MAT 501 Thermodynamics
Fall 2020

Moderator:

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Associates:

Course Data:

Hours:	Mon 11.40-13.30/Thu 11.40-12.30 (A); 12-40-13.30 (B).
Office hours:	*TBA*

Textbooks:

Callen, H.B., *Thermodynamics and an Introduction to Thermostatistics*, Wiley, 2nd Ed., 1985. QC311 .C35 1985.
Fermi, E., *Thermodynamics*, Dover, 1956. QC311 .F47 2010,

References:

Dill, K.A., Bromberg, S., and Stigter, D., *Molecular Driving Forces*, Statistical Thermodynamics in Biology. Garland Science, 2nd Ed., 2011. QC311.5 .D55 2011.
Reif, F., *Fundamentals of statistical and thermal physics*. McGraw-Hill, 1965. QC175 .R44 1965.
Zemanksy, M.W. and Dittman, R.H., *Heat and Thermodynamics.* 7th ed. McGraw-Hill, 1997.

Weeks Commencing/Topics:

Oct 5, 12 Part I

Thermodynamic systems
Piston-gas as a system
- Idealizations and assumptions about the piston, the gas, and the environment

Gases
- Ideal/perfect – what are the assumptions?
- Laws – observations/experiments
- Maxwell's "kinetic" theory
- Molecular interactions – radial distribution function*

States – a generalization: **f**(*p*, *V*, *T*, *N*) = 0 – how do we know that these variables suffice to describe a state?
Work done

Oct 19, 26 Part II

Internal energy
- Isolated systems – microcanonical formalism

Heat
- Interactions with the environment – Isothermal, adiabatic, and all else
- Canonical formalism – is there a pure mechanical correspondence? Ergodicity*

The first law
- Gases
- Expansions – what variables are fixed? Reversibility for each step or whole process?
- The maximum work theorem
  - Expansion for different gases* Different piston constructs/shapes*

Nov 2, 9 Part III

The second law
I have not used "entropy." Why not talk about entropy first?
Cycles
- Carnot – why Carnot? Are there other cycles? A general form of cycles*
- Microscopic/nanoscopic machines – what makes them different? Are they really different?

Finally, entropy
Szilard machine*

Can we relate the thermodynamic entropy to information (Shannon) and Kolmogorov entropy?
Maxwell's demon.

Nov 16 Recapitulation and the **Midterm**

Nov 23, 30 Part IV

Thermodynamic potentials
- Which variables do you want to keep constant?
- Are there any variables that are not "readily "measurable?

Helmholtz and Gibbs free energy
- Legendre transformations – that may give a helping hand for other potentials in your research
- The Maxwell relations
- Extremum principles – Maupartius did it first! (A simple calculus of variations problem*)

The Nernst postulate and the Third Law

Dec 7, 14 Part V

Stability of Thermodynamic Systems

Explain, why
- Addition of heat to a stable system must increase its temperature – volume Watson, how about volume?
- Isothermal expansion of a stable system must decrease its pressure

Revisit the original "intuitive" arguments about the cycles

Revisit the first and the second laws

Le Châtelier's principle and Braun's amendment

Dec 21, 28 Part VI

Phase diagrams
- Stabilities of phases
- Phase boundaries and typical phase diagrams

Phase transitions
- First-order phase transitions in single component systems
- The discontinuity (of the volume – the lever rule; in the entropy – latent heat)
- Phase loci – The Clapeyron equation
- First order transitions in multicomponent simple systems – Gibbs' phase rule
- Phase diagrams for binary systems
- Tisza's and Ehrenfest's theories of second-order phase transitions

Jan 4

Fluctuations and Critical phenomena*
- Work and heat fluctuations – (Jarzynsky and Crooks theorems)
- Order parameters and critical exponents. Scaling and universality.

Class Policies

Course will be online.

Hours to be synchronized: 1.5 hours/week (75 min/week) for whole class (all recorded)
1 hour*2/week (50min*2/week) for 2 times*20 (for each group, both recorded)

Hours to be asynchronized: 0.5 hours/week (25 min/week) for whole class (notes/viewgraphs/videos will be available)

Grading

Break-out room quizzes: 6 of them, one for each "mid-part;" total is for 12% of the final grade

Synchronous quizzes: 6 of them, one for each "part;" total is for 24% of the final grade

Midterm: 28% of the final grade

Final exam: 36% of the final grade; covers all the material