Test 4 - Joel Adriano

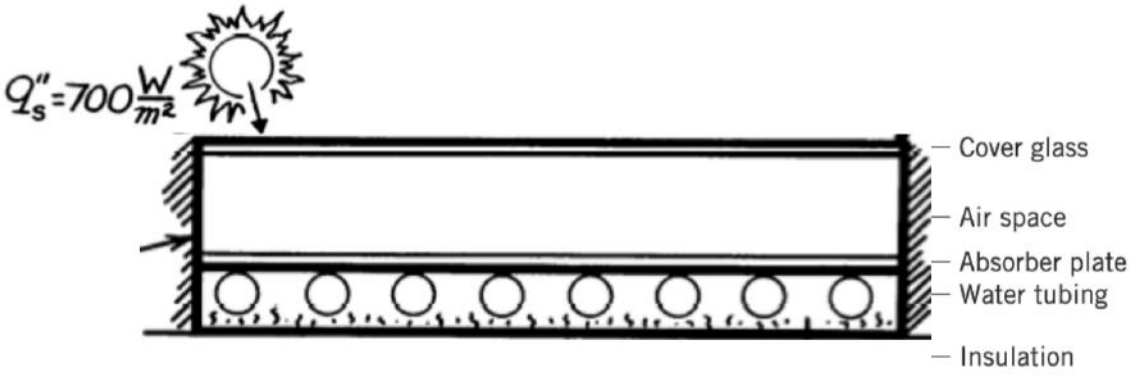
Question 1

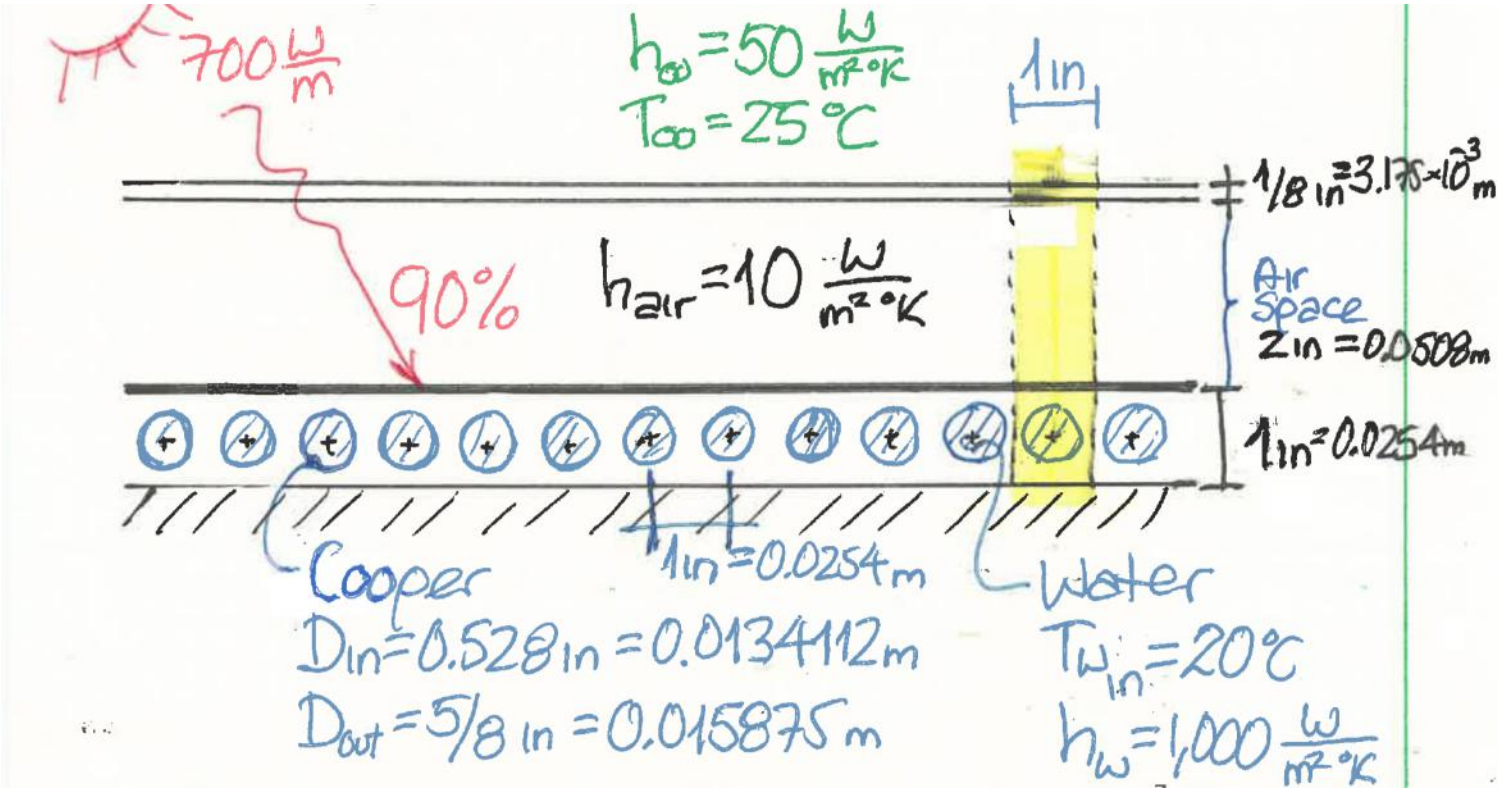
Purpose

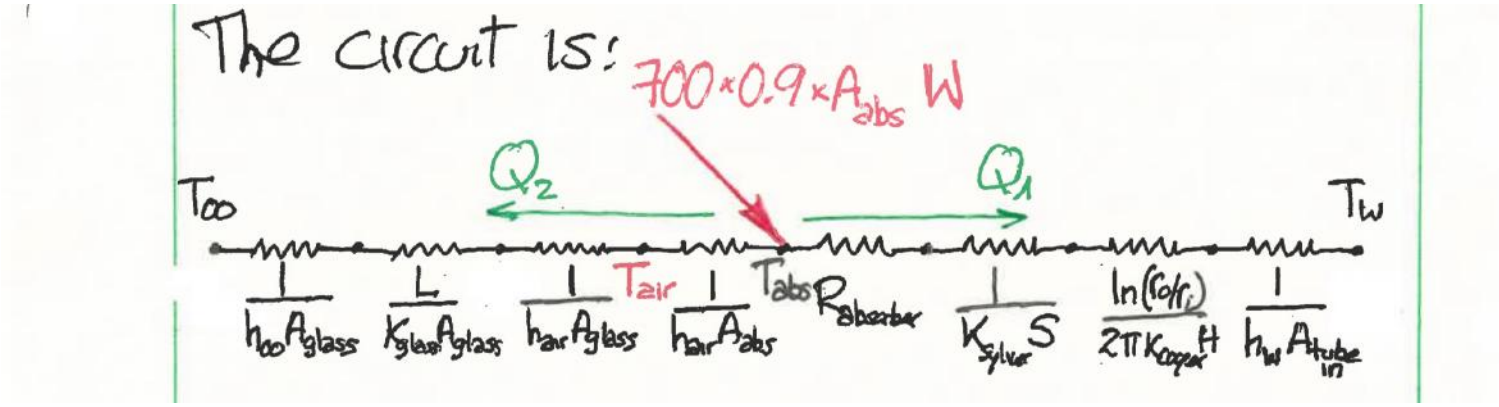
The purpose of this question is to find:

- The heat collected by the water in one of the tubes in the flat-plate solar collector.
- The flow rate of the water in the tubes.
- The efficiency of the collector (how effective is the solar collector compared to the incoming solar energy rate; need to find QT, Q1, and Q2 again).

Drawings & Diagrams







Sources

Heat Transfer Fundamentals 1st Edition, Begell House, Inc. by Yildiz Bayazitoglu & Necati Ozisik

Design Considerations

- Steady state
- Constant properties
- No heat generation
- One dimensional heat transfer
- No contact resistance
- Additional: forced convection because water temperature in is not equal to the water temperature out.

Data & Variables

Data and variables can be gathered from the first test.

Procedure

For this test, MLDT is used to find the more accurate results for heat collected by the water and heat absorbed by the water. Mass flow rate of the water will be solved for when gathering the MLDT heat absorbed by the water (Q2). Q2 will then be used to find the ratio of it to the incoming solar energy rate. This is almost the same as the first test, but using MLDT to find Q's.

Calculations

The equations that could be applied to this question are:

① $Q = \dot{m} c_p (T_{m_o} - T_{m_i}) = hA \dfrac{(T_{m_o} - T_s) - (T_{m_i} - T_s)}{\ln\left(\dfrac{T_{m_o} - T_s}{T_{m_i} - T_s}\right)}$

THERMODYNAMICS

Q_i : HEAT COLLECTED BY H_2O

$\dot{m}$: FLOW RATE

η : EFFICIENCY

② $Q = hA\Delta T_{lm} \rightarrow \Delta T_{lm} = \dfrac{\Delta T_o - \Delta T_i}{\ln\left(\dfrac{\Delta T_o}{\Delta T_i}\right)}$

HEAT TRANSFER

$\Delta T_o = T_{m_o} - T_s$

$\Delta T_i = T_{m_i} - T_s$

③ $Q = \dfrac{\Delta T_{lm}}{\Sigma R}$

$Nu = 0.023 Re^{0.8} Pr^{0.3}$

$h = \dfrac{Nu\, k}{L}$

④ $\eta = \dfrac{Q_i}{Q_T}$

Q Total

$A = 0.0254 m^2$

$Q_T = (0.9)(700 W/m^2)(0.0254 m^2)\left(\dfrac{20°C + 0.396°C}{\ln\left(\dfrac{20°C}{0.396°C}\right)}\right)$

$Q_T = 83.215 W$

Forced Convection for Q2

$$\Sigma R_{Q_2} = 0.7874\frac{^\circ C}{W} + 0.1603\frac{^\circ C}{W} + 3.9370\frac{^\circ C}{W} + 3.9370\frac{^\circ C}{W} = 8.8217\frac{^\circ C}{W}$$

$$Q_2 = \frac{\Delta T_{lm}}{\Sigma R} \Rightarrow Q_2 = \frac{\frac{\Delta T_o - \Delta T_i}{\ln\left(\frac{\Delta T_o}{\Delta T_i}\right)}}{8.8217\frac{^\circ C}{W}}$$

$\Delta T_o = T_{m_o} - T_\infty \Rightarrow \Delta T_o = 45^\circ C - 25^\circ C$

$\Delta T_o = 20^\circ C$

$\Delta T_i = T_{m_i} - T_{ABS} \Rightarrow \Delta T_i = 20^\circ C - 20.396^\circ C$

$\Delta T_i = -0.396^\circ C$

$$Q_2 = \frac{\frac{20^\circ C + 0.396^\circ C}{\ln\left(\frac{20^\circ C}{0.396^\circ C}\right)}}{8.8217\frac{^\circ C}{W}}$$

$$\boxed{Q_2 = 0.5895 W} \quad \text{Ia}$$

Forced Convection for Q1

$$\Sigma R_{Q_1} = 2.0776\times10^{-4}\frac{^\circ C}{W} + 6.9539\times10^{-5}\frac{^\circ C}{W} + 0.0237\frac{^\circ C}{W} = 0.023977\frac{^\circ C}{W}$$

$$Q_1 = \frac{\Delta T_{lm}}{\Sigma R} \Rightarrow Q_1 = \frac{\frac{\Delta T_o - \Delta T_i}{\ln\left(\frac{\Delta T_o}{\Delta T_i}\right)}}{0.023977\frac{^\circ C}{W}}$$

$$Q_1 = \frac{\frac{20^\circ C + 0.396^\circ C}{\ln\left(\frac{20^\circ C}{0.396^\circ C}\right)}}{0.023977\frac{^\circ C}{W}}$$

$$Q_1 = 218.5096 W$$

Water's Flow Rate

$$\dot{m} = \frac{Q_2}{C_p(T_{m_o} - T_{m_i})} \Rightarrow \dot{m} = \frac{0.5895W}{4179 \frac{KJ}{kgK}(45°C - 20°C)}$$

$$\dot{m} = 0.000005642 kg/s \quad 1b$$

Efficiency

$$\eta = \frac{Q_2}{Q_T} \Rightarrow \eta = \frac{0.5895W}{85.215W}$$

$$\eta = 0.7084\% \quad 1c$$

Summary

The amount of heat collected by the water in one tube is 0.5895 Watts. The mass flow rate of the water in the tubes is for the water to go from 20°C to 45°C using MLDT is 0.000005642 kg/s. The efficiency of this solar collector is 0.7084%.

Materials

- Air
- Water
- Silver
- Copper tubing
- Glass
- Absorber

Analysis

Compared to the first test, the results from this test using the MLDT method has a less erroneous efficiency. Upon researching online, this method of heating up water has bad efficiency at a daily of 30-40%. Comparing it to the ideal but inaccurate method of the first test, it has a similar behavior in mass flow rate (between 0 and 1) but it is worrying to see that the Q's do not come close at all to each other. This definitely has to do with improper setup of the MLDT portion of the equation. The excel sheet I worked on said that my answer by hand was 3% from the actual answer.