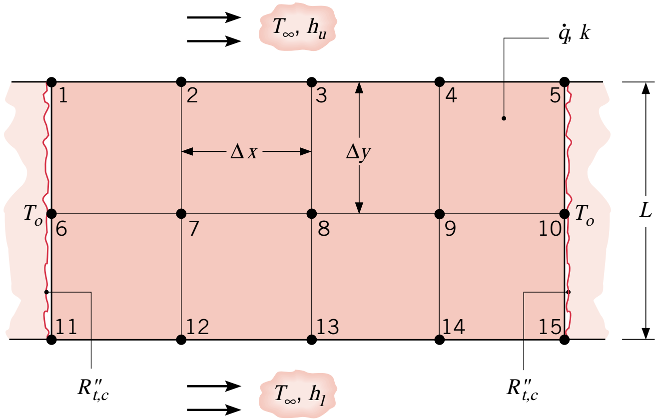
CH21004: Home assignments

1. Upper and lower surfaces of a bus bar are convectively cooled by air at T_∞, with $h_u \neq h_l$. The sides are cooled by maintaining contact with heat sinks at T_o, through a thermal contact resistance of $R''_{t,c}$. The bar is of thermal conductivity k, and its width is twice its thickness L.



   Consider steady-state conditions for which heat is uniformly generated at a volumetric rate **q** due to passage of an electric current. Using the energy balance method, derive finite-difference equations for nodes **1** and **13**.

2. Steel balls 12 mm in diameter are annealed by heating to 1150 K and then slowly cooling to 400 K in an air environment for which T_∞ = 325 K and h = 20 W/m^2 K. Assuming the properties of the steel to be k = 40 W/mK, ρ = 7800 kg/m^3 , and c = 600 J/kg K, estimate the time required for the cooling process.

3. The heat transfer coefficient for air flowing over a sphere is to be determined by observing the temperature–time history of a sphere fabricated from pure copper. The sphere, which is 12.7 mm in diameter, is at 66°C before it is inserted into an airstream having a temperature of 27°C. A thermocouple on the outer surface of the sphere indicates 55°C 69 s after the sphere is inserted in the airstream. Assume, and then justify, that the sphere behaves as a spatially isothermal object and calculate the heat transfer coefficient. For pure copper: ρ = 8933 kg/m, c_p = 389 J/kg·K, k = 398 W/m·K.

4. Carbon steel shafts of 0.1-m diameter are heat treated in a gas-fired furnace whose gases are at 1200 K and provide a convection coefficient of 100 W/m^{2}K. If the shafts enter the furnace at 300 K, how long must they remain in the furnace to achieve a centerline temperature of 800 K? For carbon steel: ρ = 7832 kg/m^3 , k = 51.2 W/m·K, c = 541 J/kg·K, α = 1.21×10^{-5} m^2/s.

5. A thermal energy storage unit consists of a large rectangular channel, which is well insulated on its outer surface and encloses alternating layers of the storage material and the flow passage. Each layer of the storage material is an aluminum slab of width W = 0.05 m, which is at an initial temperature of 25°C. Consider conditions for which the storage unit is charged by passing a hot gas through the passages, with the gas temperature and the convection coefficient assumed to have constant values of T_∞ = 600°C and h = 100 W/m^{2}K throughout the channel. How long will take to achieve 75% of the maximum possible energy storage? What is the temperature of the aluminum at this time? For aluminum: k = 231 W/m·K, c = 1033 J/kg·K, ρ = 2702 kg/m^3.