Mansoura University **Faculty of Engineering** **Program of Biomedical Engineering.** **Course Title: Heat and Mass Transfer** **Course Code: MPE 271**		**Level: 200** **Exam Type: Final** **Date: 1 September 2016** **Time: 2 Hours** **Full Mark: 50**

QUESTION NO. One: **[13 Marks]**

Pick up the most appropriate statement of the multiple-choice answers .

1. Heat conducted through unit area and unit thick face per unit time when temperature difference between opposite faces is unity, is called

(a) thermal resistance (b) thermal diffusivity (c) temperature gradient
(d) thermal conductivity (e) heat-transfer.

2. The value of the critical radius of insulation r_0 for a sphere is

(a) *k/h* (b) *2h/k* (c) *2k/h* (d) None of these

3. The ratio of heat flow Q_1/Q_2 from two walls of same thickness having their thermal conductivities as $k_2 = 2\ k_1$ will be

(a) 1 (b) 0.5 (c) 2 (d) 0.25 (e) 4.

4. A steam pipe is covered with two layers of insulating materials, with the better insulating material forming the outer part. If the two layers are interchanged, the heat conducted

(a) will decrease (b) will increase (c) will remain unaffected
(d) may increase or decrease depending upon the thickness of each layer.

5. A counterflow heat exchanger is used to heat water from 20°C to 80°C by using hot exhaust gas entering at 140°C and leaving at 80°C. The log mean temperature difference for the heat exchanger is:

(a) 80°C (b) 60°C (c) 110°C (d) not determinable as zero/zero is involved.

6. The thicknesses of thermal and hydrodynamic boundary layers are equal if (Pr=Prandtl Number,)

(a) Pr =1 (b) Pr > 1 (c) Pr <1 (d) Pr = Nu.

7. The heat dissipation from an infinitely long fin is given by:

(a) $\sqrt{hPkA}(t_o - t_\infty)$ (b) $hP(t_o - t_\infty)$

(c) $\sqrt{hPkA}(t_o - t_\infty)\tanh ml$ (d) $\sqrt{hPkA}(t_o - t_\infty)\dfrac{\tanh ml + (h/k)m}{1 + (h/km)\tanh ml}$

8. ***The vertical walls of a boiler furnace of size 4 m by 3 m by 3 m high. The walls are constructed from an inner fire brick wall 25 cm thick of thermal conductivity 0.4 W/m K, a layer of ceramic blanket insulation of thermal conductivity 0.2 W/m K and 8 cm thick, and a steel protective layer of thermal conductivity 55 W/m K and 2 mm thick. The inside temperature of the fire brick layer was measured at 600 °C and the temperature of the outside of the insulation 60 °C. The rate of heat loss may be :***

(a) Q = 6320.96 W (b) Q = 9320.96 W (c) Q = 6020.96 W (d) Q = 6300 W

9. Match List-I with List-II and select the correct answer using the codes given below the lists.

List-I	**List-II**
A .Stefan-Boltzmann law	1. $Q = hA\,(t_1 - t_2)$
B. Newton's law of cooling	2. $Q^{\bullet} = -K_{diff}A\, dC/dx$
C. Fourier's law	3. $Q = k\,A(t_1 - t_2)\,/\,L$
D. Fick's law	4. $Q = \sigma A(T_1^4 - T_2^4)$
	5. $Q = k\,A(t_2 - t_1)/L$

10. In ....flow maximum heat transfer rate can be expected.

(a) Laminar (b)Turbulent (c) Counter current (d) None of these

11. The emissivity of a grey body is ....

(a) 0.5 (b) 1 (c) Less than (d) More than 1

12. .... number gives an indication of the ratio of internal (conduction) resistance to the surface (convection) resistance,

(a) Stanton (b) Schmidt (c) Nusselt (d) Fourier.

13. .... number gives an indication of the ratio of thermal diffusivity to the mass diffusivity ,

(a) Stanton (b) Schmidt (c) Lewis (d) Prandtl.

14. .... number gives an indication of the ratio of momentum diffusivity to the mass diffusivity ,

(a) Stanton (b) Lewis (c) Schmidt (d) Prandtl.

15. .... number gives an indication of the ratio of momentum diffusivity to the thermal diffusivity ,

(a) Stanton (b) Lewis (c) Prandtl (d) Schmidt.

Question (2) [13 Marks]

a) Starting with energy balance on a rectangular volume element derive the one-dimensional steady state heat conduction equation for a plane wall with heat generation.

b) In an industrial facility, air is to be preheated before entering the furnace by geothermal water at 120°C flowing through the tubes of a tube bank located in a duct. Air enters the duct at 120°C and 1 atm with a mean velocity of 4.5 m/s, and flows over the tubes in normal direction. The outer diameter of the tubes is 1.5 cm, and the tubes are arranged in-line with longitudinal and transverse pitches of $S_L = S_T = 5$ cm. There are 6 rows in the flow direction with 10 tubes in each row. Determine the rate of heat transfer per unit length of the tube. (Correction factor for Nusselt number F= 0.945)

$k = 0.02808$ W/m · K,	$\rho = 1.06$ kg/m^3
$C_p = 1.007$ kJ/kg · K,	$\Pr = 0.7202$
$\mu = 2.008 \times 10^{-5}$ kg/m · s	$\Pr_s = \Pr_{@T_s} = 0.7073$

$$\mathrm{Nu}_D = 0.27\,\mathrm{Re}_D^{0.63}\,\Pr^{0.36}(\Pr/\Pr_s)^{0.25}$$

Question (3) [12 Marks]

a) Classify the types of Heat Exchangers? What are the factors on which the selection of Heat Exchangers depend on?

b) A thin-walled double-pipe counter flow heat exchanger is to be used to cool oil (***C_p = 2200 J/kg.K***) from 150°C to 40°C at a rate of 2 **kg/s** by water (***C_p = 4180 J/kg.K***) that enters at 22°***C*** at a rate of 1.5 **kg/s** .The diameter of the tube is 2.5 cm and its length is 6 m. Determine the overall heat transfer coefficient of this heat exchanger.

Question (4) **[12 Marks]**

a) Define the following:

Diffusion mass transfer, mass flux, molar flux, Grashof number, Emissivity, Absorptivity, Reflectivity, Transmissivty and Opaque body.

b) Two very large parallel plates are maintained at uniform temperatures of 727 °C and 800 K, and have emissivities of $\varepsilon_1 = \varepsilon_2 = 0.2$, respectively. It is desired to reduce the net rate of radiation heat transfer between the plates to one-fifth by placing thin aluminum sheets with an emissivity of $\varepsilon = 0.15$ on both sides between the plates. Determine the number of sheets that need to be inserted.

Good Luck

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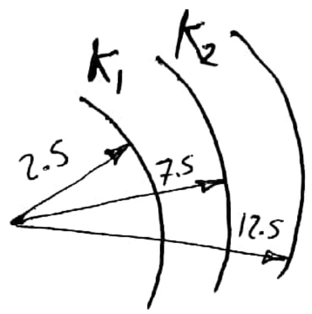
Question No. One

(a)

1. (c)
2. (d)
3. (a)
4. (b)

(b)



$$\frac{\left(\frac{\ln 7.5/2.5}{2\pi * K} + \frac{\ln 12.5/7.5}{2\pi * 4K}\right)}{\left(\frac{\ln 7.5/2.5}{2\pi * 4k} + \frac{\ln 12.5/7.5}{2\pi * k}\right)}$$

$$\frac{\left(\frac{2.7}{8\pi k}\right)}{\left(\frac{2.12}{8\pi k}\right)} = 1.27$$

$$\therefore \frac{Q_{k_1 = k_2/4}}{Q_{k_1 = 4k_2}} = \frac{1}{1.27} = \underline{\underline{0.785}}$$

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1c)

Given: $r_1 = 50$ mm

$r_2 = 85$ mm

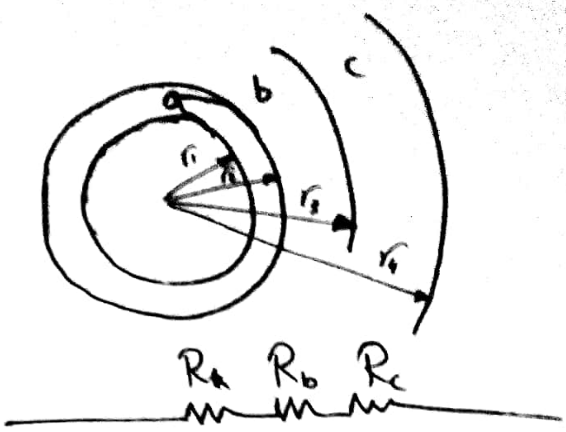
$r_3 = 115$ mm

$r_4 = 165$ mm

$K_a = 50$ W/m.k

$K_b = 0.175$ W/m.k

$K_c = 0.093$ W/m.K



$t_1 = 300°C$

$t_4 = 50°C$

$$R_{total} = R_a + R_b + R_c$$

$$= \frac{\ln(85/50)}{2\pi * 50} + \frac{\ln(115/85)}{2\pi * 0.175} + \frac{\ln(165/115)}{2\pi * 0.093}$$

$$= 1.69 * 10^{-3} + 0.275 + 0.618 = 0.895$$

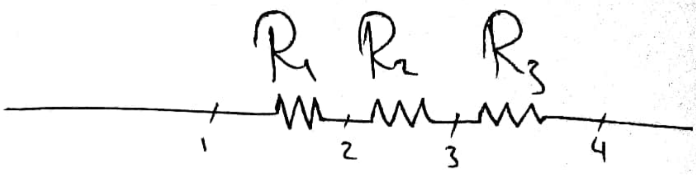
$$Q = \frac{t_1 - t_4}{R_{total}} = \frac{300 - 50}{0.895} = 279.4 \text{ W/m}$$

$$t_2 = t_1 - QR_a = 300 - 279.4 * 1.69 * 10^{-3} = 299.5°C$$

$$t_3 = t_4 + QR_c = 50 + 279.4 * 0.618 = 222.67°C$$

Question (2)

a) * Case (I)



$$R_{eq} = R_1 + R_2 + R_3$$

$$= \frac{0.03}{0.074} + \frac{0.1}{0.69} + \frac{0.03}{0.067}$$

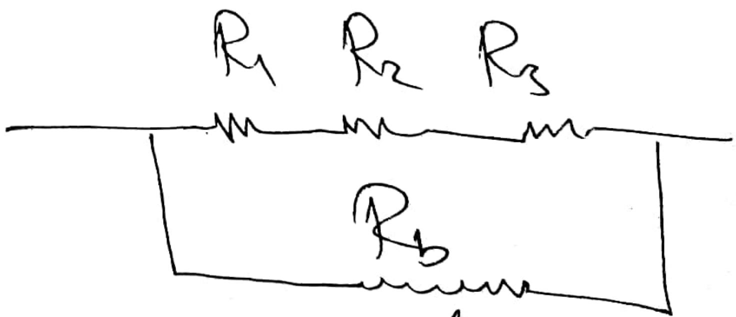
$$= 0.4054 + 0.145 + 0.45 = 1.0004 \ ^\circ c/W$$

$$q_r = \frac{t_1 - t_4}{R_{eq}} = \frac{150 - 10}{1.0004} = 140 \ W/m^2$$

$$t_2 = t_1 - q_r * R_1 = 150 - 140 * 0.4054 = 93.1^\circ C$$

$$t_3 = t_4 + q_r * R_3 = 10 + 140 * 0.45 = 72.8^\circ C$$

* Case (II)



$$R_{total} = \frac{R_b R_{eq}}{R_b + R_{eq}}$$

$$= \frac{5.093 * 1.004}{5.093 + 1.004} = 0.836$$

$$\frac{l}{KA}$$

$$\frac{0.16}{40 * 10 * \frac{\pi}{4}(0.01)^2}$$

$$R_b = 5.093 \ ^\circ c/W$$

$$q_r = \frac{150 - 10}{0.836} = 167.4 \ W/m^2$$

(b)

$$U_{max} = \frac{S_T}{S_T - D} u$$

$$= \frac{5}{5 - 1.5} * 4.5 = 6.43\ m/s$$

$$Re = \frac{\rho U_{max} D}{\mu} = \frac{1.06 * 6.43 * 1.5 * 10^{-2}}{2.008 * 10^{-5}} = 5090$$

$$Nu = 0.27 * 5090^{0.63} * 0.7202^{0.36} * \left(\frac{0.7202}{0.7073}\right)^{0.25} = 52.18$$

$$Nu_D = 0.95 * 52.18 = 49.57$$

$$h = \frac{49.57 * 0.02808}{1.5 * 10^{-2}} = 92.8\ W/m^2 \cdot K$$

$$A_s = (6 * 11) * \pi * 0.015 * 1 = 3.11\ m^2$$

$$\dot{m} = 1.06 * 4.5 * 11 * 0.05 * 1 = 2.62\ kg/s$$

$$t_e = 120 - (120 - 20)\exp\left(-\frac{92.8 * 3.11}{2.62 * 1007}\right) = 29.2\ °C$$

$$Q = \dot{m} c_p (t_e - t_i)$$

$$= 2.62 * 1.007\,(29.2 - 20) = 27.5\ kW$$