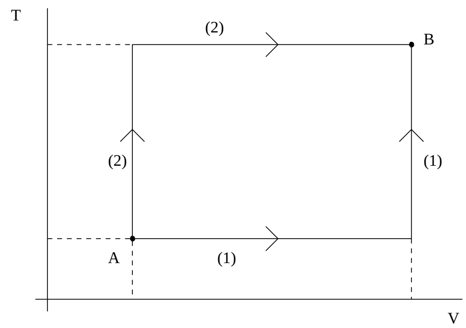
9. Calculate for a photon gas the work done on the system and the heat transferred to the system for the (reversible) paths (1) and (2), respectively, starting at (V_A, T_A) and ending at (V_B, T_B). What is the internal energy change for (1) and (2)? What is the efficiency of the cyclic process?

[Internal energy $U(V,T) = CVT^4$, equation of state $p(T) = \frac{1}{3}CT^4$, C is a constant.]



10. (a) The entropy of n moles of a particular hard-sphere gas may be written as

$$S(E,V) = nR[\ln(V - nb) + \frac{3}{2}\ln E] + \text{const.}$$

where R is the gas parameter, $R = \frac{N}{n}k_B$. Find expressions for the internal energy and the equation of state, and interprete your result.

(b) A 10 kg block of copper at a temperature of 100°C is cooled to 10°C. Calculate the change in entropy of the block, and the corresponding change in entropy of the universe, if cooling is performed (i) reversibly and (i) irreversibly by immersing the block in a large water container at 10°C.

[The specific heat capacity of copper may be regarded as constant over the temperature range indicated, with a value of 375 J kg^{-1} (°C)$^{-1}$.]

11. What is the range of possible final temperatures T_f of a closed system in equilibrium consisting of 2 subsystems A and B, if their initial temperatures are T_A and T_B, respectively? Assume constant heat capacities C_V for A and B, and consider only the 2 extreme cases:

(a) completely irreversible process: no work is extracted during the process (e.g. mixing of 2 fluids of different temperature). Calculate also the entropy change of A and B.

(b) completely reversible process. What is the work extracted from the process?

12. (a) For a Van der Waals calculate gas the critical isotherm and the coordinates V_c, p_c, and T_c of the critical point. What is the equation of state in terms of the reduced units $\bar{V} = \frac{V}{V_c}$, $\bar{p} = \frac{p}{p_c}$, and $\bar{T} = \frac{T}{T_c}$?

(b) Expand the equation of state about the critical point and use the Maxwell construction to calculate the $(T - T_c)$-dependence of the “order parameter” $V_{\text{gas}} - V_{\text{liq}}$, i.e. the jump in volume between gas and liquid phase.