

KALMAN KNIZHNIK - KITTEL AND KROEMER SOLUTIONS

K&K 2.1

Part a

Suppose $g(U) = CU^{2N/2}$, where C is a constant and N is the number of particles. Show that $U = \frac{3}{2}N\tau$.

We use the definition of temperature as

$$\left. \frac{\partial \sigma}{\partial U} \right|_N = \frac{1}{\tau} \quad (1)$$

So, let's calculate σ .

$$\sigma = \ln(g) = \frac{3N}{2} \ln(U) + \ln(C) \quad (2)$$

Therefore,

$$\frac{\partial \sigma}{\partial U} = \frac{3N}{2U} = \frac{1}{\tau} \quad (3)$$

So finally,

$$U = \frac{3}{2}N\tau \quad \square \quad (4)$$

Part b

Show that $\partial^2 \sigma / \partial U^2|_N$ is negative. This form of $g(U)$ actually applies to an ideal gas. Referring to the definition of $\frac{\partial \sigma}{\partial U}$ in equation 3 and taking another derivative:

$$\frac{\partial^2 \sigma}{\partial U^2} = -\frac{3N}{2U^2} < 0 \quad \square \quad (5)$$

This suggests that the temperature of the system will increase with increasing U .

K&K 2.2

Find the equilibrium value at temperature τ of the fractional magnetization $M/Nm = 2\langle s \rangle/N$ of the system of N spins each of magnetic moment m in a magnetic field B . The spin excess is $2s$. Take the entropy as the logarithm of the multiplicity as given in 1.35: $\sigma(s) \approx \log\{g(N, 0)\} - 2s^2/N$.

The energy of a single magnetic moment m in a magnetic field B is $U = -m \cdot B$. A spin excess of $2s$ means that there are $2s$ spins with this magnetic moment. In other words, there could be, say, $2s$ particles of magnetic moment m and $1s$ particles of magnetic moment $-m$. The energy would cancel for all but $2s$ particles. Thus, the total energy of the system is $U = -2smB$. Therefore, $s = -U/2mB$. So the entropy is

$$\sigma = \sigma_0 - \frac{2s^2}{N} = \sigma_0 - \frac{U^2}{2m^2 B^2 N} \quad (6)$$

Since $1/\tau = \partial \sigma / \partial U$, we find

$$\frac{\partial \sigma}{\partial U} = -\frac{U}{m^2 B^2 N} = \frac{1}{\tau} \Rightarrow U = -\frac{m^2 B^2 N}{\tau} \quad (7)$$

Finally, we know that $U = -MB$ since the energy is the total magnetization times the magnetic field. Therefore,

$$-\frac{m^2 B^2 N}{\tau} = -MB \Rightarrow \frac{M}{Nm} = \frac{mB}{\tau} \quad \square \quad (8)$$

Note that the magnetic susceptibility obeys Curie's law $\chi \sim M/B \sim 1/\tau$.

K&K 2.3

Part a

Find the entropy of a set of N oscillators of frequency ω as a function of the total

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E Durkheim



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