Phys 727: Thermodynamics and Statistical Mechanics
Spring 2025 – Equations to Remember for Test 1

The test will consist of conceptual questions or simple exercises on all subjects we have covered in class so far, and short problems on thermodymanics topics. Students will be expected to remember the definitions and other equations listed below, and to be familiar with all concepts and explanations introduced in class, be able to define them and explain their significance (not all of these are listed below).

The numbers on the left side of the list correspond to the lecture notes where the topics are covered.

Thermodynamics

01	Basic concepts	extensive and intensive variables, space of states, different types of equilibrium and types of processes
	Fundamental relations	$\Delta E = Q + W$ and statements of the three laws $T := (\partial S/\partial E\|_{\vec{X}})^{-1}$ and identity $\mathrm{d}E = T\,\mathrm{d}S + \vec{f}\cdot\mathrm{d}\vec{X}$ [e.g., $T\,\mathrm{d}S - p\,\mathrm{d}V + \ldots$] when $\delta Q = T\,\mathrm{d}S$ and $W = \int \vec{f}\cdot\mathrm{d}\vec{X}$ [e.g., $-\int p\,\mathrm{d}V$]
02	Potentials	$F := E - TS$ $H := E + pV$ $G := E - TS + pV$ $\Omega := E - TS - \mu N$ plus the corresponding forms of the fundamental identity and expressions for first-order quantities; e.g., $\mathrm{d}F = -S\,\mathrm{d}T - p\,\mathrm{d}V$ and $p = -\partial F/\partial V\|_T$
	Other relations	$E = TS - pV + \sum_i \mu_i N_i$ $G = \sum_i \mu_i N_i$
03	Response functions	be able to derive Maxwell relations from the thermodynamic identity $C_V = \delta Q/\delta T\|_V = T\,(\partial S/\partial T)_V$ $C_p = \delta Q/\delta T\|_p = T\,(\partial S/\partial T)_p$ $\kappa_T = -V^{-1}\,(\partial V/\partial p)_T$ $\kappa_S = -V^{-1}\,(\partial V/\partial p)_S$ $\gamma = C_p/C_V$ (also κ_T/κ_S)
04	Ideal gas	$pV = Nk_{\mathrm{B}}T$ $E = (f/2)\,Nk_{\mathrm{B}}T$
	Non-ideal gas	virial expansion: $p = k_{\mathrm{B}}T\rho\left[1 + B_2(T)\rho + \ldots\right]$
	Van der Waals fluid	$(p + aN^2/V^2)(V - Nb) = Nk_{\mathrm{B}}T$, $E = (f/2)\,Nk_{\mathrm{B}}T - a/V$ (there is no need to remember the van der Waals equations of state, they are here for completeness)

Statistical Mechanics

07	Phase space	volume $\omega(R) = \int_R \mathrm{d}\omega$ and number of states $\Omega(R) = \int_R \mathrm{d}\Omega$ for $R \subset \Gamma$, with $\mathrm{d}\omega = \mathrm{d}^{3N}q\,\mathrm{d}^{3N}p$ and $\mathrm{d}\Omega = (h^{3N}N!)^{-1}\mathrm{d}^{3N}q\,\mathrm{d}^{3N}p$ for N indistinguishable particles with continuous variables in 3D
	Distribution functions	meaning of $\rho : \Gamma \to \mathbf{R}$ and use, $\langle A\rangle = \int \mathrm{d}\Omega\,\rho(q,p)\,A(q,p)$; continuity equation $\partial\rho/\partial t + \vec{\nabla}\cdot(\rho\vec{v}) = 0$, and time evolution $\mathrm{d}\rho/\mathrm{d}t = 0$, $\partial\rho/\partial t = -\{\rho, H\}$
08	Microcanonical state	the equal probabilities assumption and its justification; form of $\rho(q,p)$ thermodynamics is obtained from the Boltzmann entropy $S(E,\vec{X}) = k_{\mathrm{B}}\ln\Omega_{\vec{X}}(E,\Delta)$ and T^{-1} as $\partial S/\partial E$

Other Physics

Commonly used definitions, expressions, equations from other areas of physics, such as Poisson brackets; the Hamiltonian formalism for dynamics and form of H for a free particle, a harmonic oscillator, and a magnetic dipole in a magnetic field.