

Ene-39.4055 Irreversible thermodynamics

Exam Tuesday 13.12.2011 at 13-17 K326.

Write your name and student number on each answer paper.

1. General theory. Attached is a copy of the first part of the article (J. Non-Equilib. Thermodyn. 2006, Lampinen et al) in which the real working power is described in terms of the effective temperatures and the entropy generation rate. With the aid of this material answer to the following questions:

1.1 Explain the Gouy-Stodolas theorem. What does it tell us if we set $T_- = T_0$ where T_0 is the temperature of the surroundings?

1.2 Explain the concepts of chemical exergy and physical exergy – and explain by the article how both these two concepts are incorporated in the theory of the article.

1.3 A turbine has an isentropic efficiency η . Derive a second law formulae for the working power and entropy generation rate for the adiabatic expansion process.

2. Operation of SOFC = Solid Oxide Fuel Cell.

2.1 Describe the principle of the operation of solid oxide fuel cell. Write the anode and cathode reactions and the Nernst equation for the open cell voltage.

2.2 Steam methane reforming. Explain the idea of that and the principle. How we avoid carbon deposition? Draw a schematic picture of the whole SOFC process when the fuel is methane gas.

2.3 The electrochemical performance of the fuel cell (SOFC) is evaluated by its polarization curve. Draw a figure of this and explain the reasons for different losses.

3. Chemical engineering problems, distillation, Onsager.

3.1 Give an example of Onsagers equations and give a motivation why the cross coefficients should be symmetric, $L_{ij} = L_{ji}$.

3.2 What is a diabatic distillation column and how it is different from adiabatic distillation column?

3.3 Distillation process is purely driven by heat and condensation – there is no work contribution in the energy balance of the system. Explain why are we still interested to minimize the amount of “lost work” when there is no work! In fact, what does it mean that by reducing the entropy generation rate the process is improved and the energy economy is better?