Consider a one cover glass flat plate solar collector that is heating water from 25°C to 50°C. Determine the mass flow rate of water that may be heated for a collector area of 50 m² operating under the following conditions:

incident solar radiation: 350 W/m²
solar absorptivity of the collector: 0.90
fraction of collector in contact with water: 0.80
specific heat of water: 4200 J/(kg·K)
convective heat transfer coefficient of water: 55 W/(m²·K)
infrared radiation heat transfer coefficient: 1.5 W/(m²·K)
air and surrounds temperature: 285 K
air convective heat transfer coefficient: 2 W/(m²·K)
air gap convective heat transfer coefficient: 0.8 W/(m²·K)
cover glass thickness: 4 mm
cover glass thermal conductivity: 1.4 W/(m·K)

**Solution:**
We can solve for the mass flow rate from the water energy balance to give

\[
\dot{m} = \frac{-h_{\text{fluid}} f_{\text{coll}} A_{\text{coll}}}{c_p} \ln \left( \frac{T_{\text{coll}} - T_{\text{fluid, out}}}{T_{\text{coll}} - T_{\text{fluid, in}}} \right)
\]

To make this calculation we need to determine the collector temperature. Starting with the water energy balance, we can write

\[
(T_{\text{coll}} - T_{\text{fluid, in}}) \exp \left( \frac{-h_{\text{fluid}} f_{\text{coll}} A_{\text{coll}}}{\dot{m} c_p} \right) = T_{\text{coll}} - T_{\text{fluid, out}}
\]

Substituting into the collector energy balance

\[
\alpha_s G_i = h_{\text{fluid}} f_{\text{coll}} (T_{\text{coll}} - T_{\text{fluid, out}}) + h_{\text{rad}} (T_{\text{coll}} - T_{\text{surr}}) + \frac{(T_{\text{coll}} - T_{\text{air}})}{R_{\text{tot}}}
\]
Solving for the collector temperature

\[
T_{\text{coll}} = \alpha_s G_i + h_{\text{fluid}} f_{\text{coll}} T_{\text{fluid,out}} + h_{\text{rad}} T_{\text{surr}} + \frac{T_{\text{air}}}{R'_{\text{tot}}} \]

\[
\div \left[ h_{\text{fluid}} f_{\text{coll}} + h_{\text{rad}} + \frac{1}{R'_{\text{tot}}} \right]
\]

Calculating \( R'_{\text{tot}} \)

\[
R'_{\text{tot}} = \frac{1}{2} + (1) \left( \frac{1}{0.8} + \frac{0.004}{1.4} \right) = 1.7529 \text{ (m}^2 \cdot \text{K})/\text{W}
\]

Now calculating the collector temperature

\[
T_{\text{coll}} = \left[ (0.90)(350) + (55)(0.80)(323) + (1.5)(285) + \frac{285}{1.7529} \right]
\]

\[
\div \left[ (55)(0.80) + 1.5 + \frac{1}{1.7529} \right]
\]

= 328.13 K

Then our mass flow rate of water becomes

\[
\bar{m} = \frac{(55)(0.80)(50)}{4200} \div \ln \left\{ \frac{328.13 - 325}{329.13 - 298} \right\} = 0.296 \text{ kg/s}
\]