Semiconductors Equation Sheet

Classical Variable		Quantum operator
x	$\rightarrow$	x
$f(x)$	$\rightarrow$	$f(x)$
$p(x)$	$\rightarrow$	$\frac{\hbar}{j}\frac{\partial}{\partial x}$
E	$\rightarrow$	$-\frac{\hbar}{j}\frac{\partial}{\partial t}$

$< Q_{op} >= \int_{-\infty}^{\infty} \Psi^* Q_{op} \Psi dx$

$(\Delta x)(\Delta P_x) \geq \frac{\hbar}{2}, \qquad (\Delta E)(\Delta t) \geq \frac{\hbar}{2}$

$f(E) = \frac{1}{1+e^{(E-E_f)/kT}}$

$n_o = \int_{E_c}^{\infty} f(E)N(E)dE, \qquad p_o = \int_{-\infty}^{E_v} [1-f(E)]N(E)dE$

At Equilibrium:
$n_o p_o = n_i^2, \qquad E_g(Si) = 1.15eV$

$n_o = n_i e^{(E_f - E_i)/kT}, \qquad p_o = n_i e^{(E_i - E_f)/kT}, \qquad n_i = \sqrt{N_c N_v} e^{-E_g/2kT},$

$J = I/A \qquad \vec{\varepsilon} = \frac{V}{\ell}$

n-type:
$J_n = qn\mu_n\vec{\varepsilon} = Q_n v_n = qnv_n$
$J_{Total_n} = J_{n_{n_o}} + J_{p_{n_o}}$
$\sigma_n = q\mu_n n$
$q\phi_{B_n} = q\phi_{F_n} = kT \ln \frac{n_{n_o}}{n_i} \approx kT \ln \frac{N_D^+}{n_i}$

p-type:
$J_p = qp\mu_p\vec{\varepsilon} = Q_p v_p = qpv_p$
$J_{Total_p} = J_{p_{p_o}} + J_{n_{p_o}}$
$\sigma_p = q\mu_p p$
$q\phi_{B_p} = q\phi_{F_p} = kT \ln \frac{p_{p_o}}{n_i} \approx kT \ln \frac{N_A^-}{n_i}$

Velocity $= v = \mu\vec{\varepsilon}$ for $\vec{\varepsilon} < \varepsilon_c, \qquad v = v_{sat} \approx v_h$ for $\vec{\varepsilon} \geq \varepsilon_c$
$\rho = R * \frac{A}{\ell}, \qquad \rho = \frac{1}{\sigma}$

$kT|_{T_0} = kT|_{300K} * \frac{T_0}{300K}$

Constants:
$h = 6.626 \times 10^{-34} m^2 kg/s$
$\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-31} Js/rad$
$m^* = 9.11 \times 10^{-31} kg$
$q = 1.6 \times 10^{-19} C$
$kT|_{T=300K} \approx 0.026eV$
$n_i(Si)|_{300K} = 1.5 \times 10^{10} cm^{-3}$
v_{th} = Thermal Velocity $\approx 10^7 cm/sec$
$\vec{\varepsilon}_c$ = critical field $= 10^4 V/cm$

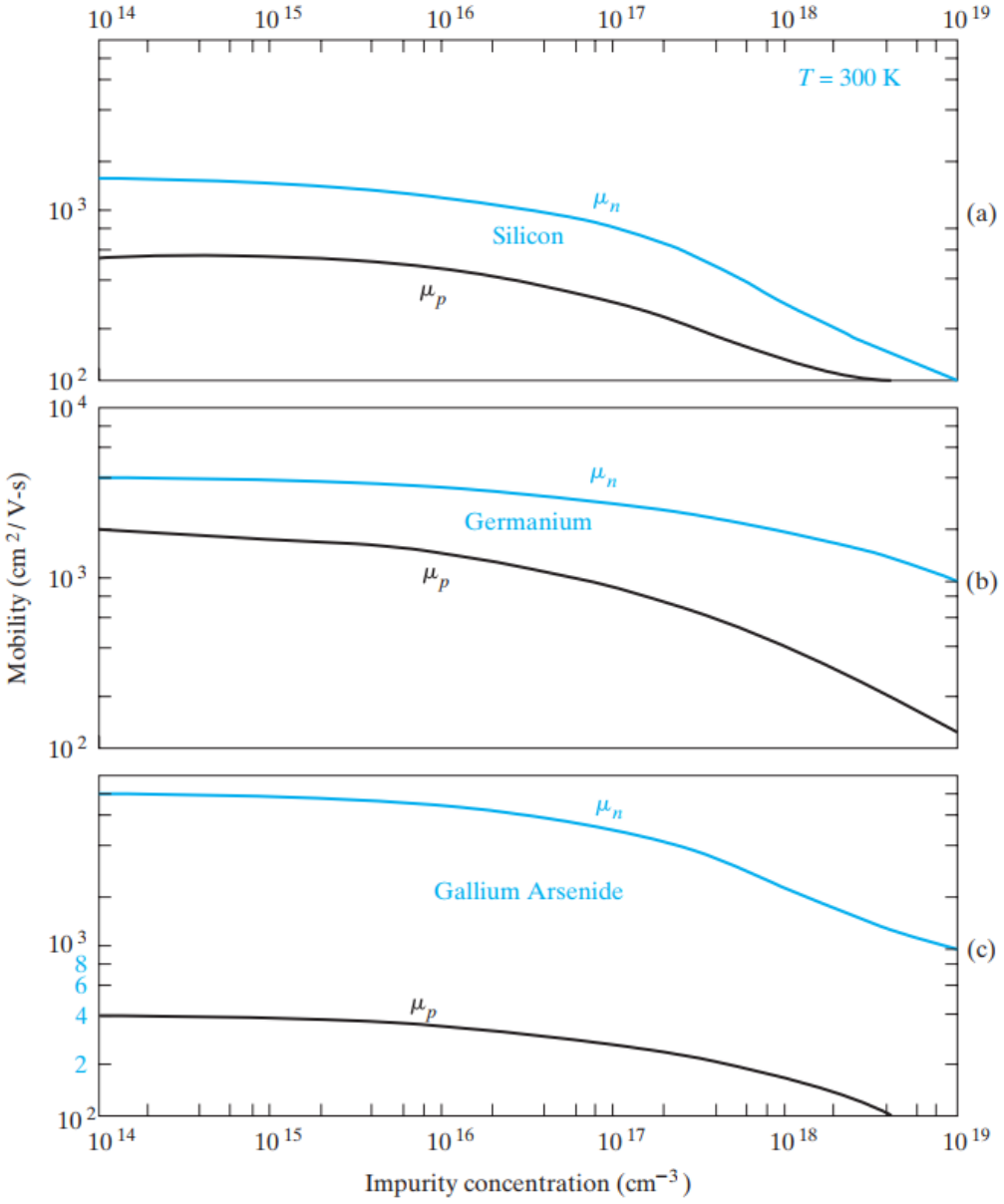
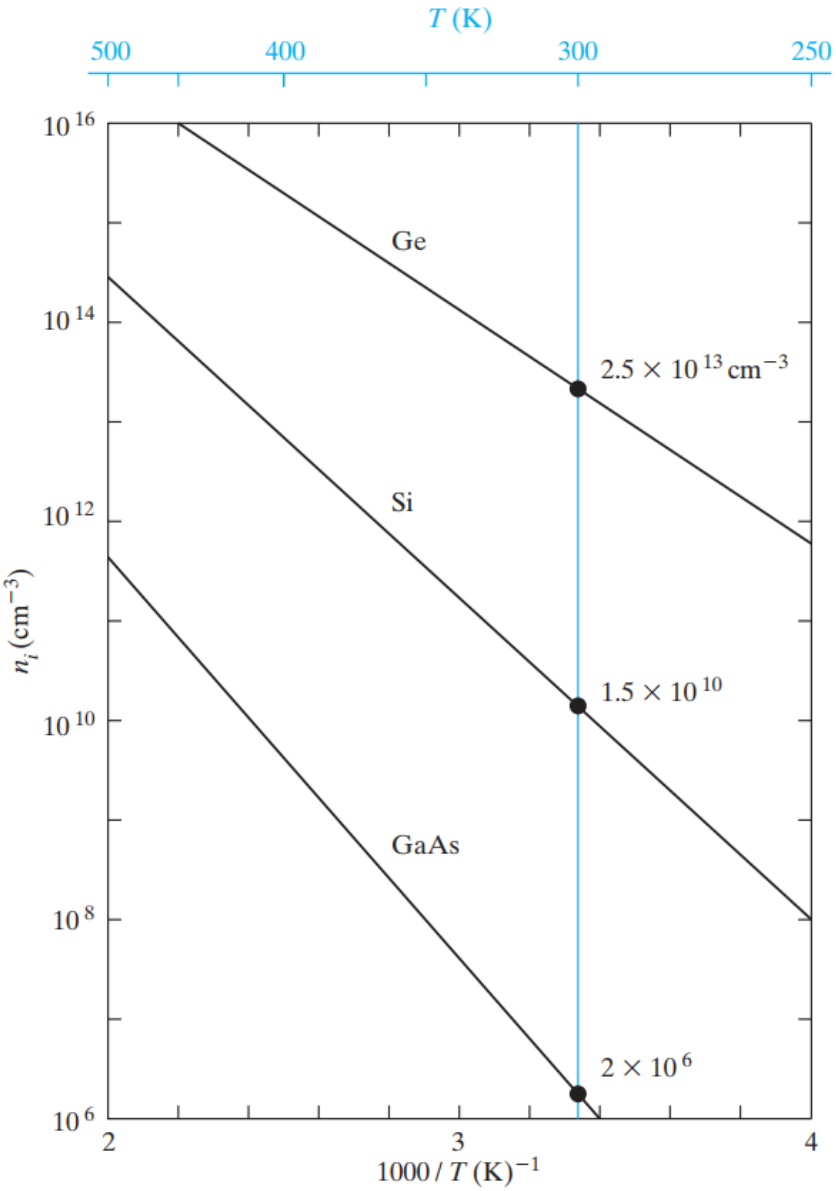
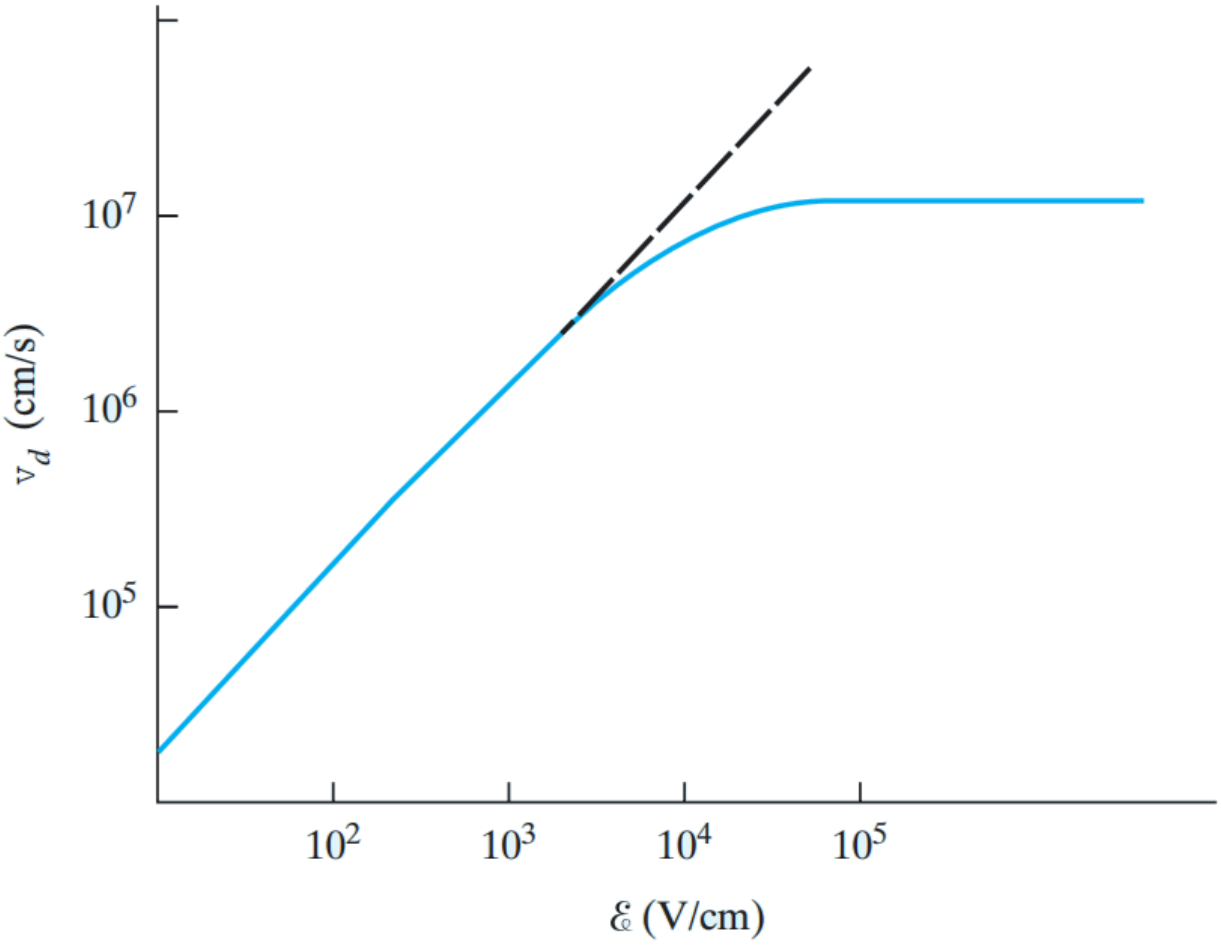


Figure 3–23
Variation of mobility with total doping impurity concentration ($N_a + N_d$) for Ge, Si, and GaAs at 300 K.

Figure 3–17
Intrinsic carrier concentration for Ge, Si, and GaAs as a function of inverse temperature. The room temperature values are marked for reference.




10^7
10^6
10^5
v_d (cm/s)
10^2
10^3
10^4
10^5
$\mathcal{E}$ (V/cm)