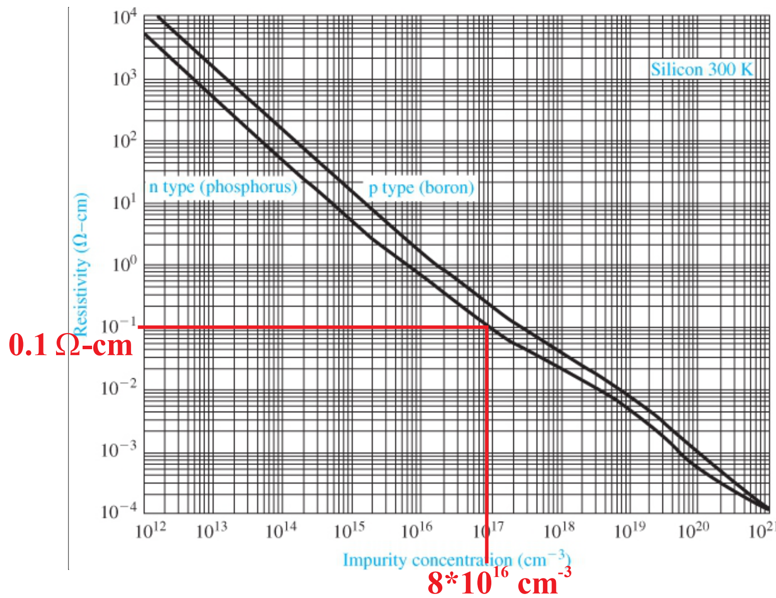
5.3 (*a*) The required conductivity of an n-type silicon sample at $T = 300$ K is to be $\sigma = 10(\Omega\text{-cm})^{-1}$. What donor impurity concentration is required? What is the electron mobility corresponding to this impurity concentration? (*b*) A p-type silicon material is required to have a resistivity of $\rho = 0.20(\Omega\text{-cm})$. What acceptor impurity concentration is required and what is the corresponding hole mobility?

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

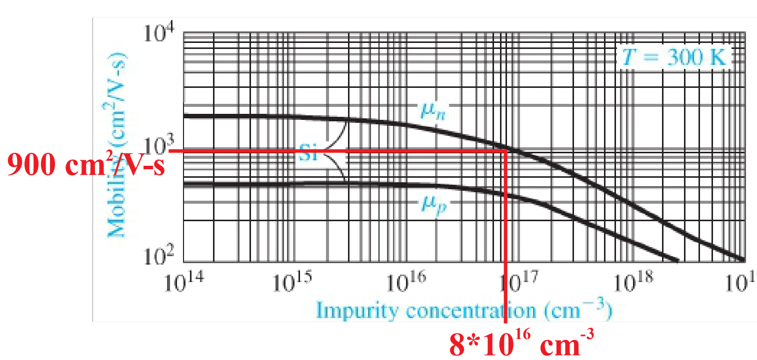
Assume the intrinsic charge concentration, $n_i = 1.5\times10^{10}$ #/cm^3, (Table B.4) is negligible compared to N_d. So, $n \approx N_d$. Also, assume $N_a = 0$. This gives $\sigma \simeq e\mu_n N_d$.

Per (5.20), the resistivity is $\rho = 1/\sigma = 1/10 = 0.1$ Ω•cm. Using Figure 5.4a, we read that the impurity concentration for *n*-type (phosphorous) should be **$N_d = 8\times10^{16}$ #/cm^3.**



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

Going to Figure 5.3 (middle graph for silicon), we can read what the electron mobility should be for this impurity concentration. This yields **$\mu_n \approx 900$ cm^2/V-s**.



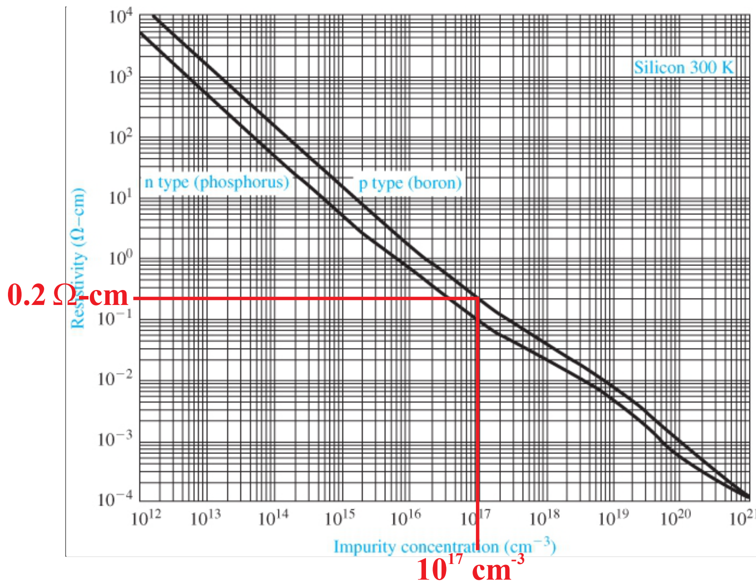
Check- $\sigma \simeq e\mu_n N_d = (1.6022\cdot10^{-19})(900)8\cdot10^{16} \quad\Rightarrow\quad \sigma \simeq 11.5$ S/cm. [So-so agreement.]

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

Assume the intrinsic charge concentration, $n_i = 1.5 \times 10^{10}$ #/cm^3, (Table B.4) is negligible compared to N_a. So, $p \approx N_a$. Also, assume $N_d = 0$. This gives $\sigma \simeq e\mu_p N_a$.

Using Figure 5.4a, we read that the impurity concentration for *p*-type (boron).

$\Rightarrow$ **$N_a = 10^{17}$ #/cm^3.**



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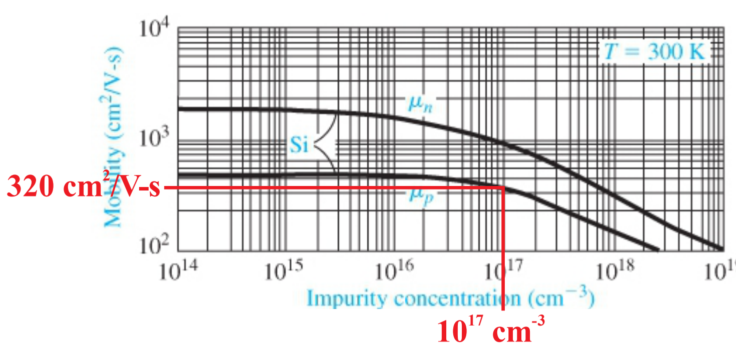
Going to Figure 5.3 (middle graph for silicon), we can read what the hole mobility should be for this impurity concentration. This yields **$\mu_p \approx 320$ cm^2/V-s**.



Check- $\sigma \simeq e\mu_p N_a = (1.6022 \bullet 10^{-19})(320)10^{17} = 5.13$ S/cm $\Rightarrow$ $\rho \simeq 0.195$ Ω•cm. Pretty good agreement.