. Citations are low quality (mostly non-peer-reviewed sources).	No citations (note, a simple list of references at the end is not enough)
Clarity	The reader can understand everything without any problem.	There might be a few places in the poster, where the reader might have trouble understanding all the details.	There might be several parts of the poster that might be unclear to the reader.	The reader might have trouble understanding what the poster is about.
Organization	The organization of the poster makes sense given the topic. All key sections are present (in the correct order).	Minor problems with the organization of the poster.	Problems with the organization of the poster might affect the ability of the reader to understand the work (e.g., the reader might feel like sections are not connected, and that the flow of the poster is abrupt or chaotic).	Not all key sections are present, e.g., there is no abstract/introduction or no conclusions or discussion.
Format and Style	The format and style match the journal's guidelines. In other words: the end product looks like an academic poster.	Minor problems with the style and the format.	Major problems with the style and the format.	The format and style of the poster violate the journal's guidelines.

Final Exam

You will be asked to solve similar problems as those that are included in the weekly problem sets. The official date for our exam is Monday, May 8 from 11 am to 1 pm, see also the official schedule at https://classes.usc.edu/term-20231/finals/.

Technological Proficiency and Hardware/Software Required

Technological proficiency can be helpful but is not required. Note, that while some students' projects might require a basic knowledge of a programming language (it could be one of many: R, Python, Julia, Java, or C++) or basic proficiency in some mathematical software (e.g., Mathematica, MATLAB), you can always choose a project that requires no programming skills (where all solutions can be solved analytically or using standard approximation techniques).

Required Readings and Supplementary Materials

We are not going to follow a single book in this class. Contrary, we will try to use at least a couple of them to get exposed to different points of view (each author might present the subject slightly differently). There is plenty of textbooks that you can download free of charge from the USC libraries, https://libraries.usc.edu/, for example:

- ★ Kerson Huang, “Statistical Mechanics” (second edition),
- ★ Mehran Kardar, “Statistical Physics of Particles”,
- ★ Frederick Reif, “Fundamentals of Statistical and Thermal Physics”,
- ★ R. K. Pathria and Paul D. Beale, “Statistical Mechanics” (fourth edition),
- ★ Claudine Hermann, “Statistical Physics Including Applications to Condensed Matter”,
- ★ M. J. R. Hoch, “Statistical and Thermal Physics” (second edition)

and several others (just type “thermodynamics”, “thermal physics”, or “statistical physics” and see the results).

Grading Breakdown

Course Element	Points
Weekly Problem Sets (10 out of 11)	200 (=20x10)
Work Plan	5
Literature Review	10
Project Outline	10
Project Draft	15
Peer Reviews	20
Student Project	60
Final Presentation	10
Academic Reflection	10
Final Exam	60
TOTAL	**400**

Grading Scale

Course final grades will be determined using the following scale.

Final Grade	% of Total Points	Number of Total Points (rounded down)
A	[92% - 100%]	368-400
A-	[89% - 92%)	356-367.9
B+	[86% - 89%)	344-355.9
B	[81% - 86%)	324-343.9
B-	[78% - 81%)	312-323.9
C+	[75% - 78%)	300-311.9
C	[70% - 75%)	280-299.9
C-	[67% - 70%)	268-279.9
D+	[64% - 67%)	256-267.9
D	[59% - 64%)	236-255.9
D-	[55% - 59%)	220-235.9
F	[0% - 55%)	0-219.9

Assignment Submission Policy

Late solutions to quizzes or problem-set solutions will not be accepted. The reason is that just after the deadline (during the following lecture) we will all discuss the correct solutions - thus if you sent me late work, I won't be able to determine whether your solution is original or not.

Because unforeseen situations might happen to anybody, when calculating the final score I will drop one problem set with the lowest score. This means, that you can forget to submit, be late, or purposely omit one problem set (nominally worth 20 points) and still be able to collect up to 400 points (100%) and receive an A (see that in the Grading Breakdown table, I include only 10 problem sets, despite the fact, that you will publish 11 of them).

Make-up Policy and Additional Points

There are only two ways to earn additional points (not included in the grading breakdown above). The first is the Piazza activity (answering other students' questions, sharing helpful notes, etc.; +3 points in total, awarded at the end of the semester). The second is the in-class activity (presenting problem solutions during our Friday session; +1 point per solution [limit to 1 point per week per person]). There will be no other make-up exams, tasks, or problem sets. If you are late or if you fail to submit your work you will not receive any points. Therefore, I encourage you to submit all your work as early as possible (to avoid last-minute internet issues), and always check whether you submitted the right file (it happened a few times in my past classes when a student submitted homework solutions from another class - in every case the mistake was possible because the files

had some generic names, e.g. “homework5.pdf” - therefore, please be extra cheerful when submitting solutions).

Grading Timeline

We will make every effort to grade and return homework within 10 days after it is received. Homework solutions will be discussed during the lectures.

Academic Integrity

You will get an individual grade at the end of this course, thus you shall write answers to any assignments individually as well. As long as the submission period for the problem set is open, you shall not share your solutions. Specifically, on Piazza, before the deadline is due, you are forbidden to explicitly discuss the solutions to the problems. However, if you see that somebody is stuck, you can help your colleague by giving them some hints, explaining the concept you see your colleague struggle with, or suggesting a helpful resource. If you are uncertain whether a particular hint or help is allowed, ask and we will be happy to assess the situation for you.

If you happened to find a solution to one of the homework problems in a textbook, on the internet, or in some other resources, you are obligated to acknowledge this by providing a proper citation. You should also clearly indicate which portion of your solution was inspired by those sources (or people) and what is your individual contribution. I acknowledge that it is hard to unseen things that you have seen, so if you happened to find a similar problem with a solution, you should not pretend that it didn’t happen, just acknowledge the source. I will never punish honest behavior. However, if we find that you copied a part of your solution without providing an appropriate acknowledgment or citation, we will see this as a violation of academic integrity. Note, that using sources without proper citations is a form of plagiarism and as such, it is a major violation of the university's academic integrity standards.

Additional Policies

Names, Gender:

If you have a name and/or pronouns that differ from those in your official USC records, please let me know.

If I am mispronouncing your name, please correct me. I am highly empathetic on this point because my given name (Marcin) is pronounced [ˈmart͡ɕin] using the International Phonetic Alphabet and is often mispronounced in the US.

Mental Health:

If you feel that experiences outside of class are impacting your course performance, please come and talk to me. If you would rather consult someone outside the classroom, you might contact the USC Counseling and Mental Health (https://studenthealth.usc.edu/counseling/) or the Academic Counseling (https://undergrad.usc.edu/services/counseling/) services.

Faculty Liaisons:

All classes in the Department of Physics & Astronomy have an assigned Faculty Liaison (previously called "Course Ombudsman") to serve students as a confidential, neutral, informal, and independent resource when they wish to discuss issues concerning their course without directly confronting their instructor. The Faculty Liaison for this class is Dr. Jack Feinberg, e-mail: feinberg@usc.edu, phone 213-740-1134. You can also find him in SSC 327 (room 327 in the Seaver Science Center).

Equity and Diversity and Title IX:

The Office of Equity and Diversity (OED) and the USC Title IX Office work with faculty, staff, visitors, applicants, and students around issues of protected classes: https://eeotix.usc.edu/. Incidents of bias, hate crimes, and microaggressions can be confidentially reported to: https://studentaffairs.usc.edu/bias-assessment-response-support/.

Accommodations:

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me as early in the semester as possible. If you have registered accommodations with the Disability Services and Programs Office (https://dsp.usc.edu/), please communicate those to me at your earliest convenience so we can discuss your needs in this course. For those on or near campus, DSP is located in STU 301 and is open from 8.30 am to 5.00 pm, Monday through Friday. They can be contacted online or by phone at (213) 740-0776 (Phone), (213) 740-6948 (TDD only), or via email, ability@usc.edu.

Statement for observance of religious holidays

USC's policy grants students excused absences from class to observe religious holidays: http://orl.usc.edu/life/calendar/absences/. In this case, please contact your instructor in advance (at least a week in advance) to agree on alternative course requirements.

Hybrid Classroom Policies

Sadly, the pandemic is not over. We should be mindful of the various risks and challenges present this year. By all means, we should protect our health and the health of other people. While the official recommendation of the university is that we should have classes in person, I will do everything possible to offer you a choice. I designed this class so it can be delivered in a hybrid format. I encourage you to attend the class in in-person. However, whenever you feel like your physical presence could put you or others at risk (e.g., you feel like you had a potential exposure; you feel unwell or you had felt unwell sometime in the last 10 days; you have any conditions that puts you at higher risk; any other reason), you can also choose to participate remotely. I will stream live our lectures, so you will be able to attend them remotely, in a synchronous way. The setup of the classroom will allow you to not only watch the lecture live but also ask questions,

receive answers and interact with other students (at least, via voice). I will do my best to make sure that your learning experience is the same regardless of whether you are in the same room as me, or your participation is remote. All assignments are compatible with the asynchronous learning principles.

Special Accommodations

If you need any special accommodations, tell me. If you are in a situation that prevents you from attending the lectures (either in person or remotely), e.g., the time of the lectures collides with your work or with other obligations (e.g., you are a primary caregiver for a child, elderly parents, or other dependants), please let me know as well.

Camera Policy (For Those Attending Remotely)

The official Camera Policy can be found at
https://www.provost.usc.edu/policy-and-guidelines-for-asynchronous-learning/.

Seeing your faces can help me to gauge if the tempo of the lectures is adequate. Therefore, it would be a great help if you keep your cameras turned on. However, I acknowledge that there might be many reasons why you might wish to keep your privacy. You might also face bandwidth limitations that prevent you from using the camera. I encourage the use of virtual backgrounds and earphones/headsets whenever it is possible to mitigate privacy concerns.

Course Schedule: A Weekly Breakdown

	Topics	Readings	Deliverables
Week 1 January 9 January 11 January 13	Introduction, mathematical background revision.	Concrete Mathematics Chapters 7 and 8.	--- ---
Week 2 --- January 18 January 20	Random variables, sampling, probability theory paradoxes, characteristic functions vs. probability-generating functions.	Concrete Mathematics Chapters 7 and 8. Kardar, Chapter 2	Problem Set 1 (January 20)
Week 3 January 23 January 25 January 27	Introduction to the Markov chain processes. Kolmogorov-Chapman-(Einstein-Smoluchowski) equation. Solving two-state Markov chain problems.		Work Plan (January 23) Problem Set 2 (January 27)
Week 4 January 30 February 1 February 3	Discrete-time Markov chains. Ergodicity theorem and its applications.		Problem Set 3 (February 3)
Week 5 February 6 February 8 February 10	Continous-time Markov chains. Diffusion models and its applications.		Problem Set 4 (February 10)
Week 6 February 13 February 15 February 17	Thermodynamics revision: Thermal equilibrium, work, heat, internal energy, model of an ideal gas, heat engines.	Kardar, Chapters 1 and 3 Huang, Chapter 1 Hoch, Chapters 1 and 2	Literature Review (February 13)

Week 7 --- February 22 February 24	Heat capacity, enthalpy, entropy. *(Midterm Grading Period begins)*	Kardar, Chapters 1 and 3 Hoch, Chapter 3	Problem Set 5 (February 24)
Week 8 February 27 March 1 March 3	Thermodynamic potentials. The entropy and chemical potential of an ideal gas.	Kardar, Chapter 4 Schroeder, Chapters 3 and 5	Project Outline (February 27) Problem Set 6 (March 3)
Week 9 March 6 March 8 March 10	Beyond the ideal gas: Interacting particles, Van der Waals equation.	Huang, Chapter 2	Problem Set 7 (March 10)
Spring recess, March 12-19			
Week 10 March 20 March 22 March 24	Microstates, thermodynamics of a two-level system, negative temperatures. Classical vs. non-classical systems: indistinguishability and the Pauli exclusion principle.	Kardar, Chapter 4 Huang, Chapter 6	Poster Draft (March 20) Problem Set 8 (March 24)
Week 11 March 27 March 29 March 31	The microcanonical and the canonical ensembles. Model of a heat transfer. Einstein's model of specific heat. *(Midterm Grading Period ends)*	Hoch, Chapter 4 Pathria, Chapters 1-2	Problem Set 9 (March 31)
Week 12 April 3 April 5 April 7	Canonical vs. grand canonical ensemble. Debye Model For Specific Heat. The statistics of a non-interacting quantum gas. Models of an electron gas and a photon gas.	Huang, Chapter 7 Pathria, Chapters 3-4	Peer Review Reports (April 3) Problem Set 10 (April 7)
Week 13 April 10 April 12 April 14	Ising model. Universality, critical phenomena, order parameter, critical exponent, the role of dimensionality. Elements of condensed state physics: Landau theorem and an introduction to the mean-field theory.	TBA	Problem Set 11 (April 14)
Week 14 April 17 April 19 April 21	Buffer (in case we got slower than the plan) or some special topics, e.g., Monte Carlo simulations, Black body radiation, or Bose-Einstein condensation.	TBA	Poster Submission (April 17)
Week 15 April 24 April 26 April 28	Final project presentations.	TBA	Academic Reflection (April 24) Final Presentation (April 24-28)
Final Exam May 8	Official Examination Day is Tuesday, May 8 from 11 a.m. to 1 p.m. *(Final Grading Period ends on May 16)*		

Note that the plan of the topics (especially the order) is provisional and can be modified during the semester. A plan should aid us, but should not restrict us. If I notice that another order (or another topic) would work better for you, I will adjust the plan of topics accordingly.

Student Hours (also known as Office Hours)

I will host one 60-minute meeting per week. Those Student Hours (also known as Office Hours) are a dedicated time when you can come to ask questions and resolve confusion about course material, as well as discuss career and educational goals as they relate to this course.

No special appointment is needed, however, if you sent me an email a day earlier, announcing a type of question you have, I might be able to prepare a better answer for you in advance. If you have any sensitive questions, you can also contact me via mail, mjabram@usc.edu and we can schedule a 1-on-1 meeting via Zoom outside the student hours period. You can also always chat with me after the class.

Improving the Syllabus

If you noticed any typos or mistakes in the syllabus, or if you find any part confusing or unclear, please let me know (either in class, after class, during office hours, writing on Piazza, or via e-mail). I put a great deal of effort into proofreading everything, but typos and omissions are still possible, therefore I would appreciate yours. When approaching this syllabus, we should follow the spirit of the law, not the letter of the law - meaning, a typo or clumsy wording should not be an excuse to create any loopholes if otherwise, the general intent of the document is easy to infer. Nevertheless, I don't want to have any students confused about what is expected from them - so if you find any ways to improve this syllabus, please tell me.

Support Systems

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
uscsa.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information