Unit 1: First and second laws

- Given Ω, compute S
- Compute the change in internal energy in an inelastic collision
- Given entropy function, find equilibrium condition
- Compute the entropy change of a gas when the volume changes
- Equilibrium condition for two volumes with a movable, but impenetrable barrier

Unit 2: S, U, T, C at constant volume

- Given $S(U)$, compute the temperature.
- Given $S(U)$, compute the heat capacity
- Given heat capacity, compute change in entropy upon a change in temperature at constant volume: $\delta S = \int C(T)/T dT$
- Given heat capacity, compute change in energy upon change in temperature at constant volume: $\Delta U = \int C(T) dT$
- Know how to convert between specific heat, molar specific heat, and heat capacity
- Given Q and constant heat capacity, compute temperature change: $\Delta T = \int 1/C dQ = \Delta Q/C$
- Two blocks with known heat capacity (may be constant or not) and different temperatures come to equilibrium; what's the final temperature?

$$1/T = dS/dU \tag{1}$$
$$\rightarrow U(T) \tag{2}$$
$$C_V = dU/dT \tag{3}$$

Unit 3: Ideal gases

- Apply $pV = NkT$.
- Compute work done using $W_{\text{by}} = \int p dV$
- Apply first law to get Q from U and W and combinations.
- Apply techniques from Units 1 and 2 on ideal gases

- Given $S(V)$, find equilibrium condition using $p/T = \partial S/\partial V$

Unit 4: Equipartition

- Equipartition: $U = \alpha NkT + \text{constant}$
- $\alpha = \frac{N_{\text{DOF}}}{2}$
- Heat capacity from equipartition
- Apply Units 1 and 2 on systems for which equipartition applies

Unit 5: Boltzmann factor

- Concept of a system and environment
- Quantum simple harmonic oscillator: energies are $0, \varepsilon, 2\varepsilon, \ldots$
- Two-state systems: energies are $0, \varepsilon$
- Entropy of n SHOs with q quanta: $\Omega = \binom{n+q-1}{q}$
- Given relative energies E_1, E_2, compute the ratio of probabilities $\frac{P(s=1)}{P(s=2)} = e^{-(E_1-E_2)/kT}$
- Given energies $\{E_i\}$, find probability of state i with energy E_i: $P(i) = \frac{e^{-E_i/kT}}{\sum_j e^{-E_j/kT}}$
- Degenerate systems: perform above with states that have the same energy

Unit 6: Boltzmann applications

- Entropy of a two-state system as a function of temperature (0 at $T = 0$, flat at $T \to \infty$)
- Compute $U(T)$ for a two-state system in a bath
- Compute $C(T)$ for a two-state system in a bath
- Compute relative pressure using Boltzmann atmosphere: $p(h)/p(0) = e^{-mgh/kT}$
- Qualitative entropy as a function of temperature for a single harmonic oscillator (slope decreases as a function of T)
- Einstein solid as a collection of harmonic oscillators

Unit 7: Thermodynamic processes

- Quasi-static processes: in equilibrium
- Compute work done in a cycle from a pV diagram
- Determine sign of work done from a pV diagram
- Use Carnot efficiency to compute maximum efficiency of an engine connected to reservoirs
- Compute entropy change of reservoir and working material as heat exchanges
- Use $\Delta S = \int \frac{1}{T} dQ$ for quasistatic processes.

Unit 8: Reversible processes

- Reversible means that $\Delta S_{\text{tot}} = 0$
- Isothermal and adiabatic are reversible
- Compute why isothermal is reversible (entropy of environment and system change the same amount)
- Using coefficient of performance for refrigerators

Unit 9: Helmholtz free energy

- Given U and S, minimize F to find equilibrium
- Given U and S functions, compute the work obtainable from a system out of equilibrium connected to a bath (hot brick in a cool room, gas unequally distributed)

Unit 10: Chemical potential

- Given U and S at some temperature T, compute the chemical potential.
- Use an equilibrium condition for the number of particles to find the density of particles under a given condition

Unit 11: Gibbs free energy

- Manipulate fundamental relation at fixed p or T or similar to find equilibrium conditions/equations of state.
- Know to use G at fixed T, p, F at fixed T, V.
- $G = \mu N$, know that at fixed T, p systems are in one phase or another.
- Latent heat is mentioned, but no hw assignments.
- Vapor pressure

Unit 12: Phases

- Read a phase diagram; know that the chemical potential of particles in the phase is lowest when phase is stable.
- Higher entropy phases have μ decrease more with higher temperature.
- Higher density phases have μ decrease more with higher pressure
- From latent heat, compute change in entropy
- Compute how altitude changes the boiling point of water.

Unit 13: Thermal radiation

- Know that higher temperature means that the peak of the radiation is maximum at shorter wavelengths/higher frequency
- Compute the total power emitted from an object of surface area A and temperature T.
- Compute equilibrium temperature due to radiative heating.