# Final Exam Energy Conversion Technologies 1

Friday November 11, 2011, 9:00-12:00

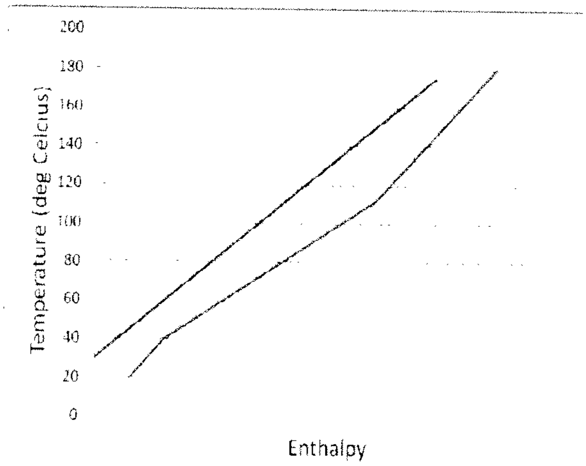
**Instructions:**

1. All questions in this exam have equal weights
2. **Select 3 of the 4 questions to answer**. Clearly indicate which 3 questions are to be graded.
3. Provide your name and student number on each separate sheet
4. You can use the two books, the reader and a calculator
5. Where necessary use the book(s) and reader to find data you need in addition to the given data.

## 1. Pinch Analysis

Heat exchange is to be optimised for a case where one hot flow (H1) and two cold flows (K1 and K2) are available. The flows are given in the following table:

| name | Input temperature | Target temperature | mcp |
|---|---|---|---|
| | °C | °C | kW/K |
| Hot flow: | | | |
| H1 | 175 | 30 | 20 |
| | | | |
| Cold flows: | | | |
| K1 | 20 | 180 | 15 |
| K2 | 40 | 112 | 10 |




The diagram on the right shows the hot and cold composite curves, where DTmin = 20 °C. The pinch occurs at the place where the cold composite curve has a temperature of 40 °C.

Below the pinch only one heat exchanger is needed which heats cold flow K1 from 20 °C to 40 °C.

a. Determine the amount of heat transferred (in kW) in the heat exchanger below the pinch, and the hot flow inlet- and outlet temperatures of this heat exchanger.
b. Determine the cold utility requirement (in kW)
c. Determine the hot utility requirement (in kW)

## 2. Water electrolysis

An electrolyser consists of 100 cells, each with 1 $m^2$ effective area. At a current density $J$=1000 A/$m^2$ the voltage required by each cell is 1.31 V.

The electrolyser is installed in a cubical room (3.00 m edge) whose walls, floor and ceiling conduct heat at a rate of 50 W/$m^2$ per kelvin of temperature difference. Outside temperature is 30 °C.

Questions: when a current of 1000 A is forced through the cells,

a. How many kg of $H_2$ are produced every day?
b. How many kg of $O_2$ are produced every day?
c. what is the efficiency of the electrolyser?
d. What is the equilibrium temperature of the room?

## 3. Absorption heat pump

A reversible absorption heat pump consists of a reversible heat engine and a reversible heat pump. The heat pump removes heat from the environment (5 °C) and supplies 22 kW heat at 35 °C. The reversible heat engine is heated by condensing saturated steam at 200 °C and operates between this temperature and the environmental temperature.

Determine:

a. The heat input $Q_{gen}$ (in kW) and the rate at which steam condenses (in kg/s)
b. The power to the reversible heat pump (in kW)
c. The COP of the complete reversible absorption heat pump

## 4. Carbon dioxide capture

A gasifier produces 1000 mol/s syngas (composition: 40 mol-% $H_2$, 60 mol-% CO). This syngas is fed into a water gas shift reactor together with just enough steam to convert all carbon monoxide. All carbon monoxide is converted in the water gas shift reaction. The pressure of the gas leaving the shift reactor is 4 bar.

a. Calculate the amount (in mol/s) and the lower heating value (in kJ/mol) of the gas leaving the water gas shift reactor.

Carbon dioxide is captured from the gas leaving the water gas shift reactor before it is used in a power plant. The amount captured is 95%.

b. What is the amount of gas (in mol/s) and the lower heating value of the gas (in kJ/mol) after capture?

The $CO_2$ capture takes place in a counter-flow absorber using Selexol. Selexol enters the absorber with a $CO_2$ concentration of 0.0100 mol per liter Selexol. Henry's constant at the prevailing conditions in the absorber is 5.4 bar/(mol/l). Assume that the volume of Selexol is independent of its $CO_2$ content. The Selexol leaving the absorber is in (absorption) equilibrium with the gas entering the absorber.

c. Calculate the $CO_2$ concentration (in mol/l) of the Selexol leaving the absorber

d. Calculate the flow rate of Selexol (in l/s) required.