Thermodynamics 1 DEN107

Problem Set 03 (due week 5, Mon 2012feb06)

Insert the SEMS homework coverpage as 1st page; this question sheet with original signatures as the 2nd page; then attach your solutions in subsequent pages. Your solutions are due before 3.30 pm on Monday February 6th 2012 in the cabinet outside the SEMS office.

By signing below I certify that I will not obtain the teaching assistant's (TA) signature for students other than myself, and that I will not forge the TA's signature on this page. Violators will be prosecuted in accordance to QMUL procedures. Please fill in the five items below.

Student Surname:	
Student Forenames:	
Student ID (9 digits):	
Student signature:	
TA confirms tutorial attendance (signature):	

50% of the assignment grade will be deducted if the TA signature above is missing

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HINT: Read the problems in part A of the exam scripts from the last three years (available in the module webpages). Read ahead in the lecture notes in order to answer questions 3, 4, 5. Work with the assistants on problem 6.

Problem 1
(a) Define unstable equilibrium, stable equilibrium, metastable equilibrium
(b) Give two examples of thermodynamics systems in each the states in (a), and carefully outline the parameters and constraints required for the systems to be in these states. The examples you give should be different from those given in the book, notes and lectures.
(c) Define steady and unsteady state
(d) Give two examples of thermodynamics systems in each the states in (c), and carefully outline the parameters and constraints required for the systems to be in these states. The examples you give should be different from those given in the book, notes and lectures.

Problem 2
State the second law of thermodynamics. Provide an engineering example, and a figure of the initial and final energy states of this example, illustrating the validity of the second law of thermodynamics. The example you give should be different from those given in the book, notes and lectures.

Problem 3
Explain what is a perpetual motion machine of the second kind (PMM2). Provide a simple logical explanation why a PMM2 is impossible.

Problem 4
Define the thermodynamic concepts of adiabatic availability Ψ, reservoir R, and available energy Ω. Provide an engineering example, and a figure of the initial, intermediate and final states in this example, illustrating the difference between Ψ and Ω, and how the reservoir contributes to $\Omega \geq \Psi$.

HINT: discuss which system provides the energy for the work obtained in Ψ, and which system provides the energy for the additional work in $(\Omega - \Psi)$

Problem 5
(a) Define entropy and temperature, with equations. Provide a pictorial representation of the concept of temperature for a stable equilibrium state for an arbitrary thermodynamic system on the system's energy-entropy graph.

Problem 6
(see page 2)

Problem 6

A block of metal A of mass $m = 45$ kg and specific heat capacity $C = 1.2$ kJ/(kg·K) obeys the constitutive relations

$$\text{Energy } E: \qquad E_2 - E_1 = m\,C\,(T_2 - T_1)$$

$$\text{Entropy } S: \qquad S_2 - S_1 = m\,C\,\ln\left(\frac{T_2}{T_1}\right)$$

where T is temperature. The block of metal is initially at temperature $T_1 = 550$ K and it is in the vicinity of a thermodynamic reservoir R, which is at temperature $T_0 = 298$ K and pressure $p_0 = 101.3$ kPa.

(a) What is the maximum amount of work that can be extracted adiabatically from the metal block in its initial state (known as the adiabatic availability Ψ)?

(b) What is the maximum amount of work that can be extracted adiabatically from the combination of the metal block A and reservoir R? (known as the available energy, or exergy, Ω)?

(c) Evaluate the energy and entropy changes of system A and reservoir R in part (b). Four numerical values are required.

(d) Draw three separate energy-entropy diagrams, one for system A, one for the reservoir R, and one for the combined system AR. Draw on these diagrams the initial and final states of the interaction described in part (b).

(e) In a practical application we only manage to extract half the available energy computer in part (b), while the final temperature of system A becomes equal to that of the reservoir. What is the amount of entropy generated by irreversibility?

(f) How would you define the first law efficiency of the process in part (e)? How would you define the second law efficiency (effectiveness) of the process in part (e)? Evaluate these two expressions of efficiency.

(g) Evaluate the energy and entropy changes of system A and reservoir R in part (e). Four values are required. Compare these values with those of part (c) and with the entropy generated by irreversibility.

(h) Draw on the diagrams of part (d) the final states of the systems A, R and AR in part (e).