Code Number :.....

HEAT TRANSFER QUALIFYING EXAM

January 2006

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

Two large steel plates at temperatures of 90°C and 70 °C are separated by a steel rod 0.3m long and 2.7cm in diameter. The rod is welded to each plate. The space between the plates is filled with insulation that also insulates the circumference of the rod. Because of a voltage difference between the two plates, current flows through the rod, uniformly dissipating the electrical energy into heat at a rate of 12W. **(a)** Determine the maximum temperature in the rod and the heat flow rate at each end. **(b)** Plot the steady-state temperature distribution along the rod. **(c)** Check your answer by writing the steady state energy balance for the rod. **(d)** Explain what will happen if the insulation between plates is replaced with a moving fluid that has a constant temperature and removes heat from the rod surface with constant convection heat transfer coefficient.

Question # 2

Water entering at 20 °C is to be heated to 50 °C in a 2cm (inner) diameter tube at a mass flow rate of 0.01 kg/s. The tube surface receives solar heat flux with the constant and uniform rate of 15,000 w/m^2. Neglecting any flow entrance effects, and the heat loss due to free convection at outer surface, answer the following questions:

(a) Is the water flow inside the tube laminar or turbulent?

(b) What is the average convection heat transfer coefficient?

(c) What is the length of pipe needed for 30 °C increase in water temperature?

(d) Find the inside surface temperature of the pipe at the outlet.

(e) Calculate the pressure drop in the pipe and the pumping power required if the pump is 50% efficient.

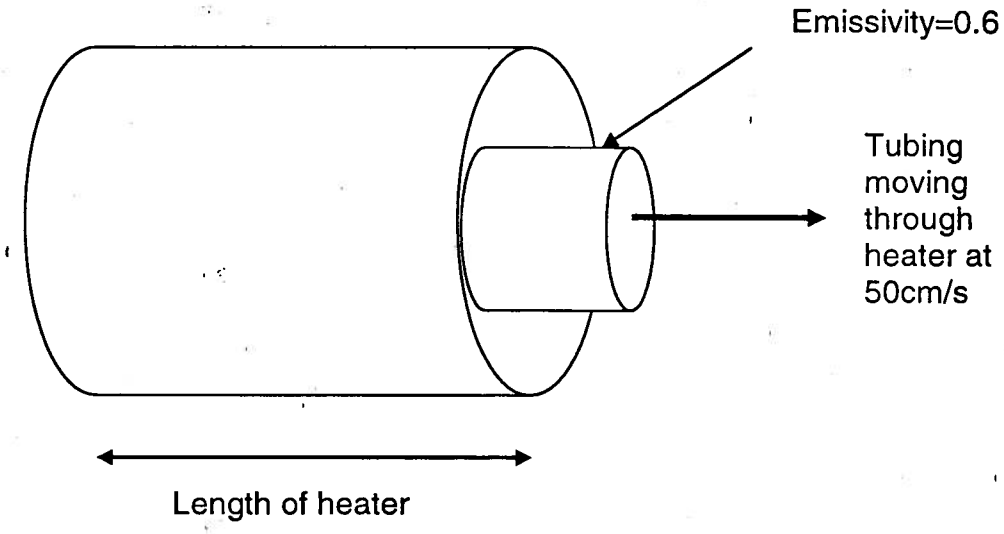
(f) What happens when the mass flow rate increases to 0.1 kg/s? Answer questions (a), (b), (c), (d) and (e) for higher mass flow rate.

(g) Discuss changes in heat transfer and temperature distribution when free or natural convection at outer surface is considered.

(h) Discuss changes in heat transfer and temperature distribution when the flow entrance effects are considered.

Question # 3

It is proposed to heat a 3cm-diameter cylindrical tubing by a radiant heating element placed all around the tubing. The tubing is fed continuously at 50cm/s and does not touch the heater. The cylindrical radiant heater is 10 cm in diameter and has an emissivity of 0.9. It can be made in any axial length. Estimate the length needed to heat the tubing from 15°C to 85°C if the specific heat per unit length of the tubing is 25 J/mK. Assume an average temperature for the tubing.



Question # 4

A toaster at 800K is used to heat 1.5cm-thick bread slices. A bread slice surface is much smaller than the broiler (what does this imply for the shape factor?). If the bread is at 15°C when placed in the toaster, find an expression for the time required to heat the toast to 120°C and compute the answer Assume that the emissivity of bread is 0.9, its mass density is 200kg/m^3, and heat capacity is 4188J/kgK. Neglect convection. Assume that the bread slice is 10cm by 15cm. Hint: you can estimate the answer using the lumped capacitance method.