PHYS 301
Thermodynamics and Statistical Mechanics

Worksheet #6

Thursday February 26 2026

Question 1.

Start with the Sackur-Tetrode formula for the entropy of a monoatomic ideal gas with volume V, mass m, and temperature T,

$$S = Nk_B\left[\ln\left(\frac{V}{N\lambda_Q^3}\right)+\frac{5}{2}\right], \qquad \text{where} \qquad \lambda_Q \equiv \frac{h}{\sqrt{2\pi m k_B T}}. \tag{1}$$

(a) Compute the chemical potential μ of this ideal gas.

(b) In the classical limit (i.e. when we can safely neglect quantum effects), we have $\lambda_Q^3 < V/N$. What is the sign of the chemical potential in this case? Use the definition of the chemical potential

$$\mu = \left.\frac{\partial E}{\partial N}\right|_{S,V} \tag{2}$$

to explain why this sign makes sense.

(c) Now, assume I have a box of volume $2V$ divided in two sections of volume V by a fixed porous barrier. The temperature is the same on both sides. On the left side there are N_1 particles of gas, and on the right side there are N_2 particles of the same gas, such that $N_1 \gg N_2$. Which side has the higher chemical potential? Use this to determine which side of the box will gain particles and which side will lose particles. You can assume that we always have $\lambda_Q^3 < V/N_1, V/N_2$.