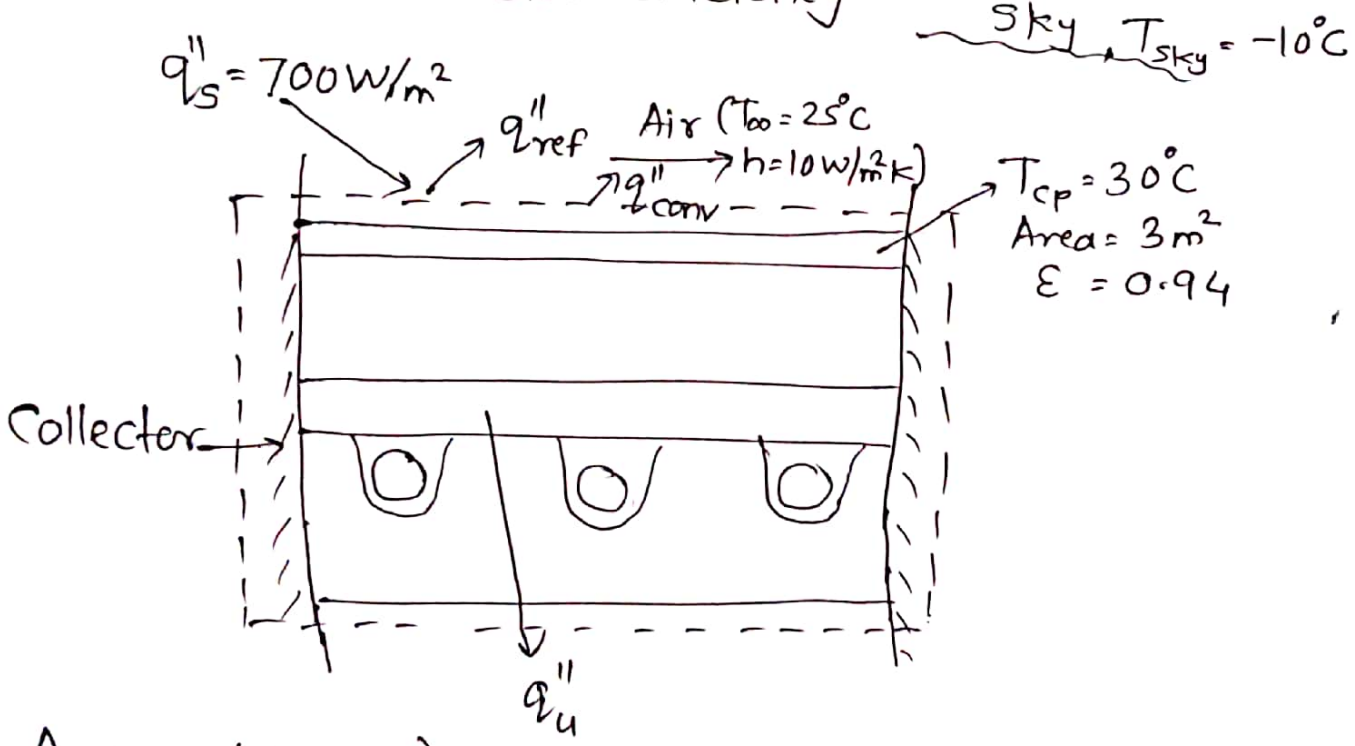
Q1)

Known: Solar collector designed to heat water operating under prescribed solar irradiation and loss conditions.

Find : a) Useful heat collected per unit area of the collector, q''_u

b) Temperature rise of the water flow, $T_o - T_i$

c) Collector efficiency



Assumptions: 1) Steady state conditions

2) No heat losses out sides or back of the collector

3) Collector area is small compared to sky surroundings.

Properties: C_p (water @ 300k) = 4179 J/kg·K

Analysis

a) Defining the collector area as the control volume and writing the conservation of Energy requirement on a per unit area basis.

$$\dot{E}_{in} - \dot{E}_{out} + \dot{E}_{gen} = \dot{E}_{st}$$

$$q''_{solar} - q''_{rad} - q''_{conv} - q''_u = 0$$

Here $q''_{solar} = 0.9\, q''_s$ (90% absorbed by collector)

$$q''_u = 0.9 \cdot q''_s - \varepsilon\sigma\left(T_{cp}^4 - T_{sky}^4\right) - h(T_s - T_\infty)$$

solving,

$$q''_u = 630\ w/m^2 - 194\ w/m^2 - 50\ w/m^2$$

$$= 386\ w/m^2$$

b) Useful heat q''_u : A this heat causes enthalpy change of water

$$q''_u \cdot A = \dot{m} C_p \cdot (T_i - T_o)$$

Solving, $T_i - T_o = 27.7^\circ C$

c) Efficiency $\eta = q''_u / q''_s = 0.55$

$\eta = 55\%$

Q2

(a) $\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{st}$

$$q_i'' (4\pi r_i^2) - h (4\pi r_o^2)(T - T_\infty) = \rho \frac{4}{3}\pi (r_o^3 - r_i^3) c_p \frac{dT}{dt}$$

$$\frac{dT}{dt} = \frac{3}{\rho c_p (r_o^3 - r_i^3)} \left[q_i'' r_i^2 - h r_o^2 (T - T_\infty) \right]$$

Substituting numerical values :→

$$\left.\frac{dT}{dt}\right)_i = \frac{3 \left[10^5 (0.5)^2 - 500 (0.6)^2 (500 - 300) \right]}{8055 (510) (0.6^3 - 0.5^3)}$$

$$= -0.084 \text{ K/s}$$

(b) For steady state, we know,

$$\dot{E}_{st} = 0$$

$$\Rightarrow q_i'' (4\pi r_i^2) = h 4\pi r_o^2 (T - T_\infty)$$

$$\Rightarrow T = T_\infty + \frac{q_i''}{h} \left(\frac{r_i}{r_o} \right)^2$$

$$= 300 + \frac{10^5}{500} \left(\frac{0.5}{0.6} \right)^2 = 439 \text{ K}$$