NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Examination May 2011

TCE 2206 Heat Transfer Processes

Duration of Examination 3 Hours

Instructions to Candidates:

1. Answer ALL FIVE questions.
2. Each question carries equal marks.
3. Show all your steps clearly in your calculation.
4. Start the answers for each question on a new page.

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1. **(a)** What is the thermal conductivity? What are its units? What role does it play in heat transfer? **[6]**

(b) A standard cast iron pipe with inner and outer diameter 50 and 55mm respectively is insulated with 85% magnesium insulation with thermal conductivity of 0.02W/mºC. Temperature at the interface between the pipe and insulation is 300 ºC. The allowable heat loss through the pipe is 600W/m per length of pipe and for the safety, the temperature of the outside surface of insulation must not exceed 100 ºC.
Determine:

i. Minimum thickness of insulation required **[10]**
ii. The temperature of inside surface of the pipe assuming its thermal conductivity is 20W/mºC **[4]**

2. **(a)** What quantities change with locations in a velocity boundary layer? A thermal boundary layer? **[4]**

(b) Forced air at 25 ºC and velocity of 10m/s is used to cool electronic elements on a curcuit board. One such element is a chip, 4mm by 4mm, located 120mm from the leading edge of the board. Experiments have revealed that flow over the board is disturbed by the elements and that convection heat transfer is correlated by an expression of the form:

$$Nu_x = 0.04\,\mathrm{Re}_x^{0.85}\,\mathrm{Pr}^{1/3}$$

Estimate the surface temperature of the chip if it is dissipating 30mW. **[16]**

3. Consider the wing of an aircraft as flat plate of 2.5 m length in the flow direction. The plane is moving at 100 m/s in air that is at a pressure of 0.7 bar and temperature of -10 ºC. The top surface of the wing absorbs solar radiation at a rate

of 800 W/m^2. Assume the wing to be of solid construction and to have a single, uniform temperature. Estimate the steady-state temperature of the wing. **[20]**

4. Atmospheric air enters the heated section of a circular tube at a flow rate of *0.005 kg/s* and a temperature of *29ºC*. The tube is of diameter *D = 50mm*, and fully developed conditions with *h = 25 W/m^2 K* exist over entire length of *2m*.

a) For a case of uniform surface heat flux at $q_S'' = 1000 W/m^2$, determine the total heat transfer rate and the mean temperature of the air leaving the tube $T_{m,o}$. What is the value of the surface temperature at the tube inlet $T_{s,i}$, and outlet $T_{s,o}$? **[10]**

b) If the surface heat flux varies linearly with *x*, such that $q_x''(W/m^2) = 500x(m)$, what are the values of $q_X, T_{m.o}, T_{s,i}$ *and* $T_{s,o}$. **[10]**

5. **(a)** What are the two possible arrangements for a concentric tube heat exchanger? For each arrangement what restrictions are associated with the fluid outlet temperature? **[4]**

(b) A shell-and-tube heat exchanger is to heat 10 000 kg/h of water from 16 to 84 ºC by hot engine oil flowing through the shell. The oil makes a single shell pass, entering at 160 ºC and leaving at 94 ºC, with an average heat transfer coefficient of 400 W/m^2 K. The water flows through 11 brass tubes of 22.9- mm inside diameter and 25.4 -mm outside diameter, with each tube making four passes through the shell. Assuming fully developed flow for the water, determine the required tube length per pass. **[16]**