Code Number :.....

HEAT TRANSFER QUALIFYING EXAM

January 2008

OPEN BOOK (only one book allowed) & CLOSED NOTES

Answer all four questions

All questions have equal weight

TIME: 3.0 hrs

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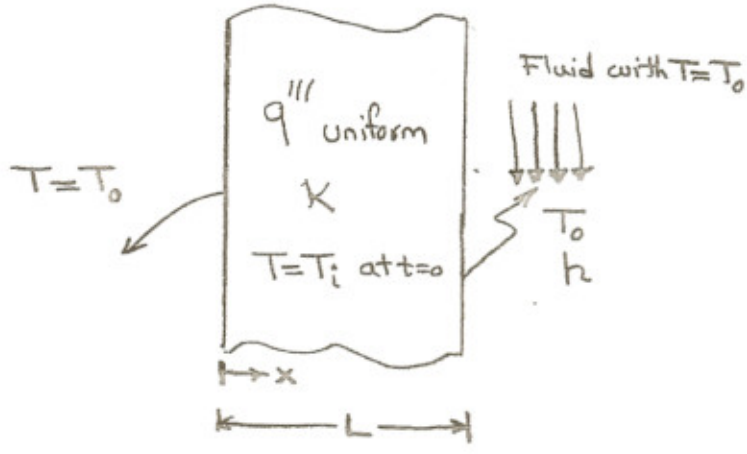
- **Take any required property from your book, approximate values if necessary.**
- **If you make any assumption to reach a solution state it clearly**

Question # 1

Consider the transient one-dimensional heat conduction in a solid slab that is being heated by a distributed heat source. The distributed heat source is constant or uniform. Answer the following questions:

(a) Write down the differential equation for the temperature inside the solid and all the boundary/initial conditions for the case that the thermal conductivity is a function of temperature.
(b) Find the long-time (or steady state) solution for constant thermal conductivity.
(c) Can you solve the transient differential equation with constant conductivity coefficient and very large h via separation of variable method? Show how as much as you can.



Question # 2

Water flows at the rate of $\dot{m} = 3.0\ kg/s$ through a pipe with an inside diameter $D = 6\ cm$ and a length $L = 5m$. The pipe wall temperature is maintained at $90°C$. If the water enters at a bulk temperature of $T_b = 20°C$ what is its exit temperature?

NOTE: You will need to look up the properties of water at the assumed bulk mean temperature. This is an *iterative* calculation.

Problem # 3

A surface is placed normal to the sun's rays outside the earth's atmosphere. Find the *equilibrium temperature* the surface would achieve if thermally isolated and the *net heat flux absorbed by the surface* if it is maintained at *130°C* when the surface is composed of (a) silicon coated aluminum foil; (b) anodized aluminum; (c) white epoxy paint on aluminum. Use the data given below:

(a) Silicon on Al: $\alpha = 0.522; \varepsilon = 0.12$
(b) Anodized Al: $\alpha = 0.923; \varepsilon = 0.841$
(c) White epoxy on Al: $\alpha = 0.248; \varepsilon = 0.882$

Question # 4

As shown below, the wall of a furnace is made of several layers, each with different thickness (L) and thermal conductivity (k). The inner wall is heated by convection and radiation from the burned gas. The outer side is cooled by convection to outside air. Answer the following questions:

(a) Identify all the modes of heat transfer in the wall and on surfaces of the wall. Write down the general energy balance and clearly state all of your assumptions.

(b) Calculate the total heat flux through the wall for steady state condition and estimate the inner and outer wall surface temperatures.

(c) Explain how the laminar boundary layer theory may be used to calculate the convection heat transfer. Do you expect this theory to generate accurate results for the inner and outer surfaces? Explain. List three ways for enhancing the heat transfer by convection.

$L_A = 0.3\ m \quad K_A = 20\ \frac{W}{mK}$

$L_B = 0.2\ m \quad K_B = 40\ "$

$L_C = 0.15\ m \quad K_C = 55\ "$

$T_{\infty_i} = 700^\circ C$

$T_{\infty_o} = 20^\circ C$

$h_{ci} = 30 \frac{W}{m^2K} \quad h_{ri} = 35\ \frac{W}{m^2K}$

$h_{co} = 90\ \frac{W}{m^2K}$