ECSE 310 Thermodynamics of Computing, Fall 2025

Homework 2: Heat Management and Thermodynamics, (Problem Analysis)

Assigned: September 22nd 2025

Due: October 19th 2025, 11:59 pm

Late policy: 1% deduction per hour

Instructions: Please use the MyCourses tool to submit your answers. If you need to attach a scanned or photographed handwritten page please check to make sure that it is legible. Illegible pages will be rejected and zero credit will be given.

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

Homework is worth 65 points in total. Weights for each sub-question are shown in square brackets.

1.
A metal heat sink with forced air cooling is used to cool a semiconductor integrated circuit which contains transistors. The heat sink and the semiconductor die are thermally connected via a thin layer of thermal epoxy. The semiconductor die is 1 millimeter thick, is 25 mm x 25 mm on each side, and has a thermal conductivity of 150 W/m.K. The epoxy film is 20 µm thick and has a thermal conductivity of 0.12 W/m.K. The heat sink has 12 fins and each fin is 25 mm wide and 15 mm deep. The base of the heat sink is 3 mm thick and has a thermal conductivity of 300 W/m.K.

When the integrated circuit is drawing 50 watts of electrical power, the transistor junction temperature is 383 kelvins and the ambient temperature is 294 kelvins. You can assume that all heat dissipated from the integrated circuit passes through the heatsink and that we can approximate the heat convection from the heat sink using the expression $Q=N_f h\, A_{fin}\,(3/4)(T_s-T_a)$ where N_f is the number of fins, h is the surface heat transfer coefficient, A_{fin} is the fin area, T_s is the temperature at the base of the heat sink and T_a is the ambient temperature.

Use this data to calculate:
a) The surface heat transfer coefficient for the heat sink [10 points]
b) The thermal resistance of the heat sink [6 points].
c) The temperature at the tip of the heat sink fins [4 points].

[20 points total]

2.

a) An ideal refrigerator operates between 4 °C and 22 °C. If it removes 80 J of heat from its interior per cycle, what is the minimum work input per cycle? [4 points]

b) Assume that the refrigerator operates by compressing and expanding an ideal monatomic gas in the reverse Carnot cycle, and that at the point of maximum volume and lowest pressure, the volume of the gas is 2 L and the pressure is one half atmospheric pressure (i.e. 50.65 kPa). Use this information to calculate the pressure and volume at the other three points in the Carnot cycle. In completing your answer please be explicit about the nature of each transition (isothermal, adiabatic, isochoric or isobaric) [9 points]

c) Now consider that due to inefficiencies, the real coefficient of performance is equal to 7.0. How much heat leaks irreversibly on each cycle? [4 points]

d) To what temperature should the refrigerant be chilled to compensate for this irreversible heat flow? [4 points]

e) Finally what is the net entropy change for the irreversible process? [4 points]

[25 points total]

3.

Two different liquids are combined in an insulated container at constant pressure. We can assume that they are 'ideal', meaning that they do not interact chemically. Liquid A has volume V_A=150 mL and is initially at temperature T_A=90 °C, has heat capacity c_A=2.11 J/g.K, density ρ_A=0.79 g/cm^3 (which we can assume remains constant with temperature and a molar mass of M_A=46 g/mole. Liquid B has volume V_B=350 mL and is initially at temperature T_B=5 °C, has heat capacity c_B=4.2 J/g.K, density ρ_B=1 g/cm^3 (which we can also assume remains constant with temperature) and molar mass M_B=18 g/mole.

a) What is the final temperature of the mixture? (Hint: see the solution to the sample problem in class 3.7 for the expression) [4 points]

b) What is the entropy change of liquid A? [5 points]

c) What is the entropy change of liquid B? [5 points]

d) What is the net entropy change after the mixing process? Does it breach the second law of thermodynamics if one of the component liquids has a negative change in entropy? Please explain your answer [3 points]

e) Please explain what (if anything) would change for this calculation process if the two liquids were chemically identical (you do not need to undertake calculations)? [3 points]

[20 points total]