Approach

The approach below gives a guideline in how to solve the problems presented during this course. Correctly applying this approach will lead to a good understanding of the concepts presented in this course.

Analysis

1. Explain the problem: which physical phenomena are important in this problem?
2. Make a sketch of the problem
3. Give the known variables (with the appropriate units!)

Approach

1. Explain the assumptions you make to solve the problem
2. Show the solution method for solving the problem

Elaboration

1. Show the calculation steps and explain the equations you use
2. Give references if values are found online or in tables

Evaluation

1. Check the units of your solution
2. Is the answer realistic/expected?
3. Did you answer all the questions asked?
4. Iterate if this is required

Assignment 4

Water flowing through a tubing system is heated up by means of of radiation. A lateral surface of 1.5 m x 2 m receives a radiation flux of 856 W/m^2. Water flows through the collector tubes with a mass flow rate 0,0145 kg/s and it is heated from the inlet at 15 ^{o}C. Assume steady-state heat transfer.

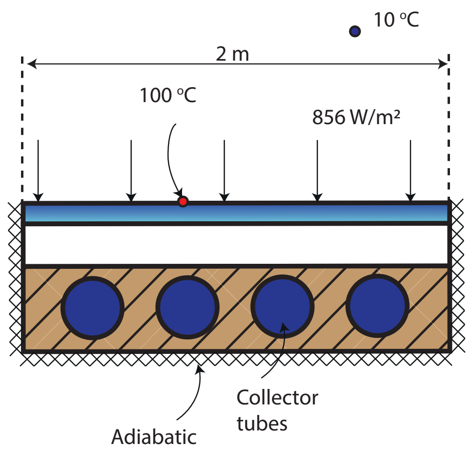

Figure 11: A solar collector subjected to a radiative heat flux

a) Explain what the Grashof number physically represents.

b) Determine the rate of heat transfer that is entering the collector tubes in the case that no heat is absorbed or reflected by the collector.

Hint:
$\dot{Q}_{\text{tubes}} = \dot{Q}_{\text{incident}} - \dot{Q}_{\text{convection}}$

c) Determine the efficiency of the solar collectors.

d) Determine the temperature of the water at the outlet.

Hint: Use the average water properties from Table 3

e) Are there any modifications that can be made to increase the efficiency of the system?

Temperature ^{o}C	Density kg/m^3	Specific heat J/kgK	Thermal conductivity W/m·K	Dynamic viscosity kg/m·s	Prandtl number	Volume expansion coefficient K^{-1}
20	998.0	4182	0.598	$1.002 \cdot 10^{-3}$	7.01	$0.195 \cdot 10^{-3}$

Table 3: Average water properties in the liquid phase

Temperature ^{o}C	Density kg/m^3	Specific heat J/kgK	Thermal conductivity W/m·K	Thermal diffusivity m^2/s	Dynamic viscosity kg/m·s	Kinematic viscosity m^2/s	Prandtl number
0	1.292	1006	0.02364	$1.818 \cdot 10^{-5}$	$1.729 \cdot 10^{-5}$	$1.338 \cdot 10^{-5}$	0.7362
10	1.246	1006	0.02439	$1.944 \cdot 10^{-5}$	$1.778 \cdot 10^{-5}$	$1.426 \cdot 10^{-5}$	0.7336
20	1.204	1007	0.02514	$2.074 \cdot 10^{-5}$	$1.825 \cdot 10^{-5}$	$1.516 \cdot 10^{-5}$	0.7309
30	1.164	1007	0.02588	$2.208 \cdot 10^{-5}$	$1.872 \cdot 10^{-5}$	$1.608 \cdot 10^{-5}$	0.7282
40	1.127	1007	0.02662	$2.346 \cdot 10^{-5}$	$1.918 \cdot 10^{-5}$	$1.702 \cdot 10^{-5}$	0.7255
50	1.092	1007	0.02375	$2.487 \cdot 10^{-5}$	$1.963 \cdot 10^{-5}$	$1.798 \cdot 10^{-5}$	0.7228
60	1.059	1007	0.02808	$2.632 \cdot 10^{-5}$	$2.008 \cdot 10^{-5}$	$1.896 \cdot 10^{-5}$	0.7202
70	1.028	1007	0.02881	$2.780 \cdot 10^{-5}$	$2.052 \cdot 10^{-5}$	$1.995 \cdot 10^{-5}$	0.7177
80	0.9994	1008	0.02953	$2.931 \cdot 10^{-5}$	$2.096 \cdot 10^{-5}$	$2.097 \cdot 10^{-5}$	0.7154
90	0.9718	1008	0.03024	$3.086 \cdot 10^{-5}$	$2.139 \cdot 10^{-5}$	$2.201 \cdot 10^{-5}$	0.7132
100	0.9458	1009	0.03095	$3.243 \cdot 10^{-5}$	$2.181 \cdot 10^{-5}$	$2.306 \cdot 10^{-5}$	0.7111

Table 4: Air properties at 1 atm pressure