5-1 A slug calorimeter can be used to measure heat flux. The device is a small, thin, disk of diameter D and thickness t and is typically mounted integral to the surface so that it is heated from one side only. The idea is that the calorimeter should behave as a lumped capacitance device and only the temperature at the center needs to be monitored to learn about the surface heating.

a. One design calls for D=15mm, t=3mm, and an aluminum disk (\(k_{al} = 200\text{W/m-K}, c_{al}=800\text{J/kg-K}, \rho_{al}=2750\text{kg/m}^3\)). What is the limiting value of “h” that can be measured and still maintain lumped capacitance conditions?

b. For the parameters in a), the surface is heated from \(\theta=500\text{K}\) to \(\theta=100\text{K}\) in 10 seconds. Estimate the value of “h”.

5-2 An copper sphere 50mm in diameter is initially at 200\text{C} and is suddenly exposed to an environment with \(T_{env} = 20\text{C}\) and \(h=28\text{W/m}^2\cdot\text{K}\). Estimate the time for the center of the sphere to reach 90\text{C}.

5-3 A thin aluminum can with a volume of 350 cm\(^3\) contains beer at 1\text{C} and is placed in an environment with \(T_{env} = 20\text{C}\) and \(h=15\text{W/m}^2\cdot\text{K}\). Assume \(L=2D\) for the can geometry and consider heat loss from all surfaces of the can.

a. Show that the lumped capacitance approximation is “not excellent” for this problem.

b. Using the lumped capacitance method, estimate the time for the contents to warm to 15\text{C}.

5-4 A large stainless steel plate (\(k=16.3\text{ W/m-K}, \alpha=4.4E-6\text{ m}^2/\text{s}\)) 30mm thick is initially at 500\text{C} and is exposed to an environment with \(h=150\text{W/m}^2\cdot\text{K}\) and \(T_{env}=40\text{C}\). The plate is cooled on both sides.

a. how long does it take for the centerline to cool to 120\text{C}?

b. what is the surface temperature at this time?

c. how long does it take for the surface temperature to cool from the initial condition to 120\text{C}?