Due: 11:59 pm on August 1, 2024

Problem 1 (10pts)

A solid object has a density ρ, mass M, and coefficient of linear expansion α. Show that at pressure p the heat capacities C_p, and C_v, are related by

$$C_p - C_v = 3\alpha M p/\rho.$$

Problem 2 (10pts)

One mole of a monatomic perfect gas initially at temperature T_0 expands from volume V_0 to $2V_0$, (a) at constant temperature, (b) at constant pressure.
Calculate the work of expansion and the heat absorbed by the gas in each case.

Problem 3 (15pts)

10 litres of gas at atmospheric pressure is compressed isothermally to a volume of 1 litre and then allowed to expand adiabatically to 10 litres.
(a) Sketch the processes on a pV diagram for a monatomic gas.
(b) Make a similar sketch for a diatomic gas.
(c) Is a net work done on or by the system?
(d) Is it greater or less for the diatomic gas?

Problem 4 (10pts)

A body of constant heat capacity C_p and a temperature T_i is put into contact with a reservoir at temperature T_f. Equilibrium between the body and the reservoir is established at constant pressure. Determine the total entropy change and prove that it is positive for either sign of $(T_f - T_i)/T_f$. You may regard $|T_f - T_i|/T_f < 1$.

Problem 5 (10pts)

A mixture of 0.1 mole of helium ($\gamma_1 = C_p/C_v = 5/3$) with 0.2 mole of nitrogen ($\gamma_2 = 7/5$), considered an ideal mixture of two ideal gases, is initially at 300K and occupies 4 litres. Show that the changes of temperature and pressure of the system which occur when the gas is compressed slowly and adiabatically can be described in terms of some intermediate value of γ. Calculate the magnitude of these changes when the volume is reduced by 1%.

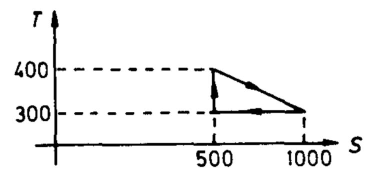
Problem 6 (15pts)

The specific heat of water is taken as 1cal/g·K, independent of temperature, where 1 calorie = 4.18 joules.
(a) Define the specific heat of a substance at constant pressure in terms of such quantities as Q (heat), S (entropy), and T (temperature).

(b) One kg of water at 0 °C is brought into sudden contact with a large heat reservoir at 100 °C. When the water has reached 100 °C, what has been the change in entropy of the water? Of the reservoir? Of the entire system consisting of both water and the heat reservoir?
(c) If the water had been heated from 0 °C to 100 °C by first bringing it into contact with a reservoir at 50 °C and then another reservoir at 100 °C, what would be the change in entropy of the entire system?
(d) Show how the water might be heated from 0 °C to 100 °C with negligible change in entropy of the entire system.

Problem 7 (15pts)

(a) What is the efficiency for a reversible engine operating around the indicated cycle, where T is the temperature in K and S is the entropy in joules/K?
(b) A mass M of a liquid at a temperature T_1 is mixed with an equal mass of the same liquid at a temperature T_2. The system is thermally insulated. If c_p is the specific heat of the liquid, find the total entropy change. Show that the result is always positive.



Problem 8 (15pts)

(a) One mole of an ideal gas is carried from temperature T_1 and molar volume V_1 to T_2, V_2. Show that the change in entropy is

$$\Delta S = C_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}.$$

(b) An ideal gas is expanded adiabatically from (p_1, V_1) to (p_2, V_2). Then it is compressed isobarically to (p_2, V_1). Finally the pressure is increased to p_1 at constant volume V_1. Show that the efficiency of the cycle is

$$\eta = 1 - \gamma(V_2/V_1 - 1)/(p_1/p_2 - 1),$$

where $\gamma = C_p/C_v$.

Congratulations on completing all Homeworks of PHYS1600J 24SU!