Thermal and Statistical Mechanics with Laboratory

PHYS 321/323 • Fall 2025

Centenary College of Louisiana

Instructor	Dr. David Kordahl	**Email**	dkordahl@centenary.edu
Office	Centenary Square 203B	**Lecture**	TR 8:20–9:35 am, Mickle Hall 110
Office Hours	T 9:40 am–12:00 pm W 9:30–11:00 am F 11:00 am–2:00 pm	**Lab**	R 1:00–4:00 pm, Centenary Square

Course at a Glance

Lecture Course	PHYS 321: Thermal and Statistical Mechanics
Laboratory Course	PHYS 323: Thermal and Statistical Mechanics Laboratory
Lecture Text	Blundell and Blundell, *Concepts in Thermal Physics*, 2nd ed.
Lab Text	Written materials from various sources, provided through Canvas
Prerequisites	PHYS 105/115 (Physics II + Lab) and MATH 201 (Calculus II)
Corequisites	PHYS 321 and PHYS 323 are designed to be taken together

Course Description

Thermal and Statistical Mechanics bridges the gap between microscopic models of the world, built from particles and their interactions, and macroscopic descriptions involving temperature, pressure, energy, entropy, and other quantities defined for large numbers of particles. The course develops the relationships among heat, work, internal energy, entropy, and temperature, leading toward the laws of thermodynamics and their technological and scientific applications.

The course also introduces the statistical foundations of thermal physics. Even before quantum mechanics, thermal physics revealed that probability and statistics are central to physics. We will use probability, multiplicity, the Boltzmann factor, partition functions, and quantum statistics to understand how microscopic possibilities give rise to macroscopic behavior.

The accompanying laboratory explores experimental applications of thermal and statistical physics. Students investigate gas laws, thermometry, thermal expansion, heat transfer, heat engines, calorimetry, phase changes, and thermal radiation. Many of the labs require iteration: trying a measurement, interpreting the result, improving the procedure, and using the revised result to deepen physical understanding.

Learning Goals

By the end of PHYS 321/323, students should be able to:

- state the zeroth, first, second, and third laws of thermodynamics;
- define temperature in practical and theoretical terms, and distinguish heat, work, and internal energy;
- apply the equipartition theorem to estimate average energy per degree of freedom;

- describe the operation and efficiency of ideal heat engines, including the Carnot cycle;
- define entropy macroscopically and statistically, including the relation $S = k_B \ln \Omega$;
- calculate multiplicities of simple systems, including coin flips and Einstein solids;
- apply the Boltzmann factor to compute probabilities and average energies;
- use partition functions to connect microscopic states with thermodynamic quantities;
- distinguish when Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics are appropriate;
- collect and analyze experimental data from thermal physics experiments;
- connect experimental measurements with thermodynamic and statistical models.

Relationship Between Lecture and Lab

The lecture course develops the conceptual and mathematical framework of thermal and statistical mechanics. The laboratory course asks students to investigate the same physical ideas experimentally, using measurement, uncertainty, data analysis, and physical interpretation.

The laboratory begins with standard thermal physics experiments and moves through applications involving heat engines, calorimetry, phase change, and thermal radiation. The combined course emphasizes the relationship between microscopic models, macroscopic observables, and experimental evidence.

Assessment

PHYS 321: Thermal and Statistical Mechanics

The lecture grade is based on homework, reflection questions, three unit tests, a cumulative final exam, and a final project. The final project applies course material by exploring a theoretical point of interest or by carrying out an experimental study, and is reported in a poster format appropriate to the Centenary Research Conference.

Component	Weight
Homework	25%
Reflection Questions	5%
Tests 1–3	36%
Final Exam	20%
Final Project	14%

PHYS 323: Thermal and Statistical Mechanics Laboratory

The laboratory grade is based on equally weighted lab activities. Written materials are provided through Canvas, and each lab asks students to connect experimental procedure, data analysis, and physical interpretation.

Letter Grades

Grade	Percentage Range
A	90–100%
B	80–89%
C	70–79%
D	60–69%
F	below 60%

Detailed Lecture Schedule

This schedule records the specific lecture topics and approximate textbook coverage. The pacing may be adjusted as needed, but the table reflects the intended structure of the course.

Date(s)	Reading	Lecture Topics
Aug. 26	Ch. 1	Introduction
Aug. 28	Ch. 2	Heat
Sept. 2	Ch. 3	Probability
Sept. 4	Ch. 4	Temperature and the Boltzmann factor
Sept. 11	Ch. 5	The Maxwell-Boltzmann distribution
Sept. 16	Ch. 6	Pressure
Sept. 18	Review Sheet 1	Review 1
Sept. 23		Test 1
Sept. 25	Ch. 11	Energy
Sept. 30	Ch. 12	Isothermal and adiabatic processes
Oct. 2, 7	Ch. 13	Heat engines and the second law
Oct. 14, 16	Ch. 14	Entropy
Oct. 21	Ch. 18	The third law
Oct. 23	Review Sheet 2	Review 2
Oct. 28		Test 2
Oct. 30	Ch. 19	Equipartition of energy
Nov. 4, 6	Ch. 20	The partition function
Nov. 11, 13	Ch. 21	Statistical mechanics of an ideal gas
Nov. 18	Ch. 23	Photons
Nov. 20	Ch. 24	Phonons
Dec. 2	Review Sheet 3	Review 3
Dec. 4		Test 3
Dec. 9, 11	Final Review Sheet	Course review
Dec. 17		Final Exam, 8:00–11:00 am

Detailed Laboratory Schedule

The laboratory sequence explores basic experimental applications of thermal and statistical physics. Each activity reinforces concepts introduced in lecture while developing experimental, analytical, and interpretive skills.

Lab	Focus
Boyle's + Charles's law	Experimental determination of ideal gas laws
Thermometers	Constructing thermometers using gas expansion and the Seebeck effect
Thermal expansion	Observing the coefficient of thermal expansion of metals
Thermal conductivity	Distinguishing the thermal conductivity of various materials
Heat engines	Exploring the steps that allow heat to be turned into work
Calorimetry	Measuring heat absorption and specific heat with calorimeters
Latent heat	Observing the latent heat of fusion and vaporization
Thermal radiation	Empirically observing the Stefan-Boltzmann law

Possible Final Projects

Students may choose a final project topic in consultation with the instructor. Possible projects include experimental, computational, and theoretical investigations such as:

- building or characterizing a simple radio telescope;
- measuring Boltzmann's constant from Brownian motion;
- measuring the heat-capacity ratio $\gamma = c_p/c_V$ for a gas;
- observing the thermal expansion of water using optical interference;
- measuring mechanical properties of gelatin through stress-strain analysis;
- estimating the effective temperature of the sky;
- determining surface tension from droplet shape;
- modeling the physics of global warming;
- simulating the Ising model of magnetism and phase transitions;
- exploring Schelling's segregation model as an example of statistical or "social" physics.

Course Policies

Academic Honesty and the Honor Code

All students at Centenary are bound by the Honor Code. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation. It is not considered cheating in this course to share suggestions on assignments with peers, although the final work must ultimately be one's own. Reflection questions can be discussed, but final versions are expected to be completed by students on their own.

Internet resources, including AI tools, are acceptable to use as aids, but only as help along the way. If such resources are consulted, students are required to document how they were used. Copying the work of others, whether AI or human, is prohibited.

Students are required to write the following pledge at the end of any examination or assignment:

> *I have neither given nor received unauthorized aid on this examination (paper), nor have I seen anyone else do so.*

If any student has received aid or suspects others of violating the Honor Code, the following clause is to be added to the pledge: "...except as I shall report immediately to the Honor Court." The complete pledge must be written and signed by the student, shall not be abbreviated, and should never be written until the test or paper has been completed for submission. Students are bound by the Honor Code even if they fail to write the pledge on their assignment or examination.

Attendance

Attendance is required. However, students are expected not to jeopardize their own health or anyone else's health to attend class. Illness-related absences will be excused. There is no penalty for missing class if students proactively communicate with the professor and complete all required work. If a qualified professional deems remaining in classes and fulfilling the necessary requirements impossible, alternatives will be sought in coordination with Student Support Services.

For PHYS 321, more than six unexcused absences will lead to a failing grade in the course. For PHYS 323, more than three unexcused absences will lead to a failing grade in the course.

Disability Accommodations

It is the policy of Centenary College to accommodate students with disabilities, pursuant to federal law, state law, and the College's commitment to equal educational opportunities. Any student with a disability who needs accommodations should inform the instructor at the beginning of the course. Students with disabilities need to contact Disability Services, a division of the Center for Teaching and Learning, located in the Learning Commons on the second floor of Magale Library. Disability Services can be reached by telephone at 318-869-5738.

Diversity Statement

Centenary College of Louisiana values human diversity in all its richly complex and multi-faceted forms, whether expressed through race and ethnicity, culture, political and social views, religious and spiritual beliefs, language and geographic characteristics, gender, gender identities and sexual orientations, learning and physical abilities, age, and social or economic classes.