NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Examination June 2007

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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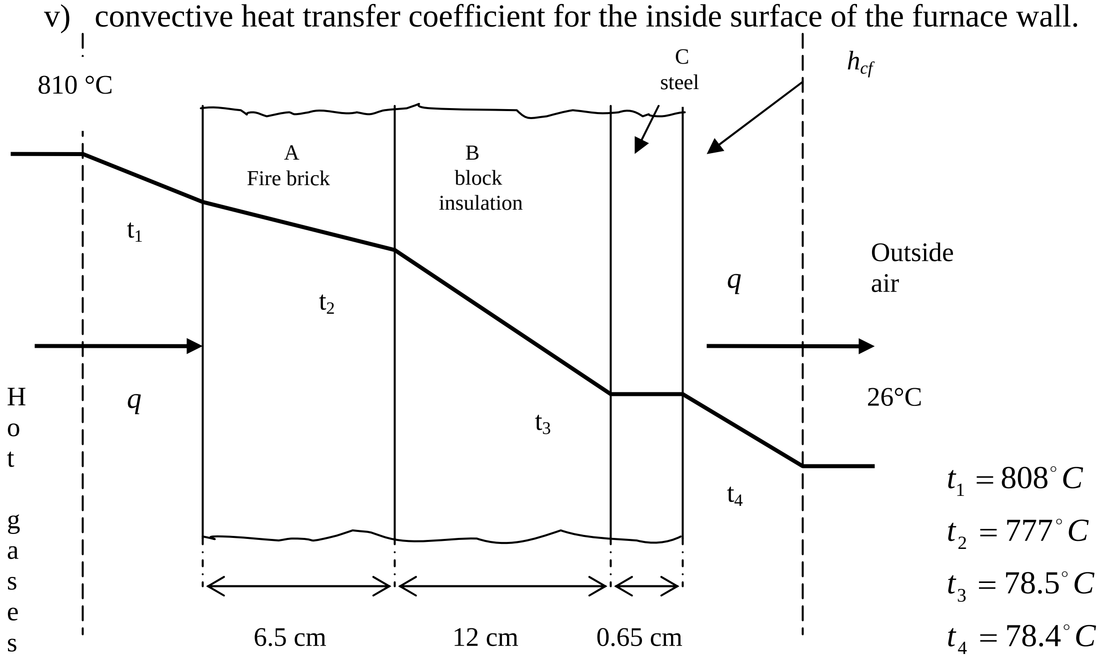
1. **(15 marks)**

(a) Figure shows the temperature distribution through a furnace wall consisting of fire brick and high temperature block insulation and steel plate. If the thermal conductivity of the fire brick is 1.13 W/m° C, determine:

i) rate of heat per unit area of furnace wall;
ii) thermal conductivities of block insulation and steel;
iii) combined convective and radiative heat transfer coefficient for the outside surface of the furnace wall;
iv) heat exchange by radiation between the hot gases and inside surface of furnace wall, the absorptivity and emissivity of the fire brick wall surface is 0.82;
v) convective heat transfer coefficient for the inside surface of the furnace wall.



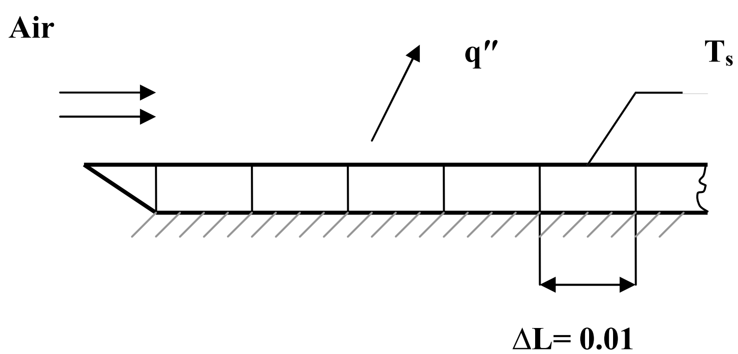
What is ove[...] ransfe[...] lefined and how is it related to the total thermal resistance? What are its units? **(5 marks)**

2. (a) What are the velocity and thermal boundary layers? Under what conditions do they develop? **(4marks)**

(b) Water at temperature of $T_\infty = 25^\circ C$ flows over one of the surfaces of a steel wall (AISI 1010) whose temperature is $T_{s,1} = 40^\circ C$. The wall is 0.35 m thick, and its other surface temperature is $T_{s,2} = 100^\circ C$. For steady-sate conditions what is the convection coefficient associated with the water flow? What are the temperature gradients in the wall and in the water that is in contact with the wall? Sketch the temperature distribution in the wall and in the adjoining water.
Take: *Steel type AISI 1010 (70°C = 343K),* k_s*=61.7 W/m K ;*
Water (32.5°C = 305 K), k_f *= 0.62 W/m K.* **(16 marks)**

3. (a) What is an external flow? **(3 marks)**

b) En electric air heater consists of a horizontal array of thin metal strips that are each ***10 mm*** long in the direction of an airstream that is in parallel flow over the top of the strips. Each strip is ***0.2 m*** wide, and ***25*** strips are arranged side by side, forming a continuous and smooth surface over which the air flows at ***2 m/s.*** During operation each strip is maintained at ***500°C*** and the air is at ***25°C***. What is the rate of convection heat transfer from the first strip? The fifth strip? The tenth strip? All the strips? Assume that $\text{Re}_c = 5\times10^5$.



Take: Air (T_f = 535 K, 1 atm): v= 43.54 · 10^{-6} m^2/s, K = 0.0429 W/m·K, Pr = 0.683.
(17 marks)

4.

(a) Consider a *very long*, concentric tube heat exchanger having hot and cold water inlet temperatures of *85* and *15°C*. The flow rate of the hot water is twice that of the cold water. Assuming equivalent hot and cold water specific heats, determine the hot water outlet temperature for the following modes of operations:

i) counterflow
ii) parallel flow

Draw a temperature distribution for both cases. **(17 marks)**

(b) What effect does *fouling* have on the overall heat transfer coefficient and hence the performance of a heat exchanger?

(3 marks)

5.

A counterflow, concentric tube heat exchanger used for engine cooling has been in service for an extended period of time. The heat transfer surface area of the exchanger is $5m^2$, and *design value* of the overall convection coefficient is $38\ W/m^2K$. During the test run, engine oil flowing at *0.1 kg/s* is cooled from *110°C* to *66 °C* by water supplied at a temperature of *25° C* and a flow rate of *0.2 kg/s*. determine whether fouling has occurred during the service period, if so calculate the fouling factor, $R''_f\,(m^2K/W)$

Take: c_{oil} = 2166 J/kg K, c_{water} = 4178 J/kg K