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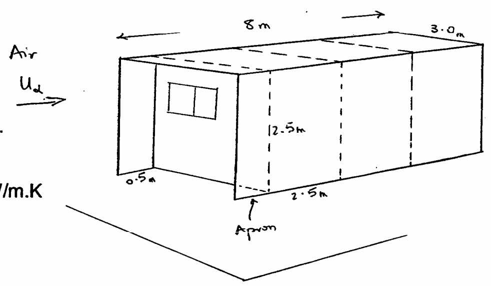
ENCH 501: Transport Processes Quiz #5 **November 4, 2003**

Time Allowed: 50 mins. **Name:**

At a remote site for drilling for oil, a trailer with three rooms served as the office, the relaxation room and the dining/kitchen. The trailer is 7.5m long, 3 m wide and 2.5m high. Each of the rooms is 2.5m long. The office is located at the front end and to keep snow from blowing over the window, an 0.5m wide apron of sheet metal is wrapped around the edge (see sketch). The bottom of the trailer is covered by a skirt and this prevents flow of air over the bottom side.

It has been suggested that on cold, windy days the office has to be heated more than the relaxation room at the other end of the trailer in order to maintain the same temperature of 18°C in each room. If the wind comes from the direction of the office at a temperature of -32°C and a velocity of 0.7m/s, estimate and compare the amounts of heat needed to be generated in the office and in the relaxation room if the sheet metal wall of the trailer (except the apron) is maintained at 18°C. That is, the apron is unheated. Also neglect heat loss from the walls perpendicular to the direction of air flow.

Show your steps and state all other assumptions.



Hint & Data

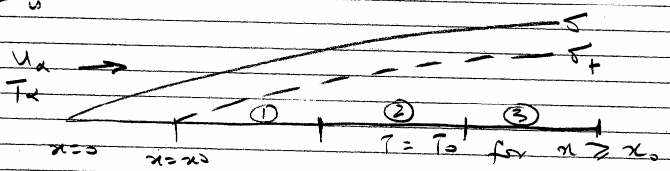
Assume the apron constitutes an unheated leading edge.

Properties of air at film conditions: $\rho = 1.4119$ kg/m^3; $\mu = 0.01606$ mPa.s; $C_p = 1.003$ kJ/kg K; $k = 0.02226$ W/m.K

ENCH 501 SOLUTION – Quiz #5 Nov. 4, 2003

Use the integral method and model this as heat loss from a flat plate of width $2(2.5\,m) + 3\,m = 8\,m$ and a length of $8\,m$ with $0.5\,m$ of the leading edge unheated.

That is



Interested in heat loss from wall to air between $0.5 \leq x \leq 3.0$ and $5.5 \leq x \leq 8.0\,m$. These are zones 1 and 3 on the plate.

This problem has been solved in the Notes, p 113 – 118, by the integral method.

The heat transfer coefficient at each x is given by eq. 5.84 (p. 117 Notes)

$$h_x = 0.332\, k\, Pr^{\frac{1}{3}} \left[\frac{u_\infty}{\nu x}\right]^{\frac{1}{2}} \left[1 - \left(\frac{x_0}{x}\right)^{3/4}\right]^{-\frac{1}{3}} \qquad (1)$$

Over a differential surface $(dx \cdot W)$ where $W = 8\,m$

$$dQ = h_x (T_0 - T_\infty) W\, dx$$

Hence

$$Q_1 = \int_{0.5}^{3} h_x (T_0 - T_\infty) W\, dx \qquad (2)$$

and

$$Q_3 = \int_{5.5}^{8} h_x (T_0 - T_\infty) W\, dx \qquad (3)$$

The integration of equations ② + ③ is complicated because of the function h_x. Hence a graphical method is useful. Plot h_x vs. x and estimate the averages h_1 and h_3 over the limits of the integral.

Then $$Q_1 = h_1 (T_0 - T_\infty) W (2.5)$$

and $$Q_3 = h_3 (T_0 - T_\infty) W (2.5)$$

also $$\frac{Q_1}{Q_3} = h_1 / h_3$$

The steps are as follows.

Data: $k = 0.02226 \text{ W/mK}$

$$Pr = \frac{c_p \mu}{k} = \frac{\nu}{\alpha} = \frac{1003(1.606)(10^{-5})}{2.226(10^{-2})} = 0.7236$$

$$\nu = \frac{\mu}{\rho} = 1.1375(10^{-5}) \text{ m}^2/\text{s}$$

$$U_\infty = 0.7 \text{ m/s}$$

$$\therefore \quad h_x = 1.64595\, x^{-1/2} \left[1 - \left(\frac{x_0}{x} \right)^{3/4} \right]^{-1/3} \quad ; \; x_0 = 0.5 \text{ m}$$

need enough points to draw a smooth curve.

x, m	h_x, W/m²K	
0.5	∞	
0.6	4.2182	— $x = 0.51$ 9.3983
1.5	1.6292	
3.0	1.0510	
4.0	0.8903	
5.5	0.7455	
7.0	0.6537	
8.0	0.6084	

The plot of h_x vs. x is shown in fig. 1

Approximately from figure

$$h_1 = 1.8 \ W/m^2 K$$

$$h_3 = 0.68 \ W/m^2 K.$$

$\therefore$ $Q_1 = 1.8\,(18-(-32))\,8\,(2.5) = 1800 \ W$

$Q_3 = 0.68\,(50)(8)(2.5) = 680 \ W$

The ratio $\dfrac{Q_1}{Q_3} = \dfrac{1.8}{0.68} = 2.65$

$\longrightarrow$

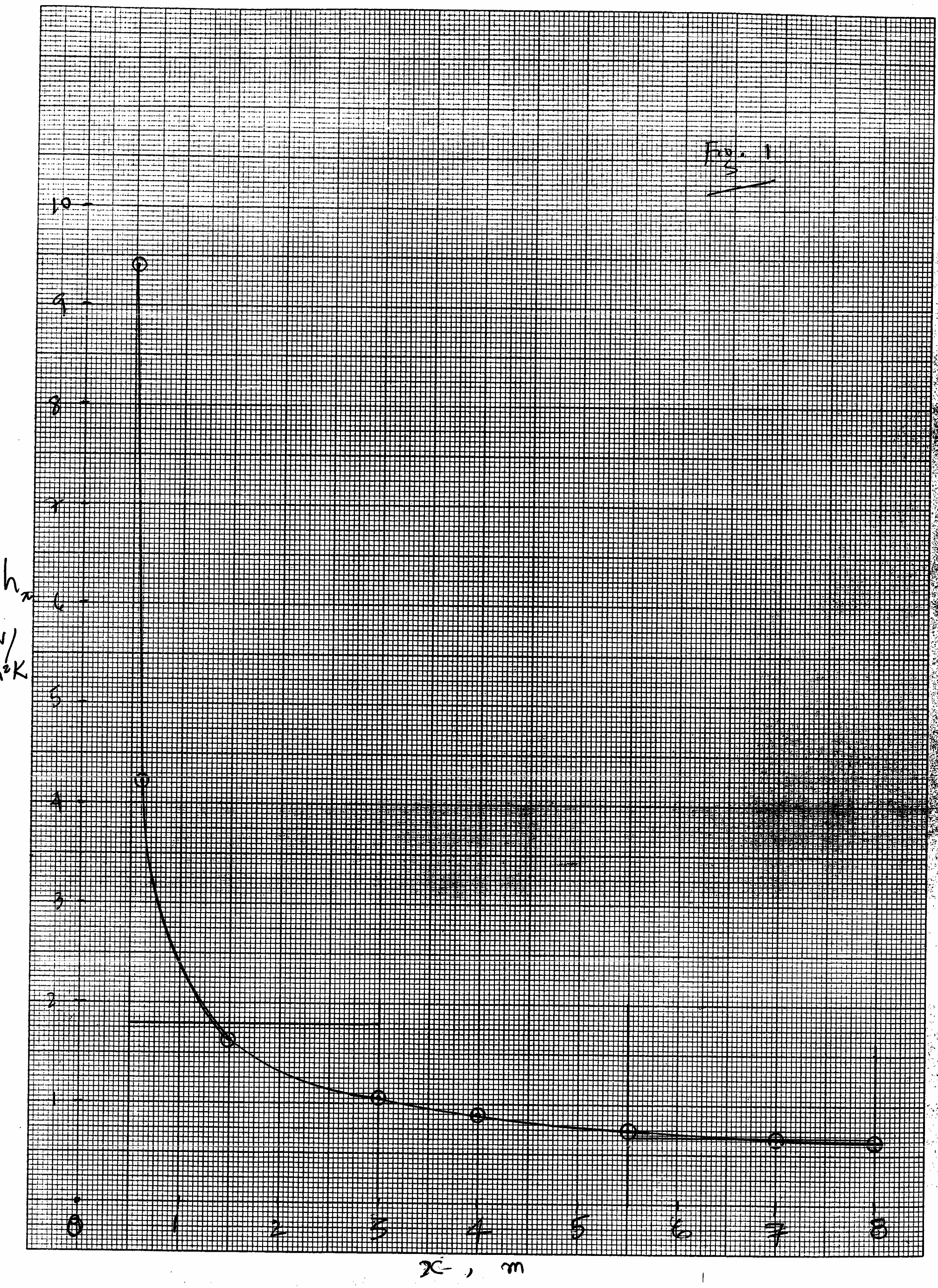


Fig. 1
h_x W/m²K
x, m
0 1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8 9 10