Test 1 - Joel Adriano

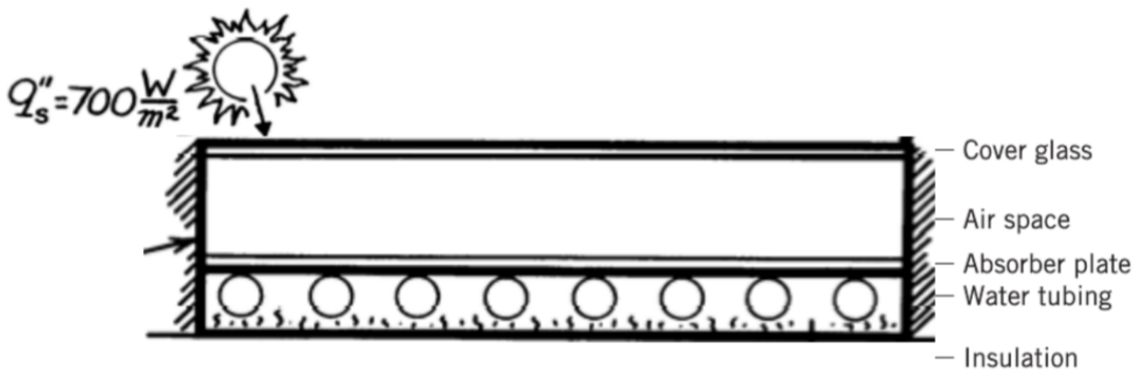
Question 1

Purpose

The purpose of the first question of this test is to find the amount of heat collected by the water in one of the copper tubes, find the air space temperature, find the flow rate of the outlet temperature of the water measured at 45°C, and find the collector efficiency.

Drawings and Diagrams

Figure provided to envision the design of the water heater



Drawing to show Q

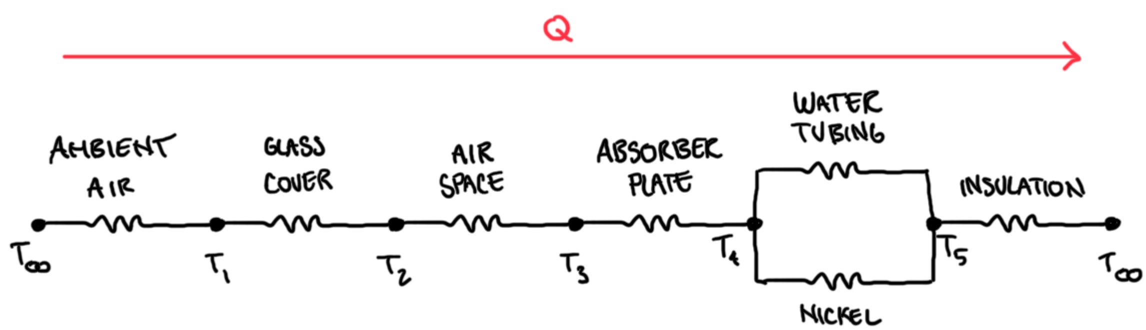
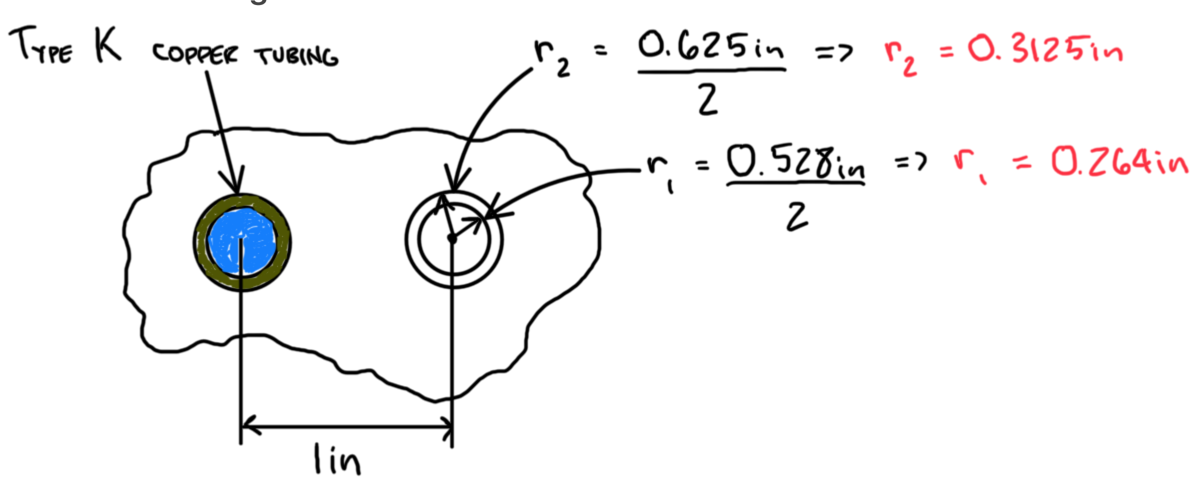


Diagram of Water Tubing



Sources

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

Design Considerations

The design of this flat-plate solar collector relies on solar heating to heat up water in copper tubes. It can be assumed that the whole system is about 4.8 inches underground without counting the absorber plate that is very thin and highly conductive. The copper tubing that holds water is buried into a nickel slab and they are spaced out center to center from each other at 1 inch. It can be assumed that this collector is in steady conduction so there is no type of heat generation.

Data and Variables

Solar Flux

$$q = 700 \frac{W}{m^2} \qquad \text{REMINDER: } q = K \frac{\Delta t}{L}$$

Temperatures

$$T_p = 20^\circ C, \quad T_{IN} = 45^\circ C, \quad T_{ATM} = 25^\circ C$$

Thermal Conductivities

$$h_W = 1000 \frac{W}{m^2 \, ^\circ K}, \quad h_{ATM} = 50 \frac{W}{m^2 \, ^\circ K}, \quad h_A = 10 \frac{W}{m^2 \, ^\circ K}$$

Copper Tubing Radiuses

$$r_1 = 0.264 \text{in}, \quad r_2 = 0.3125 \text{in}$$

Thicknesses

COVER GLASS: $\frac{1}{8}$ in => 0.125in

AIR SPACE: 2in

NICKEL SLAB: 1in

Procedure & Calculations

Collect parts a to d including the following deliverables: heat collected by the water tubes, air space temperature, heat flow rate of the water, and efficiency of the solar collector.

Part a

Since part a requires the amount of heat collected by the water in one of the tubes, the Q will need to be solved for. This can be attained by multiplying the solar flux (q) to the area of the tube (A).

$$A = \pi r^2 \Rightarrow A = (\pi)(0.264\ in^2)$$

$$A = \frac{1.66\ in^2}{1550} \Rightarrow A = 1.07E\text{-}3\ m^2$$

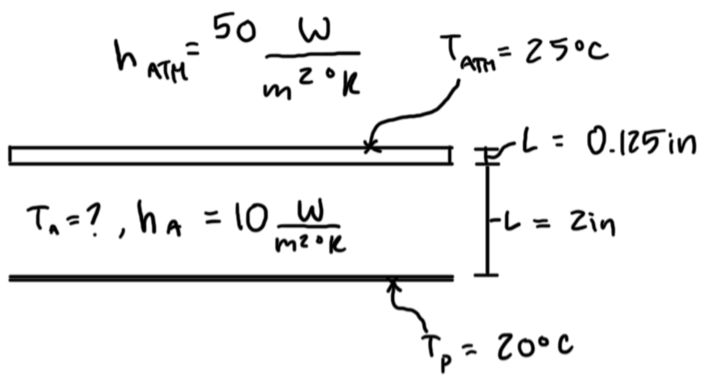
a) $$Q = qA \Rightarrow Q = \left(700\ \frac{W}{m^2}\right)(1.07E\text{-}3\ m^2)$$

$$\boxed{Q = 0.75\ W}$$ 1a

Part b

Part b requires the air space temperature. This can be attained by the radiation equation for steady conduction without heat generation.

b)



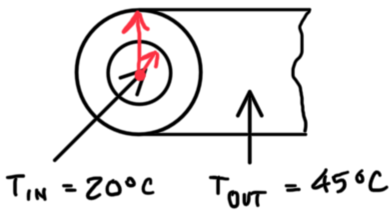
$$T = C_1 x + C_2 \Rightarrow T_{AS} = \left(\frac{T_{ATM} - T_P}{L}\right) x + T_P$$

$$T_{AS} = \left(\frac{25°C - 20°C}{2in}\right) 1in + 20°C$$

$$\boxed{T_{AS} = 22.5°C}$$ 1b

Part c

Part c asks for the HEAT flow rate of the water if the outlet temperature is 45°C and the inlet temperature is 20°C. Also note that the specific heat of the water is 4179J/kg°K and m is the thermal conductivity of copper.



$r_1 = 0.264\,in$

$r_2 = 0.3125\,in$

$k_c = 385 \frac{W}{m\,°K}$

$c_p = 4179 \frac{J}{kg\,°K}$

$Q = m c_p \Delta T$

$97.5 \frac{W}{m\,°K}$ $\quad 385 \frac{W}{m\,°K}$ $\quad 1000 \frac{W}{m^2\,°K}$

$$R_{EQ} = \frac{1}{K_n A} + \frac{1}{\frac{2\pi L}{\ln(r_2/r_1)} K_c} + \frac{1}{h_w A}$$

$$\Rightarrow R_{EQ} = \frac{1}{\left(97.5 \frac{W}{m\,°K}\right)(1m^2)} + \frac{1}{\frac{2\pi(1m^2)}{\ln\left(\frac{0.3125in}{0.264in}\right)}\left(385 \frac{W}{m\,°K}\right)} + \frac{1}{\left(1000 \frac{W}{m^2\,°K}\right)(1m^2)}$$

$$R_{EQ} = 10.345$$

$$Q_w = \frac{T_{IN} - T_{OUT}}{R_{EQ}} \Rightarrow Q_w = \frac{20°C - 45°C}{10.345 \frac{W}{m^2}} = \boxed{Q_w = -2.42 \frac{W}{m^2}}$$ 1c

Part d

Part d requires the calculation of the collector's efficiency, this will be the heat flow rate of the water divided by the solar flux.

$$\eta = \frac{Q_w}{q} = \eta = \frac{2.42 \frac{W}{m^2}}{700 \frac{W}{m^2}} \Rightarrow \boxed{\eta = 0.34\%}$$ 1d

Summary

The amount of heat collected by the water through the tubing is 0.75W. The temperature in the air space is 22.5°C. The heat flow rate of the water through the tubes is -2.42W/m^2. The thermal efficiency of this solar collector is 0.34%. This system does not really seem like the most efficient

Materials

Flat-plate Solar Collector

Analysis

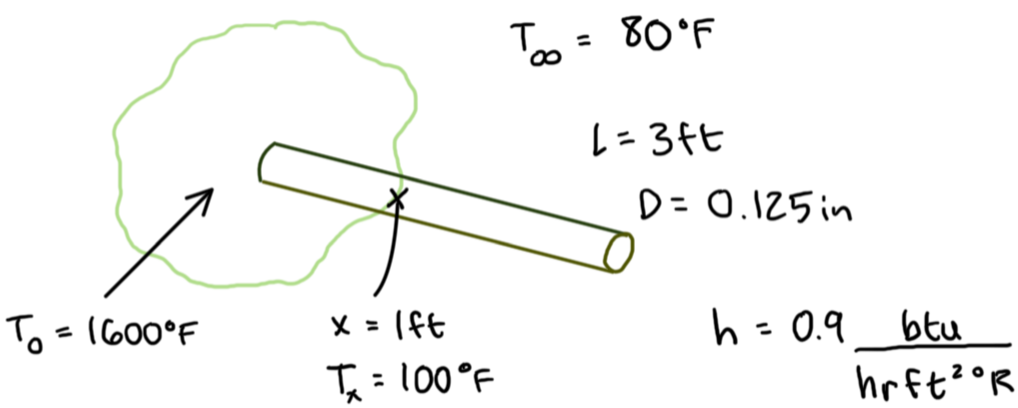
This problem needs the knowledge of Mechanisms of Heat Flow and Steady Conduction without Heat Generation.

Question 2

Purpose

The purpose of the second question of this test is to find the conductivity of the brazing material (copper alloy in a shape of a rod) at a distance of 1 foot from the base.

Drawings and Diagrams



Sources

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

Design Considerations

It is assumed that from this question, it can be solved using extended surfaces. It can also be assumed that as an extended surface, the tip of the cylinder is cooler than the base. At this instance, the base is where it is being melted so it is hotter there than the tip. It can be assumed that this rod is undergoing an adiabatic process.

Data and Variables

Temperatures

$T_0 = 1600°F, \quad T_x = 100°F, \quad T_\infty = 80°F$

Cylinder Values

$L = 3ft, \quad D = 0.125in, \quad x = 1ft, \quad A_c = 2\pi rh + 2\pi r^2$

$\Rightarrow A_c = 2\pi(0.0625in)(36in) + 2\pi(0.0625^2)$

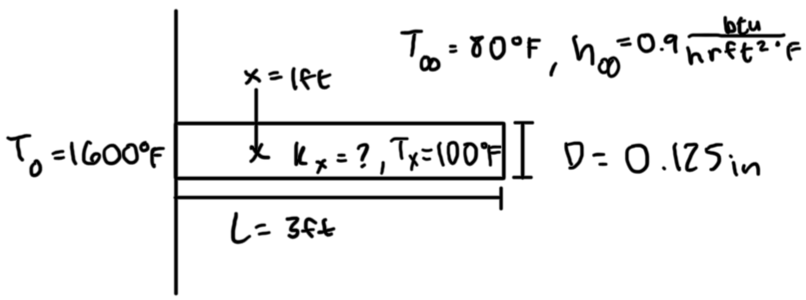
$A_c = 14.16in^2$

Thermal Conductivities

$$h_A = 0.9 \frac{btu}{hr\,ft^2\,°R}$$

Procedure

For this question, the thermal conductivity coefficient at 1 ft from the base will need to be attained. The adiabatic temperature distribution is going to be used to solve for the thermal conductivity at x.



Calculations

$$\theta/\theta_b = \frac{\cosh m(L-x)}{\cosh mL} \Rightarrow (T_x - T_\infty)/(T_0 - T_\infty) = \frac{\cosh m(L-x)}{\cosh mL}$$

$$\Rightarrow (100°F - 80°F)/(1600°F - 80°F) = \frac{\cosh m(3ft - 1ft)}{\cosh m(3ft)}$$

$$20°F/1520°F = \frac{\cosh m(2ft)}{\cosh m(3ft)}$$

$$\emptyset$$

$$m^2 = h\pi/kA_c \Rightarrow k = \frac{h\pi}{A_c m^2} \Rightarrow k = \frac{(0.9\frac{btu}{hrft^2 °F})\pi}{(14.16in^2)(1ft)}$$

$$\boxed{k = 0.2 \frac{btu}{ft°F}}$$ 2

Summary

The thermal conductivity of the brazing material at 1 foot from the base is 0.2btu/ft°F.

Materials

Copper Alloy as Brazing Rod

Analysis

This problem requires the knowledge of Extended Surfaces. I came to realize that the thermal conductivity does not depend on the location after solving and seeing it cancelled out.