Physics 3P41/5P11 Assignment 3

Due: Monday November 18, 2019 in drop box across from MC B210a.

1. Two thermally insulated cylinders, A and B, of equal volume, both equipped with pistons, are connected by a valve. Initially the valve is closed, A has its piston fully withdrawn and contains a perfect monatomic gas at temperature T, while B has its piston fully inserted. Calculate the final temperature of the gas after the following operations, which each start with the same initial arrangement described. Ignore the thermal heat capacity of the cylinders.

   (a) The valve is fully opened and the gas is slowly drawn into B by pulling out the piston B. Piston A remains stationary.

   (b) Piston B is fully withdrawn and then the valve is opened slightly. The gas is then driven as far as it will go into B by pushing in piston A at such a rate that the pressure in A remains constant.

2. An ideal air conditioner operating on a Carnot cycle absorbs heat Q_2 from a house at temperature T_2 and discharges Q_1 to the outside at temperature T_1, consuming electrical energy, E. Heat leakage into the house follows Newton's law: $Q = A(T_1 - T_2)$ where A is a constant.

   (a) Derive an expression for T_2 in terms of T_1, E and A for continuous operation when the steady state has been reached.

   (b) The air conditioner is controlled by a thermostat. The system is designed so that with the thermostat set at 20^o and outside temperature 30^o the system operates at 30% of the maximum electrical energy input. Find the highest outside temperature for which the house may be maintained inside at 20^o.

3. In the course of pumping up a bicycle tire, a liter of air at atmospheric pressure is compressed adiabatically to a pressure of 7 atm. (Consider the air to be made up of diatomic Nitrogen and Oxygen and assume rotational degrees of freedom are excited).

   (a) What is the final volume of this air after compression?

   (b) How much work is done in compressing the air?

   (c) If the temperature of the air is initially 300 K, what is the temperature after compression?

4. A 10 Ω resistor is held at a temperature of 300 K. A current of 5 A is passed through the resistor for 2 minutes. Ignoring changes in the source of the current, what is the change of entropy in:

   (a) the resistor, and

   (b) the Universe?

5. Derive the following general relation:

$$\left(\frac{\partial T}{\partial P}\right)_H = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right] \tag{1}$$

   and find the value of $\left(\frac{\partial T}{\partial P}\right)_H$ for an ideal gas.