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

\[ \Omega(N, N_{\uparrow}) = \frac{N!}{N_{\uparrow}!(N - N_{\uparrow})!} \]
\[ \Omega(N, q) = \frac{(q + N - 1)!}{q!(N - 1)!} \]
\[ \Omega(U, V, N) = f(N) V^{N} U^{N/2} \]

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 $p V = N k_{B} T$

Quasistatic vs. free expansion, microstate vs. macrostate

Laws of thermodynamics, and what they mean

\[ \Delta U = Q + W_{\text{on}} = Q - W_{\text{by}} \]
\[ \Delta S \geq 0 \]

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, $W_{\text{by}} = p(V_f - V_i)$; along an isotherm $W_{\text{by}} = N k_{B} T \ln(V_f/V_i)$
Along an adiabat $p V^{\gamma}$ is constant, as is (using the ideal gas law) $T V^{\gamma-1}$. 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 $\Omega$, $S$, $U$, $T$, $C$ 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 $\epsilon \ll 1$ of $\ln(1 \pm \epsilon)$, $\exp(1 \pm \epsilon)$, $(1 \pm \epsilon)^{\pm x}$

Important constants: $k_{B} \approx 10^{-4}$ eV/K, $C_{V}$ of 1 gm of water is 1 cal/K but of ice is $\sim 1/2$ cal/K