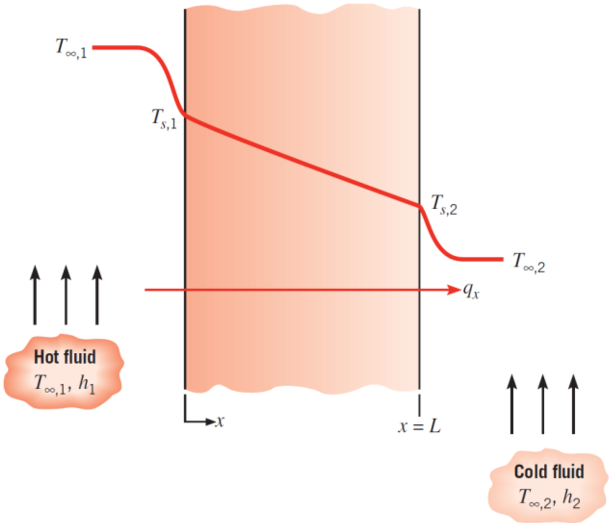
Tutorial Three

| *One-dimensional, steady-state conduction* |

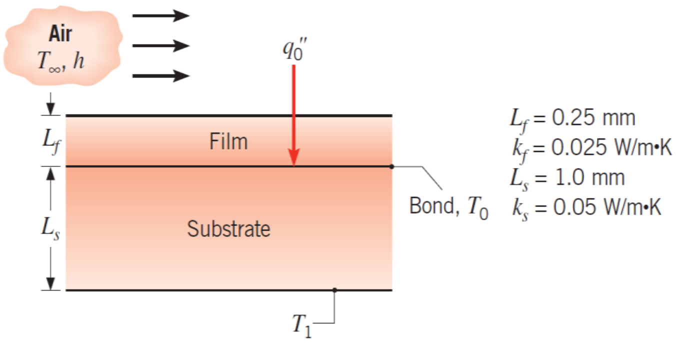
Problem 3.1 Plane and composite walls

Consider the plane wall of the figure below, separating hot and cold fluids at temperatures $T_{\infty,1}$ and $T_{\infty,2}$, respectively. Using surface energy balances as boundary conditions at (**x = 0**) and (**x = L**), obtain the temperature distribution, $T(x)$, within the wall and the heat flux in terms of $T_{\infty,1}$, $T_{\infty,2}$, **h_1**, **h_2**, **k**, and **L**.



Problem 3.2

In a manufacturing process, a transparent film is being bonded to a substrate as shown in the sketch. To cure the bond at a temperature **T_0**, a radiant source is used to provide a heat flux q''_0**(W/m²)**, all of which is absorbed at the bonded surface. The back of the substrate is maintained at T_1 while the free surface of the film is exposed to air at T_∞ and a convection coefficient **h**.



a) Show the thermal circuit representing the steady-state heat transfer situation. Be sure to label *all* elements, nodes, and heat rates. Leave in symbolic form.

b) Assume the following conditions: T_∞ **= 20°C**, **h = 50 W/m²·K**, and T_1 **= 30°C**.
Calculate the heat flux q''_0 that is required to maintain the bonded surface at T_0 **= 60°C**.

c) Compute and plot the required heat flux as a function of the film thickness for **$0 \le L_f \le 1$ mm**.

d) If the film is **<u>not transparent</u>** and all of the radiant heat flux is absorbed at its upper surface, determine the heat flux required to achieve bonding. Plot your results as a function of L_f for **$0 \le L_f \le 1$ mm**.

Problem 3.3 Cylindrical wall

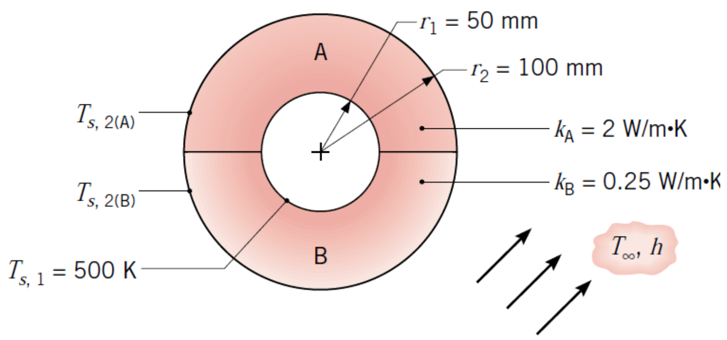
A thin electrical heater is inserted between a long circular rod and a concentric tube with inner and outer radii of **20** and **40 mm**. The rod (**A**) has a thermal conductivity of **k_A = 0.15 W/m·K**, while the tube (**B**) has a thermal conductivity of **k_B = 1.5 W/m·K** and its outer surface is subjected to convection with a fluid of temperature **T_∞ = -15°C** and heat transfer coefficient **50 W/m²·K**. The thermal contact resistance between the cylinder surfaces and the heater is negligible.

A) Determine the electrical power per unit length of the cylinders (**W/m**) that is required to maintain the outer surface of cylinder **B** at **5°C**.

B) What is the temperature at the center of cylinder **A**?

Problem 3.4

Steam flowing through a long, thin-walled pipe maintains the pipe wall at a uniform temperature of **500 K**. The pipe is covered with an insulation blanket comprised of two different materials, **A** and **B**.



The interface between the two materials may be assumed to have an infinite contact resistance, and the entire outer surface is exposed to air for which **T_∞ = 300 K** and **h = 25 W/m²·K**.

a) Sketch the thermal circuit of the system. Label (using the above symbols) all pertinent nodes and resistances.

b) For the prescribed conditions, what is the total heat loss from the pipe? What are the outer surface temperatures **$T_{S,2}$(A)** and **$T_{S,2}$(B)**?