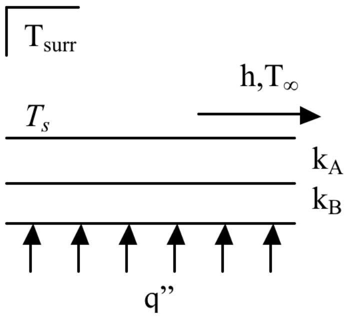
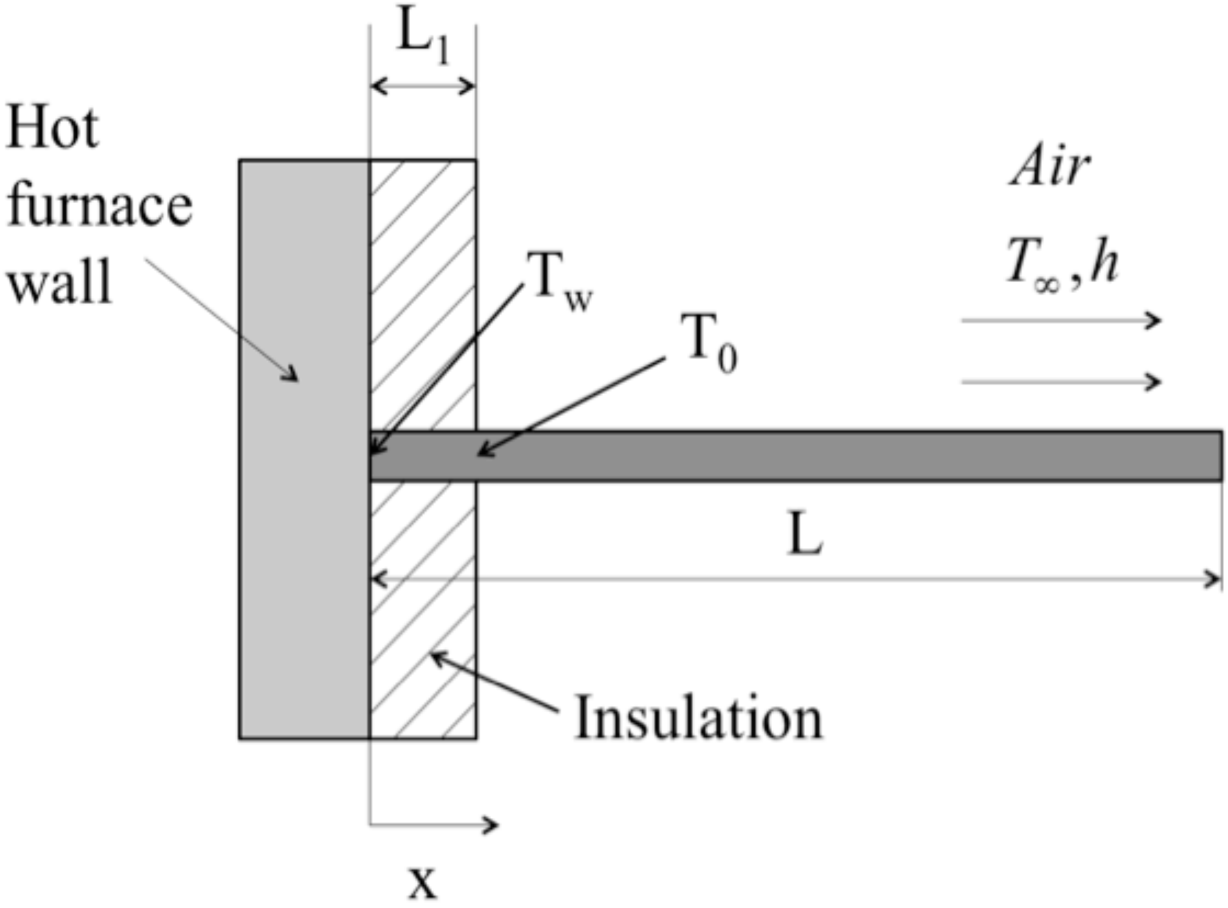
1. A heater is attached to the bottom of a compound plane (with regions A and B) with the top surface exposed to convection and radiation. The thermal conductivities of the two regions are k_A=10 W/m-K and k_B=15 W/m-K. The convective heat transfer coefficient is h=50 W/m^2-K, and the fluid temperature is T_∞=70 °C. The surrounding temperature is T_{surr}=27 °C. The temperature of top surface is T_s=66 °C and the thickness of each region is t=1 cm. A constant heat flux q" is coming into the plane at the bottom surface. The plane can be considered a blackbody. Consider 1-D conduction in the compound plane.

(a) Draw an appropriate control volume for compound plane and write the energy balance equation.
(b) What is the value of constant heat flux q"?
(c) Is radiation significant? Why (not)?
(d) Calculate the temperature at the interface of A and B and the bottom surface at steady state. Neglect any contact resistance.



2. A cylindrical rod of diameter D = 25 mm and thermal conductivity of k = 100 W/m.K protrudes normally from a furnace wall that is at T_w , and is covered by an insulation of thickness L_1 = 200 mm. A uniform heat flux of 45 kW/m^2 escapes through the furnace wall. This rod is welded to the furnace wall and is used as a hanger for supporting instrumentation cables. The exposed surface of the rod is cooled by natural convection by ambient air at 25 ^{o}C with convection coefficient h = 20 W/m^{2}K. The length of the rod is much larger than the diameter, so that the exposed portion of the rod can be considered to be an infinitely long fin.



(a) Sketch the temperature distribution within the rod from x=0 to x=L.

(b) Compute the temperature of the furnace, T_w and the exposed surface temperature of the rod, T_0 , at x=L_1.

(c) Compute the effectiveness and efficiency of the fin (the exposed portion of the rod).

(d) To avoid damaging the cables, T_0 must be maintained below a specified operating limit of 100^{o}C. Does this rod meet the operating conditions? How does T_0 change with increase in (i) Rod diameter, D, (ii) Thermal conductivity of rod, k, and (iii) Thickness of the insulation, L_1?

3. A sphere 30 mm in diameter initially at 800 K is quenched in a large bath having a constant temperature of 300 K with a convection heat transfer coefficient of 75 W/m^{2}K. The thermal conductivity of the sphere material is k = 1.7 W/mK and its thermal diffusivity of the sphere material is $\alpha = 2.5 \times 10^{-6}$ m^2/s.

(a) If we assume that the temperature of the sphere is uniform at any time (Lumped capacitance model ***is valid***), calculate the time required for the sphere to reach 500 K.

For ***parts (b) and (c)***, assume that the ***lumped capacitance model is not valid.***

(b) Show, in a qualitative manner on T-t coordinates, the temperatures at the center and at the surface of the sphere as a function of time.

(c) Calculate the time required for the center of the sphere to reach 500 K.