

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/m². 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.

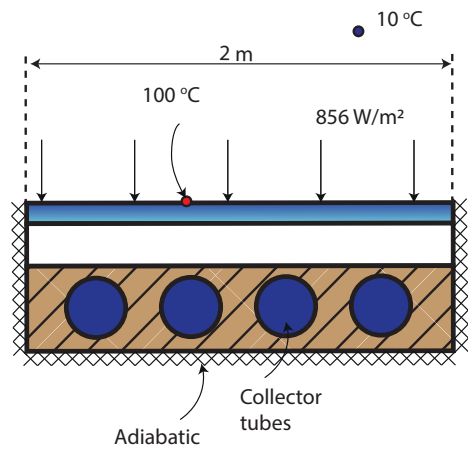


Figure 11: A solar collector subjected to a radiative heat flux

- 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 system?

Temperature °C	Density kg/m³	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	1.002·10 ⁻³	7.01	0.195·10 ⁻³

Table 3: Average water properties in the liquid phase

Temperature °C	Density kg/m³	Specific heat J/kgK	Thermal conductivity W/m · K	Thermal diffusivity m²/s	Dynamic viscosity kg/m · s	Kinematic viscosity m²/s	Prandtl number
0	1.292	1006	0.02364	1.818·10 ⁻⁵	1.729·10 ⁻⁵	1.338·10 ⁻⁵	0.7362
10	1.246	1006	0.02439	1.944·10 ⁻⁵	1.778·10 ⁻⁵	1.426·10 ⁻⁵	0.7336
20	1.204	1007	0.02514	2.074·10 ⁻⁵	1.825·10 ⁻⁵	1.516·10 ⁻⁵	0.7309
30	1.164	1007	0.02588	2.208·10 ⁻⁵	1.872·10 ⁻⁵	1.608·10 ⁻⁵	0.7282
40	1.127	1007	0.02662	2.346·10 ⁻⁵	1.918·10 ⁻⁵	1.702·10 ⁻⁵	0.7255
50	1.092	1007	0.02375	2.487·10 ⁻⁵	1.963·10 ⁻⁵	1.798·10 ⁻⁵	0.7228
60	1.059	1007	0.02808	2.632·10 ⁻⁵	2.008·10 ⁻⁵	1.896·10 ⁻⁵	0.7202
70	1.028	1007	0.02881	2.780·10 ⁻⁵	2.052·10 ⁻⁵	1.995·10 ⁻⁵	0.7177
80	0.9994	1008	0.02953	2.931·10 ⁻⁵	2.096·10 ⁻⁵	2.097·10 ⁻⁵	0.7154
90	0.9718	1008	0.03024	3.086·10 ⁻⁵	2.139·10 ⁻⁵	2.201·10 ⁻⁵	0.7132
100	0.9458	1009	0.03095	3.243·10 ⁻⁵	2.181·10 ⁻⁵	2.306·10 ⁻⁵	0.7111

Table 4: Air properties at 1 atm pressure