Mechanical Engineering Department

Michigan State University

Heat Transfer Qualifying Exam

Summer 2021

One book allowed

Time: 3.0 hrs

Answer all questions

All questions have equal weight

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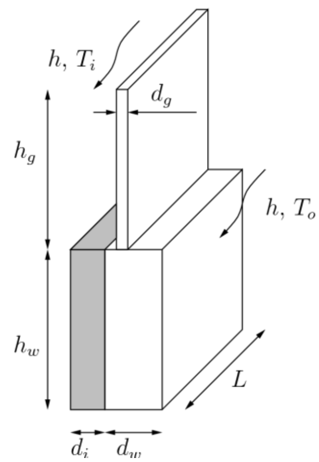
Question #1:

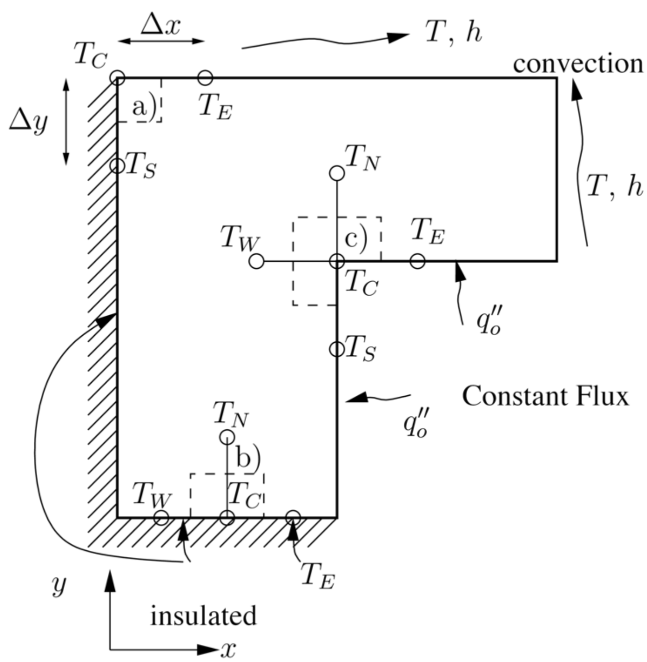
The outward facing wall configuration of an office is schematically shown below. The width, L, of the wall is 3 m. The window height, h_g, is 1.5 m, the wall height, h_w, is 1.5 m. The window consists of a single layer of glass with thickness, d_g=6 mm, and thermal conductivity, k_g=1.4 W/m/K. The wall consists of an insulation layer with thickness d_i=50 mm and conductivity k_i=0.1 W/m/K as well as a brick wall of thickness d_w=100 mm and conductivity k_w=1 W/m/K. The heat transfer coefficient on either side of the configuration, h, is uniform and constant at 10 W/m^2/K.



a) Draw an equivalent thermal resistance network indicating all conduction and convection resistances. *Hint:* There is *more than one correct solution*. You only need to show *one possible solution*.
b) Calculate the individual resistances.
c) How much heat in GJ is transferred through the whole configuration during one season of air conditioning (120 days, average outside temperature of T_o=27 °C, average inside temperature T_i=20 °C).
d) What fraction of the energy is transferred through the window section and what fraction is transferred through the wall section?
e) Make a suggestion how to reduce energy losses by changing the configuration. Would you rather change the window or the wall section? Why?

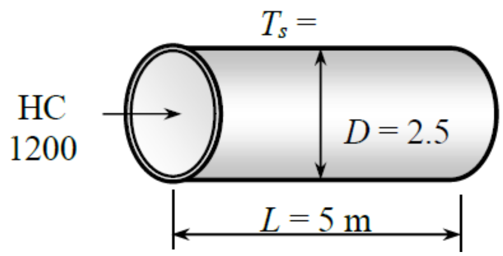
Question #2:

2 Dimensional, stationary conduction in an L-profile as depicted below is to be modelled using finite differences. Derive the finite difference approximation for energy conservation at locations a), b), and c). Grid spacing is uniform Δ*x*=Δ*y*=const.



Question #3:

A liquid hydrocarbon enters a 2.5-cm-diameter tube that is 5.0 m long. The liquid inlet temperature is 20° C and the tube wall temperature is 60° C. Average liquid properties are $c_p = 2.0$ kJ/kg·K, $\mu = 10$ mPa·s, and $\rho = 900$ kg/m^3. At a flow rate of 1200 kg/h, the liquid outlet temperature is measured to be 30° C. **Determine** the liquid outlet temperature when the flow rate is reduced to 400 kg/h. *Hint:* For heat transfer in tubes, $Nu \propto Re^{1/3}$ in laminar flow and $Nu \propto Re^{4/5}$ in turbulent flow.



Question #4:

A silicon chip is cooled by passing water through microchannels etched in the back of the chip, as shown in Fig. below. The channels are covered with a silicon cap. Consider a 12-mm × 12-mm-square chip in which $N = 60$ rectangular microchannels, each of width $W = 50\ \mu\text{m}$ and height $H = 200\ \mu\text{m}$, have been etched. Water enters the microchannels at a temperature $T_i = 290$ K and a total flow rate of 0.005 kg/s. The chip and cap are maintained at a uniform temperature of 350 K. Assuming that the flow in the channels is fully developed, all the heat generated by the circuits on the top surface of the chip is transferred to the water, and using circular tube correlations, **Determine:**

(*a*) The water outlet temperature, T_e

(*b*) The chip power dissipation, $\dot{W}_e$

Evaluate liquid water properties at a bulk mean temperature of 298 K.