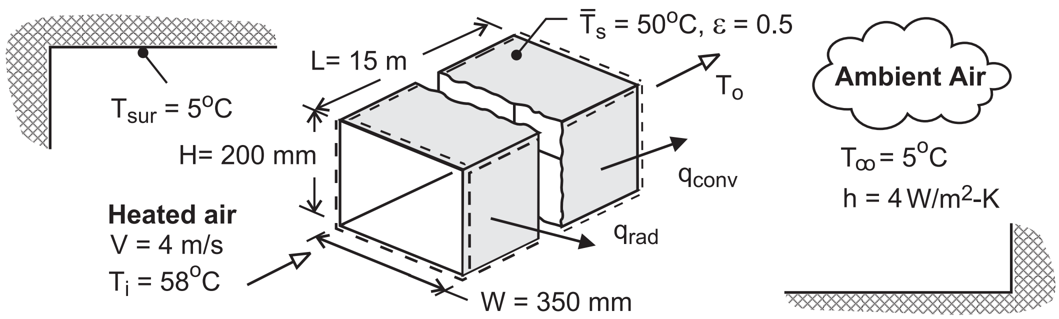
PROBLEM 1.79

KNOWN: Dimensions, average surface temperature and emissivity of heating duct. Duct air inlet temperature and velocity. Temperature of ambient air and surroundings. Convection coefficient.

FIND: (a) Heat loss from duct, (b) Air outlet temperature.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, (2) Constant air properties, (3) Negligible potential and kinetic energy changes of air flow, (4) Radiation exchange between a small surface and a large enclosure.

ANALYSIS: (a) Heat transfer from the surface of the duct to the ambient air and the surroundings is given by Eq. (1.10)

$$q = hA_s\left(T_s - T_\infty\right) + \varepsilon A_s\sigma\left(T_s^4 - T_{sur}^4\right)$$

where A_s = L (2W + 2H) = 15 m (0.7 m + 0.5 m) = 16.5 m^2. Hence,

$$q = 4\ \text{W/m}^2\cdot\text{K}\times 16.5\ \text{m}^2\left(45^\circ\text{C}\right) + 0.5\times 16.5\ \text{m}^2\times 5.67\times 10^{-8}\ \text{W/m}^2\cdot\text{K}^4\left(323^4 - 278^4\right)\text{K}^4$$

$$q = q_{conv} + q_{rad} = 2970\ \text{W} + 2298\ \text{W} = 5268\ \text{W}$$ <

(b) With i = u + pv, $\dot{W}$ = 0 and the third assumption, Eq. (1.12d) yields,

$$\dot{m}\left(i_i - i_o\right) = \dot{m}c_p\left(T_i - T_o\right) = q$$

where the sign on q has been reversed to reflect the fact that heat transfer is *from* the system. With $\dot{m} = \rho VA_c = 1.10\ \text{kg/m}^3 \times 4\ \text{m/s}\left(0.35\text{m}\times 0.20\text{m}\right) = 0.308\ \text{kg/s}$, the outlet temperature is

$$T_o = T_i - \frac{q}{\dot{m}c_p} = 58^\circ\text{C} - \frac{5268\ \text{W}}{0.308\ \text{kg/s}\times 1008\ \text{J/kg}\cdot\text{K}} = 41^\circ\text{C}$$ <

COMMENTS: The temperature drop of the air is large and unacceptable, unless the intent is to use the duct to heat the basement. If not, the duct should be insulated to insure maximum delivery of thermal energy to the intended space(s).