

Lesson 18

Problem 18.1 (from Y.A. Çengel & R.H. Turner, *Fundamentals of Thermal Fluid Sciences*, McGraw-Hill, 2001.)

An electronic device dissipating 30 W has a mass of 20 g, a specific heat of 850 J/kg-°C, and a surface area of 5 cm². The device is lightly used, and it is on for 5 min and then off for several hours, during which it cools to the ambient temperature of 25 °C. Taking the heat transfer coefficient to be 12 W/m²-°C, determine the temperature of the device at the end of the 5-min operating period. What would your answer be if the device were attached to an aluminum heat sink having a mass of 200 g and a surface area of 50 cm²? Assume the device and the heat sink to be nearly isothermal.

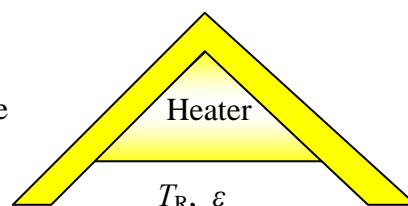
Problem 18.2 (Adapted from Shearer, Kulakowski, and Gardner, *Dynamic Modeling and Control of Engineering Systems*, 2/e, Prentice Hall, 1997.)

The ceramic object shown in the figure consists of two layers having different thermal capacitances C_1 and C_2 . The top layer is exposed to thermal radiation from a heater of temperature T_r and emissivity ε . The area exposed to radiation is A_1 . Both layers exchange heat by convection with ambient air of temperature T_a through their sides of area A_s . Heat is also transferred between the two layers at a rate given by

$$\dot{Q}_{12} = \frac{\Delta T}{R_{12}},$$

where R_{12} represents the thermal resistance of the interface between the two layers and ΔT is the temperature difference between the two layers. The surface under the lower layer is a perfect insulator.

- Derive the equations of motion for this system.
- Sketch a simulation diagram for the system.
- Assume the object has a square footprint where each side of the square has length a . Determine a range of values for length a and height b of the upper layer such that the lumped capacitance assumption is not violated. Plot the range of values in a 2D design-space with dimension a on one axis and dimension b on the other. From your range of values, select one particular design point. Show that your design satisfies the constraint. Assume that the convection coefficient is 25 W/m²K and the thermal conductivity of the ceramic is 10 W/m·K.



T_a

