PHYSICS 7B, Section 2 – Spring 2013
Midterm 1, C. Bordel
Tuesday, February 26, 2013
7pm-9pm

Show your work and always present your symbolic solution before the numerical solution.

Problem 1 – First law (20 pts)

n moles of an ideal monatomic gas initially at pressure P_A and volume V_A undergo an adiabatic compression from A to B, with a volume compression ratio of $V_B/V_A=1/5$. The gas is then cooled down at constant volume to reach C where $P_C=P_A$. Answer in terms of physical constants, n, P_A and V_A.

a- Draw these 2 thermodynamic reversible processes on a P-V diagram.

b- Determine the temperature at point A, as well as all the volume, pressure and temperature at points B and C.

c- Derive the work done by the gas in the A→B→C transformation.

d- If instead the gas is compressed isobarically from A to C, what is the work done by the gas?

Problem 2 – Heat transfer (20 pts)

The cylindrical tungsten filament of a light bulb gets heated up from room temperature (T_1) to T_2 when it's hot. Its length and radius change from l_1 and r_1 to l_2 and r_2. Tungsten is assumed to experience an isotropic thermal expansion, whose linear coefficient is α, and its emissivity is ε. Give your answers in terms of physical constants, given variables ε, x, α, as well as initial temperature and dimensions T_1, l_1 and r_1.

a- If the relative volume change $\Delta V/V_1$ of the filament observed between T_1 and T_2 is x ($x<<1$), what is the temperature change $\Delta T=T_2-T_1$?

b- Determine l_2 and approximate the final cross-sectional area A_2.

c- Assuming the filament at temperature T_2 and the surrounding air initially at temperature T_1 form an isolated system, express the net radiative power (or rate of radiant heat flow) of the filament. Assume $r_2<<l_2$.

d- If the filament heats up the diatomic nitrogen (atomic mass m_{N2}) contained in the bulb by ΔT (see part a), what is the change in rms speed of the nitrogen molecules? Express your answer as the ratio of the final over the initial rms speed.

Problem 3 - Phase change (20 pts)

During a power failure you put a block of ice of mass m=20kg at 0°C in the refrigerator, bringing the interior temperature to 0°C. The rate of heat transfer per degree difference between the inside and the outside of the refrigerator is R=5 W/K. Use L_f=300 kJ/kg as the latent heat of fusion of ice.

a- Write the relationship between *R*, the temperature difference ΔT, the amount of heat *Q* exchanged and the corresponding time interval Δt, assuming Δt is small enough so that the ice does not melt.

b- What is the amount of heat required for the ice to melt entirely?

c- If room temperature is 20°C, how long will the ice last?

d- What is the minimum amount of ice needed to have initially in order to remain at 0°C for 20h?

Problem 4 - Entropy (20 pts)

A hot meteorite of mass *m*, specific heat *c* and initial temperature T_1 falls into the ocean whose temperature is T_2 ($T_1=3T_2$). Assume the ocean is so large that its temperature rise is negligible.

a- Is the process reversible or irreversible? Explain.

b- Determine the change in entropy of the meteorite.

c- Determine the change in entropy of the surrounding environment.

d- What is the total entropy change of the closed system {meteorite + ocean}? Comment on the sign.

Note: Ln3~1.1

Problem 5 - Cyclic process (20 pts)

Some combustion engines are based on a Stirling cycle that contains 2 isothermal processes and 2 isovolumetric processes. The cycle is entirely defined by the temperatures T_A and T_C and the volumes V_A and V_C, where point A corresponds to the highest temperature T_A and highest volume V_A.

Draw the associated (ABCD) cycle on a PV diagram, calculate the efficiency of the Stirling engine and compare it with that of an ideal Carnot engine working with the same 2 temperatures.