ECSE 310 Thermodynamics of Computer, Winter 2019

Homework 2

Assigned: Feb 20th 2019

Due: Feb 28th 2019, 11:59 pm

Submission instructions: Please submit your assignment online via MyCourses assignment tool prior to the deadline. If your submission is handwritten please provide a high quality image (preferably scanned using uPrint or similar). Poor quality digital photos may be rejected. Include any workings and calculations that you performed in completing the assignment.

Late policy: 1% deduction per hour

Academic integrity reminder: In submitting this assignment on MyCourses you are attesting that it is the result of your own work.

Each question has the same weight

P1) Using your own words, define the following:

1. Adiabatic process
2. Isothermal process
3. Thermal resistance
4. Emissivity

b) Answer the following:

1. What's zeroth law of thermodynamics?
2. What's the first law of thermodynamics? Write the formula and denote it carefully.
3. Explain thermal equilibrium and thermodynamic process.
4. Explain the difference between heat capacity, specific heat, and specific heat at constant volume and pressure.
5. Explain the difference between fridge and heat pump.
6. Explain free expansion, constant-volume, and cyclical processes.
7. What's an ideal gas?
8. When we measure temperature, we can determine?
   - A. Internal energy
   - B. Pressure.
   - C. rms speed.
   - D. A and C.
   - E. A, B and C.

9. Does the average translational kinetic energy of 3/2 kT applies to all ideal gas? (Yes/No)

P2) You are given a cup of hot tea (which is at 90 °C) and a choice of either a stainless steel rod (thermal conductivity 43 W/m·°C) a wooden rod (thermal conductivity 0.17 W/ m·°C) to stir it with. Assume that both have a diameter of 5 mm and that when you hold them in your hand, 60 mm protrudes from the hot liquid to where you hold it and that your fingers are at 33 °C.

a. What is the energy transfer rate along the rod in each case, neglecting any convection of heat away from the rod?

b. Assuming that all heat is being absorbed in a skin volume of about 60 cubic mm, that the specific heat of your skin is 3.47 J/g/°C and that the density of your skin is around that of water (1 mg/mm^3), how quickly would your skin heat up by 5 °C in each case ? (Just a first order estimate is fine – you don't need to try to calculate the reduction in energy transfer rate due to the increase in skin temperature; assume h =10 W/m^2 K).

c. Assuming that the cup is very well insulated, except at the surface which has a diameter of 80 mm, what is the heat flux from the surface due to convection (assume still air above the cup and a room temperature of 21 °C)?

d. What is the radiated heat flux from the surface of the cup (assume emissivity coefficient of 0.995 for water)? Blackbody radiation is given by $J = \epsilon\sigma T^4 \left[\frac{W}{m^2}\right]$, where ϵ is the emissivity, σ is the Stefan-Boltzmann constant and T is the temperature.

P3) A 300 mm^2 silicon IC is 0.5 mm thick. It is attached to a silicone elastomer with a 75 µm thickness, which is attached to a square heat sink of 650.25 mm^2 area. The base of the heat sink is 2 mm thick, and the length and thickness of the fins are 10 mm and 1.5 mm, respectively. The gap between the fins is 1.5 mm (so there are 9 fins in total). The heat generation rate is 10 J/s. Assume temperature at junction is 85°C.

a. Draw the equivalent thermal resistance network for these components, neglecting convection for now. Calculate the thermal resistance of each element, assuming that thermal conductivities are 130 W/m·°C for silicon, 0.5 W/ m·°C for elastomer and 202 W/m·°C for the aluminum heat sink.

b. Now assume that the heat sink is cooled via convection, and that the model that we derived in class for the average fin temperature holds here: $T_S \simeq \frac{1}{4}(3T_{base}+T_0)$ where T_{base} is the temperature at the base of the heatsink and T_0 is the ambient air temperature. For an ambient temperature of 21°C what heat transfer coefficient is required in order to maintain the junction temperature of 85°C. Does this require forced air cooling (you need forced air if h is larger than 50)?

P4) You are tasked with making a refrigerator by compressing and expanding an ideal gas. In the system, the gas cycles between a volume of 0.5 L and 1 L. Assume that the gas is at atmospheric pressure (100 kPa) in its compressed state, and that the room temperature is 21 °C and the internal temperature of the fridge is 0 °C. Assume for now that all processes are reversible.

a. Complete the tables below, where the four points A,B,C and D correspond to the points of the Carnot cycle given in class

Point	Volume (L)	Pressure (kPa)	Temp. (K)	Transition	Heat flux (J)	Work (J)	Entropy change (J/K)
A				A-B			
B				B-C			
C				C-D			
D				D-E			

b. Now assume that you need to cool 250 mL of water from 21 °C to 0 °C by putting it inside the fridge. (hint: mole number: $n = \frac{m}{v_m}$. For water it is 18 g/mol)

1. How many cycles will it take?
2. By how much does the entropy of the water change on the first cycle?
3. By how much does the entropy of the water change in total?
4. If you find that the entropy has reduced, where has it gone?
5. Calculate the efficiency.