Example- For silicon at 300 K, we have an acceptor concentration of 1×10^{17} #/cm^3. We wish to add donors to make an ***n*-type** (use phosphorous) compensated semiconductor with a conductivity of 20 S/cm = 2000 S/m, i.e., determine N_d.

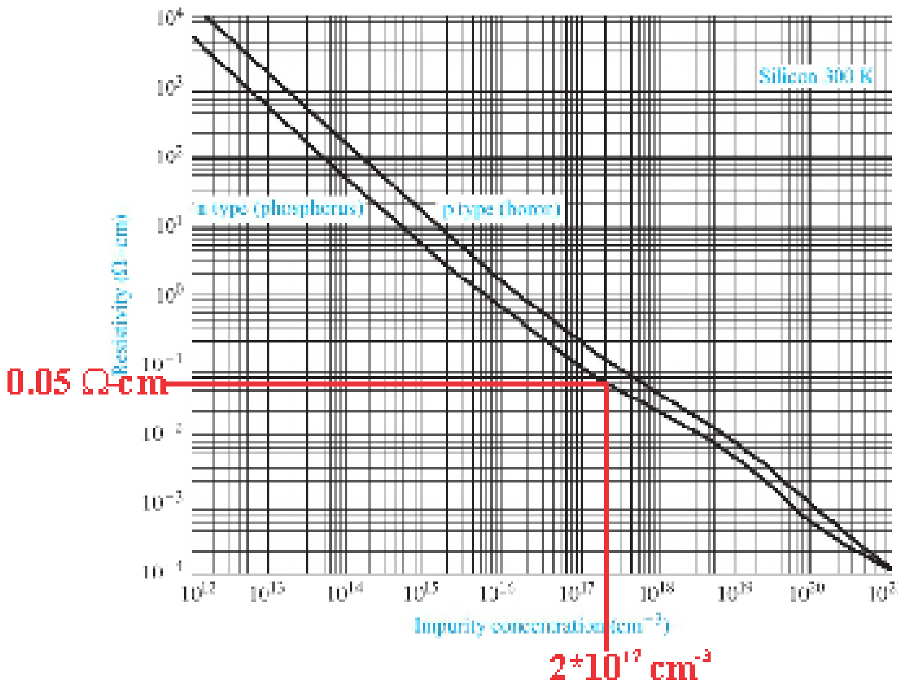
Known- T = 300 K, $N_a = 1 \times 10^{17}$ #/cm^3, and σ = 20 S/cm = 2000 S/m.

Per (5.20), the resistivity is $\rho = 1/\sigma = 1/20 = 0.05$ Ω•cm.

Using (5.23), $\sigma = e(\mu_n n + \mu_p p)$.

Assume intrinsic charge concentration, $n_i = 1.5 \times 10^{10}$ #/cm^3 (Table B.4) is negligible compared to N_a and N_d, and that the net negative charge concentration is $n \approx N_d - N_a$. having mobility μ_n. This gives $\sigma \simeq e\mu_n(N_d - N_a) = (1.6022 \bullet 10^{-19}\,\mathrm{C})\mu_n(N_d - 10^{17}\,\mathrm{cm}^{-3})$.

Using ρ = 0.05 Ω•cm and Figure 5.4a, we read that the impurity concentration for *n*-type (phosphorous) should be **2×10^{17} #/cm^3**



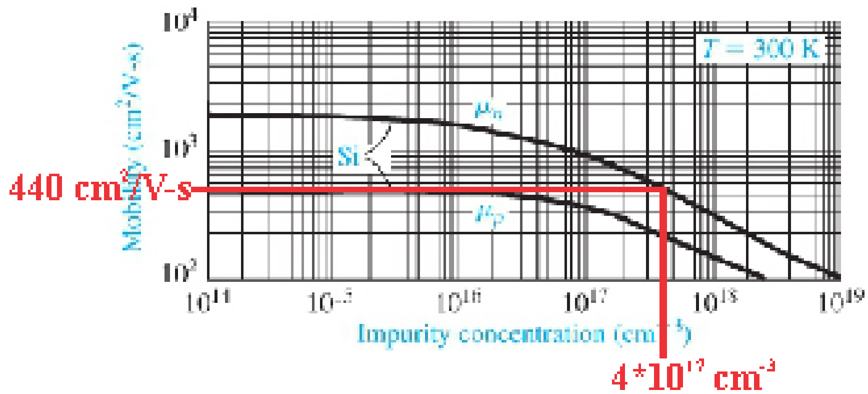
From *Semiconductor Physics and Devices: Basic Principles* (4th Edition), Donald A. Neamen, McGraw Hill, 2012, ISBN 978-0-07-352958-5.

Letting 2×10^{17} #/cm^3 = N_d - N_a = N_d - 10^{17} #/cm^3 ⇒ $N_d = 3 \times 10^{17}$ #/cm^3.

The overall ionized impurity concentration is then

$$N_I = N_d^+ + N_a^- = 3 \times 10^{17} + 10^{17} \Rightarrow N_I = 4 \times 10^{17}\ \#/\mathrm{cm}^3.$$

Going to Figure 5.3 (middle graph for silicon), we can read what the electron mobility should be for this impurity concentration. This yields <u>$\mu_n \approx 440$ cm^2/V-s</u>.



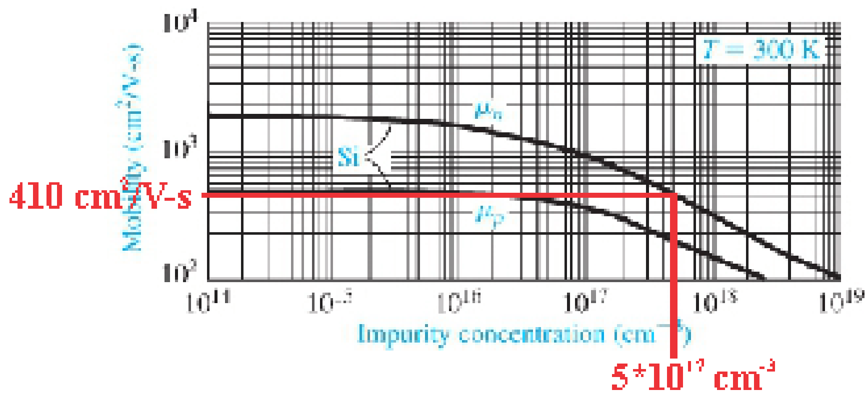
This gives $\sigma \simeq e\mu_n(N_d - N_a) = (1.6022{\bullet}10^{-19})(440)(3{\bullet}10^{17} - 10^{17}) \;\;\Rightarrow\;\; \sigma \simeq 14.1$ S/cm and $\rho = 0.07$ Ω•cm. A bit low for σ and a bit high for ρ. Looking at Figure 5.4a, we see that increasing the impurity concentration (and hence N_d) decreases the resistivity.

For a second try, let's bump the donor concentration up by the ratio of resistivities

$0.07/0.05{*}3 \times 10^{17}$ #/cm$^3 = 4.2 \times 10^{17}$ #/cm^3 $\;\;\Rightarrow\;\;$ <u>$N_d = 4 \times 10^{17}$ #/cm^3</u> (second try).

The overall ionized impurity concentration is then $4 \times 10^{17} + 10^{17} \;\Rightarrow\; N_I =$ <u>5×10^{17} #/cm^3</u>.

Going back to Figure 5.3 w/ our new N_I, we read <u>$\mu_n \approx 410$ cm^2/V-s</u>.



So <u>**$N_d = 4 \times 10^{17}$ #/cm^3**</u> gives

$$\sigma \simeq e\mu_n(N_d - N_a) = (1.6022{\bullet}10^{-19})(410)(4{\bullet}10^{17} - 10^{17})$$

$$\Rightarrow \underline{\boldsymbol{\sigma = 19.7 \text{ S/cm}}} \quad \& \quad \underline{\boldsymbol{\rho = 0.051\ \Omega{\bullet}\text{cm}}}.$$

Given graphical accuracy, this solution is acceptable (1.5% error).