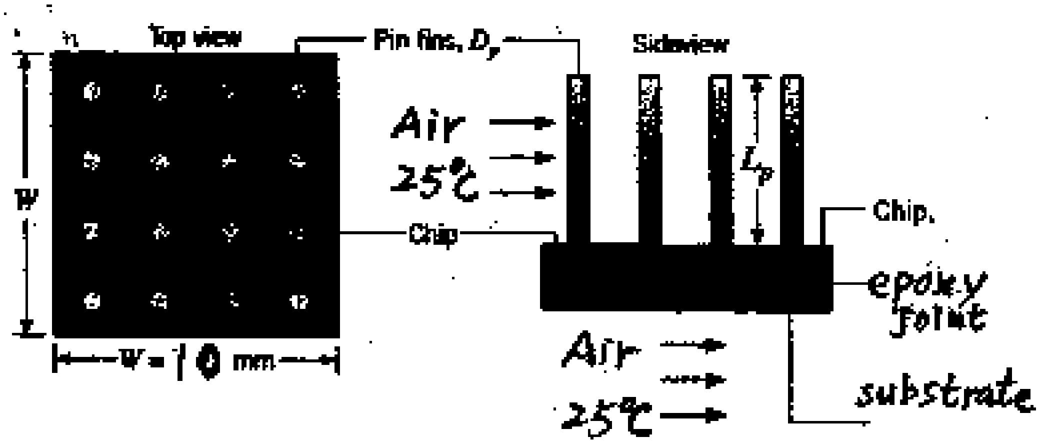
1. Derive the time-dependent, three-dimensional heat diffusion equation and describe its possible boundary conditions. (20%)

2. A thin silicon chip and a 6-mm aluminum substrate are separated by a 0.02-mm-thick epoxy joint with a contact resistance of $0.9\times10^{-4}\ m^2\cdot K/W$. The chip and substrate are each 10 mm on a side and their exposed surface are cooled by air, which is at a temperature of 25℃ and provides a convection coefficient of 200 W/m^2K. The thermal conductivity for pure aluminum substrate is 238 W/mK. Determine the maximum permissible power dissipated by the chip if the maximum allowable temperature for silicon chip is 75℃. (20%)

3. For above problem, to increase the power dissipated by the chip, it is proposed that a 4×4 array of aluminum pin fins, as shown in the following figure, be joined to the surface of the chip without contact resistance. The pin diameter and length are D_p=1 mm L_p=5 mm. Determine again the maximum permissible power dissipated by the chip. (20%)



4. Consider a circular channel with an inner radius of R and a constant wall temperature of T_s. The coolant enters the channel with a mass flow rate of W and at a temperature of $T_i < T_s$. Determine the coolant mean temperature as a function of distance (z) from the entrance. Assume that there is no boiling in the channel and the heat transfer coefficient (h) between the wall and coolant is constant along the channel. The specific heat for the coolant is assumed to be C_p. (20%)

5. A horizontal, high pressure steam pipe of 0.1 m outside diameter passes though a large room whose wall and air temperature are 24℃. The pipe has an outside surface temperature of 130℃ and an emissivity of ε=0.85. Estimate the heat loss from the pipe per unit length. The thermophysical properties of air at the film temperature (350 K) are :

$\rho = 0.9950\ kg/m^3$; $C_p = 1.009\times10^3\ J/kgK$; $\mu = 208.2\times10^{-7}\ kg/ms$

$k = 30.0\times10^{-3}\ W/mK$; $\beta = 2.857\times10^{-3}\ K^{-1}$.

Hint: Assume the room air is quiescent and the natural convection heat transfer coefficient from the pipe surface may be obtained from the following equation. (20%)

$$Nu = \left\{ 0.60 + \frac{0.387\ Ra^{1/6}}{[1 + (0.559\ / Pr)^{9/16}]^{8/27}} \right\}^2$$

$$Ra = \frac{g\beta(T_s - T_\infty)D^3}{\nu\alpha}$$

ν = kinematic viscosity
α = thermal diffusivity

The Stefan-Boltzmann constant is $5.67\times10^{-8}\ W/m^2K^4$.