Menoufiya University Faculty of Engineering Shebin El-Kom Academic Year 2014-2015	Minufiya University	Department: Mech. Power Eng. Year: Third year Subject / Heat Transfer MPE 312 Time: 3 hours Date: 5/1/2015

Please, answer the following questions: **[Total 100 marks]**

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Question (1): [20 marks]

1.1) *It is necessary to insulate the shell of a heat exchanger. The outside diameter of the shell is 300 mm and its outer surface temperature is 280°C, which can be assumed remaining the same after a layer of insulation of thickness 136 mm is applied on the shell. The ambient temperature is 30°C. The heat transfer coefficient from the outer surface of insulation to the surrounding air is 8 W/m^{2}K.*
Is it expedient to use slag wool of thermal conductivity 0.082 W/mK as an insulating material? If suitable, what is the rate of heat loss from 1 m length of the shell? and what is the percentage reduction of heat loss due to insulation? **[10 marks]**

1.2) *A 30 cm diameter hemisphere is maintained at a constant temperature of 500°C and insulated on its back side. The surface emissivity is 0.4. The opening exchanges radiant energy with a large enclosure at 30°C. Calculate:*

a) *The configuration factor between the hemisphere and the enclosure,*

b) *The net radiant energy exchange.* **[10 marks]**

Question (2): [15 marks]

A water economizer is built up of round finned iron tubes of an outside diameter of 70 mm. The diameter of the circular fins is 200 mm and the fin thickness is 4 mm. Determine the temperature at the tip of a fin and the rate of heat that will be transferred from the flue gas to the external surface of one economizer tube, if flue gas temperature is 400°C and the temperature at the base of fins is 180°C, the length of the tube exposed to the hot flue gas is 3 m and the number of fins placed along this length is 150. The coefficient of heat transfer from the hot flue gas to the finned surface is 41.6 W/m^{2}K and the thermal conductivity of iron is 52 W/mK.

Question (3): [15 marks]

3.1) *Beginning from Fourier's law for heat conduction, prove that the instantaneous and the total heat removed from a semi-infinite body subjected to a sudden cooling may be given by the following relations respectively:* **[5 marks]**

$$\dot{Q}(\tau) = \frac{kA(T_o - T_i)}{\sqrt{\pi\alpha\tau}} \quad , \quad \dot{Q}_{total} = 2k(T_o - T_i)\sqrt{\frac{\tau}{\pi\alpha}}$$

3.2) *A large slab of aluminum (k = 215 W/mK , α = 9.64×10^{-5}m^2/s) at a uniform temperature of 200°C has its surface temperature suddenly lowered to 69°C. What is the time required so that the temperature at a depth 4 cm attains 120°C? Determine also the instantaneous and the total heat removed from the slab per unit area.* **[10 marks]**

Question (4): (18 marks):

a) The upper and lower compartments of a well insulated container are separated by two parallel sheets of glass with an air space between them. One of the compartments is to be filled with a hot fluid and the other with a cold fluid. If it is desired that heat transfer between the two compartments be minimal, would you recommend putting the hot fluid into the upper or the lower compartment of the container? Why? (3 marks).

b) Consider turbulent flow of a fluid through a square channel maintained at a constant temperature. Now the mean velocity of the fluid is doubled. Determine the change in the pressure drop and the change in the rate of heat transfer between the fluid and the walls of the channel. Assume the flow regime remains unchanged. (3 marks).

c) Consider an oil-to-oil double-pipe heat exchanger whose flow arrangement is not known. The temperature measurements indicate that the cold oil enters at 20°C and leaves at 55°C, while the hot oil enters at 80°C and leaves at 45°C. Do you think this is a parallel-flow or counter-flow heat exchanger? Why? Assuming the mass flow rates of both fluids to be identical, determine: a) the effectiveness of this heat exchanger. b) When the parallel-flow heat exchanger effectiveness equals to that of the counter-flow?. c) Under wha conditions can the overall heat transfer coefficient of a unit be determined from $U = (1/hi+1/ho)^{-1}$? (4 marks).

d) The following measurements, shown in Table 1, were recorded for an external and/or internal flow of a fluid in industrial units to determine the unit thermo-fluid characteristics according to heating or cooling process. You can choose from the different cases shown in Table 1: A, B, C and D that consistent with one of the following processes indicating the reason of your choice. Note that each case may be used only one time or more, and/or may not be used at all.

1- Flow over flat plates, 2- Flow across cylinders, 3- Flow across spheres,
4- Flow across tube banks 5- Flow inside tubes 6- Turbulent flow in tubes

Calculate also for each case:

a- The total drag force affected on the unit surface; b- The surface shear stress; c- The friction factor; d- The convection heat transfer coefficients; e- The accurate total rate o heat transfer from the unit; f- The percentage decrease or increase in the heat transfer coefficient for the flow over a cylinder relative to the convection coefficient for the flow over a sphere. g- The inner surface temperature of the pipe at the exit for the case of flow inside tube and the power rating of the resistance heater whish used to provide uniform heating throughout the tube surface. Consider all the heat generated in the heater is transferred to the water in the tube? Results should be illustrated in clear Table.

Notation: T_ω: fluid free-stream temperature [°C,]; P_∞: fluid free-stream pressure; [atm]; T_s: constant surface temperature of the unit; [°C,]; V_∞: free stream flowing velocity in cross flow; [m/sec;]; D_o: outer diameter, [mm]; L; length of flat plate, pipe and/or cylinder length; [m]; W: flat plate width [m]; D_{in}: inner diameter of pipe; [mm]; K: thermal conductivity [W/m. °C]; T_w, range of heated water inside tube; [°C]; m; hot water flow rate, [L/min]; (8 marks).

Table -1:

Parameter	Case A	Case B	Case C	Case D
T_∞, air, °C	-		-10	5
T_∞, for flow of water over a sphere, °C	30		-	-
P_∞, atm	1		1	1
V_∞, for flow over a flat plate, m/sec	2.5		5	15.3
W, m	-		-	4
D_o, mm	22		-	-
T_s, °C	60		150	12
m, L/min;	-	8	-	
D_{io}, for Flow inside tube, mm	-	20	-	-
D_{in}, mm	-		500	-
K, for flow over a cylinder W/m. K	-		0.026	-
L, m	-	7	1	10
T_w; water heated range as it flows through an inner tube; °C		10-80		

Question (5): (16 marks)

a) Someone claims that the average Nusselt number for forced convection over a hexagon channel is equal to that of the inclined hexagon one as tilted with 45° from the horizontal at the same flow conditions. Do you agree with this claim? Explain. (3 marks).

b) Three different industrial tubes made of cast iron; galvanized iron and concrete are proposed to be used in a double pipe water-to-water heat exchanger unit. The tubes have an inside diameter of 10 [cm]. Choose the suitable material required to be manufactured in the heat exchanger unit if the water flowing inside the tubes operates at a complete turbulence regime of $Re= 10^6$.. (3 marks).

c) Three different heat exchanger units operate at the same capacity ratio of zero. The units are proposed to be used in an indirect liquid cooling system for the purpose of power transistor cooling process. The heat exchanger units are: parallel flow, counter flow and cross flow with both fluids unmixed. The three units operate at the same specified number of transfer units of 2. If this value increases by 50%, choose the suitable unit required to be used in the cooling process. Neglecting any thermal losses from the heat exchanger to the environment, determine the percentage increase or decrease in the effectiveness if the double-pipe parallel-flow heat exchanger is used instead of counter-flow heat exchanger. What is your answer if the same capacity ratio of unity is used? Assume all the other conditions remain the same. (4 marks).

d) Consider a 0.6-m x 0.6-m thin square plate in a room at 30°C. One side of the plate is maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is (a) vertical, (b) horizontal, with hot surface facing up, and (c) horizontal with hot surface facing down. What is the effect of the room temperature on the plate surface temperature for different orientations of the board? . (6 marks).

Question (6): (16 marks)

a) Determine the ratio of the Nusselt number to that of Rayleigh number for the air layer in free convection conditions as it flows between two vertical parallel plates at the same temperature if the space between the two plates is equal to the plate height. Will the results change if the two vertical parallel plates are at different temperatures? Assume all conditions remain the same. Considering the previous conditions, what about the turbulent flow? (3 marks).

b) A 12-cm-high and 20-cm-wide circuit board houses 100 closely spaced logic chips on its surface, each dissipating 0.05 W. The board is cooled by a fan that blows air over the hot surface of the board at 35 °C at a velocity of 0.5 m/s. The heat transfer from the back surface of the board is negligible. Determine the average temperature on the surface of the circuit board assuming the air flows vertically upwards along the 12- cm-long side by: (a) ignoring natural convection; and (b) considering the contribution of natural convection. Disregard any heat transfer by radiation. (3 marks).

c) Steam of three liquids: water; acetic acid and aniline are proposed to be condensed on the outer surface of three tubes of a condenser unit. The tubes, 2.54 cm diameter, are horizontally placed. The outer surface of the tubes is separately exposed to the saturated steam of each previous proposal liquids at atmospheric pressure. If the average wall surfaces temperature is maintained at 95 °C for each case during the experiment by the flow of cool water through the tubes. It is required to choose the suitable liquid to be used in this condenser unit. (3 marks).

d) Combustion air in a manufacturing facility is to be preheated before entering a furnace by hot water at 90ºC flowing through the tubes of a tube bank located in a duct. Air enters the duct at 15ºC and 1 atm with a mean velocity of 3.8 m/s, and flows over the tubes in normal direction. The outer diameter of the tubes is 2.1 cm, and the tubes are arranged in-line with longitudinal and transverse pitches of $S_L = S_T = 5$ cm. There are eight rows in the flow direction with eight tubes in each row. Determine the rate of heat transfer per unit length of the tubes, and the pressure drop across the tube bank. What is the percentage change in the heat transfer coefficient if the flow is in a parallel direction? Assume all the other conditions remain unchanged. (7 marks).