Student #____________________

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Ph.D. Qualifying Exam in Heat Transfer

- One open book.
- Answer all questions.
- All questions carry the same weight.

Exam prepared by

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Problem 1: Assume that the diameter of the Earth is 12, 756 km and that the extraterrestrial solar constant is 1350 W/m^2.

a. Calculate the equilibrium temperature of the Earth.
b. Explain how this temperature might disagree with your experience.
c. Explain how greenhouse gases might change this value of the temperature.
d. Explain how the ozone layer might change this temperature.

Problem 2: Freon (*R-12*) enters a tube at *12 °C*, flowing at *100 g/s*. The inner diameter of the tube is *1 cm* and the outer diameter is *1.5 cm*. Ambient air at *300 K* flows across the outside of the tube at *10 m/s*. The properties of the tube wall are $k = 72.7\ W/m \cdot K$, $\rho = 7870\ kg/m^3$, and $c = 434\ J/kg \cdot K$.

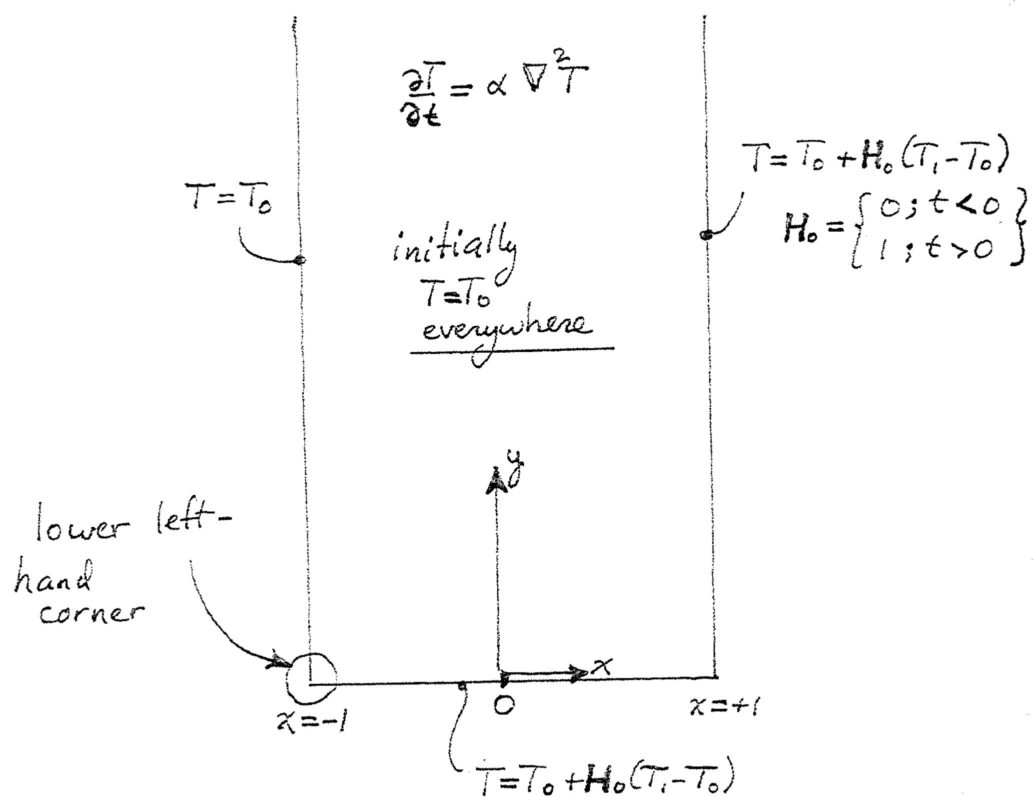
a. Calculate the internal heat transfer coefficient.
b. Calculate the external heat transfer coefficient.
c. Calculate the length of tube required for the mean temperature of the Freon to be *22 °C*.

Problem 3:

The initial temperature in the solid bar is T_0. At time $t = 0$ the two boundaries at $-1 < x < +1$, $y = 0$, and $x = +1$, $y > 0$ are *impulsively raised* from T_0 to T_1. See the **Figure** below. The function H_0 equals zero for $t < 0$ and equals unity for $t > 0$. In other words, it is a Heaviside step function.

- Solve the transient heat conduction problem far from the lower boundary (large y).
- Draw the temperature distribution evolution from the initial (everywhere T_0) through the transient to the steady-state distribution.
- Draw the steady-state temperature contours in and near the lower left corner of the domain near $x \sim -1$ and $y \sim 0$. Do not produce mathematical solutions but simply *draw* the expected T-distributions. What happens very near the corner?

Figure for Problem 3:



Problem 4:

Consider radiant exchange between two surfaces as shown in the **Figure** below. One surface has temperature T_h ('h' for 'hot') while the other has temperature T_c ('c' for 'cold'). The surrounding ambient also has temperature T_c. Consider that the hot two-dimensional surface spans the length $-x_o < x < +x_o$.

1. Calculate the radiant flux to the surface $-x_o < x < +x_o$ immediately beneath the heated surface.
2. Calculate the heat flux to the remainder of the surface, $-\infty < x < -x_o$ and $x_o < x < \infty$.
3. Calculate the heat flux to the ambient surroundings above the interface.

Now consider that the 'hot surface' is actually a flame. It is just a "sheet" of reacted gas that is heated to the temperature T_h by exothermic chemical reaction. How do the fluxes in parts 1-3 change, if at all? For example, since the surface is no longer solid, radiation emitted from one part of the flame can presumably (?) pass through another segment of the flame. Discuss what happens when this is the case. You do not need to write any more equations, just convince the reader that you know how to proceed with the calculation.

Figure for Problem 4: