Applied Physics – Problem set #9

1. With 5 mol nitrogen, initially with 2-liter volume, we perform a cycle consisting three processes. First, we compress the gas to half of its volume at constant temperature. Then, the gas expands to its original volume at constant pressure, while its temperature increases to 300K. Finally, the gas cools down to its original temperature at constant volume.
(a) What is the initial temperature?
(b) What is the change in internal energy and entropy during the three processes, how much heat is given to the gas and how much work is done by the gas during the processes?
(c) What is the efficiency of this heat engine?

2. A highway is to be made of blocks of concrete 10m long placed end to end with no space between them to allow for expansion. If the blocks were placed at a temperature of 10°C, what compressive stress would occur if the temperature reached 40°C? The contact area between each block is $0.20m^2$. Will fracture occur? The coefficient of linear thermal expansion is $1.2 \cdot 10^{-5}$ $ºC^{-1}$, the compressive modulus of elasticity is $2 \cdot 10^{10} N/m^2$, and the ultimate strength of concrete is $2 \cdot 10^7 N/m^2$.

3. The speed of sound in dry air at 20ºC is about 343m/s. If we can assume that air is made up of linear molecules (N_2, O_2, CO_2), then what is the average molar mass of air based on this speed value? What is the speed of sound in helium and SF_6 at this temperature? The molar masses are 4g/mol and 146g/mol for the helium and sulfur hexafluoride, respectively.

4. The atmospheric pressure at sea level is 101.325kPa. What is the pressure at the top of the Mount-Everest that has an altitude of 8848m if the temperature is -30ºC?

Homework 9

1. An ideal CO_2 gas undergoes a cycle consisting three processes. First i) and adiabatic compression into the state where $p_2=2 \cdot 10^5 Pa$, $V_2=0.6m^3$, $T_2=400K$. Then ii) the gas expands to its original V_1 volume at constant temperature, while its pressure decreases to $p_3 = 1.5 \cdot 10^5 Pa$. Finally, iii) the gas cools down to its original temperature at constant volume.
(a) What is the initial V_1 volume and T_1 temperature?
(b) What is the work done by the gas and the heat released by the gas during the ii) and iii) processes?
(c) What is the change of entropy during the isothermal process?

2. A horizontal steel I-beam of cross-sectional area $0.041m^2$ is rigidly connected to two fixed vertical supports.
(a) If the beam was installed when the temperature was 25°C, what stress is developed in the beam when the temperature drops to -25°C?
(b) Is the ultimate strength of the steel exceeded?
The coefficient of linear thermal expansion is $1.2 \cdot 10^{-5}$ $ºC^{-1}$, the elastic modulus is $2 \cdot 10^{11} N/m^2$, and the ultimate strength of steel is $5 \cdot 10^8 N/m^2$.