

## Midterm (2025)

1. 25 pt Consider classical ideal gas with indistinguishable particles, in 3D.

(a) Compute the canonical partition function  $Z$  and the Helmholtz free energy  $F$  for this system.

(b) Derive the equation of state.

(c) Find the work  $W$  done on the gas as its volume changes isothermally from  $V_1$  to  $V_2$ , and the pressure changes from  $p_1$  to  $p_2$ . Find the corresponding amount of heat  $Q$  transferred to the gas (i.e., absorbed by the gas).





2.

25 pt

Consider a system of  $N$  non-interacting QM harmonic oscillators with natural frequency  $\omega_0$ . Assume that the oscillators obey Bose statistics.

Write down the expressions for the grand canonical partition function,  $\Sigma$  (N is no longer fixed) and the average number of particles  $\langle N \rangle$  in this system. Note: do not evaluate any resulting sums or integrals; express both  $\Sigma$  and  $\langle N \rangle$  as a single sum.

