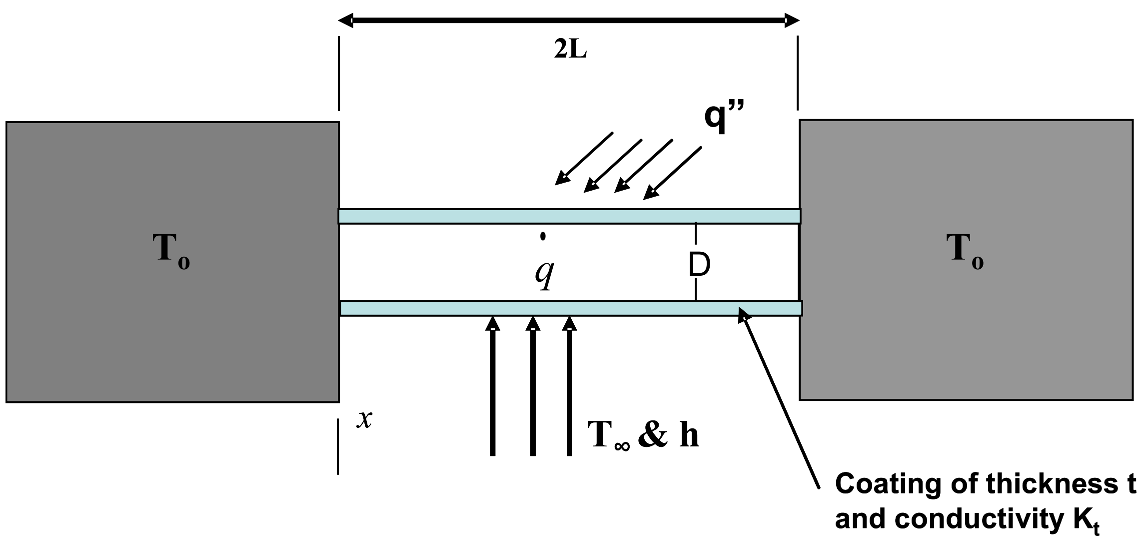
Spring 2008 Heat Transfer Qualifier Exam **NAME**______________________

1. Consider a power transmission line of radius **D** and length **2L (2L>>D)** and thermal conductivity K which is suspended between 2 contacts held at a constant temperature $\mathbf{T_o}$. The line has a thin, optically transparent coating of thickness t and thermal conductivity K_t. Current flows through the wire, generating thermal energy at a rate of $\dot{q}$ W/m^3. The wire is also subjected to a uniform solar heat flux of q" W/m^2 which passes through the optical coating, but is absorbed by the transmission line. Finally, the outside of the line is subjected to convective heat transfer with air flow at a temperature of $\mathbf{T_\infty}$ and a convection coefficient of **h.**

1. Derive the governing differential equation which describes the temperature distribution in the transmission line.
2. Determine the expression for the temperature distribution in the transmission line.



2. A steel pipe carrying 177°C air is 30.5 m long. The outside and inside diameters of the pipe are 10.2 cm and 8.9 cm, respectively. The pipe is covered with 5.1 cm of insulation having a thermal conductivity of 0.1 W/m°C. The pipe passes through a 10°C basement. Please assume that the flow is laminar and fully developed within the pipe, assume steady-state conditions, and also neglect radiation. In your analysis, please state clearly any assumptions that you make.

a.) What is the heat loss, in Watts from the pipe to the basement environment?

b.) What is the temperature on the outside of the insulation, in °C?

Additional information:

$k_{steel} = 44.3 \dfrac{W}{m\,°C}$, $k_{air} = 0.035 \dfrac{W}{m\,°C}$

The heat transfer coefficient for natural convection in a still room is between 4.5 and 25.0 $\dfrac{W}{m^2\,°C}$.

For Laminar flow inside pipes where Re < 2000 and Pr > 0.6:

Constant wall temperature case: $Nu_d = 3.658$ [Re < 2000; Pr > 0.6]

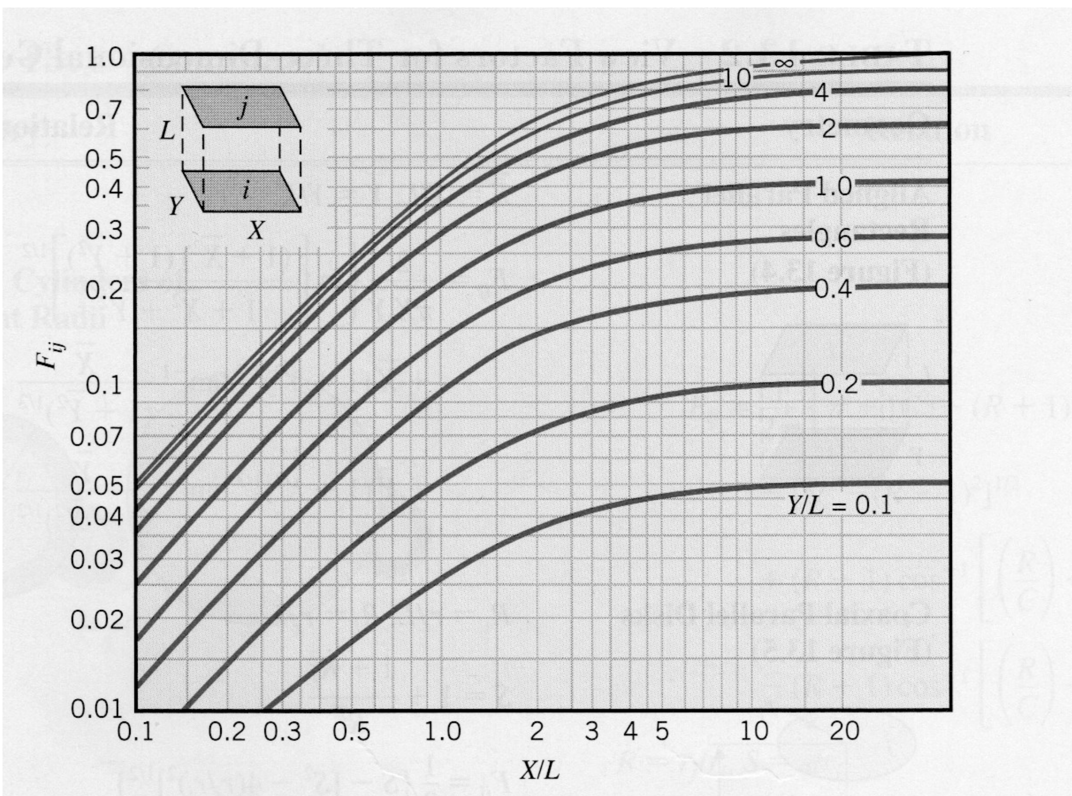
Constant heat flux case: $Nu_d = 4.364$ [Re < 2000; Pr > 0.6]

3. A solar power plant consists of a large assembly of mirrors on the ground. They focus solar energy into a 3m x 3m x 3m cubical enclosure mounted on a high tower south of the assembly of mirrors. The solar energy falls only on the back opaque wall A1, for which $\varepsilon_1 = \alpha_{1s} = 1$, for both the solar and infra-red radiation. The solar irradiation over A1 is uniformly 1.1 x 10^5 W/m^2. The absorber wall A1 is cooled to a surface temperature of 1111 K by circulating a liquid metal in tubes embedded in the wall. The other four walls have a common edge with the heated wall. They are covered with heavy insulation and have an emissivity of 0.8. The sixth surface A2 is an opening through which the solar irradiation enters the enclosure. Neglect convection in the following calculations.

(a) Define completely the simplest possible "equivalent enclosure" and determine the view factors.

(b) Determine the loss of radiant energy from the enclosure, as a fraction of the total solar input to the cavity.

(c) Calculate the net radiant energy gain at the back wall A_1, including both solar effects and all radiant emissions.



View factor for aligned parallel rectangles.