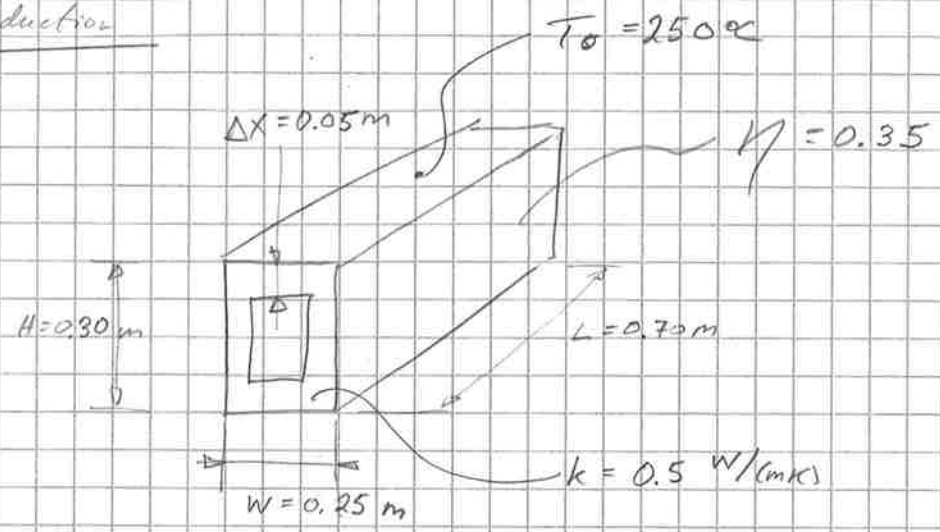
14 - 02 -2020

Open Book test
MEC 3204

1) Conduction



$\dot{m}_{wood} = 4 kg/h$

$H_{LHV,wood} = 10 MJ/kg$

a) $q''_{cond} = \frac{?}{0}$

$q''_{cond} = \frac{q_{cond}}{A}$

$A = 2(L \cdot W + L \cdot H + W \cdot H) = 2(0.70 \cdot 0.30 + 0.70 \cdot 0.25 + 0.30 \cdot 0.25)\ m^2$

$A = \underline{0,92\ m^2}$

$q_{cond} = E_{comb,eff}$

$E_{comb,eff} = \eta E_{comb}$

$E_{comb} = H_{LHV,wood} \cdot \dot{m}_{wood} = \left(10 \cdot 10^6 \cdot 4 \frac{1}{3600}\right) W = \underline{11111\ W}$

$E_{comb,eff} = (0.35 \cdot 11111)\ W = \underline{3889\ W} = q_{cond}$

$q''_{cond} = \frac{3889}{0.92}\ W/m^2 = \underline{4227\ W/m^2}$

b) $q_{cond} = \underline{3889\ W}$

1) $q''_{cond} = -k\frac{dT}{dx} = -k\frac{T_i - T_o}{x_i - x_o} = k\frac{T_i - T_o}{\Delta x}$

$T_i = T_o + \frac{q''_{cond}}{k}\Delta x = \left(250 + \frac{4227}{0.5} \cdot 0.05\right)°C$

$\underline{\underline{T_i = 673\,°C}}$

2) $q''_{rad} = \delta\,\varepsilon\left(T_s^4 - T_\infty^4\right)$

$T_s^4 - T_\infty^4 = \left(T_s^2 - T_\infty^2\right)\left(T_s^2 + T_\infty^2\right)$

$T_s^2 - T_\infty^2 = \left(T_s - T_\infty\right)\left(T_s + T_\infty\right)$

$q''_{rad} = \underbrace{\delta\,\varepsilon\left(T_s^2 + T_\infty^2\right)\left(T_s + T_\infty\right)}_{\downarrow\downarrow}\left(T_s - T_\infty\right)$

h_{rad}

$q''_{rad} = h_{rad}\left(T_s - T_\infty\right)$ $\underline{\underline{q.e.d.}}$

3) $\varepsilon = 0.9$

$\alpha = 0.9$

$h_o = 3.5\ W/m^2K$

Surface balance gives: $q''_{conv} + q''_{rad} - q''_{cond} = 0$

$q''_{conv} = h_o\left(T_s - T_{room}\right)$

$q''_{rad} = \delta\,\varepsilon\left(T_s^4 - T_{wall}^4\right)$

Solution by trial and error: Assume $T_{room,1} = 25\,°C$

$\Rightarrow q''_{conv,1} = 3.5\,(250-25)\ W/m^2 = 788\ W/m^2$

$q''_{rad,1} = 5.67\cdot10^{-8}\cdot 0.9\left((250+273)^4 - (25+273)^4\right) = 3467\ W/m^2$

$$q''_{conv_1} + q''_{rad_1} = 4254 \ W/m^2$$

$$q''_{cond} = 4227 \ W/m^2$$

$$q''_{cond} - q''_{conv_1} - q''_{rad_1} = -27 \ W/m^2 < 0 \Rightarrow T'_{room} > T_{room}$$

Assume: $T_{room_2} = 30\,^\circ C$

$$\Downarrow$$

$$q''_{conv_2} = 770 \ W/m^2$$

$$q''_{rad_2} = 3442 \ W/m^2 \ ; \quad q''_{conv_2} + q''_{rad_2} = 4212 \ \frac{W}{m^2}$$

$$q''_{cond} - q''_{conv_2} - q''_{rad_2} = +15\,^\circ C$$

Linear interpolation:

$$T_{room} \approx T_{room_1} + \frac{T_{room_2} - T_{room_1}}{\left(q''_{conv_2} + q''_{rad_2}\right) - \left(q''_{conv_1} + q''_{rad_1}\right)} \left(q''_{cond} - \left(q''_{conv_1} + q''_{rad_1}\right)\right)$$

$$T_{room} \approx \left(25 + \frac{30 - 25}{4212 - 4254}\left(4227 - 4254\right)\right)^\circ C$$

$$T_{room} = 28.2\,^\circ C$$

Check:

$$\left.\begin{aligned} q''_{conv} &= 776 \ \frac{W}{m^2} \\ q''_{rad} &= 3451 \ \frac{W}{m^2} \end{aligned}\right\} \Rightarrow$$

$$q''_{conv} + q''_{rad} = 4227 \ \frac{W}{m^2} = q''_{cond}$$

:) OK!

$$\underline{\underline{T_{room} \approx 28.2\,^\circ C}}$$