Extrinsic Semiconduction
Factors That Affect Carrier Mobility

18.D4 First of all, those elements which, when added to silicon render it *n*-type, lie one group to the right of silicon in the periodic table; these include the group VA elements (Figure 2.6)--i.e., nitrogen, phosphorus, arsenic, and antimony.

Since this material is extrinsic and *n*-type, $n >> p$, and the electrical conductivity is a function of the hole concentration according to Equation 18.16. Also, the number of free electrons is about equal to the number of donor impurities, N_d. That is

$$n \sim N_d$$

From Equation 18.16, the conductivity is a function of both the electron concentration (*n*) and the electron mobility (μ_e). Furthermore, the room-temperature electron 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 donor impurity concentration (which will also equal the value of *n*), then determine a "calculated" electron mobility from Equation 18.16—i.e.,

$$\mu_e = \frac{\sigma}{n\,|e|}$$

and, finally, compare this mobility with the "measured" value from Figure 18.18, taken at the assumed *n* (i.e., N_d) value.

Let us begin by assuming that $N_d = 10^{22}$ m^{-3}. Thus, the "calculated" mobility value is

$$\mu_e = \frac{\sigma}{n|e|} = \frac{200\ (\Omega - \text{m})^{-1}}{(10^{22}\ \text{m}^{-3})(1.602 \text{ x } 10^{-19}\ \text{C})} = 0.125\ \text{m}^2/\text{V} - \text{s}$$

From Figure 18.18, at an impurity concentration of 10^{22} m^{-3} the "measured" electron mobility is 0.10 m^2/V-s, which is slightly lower than the "calculated" value.

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

$$\mu_e = \frac{\sigma}{n\,|e|} = \frac{200\ (\Omega - \text{m})^{-1}}{(10^{23}\ \text{m}^{-3})(1.602 \text{ x } 10^{-19}\ \text{C})} = 0.0125\ \text{m}^2/\text{V} - \text{s}$$