Exam
Thermal Energy Conversion (SEE020)

2022-01-11, 08:30 - 12:30

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Exam review	week 3 (after agreement via e-mail: david.pallares@chalmers.se)
Mark scale	Mark 5: at least 24 p Mark 4: at least 18 p Mark 3: at least 12 p Not passed: less than 12p

1. BECCS stands for bioenergy carbon capture and storage. Describe shortly the concept and explain under which circumstances, if any, it is: a) renewable, and b) sustainable. (2p)

2. In which type of energy plant is it more critical to have a fuel with low moisture content: one mainly dedicated to deliver district heating, or one mainly dedicated to electricity production? Explain your answer. (2p)

3. Write the equation describing an energy balance in a tank containing a mass, *m*, of a gas with a certain heat capacity, C_p, inflow, F_{in}, and outflow, F_{out}. Assume the heat loss of the gas to be governed by a total thermal resistance, R_{tot}. (1p). How should the equation be modified if the gas in the tank reacted at a rate, *r* [kg/s], releasing a reaction energy of ΔH_{rx} [J/kg]? (2p)

4. An energy storage tank in a solar power plant contains molten salt at 500 °C and stands on soil at 30 °C. The tank has a radius of 6 m and its wall has a thickness of 20 cm and a thermal conductivity of 0.12 W/m·K. You can assume the wall surface temperature at the inside of the tank equal to that of the molten salt.

a. What is the heat loss through the bottom of the tank? (2p)

In order to reduce this heat loss, the tank is set upon plastic blocks. The pins are 0.45 m-long, have a thermal conductivity of 0.23 W/m·K, and their total cross-sectional area in contact with the bottom of the tank is 15.3 m^2.

b. Draw the thermal resistance scheme for the heat losses from the tank bottom to the soil, indicating the value of each thermal resistance. Identify whether any of the thermal resistances is dominating, and indicate which one in such case. (2p)
   Thermal conductivity of air: 0.04 W/m·K
c. What is the heat loss through the bottom of the tank with this new arrangement? (2p)
d. What measure would be more effective to further reduce the heat loss through the bottom of the tank: use pins of a material with lower thermal conductivity, use a tank wall material with lower thermal conductivity, or use longer pins so that the gap between the soil and the tank bottom increases? (1p)
e. If the tank contained a liquid colder than the soil, explain why the thermal resistance scheme would change (1p). Would the total thermal resistance become larger or smaller – and why? (1p)

5. You have just bought a new radiometer and you are interested in examining the radiative properties of some different metal plates you found in a box.

a. Explain shortly the concept of *Radiosity* and write an expression that shows how the radiosity for a surface is dependent on the radiative properties and the temperature of the surface. (1p)

The plates in the box consists of different metals, but you can't tell them apart by looking at them. Instead, you figured that you could calculate the emissivity of a plate using your radiometer and compare your value to what is found in tables. The box is said to contain plates of *aluminum*, *chrome-nickel*, and *oxidated steel* with tabulated emissivity's as *0.10*, *0.65* and *0.95* respectively.

b. A plate that you selected at random, is shaped as a square with one side being 0.1m. Your radiometer detector is circular with a radius of 5 mm. You have placed the metal plate and the radiometer detector with a distance so that the view factor from the plate (1) to the detector (2) is 0.007. What are the view factors F_{21} & F_{23}? Where “3” corresponds to the very large surroundings? (1p)

c. Using your radiometer, you are measuring a total radiative heat flux into your detector of 880 W/m^2 as you are directing it towards the plate. Removing the plate, the total radiative heat flux from the surrounding to the detector is measured to 400 W/m^2. As you are examining the plate it holds a temperature of 110°C. Which of the three metals are you examining? You may neglect any radiative heat transfer contribution from the detector to the metal surface in your calculations. (4p)

6. Explain how a vacuum at the absorbing surface in a thermal solar collector may reduce the collector’s heat losses. (1p)

7. Arranging the mirrors in a concentrated solar power park, using a solar power tower, requires a certain land area. What problems are related to using a too small land area, that is arranging the mirrors too close to each other? How does this affect the efficiency of the CSP plant? (2p)

8. A product stream of an oil derivative needs to be preheated before conversion by heat exchange with hot water. You design a tube and shell heat exchanger with 1 shell path and 2 tube pathes for the given design parameters. Calculate the required area and the missing temperature in the table below, knowing that U=1300 W/m^{2}K. (3p)

	$\dot{m}$ [kg/s]	C_p [J/kgK]	T_{in} [°C]	T_{out} [°C]
cold (oil)	40	2210	25	65
hot (water)	35	4200	100	?

After taking the heat exchanger in operation, the measured outlet temperatures deviate from the designed ones (see table below). Discuss possible reasons for these deviations between design and reality, and calculate the correct values for one of these possible cases. Assume the above given properties of the fluids and the measured temperatures to be correct. (3p)

	T_{in} [°C]	T_{out} [°C]
cold (oil)	25	66.3
hot (water)	100	80.0