ENSC 388 Quiz #2

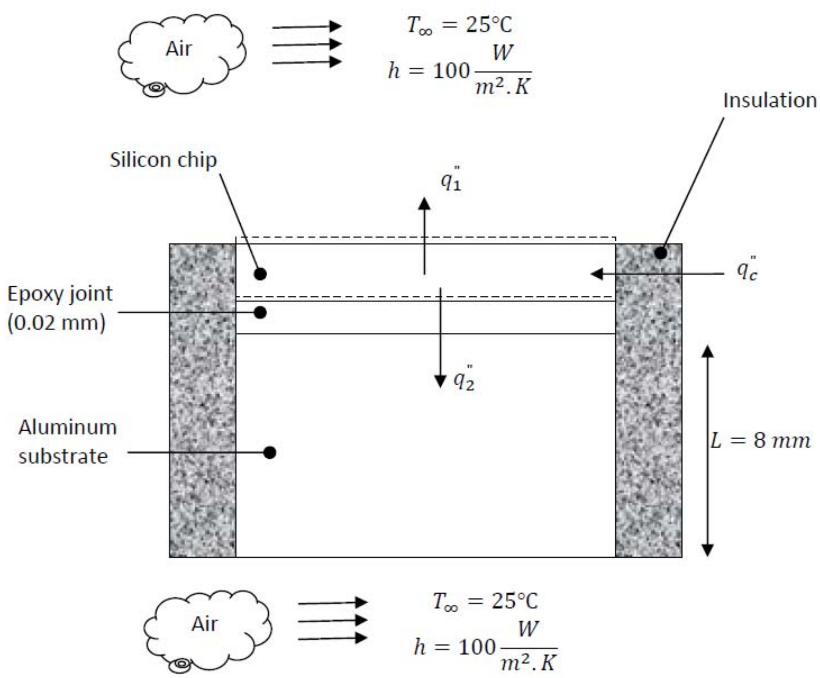
Oct. 7, 2009

Name: ……………………………………… Student ID:………………………………..

Time: 45 minutes or less. Develop answers on available place. The quiz has 5% (bonus) of the total mark. Closed books & closed notes.

Problem 1 (50%):

A thin silicon chip and an 8-mm-thick aluminum substrate are separated by a 0.02-*mm* thick epoxy joint. The chip and substrate are each 10 *mm* on a side, and their exposed surfaces are cooled by air, which is at a temperature of 25°C and provides a convection coefficient of 100 W/m^2• K. If the chip dissipates 10^4 W/m^2 under normal conditions, will it operate below a maximum allowable temperature of 85°C?
Note: the thermal resistant at the interface between the silicon chip and the aluminum plate with 0.02-*mm* epoxy is: $R_{t,c} = 0.9 \times 10^{-4}\ m^2K/W$



Pure aluminum (T ~ 350 K): k = 239 W/m· K

Problem 2 (50%):

Consider a 0.6m ×0.6m thin square plate in a room at 30˚C. One side of the plate is maintained at a temperature of 90˚C, while the other side is insulated. Determine the rate of heat transfer by natural convection from the plate if the plate is: a) vertical, b) horizontal with hot surface up, and c) horizontal with hot surface facing down.

Use the following properties for air at the film temperature:

$$k = 0.02808\ W/mK,\ \Pr = 0.7202,\ \text{and}\ \upsilon = 1.896\times10^{-5}\ m^2/s.$$

Also:

$$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2}\Pr$$

Problem 1:

Known:

Dimensions, heat dissipation, and maximum allowable temperature of a silicon chip. Thickness of aluminum substrate and epoxy joint. Convection conditions at exposed chip and substrate surfaces.

Find:

- Whether maximum allowable temperature is exceeded.

Assumptions:

1. Steady-state conditions.
2. One-dimensional conduction (negligible heat transfer from sides of composite).
3. Negligible chip thermal resistance (an isothermal chip).
4. Constant properties.
5. Negligible radiation exchange with surroundings.

Properties:

Pure aluminum *(T* ~ 350 K): *k* = 239 W/m· K (Table A-24).

Analysis:

Heat dissipated in the chip is transferred to the air directly from the exposed surface and indirectly through the joint and substrate. Performing an energy balance on a control surface about the chip, it follows that, on the basis of a unit surface area,

$$q_c'' = q_1'' + q_2''$$

Or

$$q_c'' = \frac{T_c - T_\infty}{(1/h)} + \frac{T_c - T_\infty}{R_{t,c}'' + (L/k) + (1/h)}$$

To conservatively estimate *Tc* , the maximum possible value of $R_{t,c}'' = 0.9 \times 10^{-4}$ m^2 • K/W is obtained from Table. Hence

$$T_c = T_{\infty +} q_c'' \left[h + \frac{1}{R_{t,c}'' + (L/k) + (1/h)} \right]^{-1}$$

Or

$$T_c = 25°C + \frac{10^4 W}{m^2} \times \left[100 + \frac{1}{(0.9 + 0.34 + 100) \times 10^{-4}} \right]^{-1} m^2.K/W$$

$$T_c = 25°C + 50.3°C = 75.3°C$$

Hence the chip will operate below its maximum allowable temperature.

Problem 2:

See Example 14-2, page 623, Cengel book.