Fall 2022 Syllabus

Physics 528: Statistical Mechanics

The statistical foundations of thermodynamics. Micro-canonical, canonical, and grand canonical ensembles. Quantum statistics. Ideal Bose and Fermi systems. Fluctuations and linear-response theory. Phase transitions and critical phenomena.

This is a graduate-level course on statistical mechanics. Some background in undergraduate statistical physics at the level of e.g., Kittel and Kroemer, "Thermal Physics" or Reif, "Statistical and Thermal Physics" is assumed.

Each student must investigate an advanced topic in statistical mechanics to be agreed upon with the instructor, and present their findings in a 15-minute oral presentation.

Professor: Charles A. Stafford
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Web: `www.physics.arizona.edu/∼stafford/teaching.html`
and `d2l.arizona.edu`

Course modality:

This class is scheduled to be taught in the IN-PERSON modality. Following UA and CDC guidance, masks covering nose and mouth are recommended but not required until further notice.

Meeting times and location: TuTh 9:30–10:45am in Bio. Sci. W 219.

Office hours: Wednesday 3-4pm (tentative). Office hours will be held via Zoom until further notice at `https://arizona.zoom.us/j/81750438387`.

Required Texts:

Mehran Kardar, "Statistical Physics of Particles" (Cambridge University Press, 2007); "Statistical Physics of Fields" (Cambridge University Press, 2007). Both textbooks are available as Ebooks from the UA Library, but access to "Statistical Physics of Particles" is limited.

Additional suggested references:

Landau and Lifshitz, "Statistical Physics, Part 1" (3rd Edition, Pergamon Press, 1980).

R.P. Feynman, "Statistical Mechanics" (Benjamin/Cummings, 1972).

David Tong, "Lectures on Statistical Physics"
`http://www.damtp.cam.ac.uk/user/tong/statphys.html`

Pathria and Beale, "Statistical Mechanics" (3rd Edition, Elsevier, 2011). Comprehensive textbook, but uses non-standard notation!

Learning Outcomes:

- Use the micro-canonical, canonical, and grand canonical ensembles to describe the statistical behavior of a system, and explain the experimental conditions under which each ensemble is applicable.
- Derive the laws of thermodynamics from microscopic principles using statistical arguments.
- Use the density matrix to describe the statistical state of a quantum system.
- Compute the thermodynamic properties of a system of identical quantum particles.
- Analyze the equilibrium fluctuations of a system, and relate them to linear-response transport coefficients.
- Use the concept of broken symmetry to describe different phases of matter and the transitions between them.

Exams and Assessments:

The course grade will be based on the cumulative score determined as follows:

Homework: 10% (weekly, lowest two scores dropped)
Midterm 1 (Sept. 29): 20%
Midterm 2 (Nov. 3): 20%
Project (15-min. oral presentations Date(s): TBD): 15%
Final Exam (8-10am Tuesday December 13): 35%

Grading scale and policies

The course is graded on a curve, based on the cumulative score. The minimum cumulative percentages necessary to obtain the following letter grades will be approximately (but not greater than): $A \geq 85\%$, $B \geq 70\%$, $C \geq 55\%$, $D \geq 40\%$.

A missed exam due to an excused absence or a planned absence that is documented ahead of time by the student and approved by the instructor may be substituted with a make-up exam or an alternative arrangement at the discretion of the instructor.

All work to be considered for a regrade must be submitted at most one week after it has been returned to the student.

Homework:

Homework assignments will be challenging and may be time-consuming. You may work in groups on homework problems.

No excuses accepted for missed homework, but the lowest two homework scores will be dropped.

Classroom attendance:

- If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
- Notify your instructor(s) if you will be missing a course meeting or an assignment deadline.
- Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments. Please communicate and coordinate any request directly with your instructor.
- If you must miss the equivalent of more than one week of class, you should contact the Dean of Students Office:
  `DOS-deanofstudents@email.arizona.edu`
  to share documentation about the challenges you are facing.
- Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus.
- If you test positive for COVID-19 and you are participating in on-campus activities, you must report your results to Campus Health. To learn more about the process for reporting a positive test, visit the Case Notification Protocol.
- COVID-19 vaccine is available for all students at Campus Health.
- Visit the UArizona COVID-19 page for regular updates.

Life challenges:

If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at (520) 621-2057 or `DOS-deanofstudents@email.arizona.edu`.

Physical and mental-health challenges:

If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520) 621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline,

call (520) 621-3334.

Graduate Student Resources

University of Arizona's Basic Needs Resources page:
`http://basicneeds.arizona.edu/index.html`.

University Policies:

All university policies related to a syllabus are available at:
`https://academicaffairs.arizona.edu/syllabus-policies`.

Schedule of topics, exams, and assigned reading in *Kardar, Statistical Physics of Particles (I); Statistical Physics of Fields (II)*:

Aug. 23, 25 Introduction: The Laws of Thermodynamics, I: Ch. 1

Aug. 30, Sept. 1, 6 Micro-canonical ensemble, I: Ch. 4

Sept. 8, 13, 15 Canonical ensemble, I: Ch. 4

Sept. 20, 22 Grand canonical ensemble, I: Ch. 4

Sept. 27–Oct. 13 The density matrix and quantum statistics, I: Ch.6

Sept. 29 Midterm 1

Oct. 18, 20 The Fermi gas, I: Ch. 7

Oct. 25, 27 The Bose gas, I: Ch. 7

Nov. 1, 8 Fluctuations and broken symmetry, II: Ch. 1-2

Nov. 3 Midterm 2

Nov. 10, 15, 17 Phase transitions and critical phenomena, II: Ch. 1-2

Nov. 22, 29 Fluctuation-dissipation theorem, II: Ch. 9

Dec. 1, 6 Linear thermoelectric response

Dec. 5, 7 Student presentations

Dec. 9 Reading Day (no class activities)

Tuesday, December 13, 8-10am Final Exam

Note: The information contained herein is subject to change with reasonable notice from the instructor. Version 8-17-2022.