is in thermal contact with a large reservoir at temperature τ. The number of particles in the system is assumed constant.

2. The partition function is

$$Z \equiv \sum_s \exp(-\varepsilon_s/\tau).$$

3. The pressure is given by

$$p = -(\partial U/\partial V)_\sigma = \tau(\partial\sigma/\partial V)_U.$$

4. The Helmholtz free energy is defined as $F \equiv U - \tau\sigma$. It is a minimum in equilibrium for a system held at constant τ, V.

5. $\sigma = -(\partial F/\partial\tau)_V; \qquad p = -(\partial F/\partial V)_\tau.$

6. $F = -\tau \log Z$. This result is very useful in calculations of F and of quantities such as p and σ derived from F.

7. For an ideal monatomic gas of N atoms of spin zero,

$$Z_N = (n_Q V)^N/N!\ ,$$

if $n = N/V \ll n_Q$. The quantum concentration $n_Q \equiv (M\tau/2\pi\hbar^2)^{3/2}$. Further,

$$pV = N\tau; \qquad \sigma = N[\log(n_Q/n) + \tfrac{5}{2}]; \qquad C_V = \tfrac{3}{2}N.$$

8. A process is reversible if the system remains infinitesimally close to the equilibrium state at all times during the process.

PROBLEMS

1. Free energy of a two state system. (a) Find an expression for the free energy as a function of τ of a system with two states, one at energy 0 and one at energy ε. (b) From the free energy, find expressions for the energy and entropy of the system. The entropy is plotted in Figure 3.11.

2. Magnetic susceptibility. (a) Use the partition function to find an exact expression for the magnetization M and the susceptibility $\chi \equiv dM/dB$ as a function of temperature and magnetic field for the model system of magnetic moments in a magnetic field. The result for the magnetization is $M = nm\tanh(mB/\tau)$, as derived in (46) by another method. Here n is the particle