Mechanical Engineering Department

Second Semester- First Midterm Examination (1429)

Subject: THERMAL SCIENCES FOR INDUSTRAIL ENGG. STUDENTS-ME 329

Time: 1.5 hr.

QUESTION (1)

(a) A house has a composite wall of plywood, fiberglass insulation, and plaster board, as indicated in Fig. 1. On a cold winter day the temperatures on the inside and out side of the wall are 20^0C and 15^0C respectively. The convection heat transfer coefficients are $h_o = 60$ W/m °C, and $h_i = 30$ W/m^2 °C. The total wall surface area is 350 m^2. The thermal conductivities of the wall are $k_P = 0.22$ W/m °C, $k_b = 0.038$ W/m °C, and $k_s = 0.12$ W/ m °C as shown in the figure (1). Assuming heat transfer through the wall to be one dimensional, steady and neglect the radiation heat transfer, determine:

i- the total thermal resistance of the wall, including inside and outside convection effects for the prescribed conditions.

ii- the rate of heat transfer through the wall.

iii- the temperature at the interface between the plaster board and the glass fiber blanket

iv- the temperature at the interface between the glass fiber blanket and the plywood siding .

v- draw the electrical analogy circuit of the wall,

vi- draw the temperature profile through the wall.

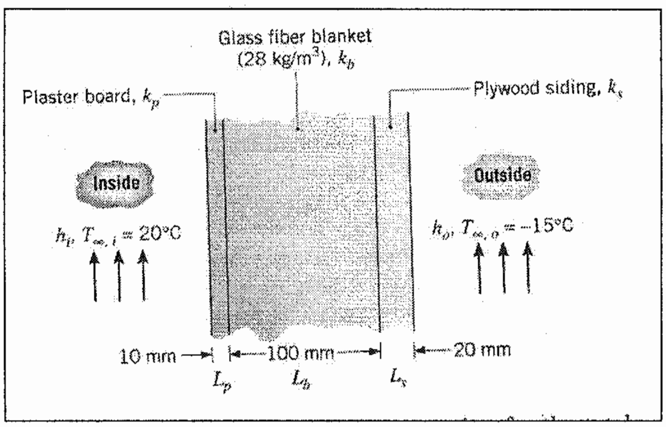


Figure (1) for Question 1(a)

(b) Steam passes through a 50m long pipe whose outside diameter is 100 mm. The outer side temperature of the pipe is 150^0C where as the ambient temperature is 25^0C. The combined outer side heat transfer coefficient is 25 W/m^2-^{0}C. Calculate the heat loss through the pipe.

QUESTION (2)

(a) The reversing and reducing elbow (180^0 reducing elbow) as shown in figure(2) is used to reverse he direction of water by 180^0. The elbow discharges the water to the atmosphere at a flow rate of 14 kg/s. The elevation difference between centerlines of inlet and exit is 0.3 m and the inlet and exit diameters of the elbow are 30mm and 15 mm respectively. Neglecting the weight of water in the elbow and the elbow find

(i) the velocities at the inlet and exit
(ii) the pressure at the inlet.
(iii) the magnitude and direction of restraining force.

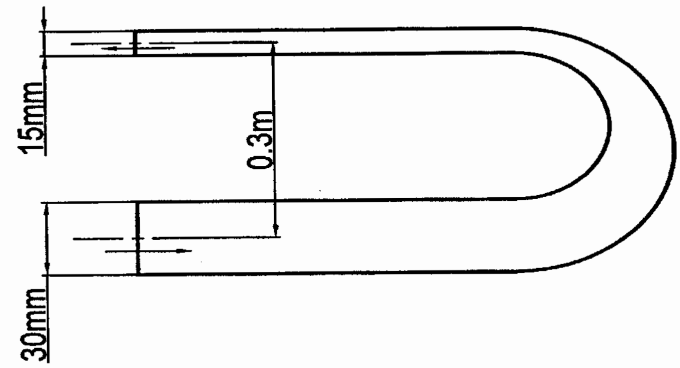
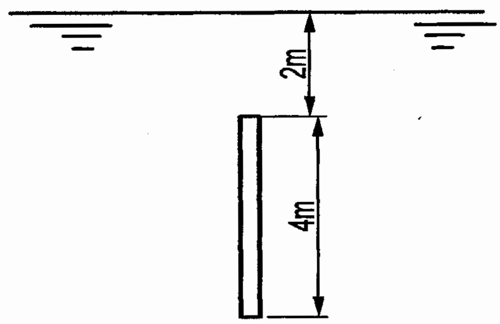


Figure (2) for question 2(a)

(b) A 5m x 4m plate is immersed in water as shown in diagram such that the tip of the plate is 2 m below the free surface of water. Calculate the hydrostatic force on the plate and its point of application.



Figure(3) for Question2(b)

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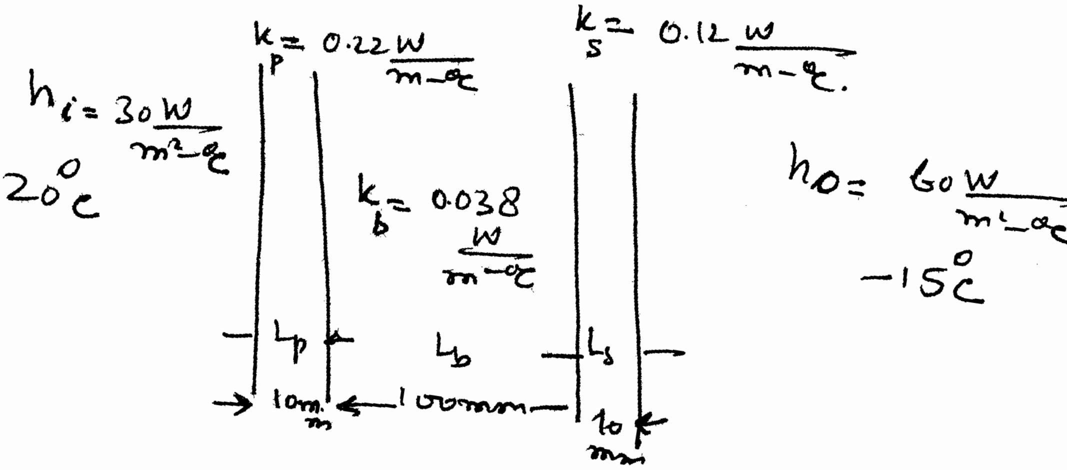
Q1

(1)

$A = 350\ m^2$



$R_i = \frac{1}{h_i A} = 0.000095\ °C/W$

$R_o = \frac{1}{h_o A} = 0.000048\ °C/W$

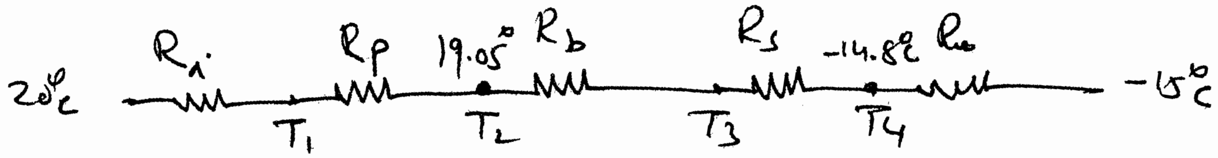
$R_p = \frac{L_p}{k_p A} = 0.00013\ °C/W$

$R_b = \frac{L_b}{k_b A} = 0.00752\ °C/W$

$R_s = \frac{L_s}{k_s A} = 0.00048\ °C/W$

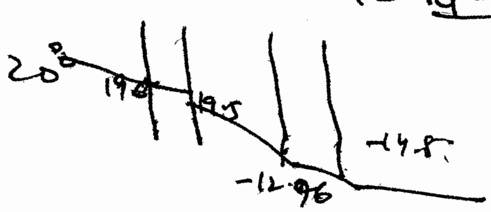
$R_T = R_i + R_o + R_p + R_b + R_s = 0.0083\ °C/W$

$\therefore\ q = \frac{\Delta T}{R_T} = \frac{20-(-15)}{0.0083} = 4230.63\ W$

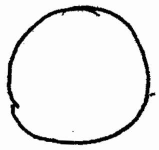


$q = \frac{20 - T_1}{R_i}$ $T_1 = 19.6°C$ $q = \frac{T_1 - T_2}{R_p}$ $T_2 = 19.05°C$

$q = \frac{T_2 - T_3}{R_b}$ $T_3 = -12.76°C$ $q = \frac{T_4 - (-15)}{R_o}$ $T_4 = -14.8°C$



(b)



$L = 50 m$

$d = 100 mm = 0.1 m$

$T_s = 150°C \quad T_a = 25°C$

$h_o = 25 \frac{W}{m^2 °C}$

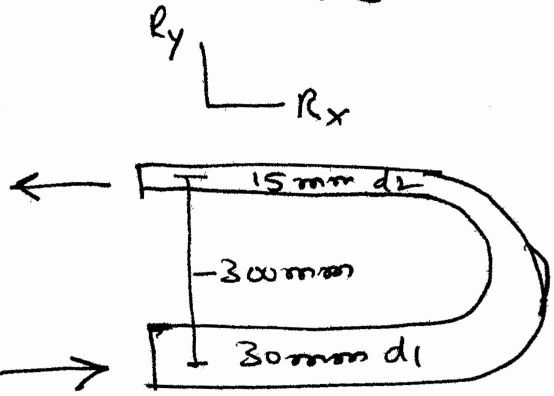
$A = \pi d L$

$q = h A (T_s - T_a)$

$= 25 \times \pi \times 0.1 \times 50 (150 - 25)$

$= 49062.5 W \qquad \underline{49.06 kW}$

Q2



$\dot m = 14 kg/s$

$\rho = 1000 kg/m^3$

$P_2 = atm \cdot P_2 = 0$ Neglecting

Continuity equation

$$\dot m = \rho A_1 V_1 = \rho A_2 V_2$$

$$V_1 = \frac{\dot m}{\rho A_1} = \frac{\dot m}{\frac{\pi}{4} d_1^2 \rho} = 19.82 m/s$$

$$V_2 = \frac{\dot m}{\rho A_2} = \frac{\dot m}{\frac{\pi}{4} d_2^2 \rho} = 79.264 m/s$$

Bernoulli's Equation

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + g Z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + g Z_2$$

$$Z_1 = 0 \quad Z_2 = 0.3 m$$

$$\frac{P_1 - P_2}{\rho} = \frac{V_2^2 - V_1^2}{2} + g (Z_2 - Z_1)$$

$$P_1 = \rho \left[\frac{V_2^2 - V_1^2}{2} + g (Z_2) \right] \text{ (gage)}$$

$$P_1 = 2947.99 = 2948 \underline{kPa}$$

momentum equation

$F_{x=0}$ $\quad F_{Rx} + \sum_x P_i A_i = \dot{m}\left(V_{ex}^2 - V_{ix}^2\right)$

$V_{ex} = -V_2 \quad V_1 = V_1$

$F_R = \dot{m}\left(-V_2^2 - V_1\right) - \sum P_1 A_1$

$= -\dot{m}\left(V_2 + V_1\right) - P_1 A_1 - P_2 A_2$ ($P_2 A_2 \to 0$)

$= -\dot{m}\left(V_2 + V_1\right) - P_1 A$

$F_{Rx} = -2360.97\ N \simeq -2361\ N$

Direction as reversed

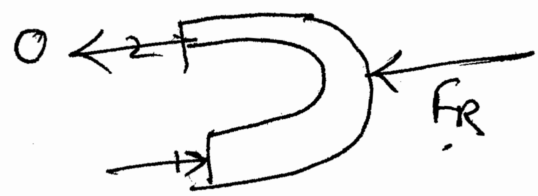
$\sum F_{y} = $ $\quad F_{Ry} + \sum P_y A_y = \dot{m}\left(V_{ye} - V_{yi}\right)$

$P_{y1} = P_{y2} = 0 \quad V_{ye} = V_{yi} = 0$

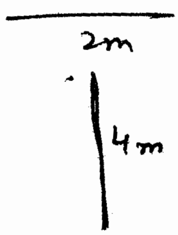
$F_{Ry} = 0$

$\therefore F_R = \sqrt{F_x^2 + F_y^2} = F_x = 2360\ N.$ in -ve x dir

$\theta = \tan^{-1} \frac{F_y}{F_x} = 0$



(b)



$A = 4 \times 5 = 20\,m^2$

$h_c = \frac{4}{2} + 2 = 4\,m$

$\therefore F = \rho g h_c A = 784.8\,kN$

$I_{xx} = \frac{5 \times 4^3}{12} = 26.67\,m^4$

$Y_p = Y_c + \frac{I_{xx}}{Y_c A}$ $\quad h_c = Y_c$

$Y_p = 4 + \frac{26.67}{4 \times 20} = 4.33\,m$

$F = 784.8\,kN$ $Y_p = 4.33\,m$