Study Guide for First Midterm Test, Phys 404, Spring 2007

ver. 1.1

Heat, work (on or by), [internal] energy, temperature, heat capacity, latent heat, entropy, enthalpy

3 basic models: paramagnet (2-state), Einstein solid, ideal gas
– What N and q (or U) mean for each,
and the resulting multiplicities $\Omega(N,...)$
– Two weakly interacting systems, thermodynamic limit
– Applicability of these models to other physical systems

$$\Omega(N, N_\uparrow) = \frac{N!}{N_\uparrow!\left(N - N_\uparrow\right)!}$$

$$\Omega(N, q) = \frac{(q + N - 1)!}{q!\left(N-1\right)!}$$

$$\Omega(U, V, N) = f(N) V^N U^{fN/2}$$

Equipartition theorem at thermal equilibrium:
$U = (f/2)\, N k_B T$; determining f: 3 for atoms,
5 for diatomic molecules, 2 for each direction of an Einstein oscillator

Ideal gas law $pV = Nk_BT$

Quasistatic vs. free expansion, microstate vs. macrostate

Laws of thermodynamics, and what they mean

$\Delta U = Q + W_{on} = Q - W_{by}$ $\Delta S \geq 0$

Change in internal energy, change in temperature, heat, work, during "simple" processes: isobaric ($\Delta p = 0$), isochoric ($\Delta V = 0 = W$), isothermal ($\Delta U = \Delta T = 0$), adiabatic ($Q = 0$).
Along an isobar, $W_{by} = p(V_f - V_i)$; along an isotherm $W_{by} = Nk_BT \ln(V_f/V_i)$
Along an adiabat pV^γ is constant, as is (using the ideal gas law) $TV^{\gamma-1}$. Note $\gamma = (f+2)/f$

(These are all put together and reviewed when doing heat engines, though topics such as engine efficiency that are new in Chap. 4 are not covered on this test.)

Thermodynamic identity (not including chemical potential) $T\,dS = dU + p\,dV$ and its uses; temperature and pressure in equilibrium in terms of partial derivatives of entropy

Spreadsheet computations of Ω, S, U, T, C for these models, esp. Einstein solid

Very large numbers; Stirling's approximation, $\ln n! \approx n \ln n - n$, and how to use it

Expansions in $\varepsilon \ll 1$ of $\ln(1 \pm \varepsilon)$, $\exp(1 \pm \varepsilon)$, $(1 \pm \varepsilon)^{\pm x}$

Important constants: $k_B \approx 10^{-4}$ eV/K, C_V of 1 gm of water is 1 cal/K but of ice is ~½ cal/K