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.

(*) Topics, a thorough coverage of which, go beyond the scope of the course.

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: (5-best/6) of them, one for each “mid-part;” total is for 15% of the final grade
Synchronous quizzes: (5-best/6) of them, one for each “part;” total is for 20% of the final grade
Midterm: 30% of the final grade
Final exam: 35% of the final grade; covers all the material