Consider a cylindrical tube with internal coolant flow and hot air flowing externally over the cylinder. The external flow velocity is 30 m/s. The Nusselt number for external heat transfer is given as

\[
\bar{N}_u = \frac{\bar{h} d_2}{k_f} = C R_{d_2}^m P_{r_{ext}}^{1/3}
\]

The constants C and m can be obtained from the table and Prandtl number is \( P_{r_{ext}} = 0.7 \).

The coolant (water) enters the tube at a temperature of 300 K. The flow in the tube can be assumed to be fully developed Laminar flow from \( x = 0 \) to \( x = L \). The internal flow Reynolds number is 500. The Nusselt number for the internal flow is 20.

\[
d_1 = 2.54 \text{ cm}, \quad d_2 = 1.1 d_1.
\]

**Internal flow:** \( \rho_c = 996 \frac{kg}{m^3}, \mu_c = 0.008508 \frac{kg}{ms}, k_c = 0.61 \frac{W}{mK}, c_p = 4.180 \frac{J}{gK} \)

**External flow:** \( \rho_{air} = 0.9413 \frac{kg}{m^3}, \mu_{air} = 2.181 \times 10^{-5} \frac{kg}{ms}, k_{air} = 0.03186 \frac{W}{mK} \)

(a) Find the required heat transfer coefficients and the overall heat transfer coefficient. (10 points)
(b) Find the expression for the coolant temperature as a function of \( x \) and sketch the fluid temperatures as a function of \( x \). (35 points)
(c) Find the coolant exit temperature (\( T_{c_{out}} \)). (15 points)
(d) Find the heat flux as a function of \( x \) and sketch the heat flux as a function of \( x \). (25 points)

Find the overall heat transfer to the fluid. (15 points)