

# 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 1367 W/m<sup>2</sup>. Water flows through the collector tubes with a mass flow rate 0,0145 kg/s and it is heated from the inlet at 15 °C. Assume steady-state heat transfer.

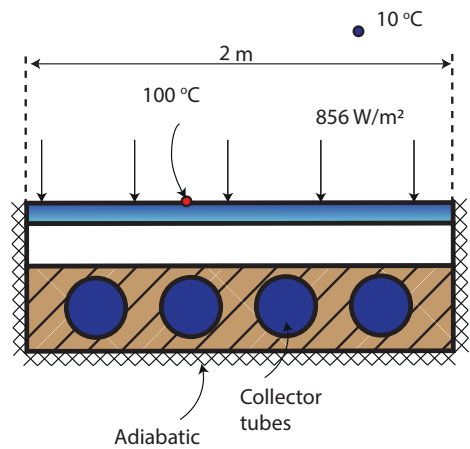


Figure 11: A solar collector subjected to a radiative heat flux

- 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 solar collector?

Temperature °C	Density kg/m <sup>3</sup>	Specific heat J/kgK	Thermal conductivity W/m · K	Dynamic viscosity kg/m · s	Prandtl number	Volume expansion coefficient K <sup>-1</sup>
20	998.0	4182	0.598	1.002·10 <sup>-3</sup>	7.01	0.195·10 <sup>-3</sup>

Table 3: Average water properties in the liquid phase

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

Table 4: Air properties at 1 atm pressure