1. A bimetallic strip of total thickness x is straight at temperature T. What is the radius of curvature of the strip R, when it is heated to temperature $T + \Delta T$. The coefficient of linear expansion are α_1 and α_2, with $\alpha_2 > \alpha_1$. Assume that the thickness of each strip is $x/2$ and that $x << R$.

2. Two systems with heat capacities C_1 and C_2 are at temperatures T_1 and T_2, respectively. They are brought in contact with each other. Calculate the final temperature of the system T_f.

3. An ideal gas with γ as the ratio of specific heats, is contained in a large jar of volume V_0. Fitted to the jar is a glass tube of cross-sectional area A in which a metal ball of mass m is fitted. The equilibrium pressure inside the jar is slightly large compared to the atmospheric pressure p_0. If the ball is displaced from its position, then it performs a simple harmonic motion. Determine the frequency of oscillation, assuming that the process is adiabatic.

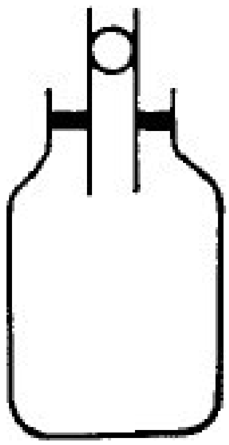

Figure 1: Schematic illustration for problem 3

4. A Carnot engine has a cycle as shown in the figure below. If W and W' represent the work done by 1 mole of monoatomic and diatomic gas respectively, calculate the ratio W'/W.

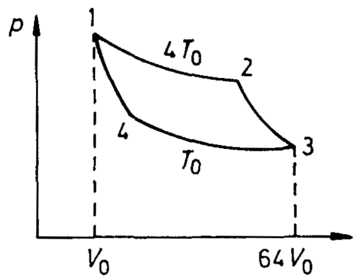

Figure 2: Schematic illustration for problem 4

5. A self-contained machine only inputs two equal steady streams of hot and cold water at temperatures T_1 and T_2. Its only output is a single high-speed jet of water. The heat ca-

pacity per unit mass of water, C , may be assumed to be independent of temperature. The machine is in a steady state and the kinetic energy in the incoming streams is negligible.

a) What is the speed of the jet in terms of T_1,T_2 and T , where T is the temperature of water in the jet?

b) Calculate the entropy change in the process. Using this, argue that $T \geq \sqrt{T_1 T_2}$.

c) Hence, calculate the maximum possible speed of the jet. Can you figure out the maximum velocity of the water coming out of the bathroom shower during winter?

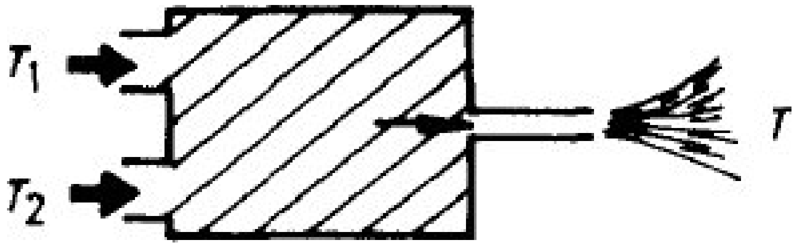

Figure 3: Schematic illustration for problem 5

6. Suppose you are given the following relation among the entropy S, volume V , internal energy U , and number of particles N of a thermodynamic system: $S = A[NVU]^{1/3}$ where A is a constant. Derive a relation among:

   a) U,V,N and T.

   b) the pressure p,N,V, and T.

   c) calculate the specific heat at constant volume.

   d) Now imagine that two bodies made up of this material are initially at temperatures T_1 and T_2. They are brought in contact to each other. Calculate the final temperature T_f. Assume, that N and V for both the bodies are same.

7. A system, maintained at constant volume, is brought in contact with a thermal reservoir at temperature T_f. The initial temperature of the system is T_i.

   a) Calculate ΔS , change in the total entropy of the system +reservoir. You may assume that c_v, the specific heat of the system, is independent of temperature.

   b) Assume now that the change in system temperature is brought about through successive contacts with N reservoirs at temperature $T_i + \Delta T$,$T_i + 2\Delta T$, $\cdots$,$T_f - \Delta T$,T_f,where $N\Delta T = T_f - T_i$. Show that in the limit $N \to \infty$, $\Delta T \to 0$ with $N\Delta T = T_f - T_i$ fixed, the change in entropy of the system +reservoir is zero.

   c) Comment on the difference between (a) and (b) in the light of the second law of thermodynamics.