

Assignment 4

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

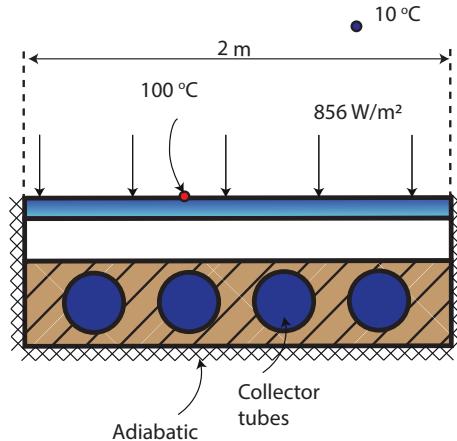


Figure 11: A solar collector subjected to a radiative heat flux

- Explain what the Grashof number physically represents.
 - 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:**
- $$Q_{\text{tubes}} = \dot{Q}_{\text{incident}} - \dot{Q}_{\text{convection}}$$
- Determine the efficiency of the solar collectors.
 - Determine the temperature of the water at the outlet.

Hint: Use the average water properties from Table 3

- 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	$1.002 \cdot 10^{-3}$	7.01	$0.195 \cdot 10^{-3}$

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	$1.818 \cdot 10^{-5}$	$1.729 \cdot 10^{-5}$	$1.338 \cdot 10^{-5}$	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