Mansoura University Faculty of Engineering Medical and Biomedical Engg. Program	Final Exam Summer Semester Time Allowed: 2 hrs	جامعة المنصورة كلية الهندســـــة برنامج الهندسة الطبية والحيوية

MPE 271 Heat and Mass Transfer

Answer the following questions

Question No.1

a) Compare between conduction, convection and radiation modes of heat transfer.

b) Consider a plane composite wall that is composed of two materials of thermal conductivities k_A=0.1 W.m.K and k_B=0.04 W/m.K and thickness L_A=10 mm and L_B=20 mm. The contact resistance at the interface between the two materials is **0.3 m²·K/W**. The material A adjoins a fluid at 200°C for which **h=10 W/m²·K** while material B adjoins a fluid at 40°C for which **h=20 W/m²·K**. Draw the temperature distribution and determine the net rate of heat transfer if the wall has an area of **20 m²**.

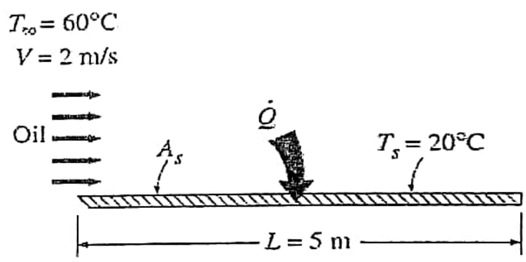
c) A rectangular fin 0.1thickness, 10 cm width and length **15 cm** (**k=400 W/m.K**) is fitted to a plate which has a base temperature of 120°C. If the ambient temperature is 30°C and convective heat transfer coefficient is **8 W/m²·K**, find the rate of heat transfer by the fin and fin efficiency.

Question No.2

a) Draw the temperature distribution along a certain plate under laminar flow conditions.

b) Engine oil at **60°C** flows over the upper surface of a **5-m** long flat plate, whose temperature is **20°C**, with a velocity of **2 m/s**. **Determine:**

   i. Total drag force
   ii. The hydrodynamic boundary layer thickness
   iii. Rate of heat transfer per unit width of plate.



c) A horizontal pipe of **8 cm** diameter and **10 m** length passes through a room whose temperature is **20°C**. If the outer surface temperature of the pipe is **80°C**, determine both convective heat transfer coefficient and the rate of heat transfer by natural convection from the pipe.

Question No.3

a) What is the driving force of mass diffusion?

b) Sketch the fully developed velocity in circular pipe.

c) Consider the flow of oil at **20°C** in a 30-cm-diameter pipeline at an average velocity of **2 m/s**. A **200-m**-long section of the horizontal pipeline passes through icy waters of a lake at **0°C**. Measurements indicate that the surface temperature of the pipe is very nearly **0°C**. Disregarding the thermal resistance of the pipe material, **determine** the convective heat transfer coefficient of the fluid, and the pressure losses in the pipe.

Question No.4

a) What is the function of heat exchanger?

b) A **counterflow**, concentric tube heat exchanger is used to cool the engine oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (**Di=25 mm**) is **0.2 kg/s**, while the flow rate of oil through the outer annulus (**Do=45 mm**) is **0.1 kg/s**. The oil and water enter at temperatures of **100** and **30°C**, respectively. How long must the tube be made if the outlet temperature of the oil is to be **60°C**?

With My Best Wishes

Prof. Dr. Gamal Sultan

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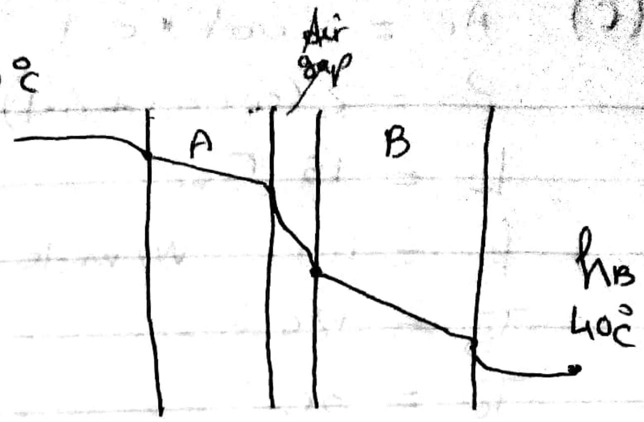
(b)

200°C

$$R_{o,A} = \frac{1}{h_o} = \frac{1}{10} \quad \frac{m^2.K}{W} \quad h_{B,A}$$



$$= 0.1$$

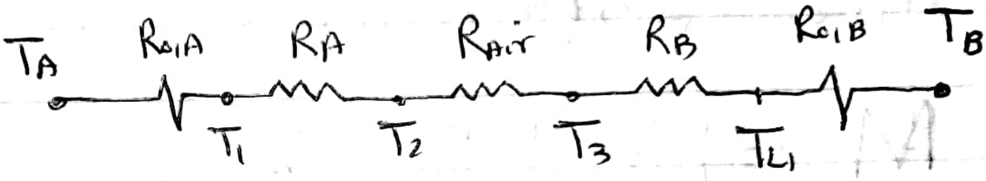
$$R_A = L_A / k_A = \frac{0.01}{0.1}$$

$$= 0.1$$

$$R_{Air} = 0.3$$

$$R_B = L_B / k_B = \frac{0.02}{0.04} = 0.5$$

$$R_{B,o} = \frac{1}{h_B} = \frac{1}{20} = 0.05$$



$$q = \frac{T_A - T_B}{\sum R} = \frac{200 - 40}{0.1 + 0.1 + 0.3 + 0.5 + 0.05}$$

$$= 152.381 \ W/m^2$$

$$Q = q \cdot A = 152.381 * 20$$

$$= 3047.619 \ W$$

$$q = 152.381 \ W/m^2 = \frac{200 - T_1}{0.1} \Rightarrow T_1 = 184.76 \ °C$$

$$= \frac{T_1 - T_2}{0.1} = \frac{184.76 - T_2}{0.1} \Rightarrow T_2 = 169.52 \ °C$$

$$= \frac{T_2 - T_3}{0.3} = \frac{169.52 - T_3}{0.3} \Rightarrow T_3 = 123.81 \ °C$$

$$= \frac{T_3 - T_4}{0.5} = \frac{123.81 - T_4}{0.5} \Rightarrow T_4 = 47.61 \ °C$$

(c) $A_c = 0.001 * 0.1 = 0.0001 \ m^2$

$P = 2(0.001 + 0.1) = 0.202 \ m$

$L = 15 \ Cm$

$k = 400 \ W/m\,k$

$T_B = 120 \ ^\circ C$

$T_\infty = 30 \ ^\circ C$

$h = 8 \ W/m^2 . k$

$$m = \sqrt{\frac{hP}{kA_c}} = \sqrt{\frac{8 * 0.202}{400 * 0.0001}} = 6.35$$

$mL_c = 6.35 * 0.15 < 2.67$ short fin $= 0.9534$

$$M = \sqrt{hPkA_c}\ \theta_b$$

$$= \sqrt{8 * 0.022 * 400 * 0.0001}\ (120 - 30) = 7.5541$$

$$q_f = M \left[\frac{\sinh mL + \frac{h}{km} \cosh mL}{\cosh mL + \frac{h}{km} \sinh mL} \right]$$

$$\eta = \frac{q_f}{h A_f \theta_b}$$

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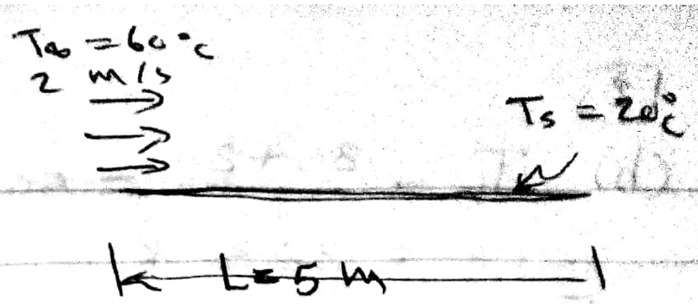
b) $T_b = \frac{20+60}{2} = 40^\circ C$

$= 313\ K$



From table:

$\rho = 1.1614$ $\qquad$ $k = 0.0263 \ W/m.K$

$\nu = 15.89 \times 10^{-6} \ m^2/s$ $\qquad$ $Pr = 0.707$

$$Re = \frac{U L}{\nu} = \frac{2 \times 5}{15.89 \times 10^{-6}} = 629327 > 10^5 \text{ turbulent}$$

$$C_f = \frac{0.074}{Re_L^{0.2}} - \frac{1742}{Re_L} = 0.0063354$$

$$F_D = C_f \left[\tfrac{1}{2} \rho U^2\right] A_s$$

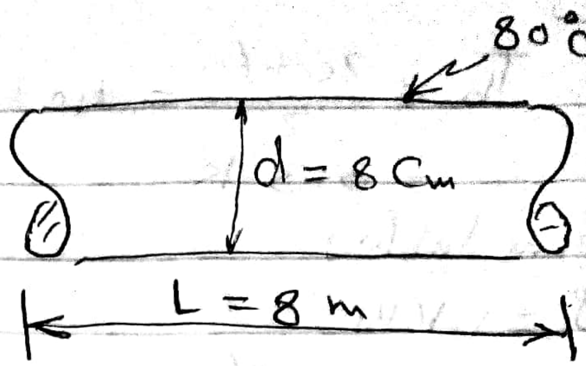
$$= 1.0663 \left[\tfrac{1}{2} (0.00235) \times 4\right] \times 5 \times 1$$

$$= 0.0351 \ N$$

$$\delta_v = \frac{0.37\ L}{Re_L^{1/5}} = \frac{0.37 \times 5}{(629327)^{0.2}} = 0.12805 \ m$$

$=$

$T_\infty = 20\,°C$



[2]

(b) $T_b = \frac{80+20}{2} = 50\,°C$

$= 323\ K$

From table:

$\beta = \frac{1}{T_b} = 0.003096$

$k = 0.02815$

$Pr = 0.7035$

$\rho = 1.0782$

$\nu = 18.405 * 10^{-6}\ m^2/s$

$Gr = \frac{\beta g \Delta T L^3}{\nu^2} = \frac{0.003096 * 9.81 * 60 * 0.08^3}{(18.405 * 10^{-6})^2}$

$= 2.75433 * 10^{7}$

$Ra = Gr \cdot Pr = 1937671.5$

$Nu_L = \left\{ 0.6 + \frac{0.387\ (1937671.5)^{1/6}}{\left[1 + \left(\frac{0.559}{0.7035}\right)^{9/16}\right]^{8/27}} \right\}^2 \cong 17.51$

$= \frac{hD}{k}$

$17.51 = \frac{h \cdot 0.08}{0.02815} \Rightarrow h = 6.1618\ \frac{W}{m^2 K}$

$Q = h A \Delta T = 6.1618\,[\pi(0.08) * 8]\,(80 - 20)$

$= 743.34\ W$

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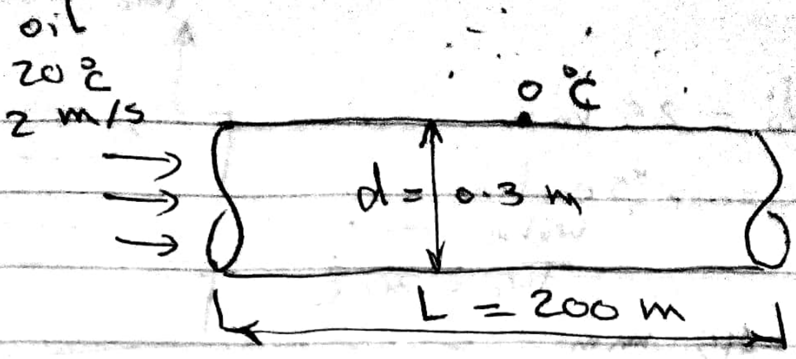
(c)



$$T_b = \frac{20 + 0}{2} = 10 + 273 = 283\ K$$

From table:

$\rho = 895.3$

$\nu = 2430 \times 10^{-6}$

$k = 0.144 \quad W/m.K$

$Pr = 27500$

$$Re_D = \frac{u D}{\nu} = \frac{2 \times 0.3}{2430 \times 10^{-6}} = 246.9136 < 2000$$

Laminar

$$L_{t,t} = 0.05\ Re \cdot Pr = 0.05\,(246.91) \times 27500 = 339506 > L \quad \text{Entrance Region}$$

$$Nu = 3.66 + \frac{0.065\left(\frac{D}{L}\right) Re \cdot Pr}{1 + 0.04\left[\left(\frac{D}{L}\right) \cdot Re \cdot Pr\right]^{2/3}}$$

$$= 37.3 = \frac{h D}{k}$$

$$h = 37.3\,(0.144)/0.3 = 17.9 \ \frac{W}{m^2.K}$$

$$Q = h\,A_s\,\Delta T = 17.9\,(\pi \times 0.3 \times 200)(20 - 0)$$

$$= 67494.5 \ W$$

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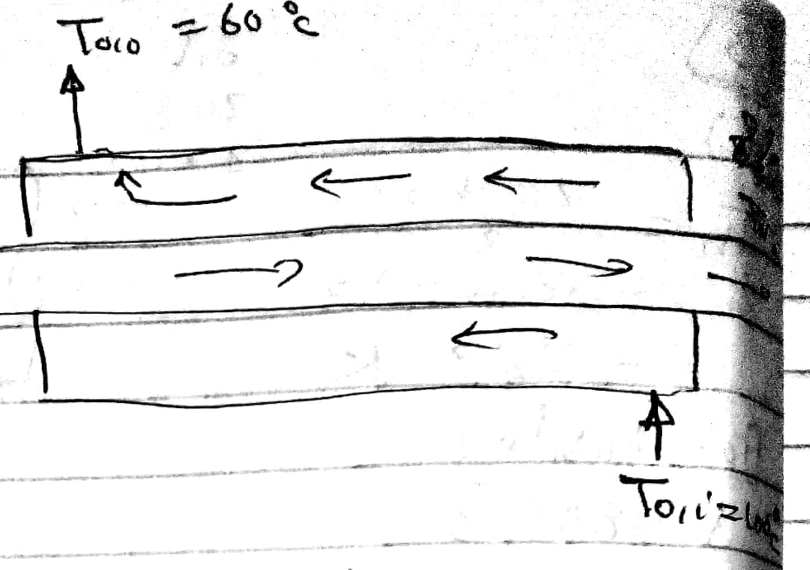
(b) $d_i = 25$ mm

$\dot{m}_w = 0.2 \frac{kg}{s}$ cooling water →

$T_{w_i} = 30$ °C



$d_o = 45$ mm

$M_{oil} = 0.1$ kg/s

$Cp_{oil} = 2.118$

Heat Rate $= m_w Cp_w \Delta t_w = m_o Cp_o \Delta t_o$

$= 0.1 * 2.118 (100 - 60) = 8.472$ KW

$= 0.2 * 4.18 (T_o - 30)$

$\Rightarrow 40.134$ °C