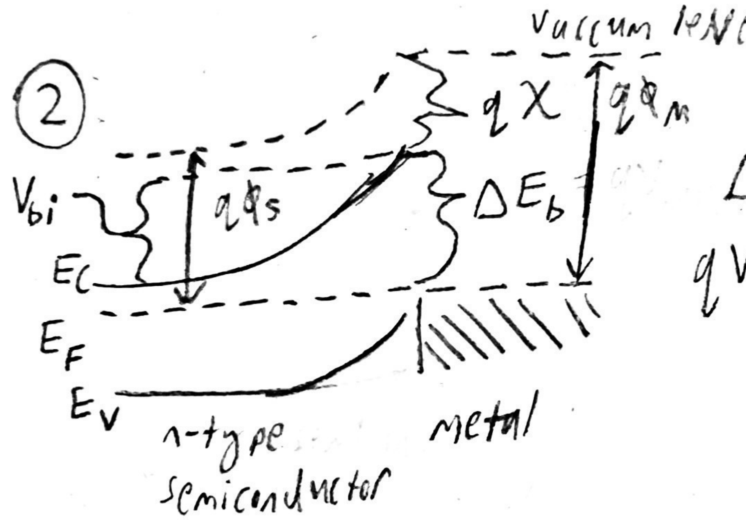
solutions to chapter 3 problems

① At the interface between semiconductors and metals, there exists a slant in both E_C and E_V within the semiconductor. The height of this slant is $q \cdot V_{built\text{-}in}$, where $V_{built\text{-}in}$ is the difference between the metal's work function and the semiconductor's electron affinity. The fermi energy level remains static throughout (when the two regions are making contact). The work function of a material (either metal or semiconductor) is the energy difference between its fermi energy level and electron vaccum energy. A semiconductor's electron affinity is the energy difference between the bottom of its conduction band and the vaccum energy level.

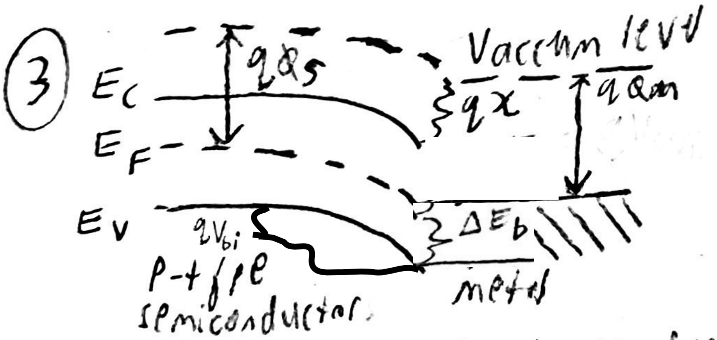
②



$$\Delta E_b = q(\Phi_m - \chi_s)$$

$$qV_{bi} = q(\Phi_m - \Phi_s)$$

③



$$\Delta E_b = q(\chi_s - \Phi_m)$$

in p-type semiconductors the fermi level tends to be near the bottom of the conduction band while in n-type semiconductors it is near the top of the valence band. It is to this dicotomy that the differences in the above energy diagrams may be attributed.

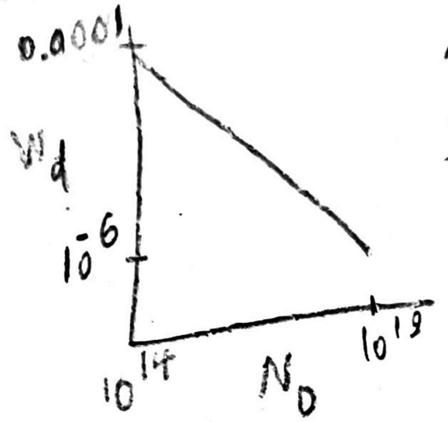
④ depletion region width as a function of dopant concentration is given as follows:

assume chrome -silicon junction

$$W_D = \sqrt{\frac{2\varepsilon_0\varepsilon_s \Phi}{q N_D}} \quad \text{where } \Phi = V_{BI} + \underbrace{V_{applied}}_{\text{zero in this case}}$$

and $V_{BI} = \frac{1}{q}\left(\Delta E_b - k_B T \ln \frac{N_c}{N_D}\right)$

↓



note $\frac{K_B T}{q} = 0.026$

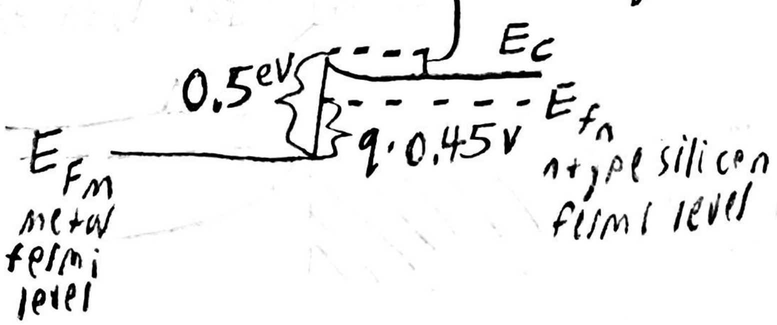
and $E_B = \Phi_m - \chi_s$
$= 4.5 - 4.05\,eV$
$= 0.45\,eV$

applying a double log scaling to both the x and y axes yields a linear graph

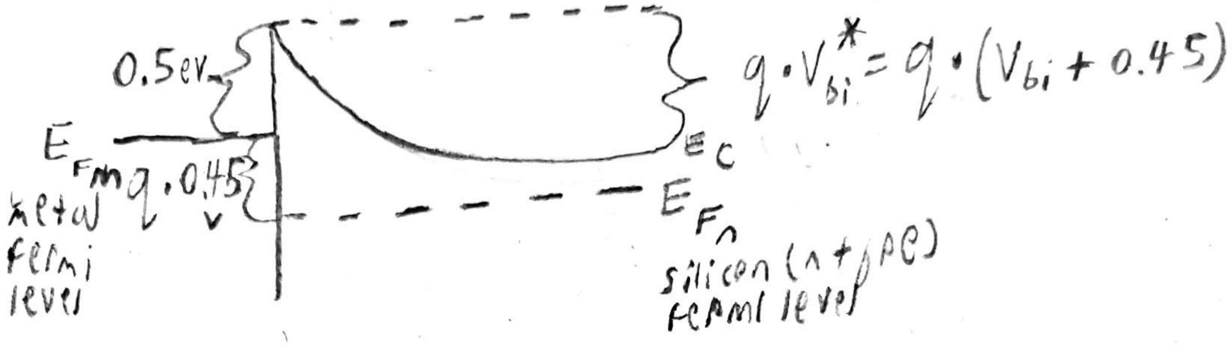
⑤ a reverse bias (applied potential) has the same sign as the built-in voltage (negative terminal applied to n-type silicon and vice versa) and increases the width of the depletion region and the height of the energy barrier while a forward bias has the opposite sign of $V_{built\text{-}in}$ and the opposite effects on W_D and ΔE_b

⑥

$$q \cdot V_{bi}^{*} = q \cdot (V_{bi} - 0.45)$$



⑦



⑧

$$\frac{A}{cm^2K^2}\cdot K^2 e^{\left(\frac{eV}{\frac{eV}{K}\cdot K}\right)}$$

3.13

$$\frac{A}{cm^2}e^{\left(\frac{eV}{K}\cdot\frac{K}{eV}\right)}$$

$$\frac{A}{cm^2}e^1$$

$$\frac{A}{cm^2}$$

$$e^{cm\sqrt{\frac{kg}{eV^2\cdot s^2}(eV-eV)}}$$

$$e^{cm\sqrt{\frac{kg}{eV^2\cdot s^2}eV}}$$

$$e^{cm\sqrt{\frac{kg}{eV\cdot s^2}}}$$

3.14

$$e^{\frac{cm}{s}\sqrt{\frac{kg}{eV}}}$$

⑩ the expression for sheet resistance

$$R_s = \frac{1}{\int_0^d q\mu N_D(x)\,dx}$$

$\downarrow$

assume room temperature and low dopant concentration

this integral would evaluate differently if N_D were a function of implantation depth d

$$R_s = \frac{1}{\int_0^d (1.602\cdot 10^{-19})(4.9\cdot 10^{7}\cdot (300)^{-3/2})\cdot 10^{17}\,dx}$$

$$R_s = \frac{1}{\underbrace{d}_{\text{implantation depth}}\cdot 151.07}\ \Omega$$