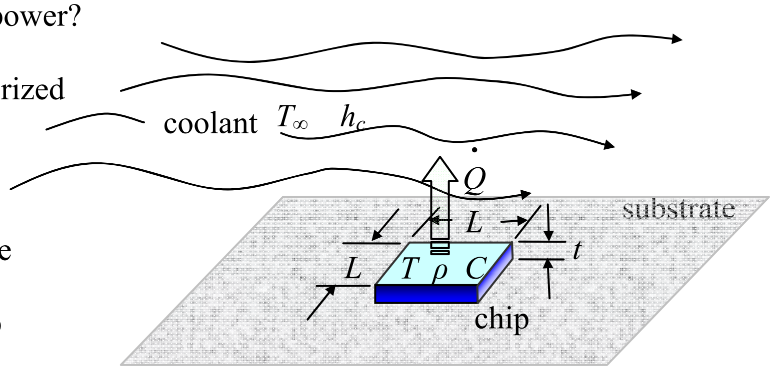
Lesson 19

Problem 19.1 (from *Fundamentals of Heat and Mass Transfer* by Icropera and DeWitt)

A chip of length L = 5 mm on a side and thickness t = 1 mm is embedded in a ceramic substrate, and its exposed surface is convectively cooled by a fluid for which h_c =150 W/m^2-K and T_∞ = 20^{o}C. In the off-mode, the chip is in thermal equilibrium with the coolant ($T = T_\infty$). When the chip is energized, its temperature increases until a new steady-state is established. The chip temperature must not exceed 85 ^{o}C. Assume an infinite contact thermal resistance between the chip and substrate and negligible conduction resistance within the chip (that is the chip is always spatially uniform and there is no conduction heat transfer from the chip to the substrate). The chip's density is ρ = 2000 kg/m^3 and specific heat is C = 700 J/kg-K.

a) What is the maximum allowable chip power?



If when the chip is energized, it is characterized by uniform volumetric heating with $\dot{W}_{in}$ = 9x10^6 W/m^3, determine:

b) the differential equation that models the temperature of the chip.
c) the steady state temperature of the chip
d) how long it takes for the chip to come within 1^{o}C if this temperature.

Problem 19.2

To warm up some milk for a baby, a mother pours milk into a thin-walled glass whose diameter is 6 cm. The height of the milk in the glass is 7 cm. She then places the glass into a large pan filled with hot water at 60 C. The milk is stirred constantly, so that its temperature is uniform at all times. The heat transfer coefficient between the water and the glass is 120 W/(m^2-C). Take the properties of the milk to be the same as water.

a) Why can the milk be treated as a lumped system?
b) Determine approximately how long it will take for the milk to warm up from 3 C to 38 C. Since it is not clear from the problem statement how much heat transfer will occur between the top of the milk and air, determine a range of values for the time. A lower bound can be determined assuming that there is no heat transfer out of the top and an upper bound can be determined by assuming the same heat transfer coefficient on the top as the sides.