# HEAT TRANSFER QUALIFYING EXAM

## January 2004

### 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

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# Question # 1

Consider the transient heat conduction in an axisymmetric solid object. Assume the heat transfer to be one-dimensional in the axial, x direction and the conductivity and heat capacity coefficients of the solid (k and $C_p$) as well as the cross sectional diameter, D to be function of x. As a result of irradiation, heat is generated inside the solid with a uniform rate of $u'''$ and there is a heat loss to ambient air at surface due to convection heat transfer. The ambient air temperature, $T_0$ and convection heat transfer coefficient, h are both constant. The solid is initially at uniform temperature of $T_i$, while the left and right surfaces at x=0,L are maintained at constant temperature of $T_i$.

   a) Draw a differential control volume, identify all the relevant terms in the energy equation, and drive the governing differential equation for T(x,t).
   b) Write the appropriate initial and boundary conditions.
   c) Find the long-time (steady state) temperature distribution, T(x) inside the solid by solving the differential equation under steady state conditions assuming the properties (k, $C_p$) to be constant.
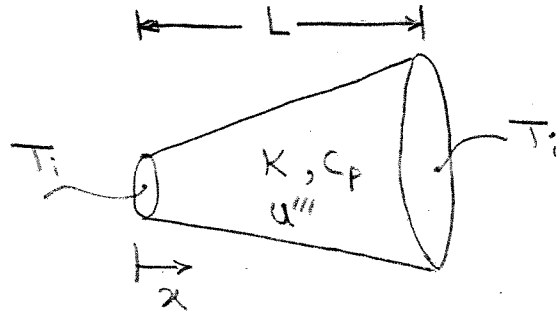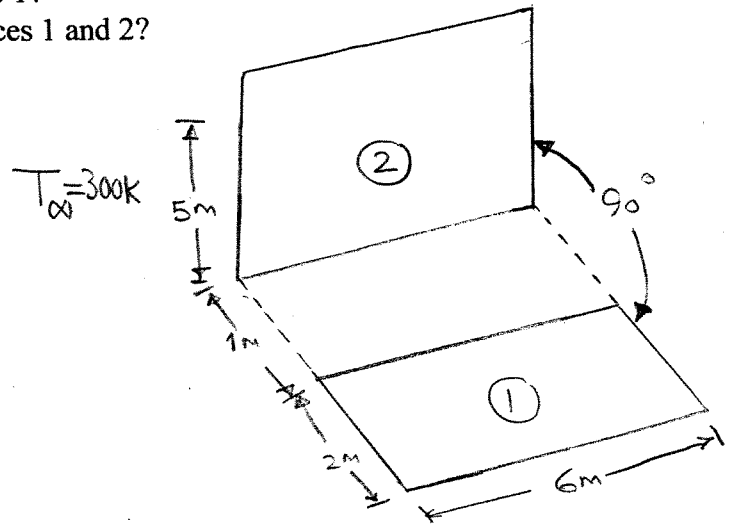
# Question # 2

A vertical flat plate 0.3 m high and 1.0 m wide is maintained at a uniform temperature of 124 °C. It is exposed to a quiescent atmospheric air at 30 °C.

a) What is the Rayleigh number for this condition?
b) What is the average heat transfer coefficient over the entire plate for natural convection?
c) Is the local heat transfer coefficient at the mid height (0.15 m) less than, more than, or equal to the average heat transfer coefficient calculated above? Explain why.
d) Draw both the temperature and velocity profiles at 0.15 m up the plate.
e) If the fluid was water, what would the profiles look like?
f) What is the total heat transfer from both surfaces of the plate?

# Question # 3

Two surfaces that exchange thermal radiation are shown in the figure below. Surface 1 is at a temperature of 200 K, and surface 2 is at 400 K. The surroundings are at 300K. Both surfaces are diffuse with $\alpha_1 = 0.8$ and $\alpha_2 = 0.9$ for surface 2 for all wavelengths. Answer the following questions.

a) What is the shape factor $F_{1-2}$ between the two surfaces?

b) What is the shape factor $F_{2-1}$ between the two surfaces?

c) Write down an expression for the radiosity, J, of surface 1 in terms of the emissivity of surface 1 and the irradiation at surface 1.

d) What is the value of the irradiation of surface 1?

e) What is the value of the radiosity of surface 1?

f) What is the net heat transfer between surfaces 1 and 2?

## Question # 4

For analysis of human comfort in indoor environments, consider a person (like yourself) in a ventilated room as a system.

  **a)** Identify all mechanisms of energy transfer/generation including the evaporation at skin for this system.

  **b)** Apply the global (integrated) energy balance and derive a mathematical model for the average skin temperature and the amount of food (calories) needed to maintain a constant body temperature. Write down all your assumptions, including those you make to simplify your analysis. If needed you may assume the room and inner body temperatures to be at 20°C and 37°C, respectively.