\[ \frac{3.2}{4} \]

\[
V_d = 10^3 \text{ cm/sec} \\
E = \frac{\Delta V}{L} = 2 \text{ V/cm} \\
\mu_p = \frac{V_d}{E} = 500 \text{ cm}^2/\text{Vsec}
\]

b) (i) Lattice scattering
(ii) Ionized impurity scattering

c) In intrinsic material the scattering is due exclusively to lattice scattering. In heavily doped materials ionizing scattering is also important. The more scattering there is, the lower the mobility.

d) \( N_{D1} \gg N_{A2} > n_i \)

\[
\ell = \frac{L}{q_m N_{D1}} \quad (\text{n-type}) \\
\ell = \frac{1}{q_m \mu_p N_{A2}} \quad (\text{p-type})
\]

In most semiconductors including GaAs, \( \mu_n \) is greater than \( \mu_p \) for a given doping and system temperature. Since \( N_{D1} = N_{A2} \), taking temperatures to be the same \( \Rightarrow \ell \) (wafer 2) > \( \ell \) (wafer 1).
e) \[ D_N = \left( \frac{kT}{q} \right) \mu_n \]
\[ = (0.0259) (1300) \]
\[ = 33.7 \text{ cm}^2/\text{sec} \]

f) \[ \Delta p < n_0 \quad n = n_0 \quad (n \text{ type}) \]
\[ \Delta n < p_0 \quad p = p_0 \quad (p \text{ type}) \]

9) R-G center

h) Increase.

\[ \text{from} \quad T_p = \frac{1}{qN_T} \quad N_T \text{ decreased after processing} \]
\[ \implies T_p \text{ increased.} \]

3.15

a) In an intrinsic semiconductor \( n = p = n_i \)
\[ \ell = \frac{1}{q(n_i^n + n_i^p)n_i} \]

The intrinsic values recorded were computed using the maximum mobility values deduced from Fig 3.5 and the \( n_i \) values from Fig 2.20 (or adjacent tables)
\[ b) \text{ If np product relationship is used to eliminate } p \text{ in terms of } n \text{ in } \mu (\text{eq} 33) \]

\[ e = \frac{1}{q(\mu_p n + \mu_n n^2/n)} \]

Assume \[ \frac{d \mu_n}{dn} = 0 \quad \text{and} \quad \frac{d \mu_p}{dn} = 0 \]

\[ \Rightarrow \text{max resistivity is expected to occur at very low carrier concentrations} \]

\[ \frac{de}{dn} = \frac{1}{q(\mu_p n + \mu_n n^2/n)^2} (\mu_p - \mu_n n^2/n^2) = 0 \]

At max resistivity:

\[ \mu_n = \frac{\mu_p n^2}{n^2} \]

\[ n = \sqrt{\frac{\mu_p}{\mu_n}} n_i \]

\[ e_{\text{max}} = \frac{1}{q(\sqrt{\mu_p n_i} + \sqrt{\mu_n n_i})} = \frac{1}{2q\sqrt{\mu_p n_i}} n_i \]
a) Yes for all cases. The semiconductor is concluded to be in equilibrium because the Fermi level has the same energy value (constant) as a function of position.

b) \( V \) vs. \( x \) has the same functional form as the "upside down" of \( E_C \) (or \( E_i \) vs. \( E_r \)). The sketches that follow were constructed taking the arbitrary reference voltage to be \( V = 0 \) at \( x = 0 \).

c) \( E \) vs. \( x \) is determined by noting the slope at the energy bands as a function of position.

d) For electrons, \( \text{PE} = E_C - E_F + \text{KE} = E - E_C \).

For holes, \( \text{PE} = E_F - E_v + \text{KE} = E_v - E \).

e) The general carrier concentration variation with position can be deduced by conceptually forming the product of the \( E \) vs. \( x \) dependence sketched in part(c) and the \( n \) vs. \( x \) dependence sketched in part(c). Under equilibrium conditions,

\[
J_N = J_{N\text{drift}} + J_{N\text{diff}} = 0
\]

Thus

\[
J_{N\text{diff}} = -J_{N\text{drift}}
\]
\[ n_0 = n_i \, e^{(E_F - E_i)/kT} = 10^{10} \, e^{-0.3/0.0259} = 1.07 \times 10^{15} \text{ cm}^{-3} \]
\[ p_0 = n_i \, e^{(E_i - E_F)/kT} = 10^{10} \, e^{-0.3/0.0259} = 9.32 \times 10^4 \text{ cm}^{-3} \]

b) \[ n = n_i \, e^{(E_N - E_i)/kT} = 10^{10} \, e^{0.318/0.0259} = 2.15 \times 10^{15} \text{ cm}^{-3} \]
\[ p = n_i \, e^{(E_i - E_F)/kT} = 10^{10} \, e^{-0.3/0.0259} = 1.07 \times 10^{15} \text{ cm}^{-3} \]

c) \[ N_0 \approx n_0 = 1.07 \times 10^{15} \text{ cm}^{-3} \]

d) No. Due to illumination, \( \Delta p = n_0 \) & \( \Delta n \) differs significantly from \( n_0 \). For low level injection one must have \( \Delta p < n_0 \) and \( n \approx n_0 \).

e) \[ \rho_{\text{before}} = \frac{1}{q \mu_n N_0} = \frac{1}{(1.6 \times 10^{-19}) (1.345)(1.07 \times 10^5)} = 4.84 \text{ ohm cm} \]

\[ \rho_{\text{after}} = \frac{1}{q (\mu_n + \mu_P)} = \frac{1}{(1.6 \times 10^{-19}) (1.345)(2.15 \times 10^5)(4.58 \times 10^4)} = 1.85 \text{ ohm cm} \]