Thermodynamics and Statistical Physics, **Physics-4XXX** **Fall 2024**

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pre-requisite: Prerequisites/Corequisites: PHYS 2210; Also MATH 2400 and MATH 2010.

course objective: Learning fundamental concepts and developing problem solving skills in thermodynamics and statistical mechanics

learning outcomes: Students will be able to employ fundamental physics concepts and theories to set up and formulate problems in thermodynamics and statistical mechanics. Students will be able to apply differential and integral calculus, differential equations, and elementary concepts form probability theory to solve problems in thermodynamics and statistical mechanics.

text: R.K. Pathria, *Statistical Mechanics*, 4th ed.

Additional useful resources on the web: http://stp.clarku.edu/
in particular, Gould/Tobochnik lecture notes: http://stp.clarku.edu/notes/

Meetings: twice a week (TBD)

Grading: **based on Homeworks (roughly every two weeks)**

Letter Grades:
A: 92-100%, **A-**: 90-91.999%; **B+**: 87-89.999%, **B**: 82-86.999%, **B-**: 80-81.999%;
C+: 77-79.999%, **C**: 72-76.999%, **C-**: 70-71.999%; **D+** : 67-69.999%, **D**: 60-66.999%;
F: 0-59.999%

Graded material:
It is your responsibility to check graded HWs, and to bring any discrepancies/contests to my attention. No contests will be considered after a week following the return/posting of scores of the material. Further, you must keep all your graded HWs and exams until the end of the semester in case there are any clerical errors (this may be a non-issue now, if all submitted assignments now will be saved and graded on LMS).

Homework assignments:
Homework assignments will be posted roughly every two weeks. Late homework will not be accepted without prior approval from the instructor.

Covered material:
The principles and physical applications of classical thermodynamics are developed. Basic concepts in classical and quantum statistical mechanics are introduced and their relations to thermodynamics are developed.

Academic Integrity Policy:
Academic integrity is one of the cornerstones of RPI. Students taking courses at RPI have a right to expect that their work will be evaluated fairly with respect to other students. They have a right to expect that other students will not attempt to enhance their own grades or the grades of their friends by cheating. Professors have a right to expect that their students are honest and submit work reflecting their own efforts. In an atmosphere of academic integrity, students and professors are on the same team trying to achieve the same learning objectives.

Collaboration and discussion is allowed and encouraged in homeworks. **However, you must carry out, write up, and turn in your own solutions. On exams, you're on your own and not allowed to discuss anything with your classmates.** Thus, don't copy someone else's solutions, and don't cheat on exams. If I suspect you of either, I'll ask for an explanation. If your explanation is unsatisfactory, you'll be given a grade of zero and reported to the Dean of Students. If this happens more than once, you will be given an *F* for the course.

Using **artificial intelligence (AI)** to generate text or problem solutions is prohibited. Submission of work generated by AI will be considered a violation of academic integrity.

Diversity:
At RPI we support an inclusive learning environment where diversity and individual differences are understood, respected, appreciated, and recognized as a source of strength. I expect that students, and faculty will respect differences and demonstrate diligence in understanding how other peoples' perspectives, behaviors, and world views may be different from their own. Students in this class are encouraged to speak up and participate during class. Because the class will represent a diversity of individual beliefs, backgrounds, and experiences, every member of this class must show respect for every other member of this class.

Accommodations:
We all learn differently, and we want every student to succeed in the course. If you have a learning need or disability, please contact Student Life office so that they can provide the appropriate documentation for accommodations.

COVID-19 Notice:
Rensselaer is committed to the health and safety of all students. Rensselaer will continue to monitor all new developments with COVID-19 and determine a best course of action to uphold the well-being of its students while maintaining a high quality educational experience.

Covid-19 measures can change as they will be reviewed and updated as circumstances change.
Please check the RPI Covid-19 policy website: https://covid19.rpi.edu/

PHYS-4XXX Thermodynamics and Statistical Physics (Independent Study) *4 credit hours*
Course Topics:

Review and fundamentals of thermodynamics:
Equation of state, I. and II. laws of thermodynamics, basic thermodynamic processes, thermodynamic potentials.

Review of probability and statistics:
Basic concepts of probability, probability densities, generating function, independent random variables, the central limit theorem.

The Gamma function and the factorial, the saddle point method, asymptotic expansion of the Gamma function (Sterling approximation); The area and volume of d-dimensional sphere for arbitrary d.

Statistical basis of thermodynamics and elements of ensemble theory:
Partition function in the microcanonical, canonical, and grand-canonical ensembles, connection to the corresponding thermodynamic potentials.

Quantum statistical physics:
The density matrix, thermodynamic and quantum mechanical averages, indistinguishable particles, the density matrix for ideal Fermi and Bose gas in coordinate representation, number representation, ideal quantum gases in the grand-canonical ensemble, classical limit of ideal quantum gases and corrections to it.

Degenerate quantum gases:
Degenerate electron gas, the Sommerfeld expansion, the specific heat of degenerate Fermi systems (electrons in metals), Pauli paramagnetism; the Bose-Einstein condensation; black-body radiation (photons); Lattice vibrations (phonons) and the Debye interpolation: low temperature behavior of solids.

Interacting systems:
The Van der Waals gas:
Cluster expansion for an interacting classical gas, phase transition and critical exponents in the Van der Waals gas; density correlations and response functions in many-particle systems, sum rule; the lattice-gas approximation and its equivalence to the Ising model.
Magnetic phase transitions and the Ising model:
Mean-field approximation and critical exponents, Landau theory of continuous phase transitions, linear response theory, and static susceptibility sum rule. Exact solution in one dimension for the Ising model; the transfer matrix method.

Possible Optional Materials:
Coarse-graining and the Landau theory for inhomogeneous systems. Scaling Hypothesis.
Real-Space Renormalization Group Transformation for the Ising Model
Diffusion, random walk, and Brownian motion.