18.D5 This problem asks for us to determine the temperature at which boron is to be diffused into high-purity silicon in order to achieve a room-temperature electrical conductivity of 1000 $(\Omega\text{-m})^{-1}$ at a distance 0.2 μm from the surface if the B concentration at the surface is maintained at 1.0×10^{25} m^{-3}. It is first necessary for us to compute the hole concentration (since B is an acceptor in Si) at this 0.2 μm location.

From Equation 18.17, the conductivity is a function of both the hole concentration (*p*) and the hole mobility (μ_h). Furthermore, the room-temperature hole mobility is dependent on impurity concentration (Figure 18.18). One way to solve this problem is to use an iterative approach—i.e., assume some boron concentration, N_B (which will also equal the value of *p*), then determine a "calculated" hole mobility from Equation 18.17—i.e.,

$$\mu_h = \frac{\sigma}{p|e|}$$

and then compare this mobility with the "measured" value from Figure 18.18, taken at the assumed *p* (i.e., N_B).

Let us begin by assuming that $N_B = 10^{24}$ m^{-3}. Thus, the "calculated" mobility value is

$$\mu_h = \frac{\sigma}{p|e|} = \frac{1000\ (\Omega - \text{m})^{-1}}{(10^{24}\ \text{m}^{-3})(1.602 \times 10^{-19}\ \text{C})} = 0.0062\ \text{m}^2/\text{V}-\text{s}$$

From Figure 18.18, at an impurity concentration of 10^{24} m^{-3} the "measured" hole mobility is 0.01 m^2/V-s, which is higher than the "calculated" value.

For our next choice, let us assume a lower boron concentration, say 10^{23} m^{-3}. At this lower concentration there will be an increase of both "calculated" and "measured" hole mobilities. The "calculated" value is just

$$\mu_h = \frac{\sigma}{p|e|} = \frac{1000\ (\Omega - \text{m})^{-1}}{(10^{23}\ \text{m}^{-3})(1.602 \times 10^{-19}\ \text{C})} = 0.062\ \text{m}^2/\text{V}-\text{s}$$

Whereas, Figure 18.18 yields a "measured" μ_h of 0.024 m^2/V-s, which is lower than the "calculated" value. Therefore, the correct impurity concentration will lie somewhere between 10^{23} and 10^{24} m^{-3}. At 4.0×10^{23} m^{-3}, "measured" and "calculated" values are about equal (0.015 m^2/V-s).

With regard to diffusion, the problem is one involving the nonsteady-state diffusion of B into the Si, wherein we have to solve for temperature. Temperature is incorporated into the diffusion coefficient expression given in the problem. But we must first employ the solution to Fick's second law for constant surface composition boundary conditions, Equation 5.5; in this expression C_0 is taken to be zero inasmuch as the problem stipulates that the initial boron concentration may be neglected. Thus,