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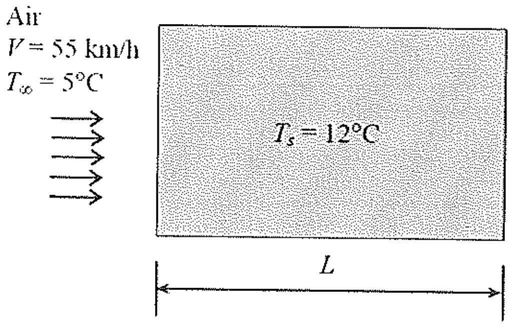
December 19, 2015

Cankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 313 Heat Transfer
Midterm Exam II
Closed Notes Open Book
Fall 2015

1) During a cold winter day, wind at 55 km/h is blowing parallel to a 4-m-high and 10-m-long wall of a house. If the air outside is at 5 ^{0}C and the surface temperature of the wall is 12 ^{0}C, determine the rate of heat loss from that wall by convection. Air flows parallel to 10 m side



$$u_\infty = 55 \frac{km}{hr} \cdot \frac{1000 m}{km} \frac{hr}{3600 s} = 15,27 \text{ m/s}$$

Air Properties:
$k = 0.02428 \text{ W/m.}^0\text{C}, \nu = 1.413 \times 10^{-5} \text{ m}^2/\text{s}, \text{Pr} = 0.734$

$$Re_L = \frac{u_\infty L}{\nu} \cdot \frac{(\qquad)}{1.413 \times 10^{-5}} = 1.081 \times 10^7 < 500\,000$$
turbulent flow

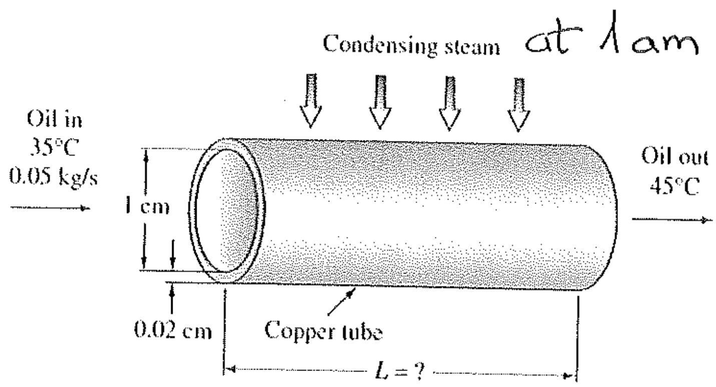
$$\overline{Nu}_L = \frac{\bar{h} L}{k} = [0.037 Re_L^{0.8} - 871] Pr^{1/3} = 1.336 \times 10^4$$

$$\bar{h} = \frac{k}{L} \overline{Nu}_L = 32.43 \text{ W/m}^2 \text{°C}$$

$$A_s = WL = 40 \text{ m}^2$$

$$q = \bar{h} A_s (T_s - T_\infty) = 9.08 \text{ kW}$$

2) Used engine oil can be recycled by a patented reprocessing system. Suppose that such a system includes a process during which engine oil flows through a 1-cm-ID, 0.02-cm-wall copper tube at the rate of 0.05 kg/s. The oil enters at 35°C and is to be heated to 45°C by atmospheric-pressure steam condensing on the outside, as shown in figure given below. Calculate the length of the tube required.



Note: ID-Inside diameter, OD-Outside Diameter

Properties of air at 40 °C:

$$c_p = 1964\,\mathrm{J/kg.K}, \rho = 876\,\mathrm{kg/m^3}, k = 0.144\,\mathrm{W/m.K}, \mu = 0.210\,\mathrm{N.s/m^2}, Pr = 2870$$

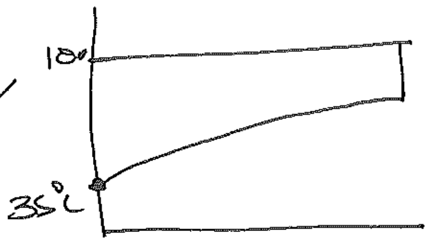
$Re_D = \dfrac{4\dot{m}}{\mu \pi D} = 30.3 < 2300$ laminar flow

$T_s =$ const. so

$\overline{Nu}_D = 3.66 \Rightarrow \bar{h} = \dfrac{k}{D}\overline{Nu}_D = 52.7\ \mathrm{W/m^2 K}$

the heat transported

$q_c = \dot{m} c_p (T_{mo} - T_{mi}) = 982\ W$



$\Delta T_{LMTD} = \dfrac{\Delta T_{out} - \Delta T_{in}}{\ln\left(\dfrac{\Delta T_{out}}{\Delta T_{in}}\right)}$

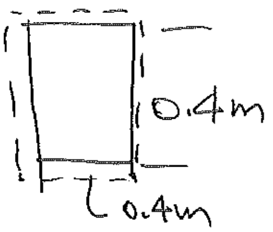
$\Delta T_{in} = 100 - 35 = 65°C$

$\Delta T_{out} = 100 - 45 = 55°C$

$= \dfrac{55 - 65}{\ln\left(\dfrac{55}{65}\right)} = 59.9K$

$L = \dfrac{q_c}{\pi D_i \bar{h}\, \Delta T_{LMTD}} = 9.91\ m$

3) An electrically heated square (0.4m by 0.4 m) vertical plate is to be kept at $T_s = 95\,^0C$ in ambient air at $T_\infty = 25\,^0C$ .We wish to determine the power supply to the plate. Hint: Evaluate the air properties at the temperature closest to film temperature T_f .



$$\dot{W}_e = 2q_c \qquad \cancel{\dot{E}_{in}}^{0} - \dot{E}_{out} + \dot{E}_g = \cancel{\dot{E}_{st}}^{0}$$

$$q_c = \bar{h}A(T_s - T_\infty)$$

$$T_f = \frac{95+25}{2} = 60^0C \quad (333\,K)$$

nearest temperature is 350 K

$\rho = 0.995\ kg/m^3$; $c_p = 1.009\ kJ/kgK$, $\mu = 208.2\times10^{-7}\ \frac{Ns}{m^2}$

$\nu = 20.92\times10^{-6}\ m^2/s$, $k = 30\times10^{-3}\ W/mK$ $\quad Pr = 0.7$

$$Ra_L = Gr_L Pr = \left[\frac{g\beta(T_s - T_\infty)}{\nu^2}L^3\right](Pr) = 2\times10^8$$

$$\overline{Nu}_L = \left\{0.68 + \frac{0.67\,Ra_L^{1/4}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{9/16}\right]^{4/9}}\right. = 61.2$$

$$\bar{h} = \frac{k}{L}\overline{Nu}_L$$

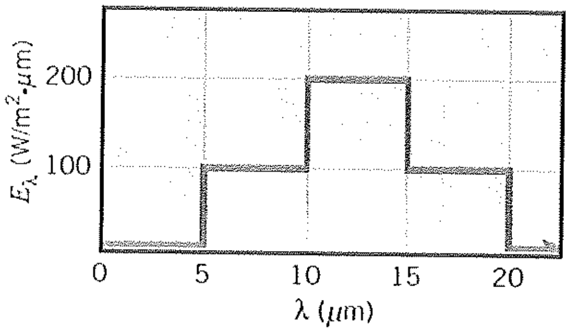
$$= \left(\frac{30\times10^{-3}}{0.4}\right)(61.2) = 4.63\ W/m^2\,^0C$$

$$W_e = (2)(4.63)(0.4)^2(95-25) = 103.71\ W$$

4)

a) A 5 -cm -diameter cylinder has a surface temperature of 900 K. Assuming that the cylinder radiates as a black body, find the total blackbody emissive power.

b) The spectral distribution of the radiation emitted by a diffuse surface may be approximated as follows.



What is the total emissive power? What is the total intensity of the radiation emitted in the normal direction ?

c) Determine the radiant energy emission between wavelengths 2 to 5 μm at 1400 K by a black body of area 1 m^2.

a) $E_b = \sigma T^4 = \left(5,669 \times 10^{-8} \frac{W}{m^2 K^4}\right)(900K)^4 = 3,72 \times 10^4 \frac{W}{m^2}$

b) $E_b = \int_0^\infty E_{\lambda b} d\lambda = (5)(100) + 5(200) + 5 \times 100 = 2000\, W/m^2$

$I = \frac{E_b}{\pi} = 2000/\pi = 636.6\, W/m^2$

c) $\lambda_1 T = (1400)(2)10^{-6} = 2,8 \times 10^{-3}\, mK = 2800\, \mu m.K$

$\lambda_2 T = (1400)(5 \times 10^{-6}) = 7 \times 10^{-3}\, m.K = 7000\, \mu m.K$

$\frac{E_b(0-0.2)}{E_b} = 0.2279 \qquad \frac{E_b(0-5)}{E_b} = 0.80816$

$\frac{E_b(2-5)}{E_b} = 0.80816 - 0.2279 = 0.58026$

$q_r = (0.58026)(5,67 \times 10^{-8})(1400)^4 = 126391\, W/m^2$