First Name-- November 14, 2016

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Cankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 313 Heat Transfer
Midterm Exam I
Open Book Closed Notes
Fall 2016

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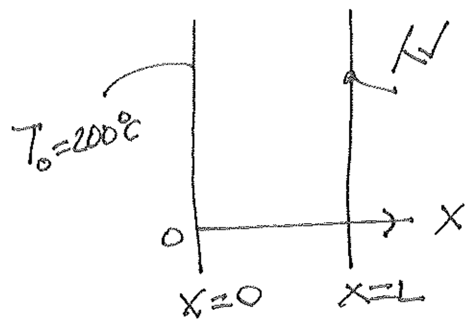
1) The temperature distribution across a wall 0.3 m thick at a certain instant of time is $T(x) = a + bx + cx^2$,where T is in degrees Celsius and x is in meters, a= 200 ^{0}C, b =-200 ^{0}C/ m, and c =30 ^{0}C/ m^2. The wall has a thermal conductivity of 1W/ m K.

(a) on a unit surface area basis, determine the rate of heat transfer into the wall on left face

(b) on a unit surface area basis, determine the rate of heat transfer out of the wall on right face

(c) the rate of change of energy stored by the wall.

(d) If the cold surface is exposed to a fluid at 100 ^{0}C, what is the convection coefficient $h(W/m^2.K)$?



$T = 200 - 200x + 30x^2$

$L = 0.3 m$

$k = 1 \ W/mK$

$q''_x = -k \frac{dT}{dx} = -(1)(-200+60x)$

a) $q_{in} = (q''_x)_{x=0} = 200 \ W/m^2$

b) $q_{out} = (q''_x)_{x=L} = -1(-200+60\times0.3) = 182 \ W/m^2$

c) $\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{st}$

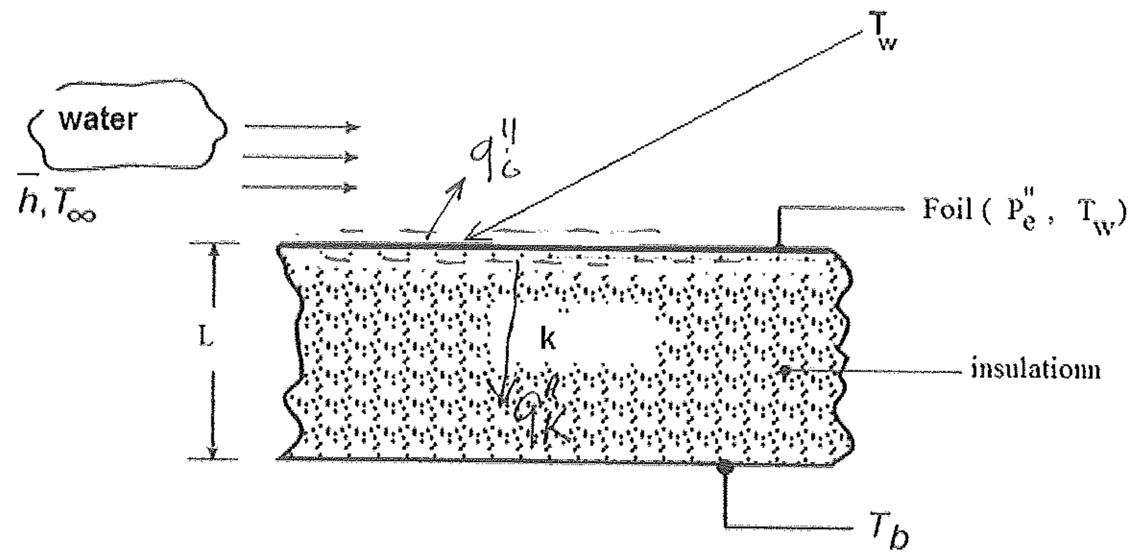
$$\dot{E}_{st} = 200 - 182 = 18 \text{ W/m}^2$$

d) $$q''_{out} = q''_c = \bar{h}\left[T_L - T_\infty\right]$$

$$T(L) = T_L = 200 - 200(0.3) + 30(0.3)^2$$
$$= 142.7 \text{ °C}$$

$$\bar{h} = \frac{182}{142.7 - 100} = 4.3 \text{ W/m}^2\text{K}$$

2) A technique for measuring convection heat transfer coefficients involves bonding one surface of a thin metallic foil to an insulating material and exposing the other surface to the fluid flow conditions of interest.



By passing an electric current through the foil, heat is generated and distributed uniformly within the foil and the corresponding energy flux, P''_e , may be inferred from related voltage and current measurements. If the insulation thickness L and thermal conductivity k are known and

T_∞ =the water temperature
T_w =foil top surface temperature
T_b=foil bottom surface temperature

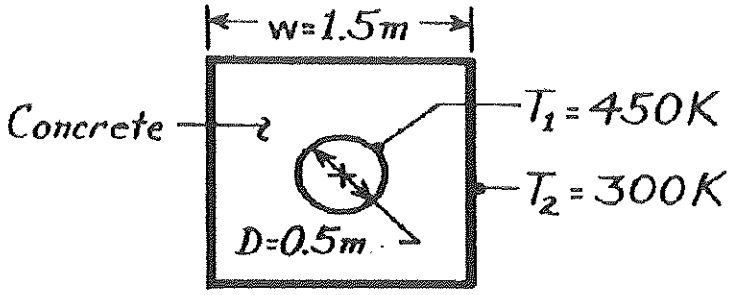
are measured, the convection coefficient $\bar{h}$ may be determined. Since foil thickness is very small it can be neglected. Consider conditions for which $T_\infty = T_b = 25\,^0C, P''_e = 2000\ W/m^2$ L= 10 mm, and k=0.04 W/m K. With water flow over the surface, the top foil surface temperature measurement yields $T_w = 27\,^0C$. Determine the convection coefficient. Recall that there is no radiative heat loss.

$$P''_e = \bar{h}(T_w - T_\infty) + K(T_w - T_b)/L$$

$$\bar{h} = \frac{P''_e - K(T_w - T_b)/L}{T_w - T_\infty} = \frac{2000 - 0.04(27-25)}{(27-25)}$$

$$= 999\ W/m^2K$$

3) Pressurized steam at 450 K flows through a long, thin- walled pipe of 0.5-m diameter. The pipe is enclosed in a concrete casing that is of square cross section and 1.5 m on a side.



The axis of the pipe is centered in the casing, and the outer surfaces of the casing are maintained at 300 K. What is the heat loss per unit length of pipe?

$k = 1.4\ W/mK$ at 300K

$q = kS(T_1 - T_2)$

$$S = \frac{2\pi L}{\ln\left[\frac{1.08W}{D}\right]}$$

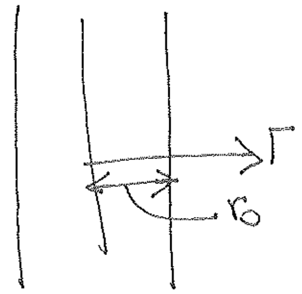
$$\frac{q}{L} = \frac{2\pi k(T_1 - T_2)}{\ln\left(\frac{1.08W}{D}\right)} = \frac{2\pi)(1.4)(450-30)}{\ln\left[\frac{1.08\times1.5}{0.5}\right]}$$

$= 1122\ W/m$

4) A long, 6.50 cm diameter, solid cylinder is made of Cr-Ni steel, **18%** Cr, **8%** Ni .
$\left(k = 16.5\, W/m.K, \alpha = 0.444\times10^{-5}\, m^2/s, \rho = 7817\, kg/m^3, c = 460\, J/kg.K\right)$.

It **is** initially at a uniform temperature $T_i = 150\,^0C$. It is suddenly exposed to a convective environment at $T_\infty = 50\,^0C$, and the surface convective heat transfer coefficient is $\bar{h} = 285\, W/m^2K$ .Calculate the temperature at

(a) the axis of the cylinder and
(b) a 2.5 cm radial distance from the center
after 5 minutes of exposure to the cooling flow.
(c) Determine the total energy transferred from the cylinder per unit of length during the first 5 minutes of cooling.



$$L_c = \frac{V}{A_s} = \frac{\pi r^2 L}{2\pi r L} = r/2$$

$k = 16.3\, W/mK$

$$Bi = \frac{(285)(3.25/100)}{2\times16.3} = 0.284$$

$Bi > 0.1$
use charts

a) $$\frac{1}{Bi} = \frac{k}{h r_o} = \frac{16.3}{(285)(3.25/100)} \cong 1.76$$

$$Fo = \frac{\alpha t}{r_o^2} = \frac{(0.44\times10^{-5})(5\times60)}{(3.25/100)^2} = 1.25$$

$$\frac{\theta_o}{\theta_i} = 0.35$$

$$\frac{T_o - T_\infty}{T_i - T_\infty} = 0.35 \rightarrow T_o = T_\infty + 0.35(T_i - T_\infty)$$
$$= 50 + 0.35(150 - 50)$$
$$= 85\,^\circ C$$

b) Use now position correction chart

$$\frac{1}{Bi} = 1.76$$

$$r/r_0 = \frac{2.5}{3.25} \cong 0.77$$

$$\left.\right\} \frac{\theta}{\theta_0} = \frac{T - T_\infty}{T_0 - T_\infty} \cong 0.86$$

$$T = 50 + 0.86(85 - 50) = 80°C$$

c) $Bi^2 Fo = (0.568)^2 (1.26) = 0.406$

$Bi = 1.26$

$$\frac{Q}{Q_0} = 0.7$$

$$\frac{Q_0}{L} = \pi r_0^2 \rho c (T_i - T_\infty)$$

$$= \pi (0.0325)^2 (7817)(460)(150 - 50)$$

$$= 1\,192\,598 \text{ J}$$

$$Q = 0.7(1192598) \cong 823\,170 \text{ J/m}$$