1)
  1)
    a) $V_G > V_{th}$; Since $q\Psi_B$ is 0.466 eV, and the gap between E_F and E_i after the shift is 0.522 eV, the total shift is 0.988 eV, which is greater than $2q\Psi_B$ = 0.466 eV * 2 = 0.932 eV. If $V_G = V_{th}$, the gap between E_F and E_i after the shift would be 0.466 eV.
    b) $V_G < V_{th}$; Since E_F is still closer to E_V than to E_C after the shift, the depletion region is still p-type and has not yet become n-type. This means that V_G is way less than V_{th}.
    c) $V_G < V_{th}$; Since $q\Psi_B$ is 0.466 eV, and the gap between E_F and E_i after the shift is 0.326 eV, the total shift is 0.792 eV, which is less than $2q\Psi_B$ = 0.466 eV * 2 = 0.932 eV. If $V_G = V_{th}$, the gap between E_F and E_i after the shift would be 0.466 eV.
  2)
    a) When x = 0,
       $n = N_D = N_C * e^{-(Ec-Ef)/kT} = 10^{25} * e^{-(0.55-0.522)/0.025} = 3.263*10^{24}$ / m^3
       $p = N_A = N_V * e^{-(Ef-Ev)/kT} = 10^{25} * e^{-(0.522+0.55)/0.025} = 2.385 * 10^6$ / m3
       When x = 60 nm,
       $n = N_D = N_C * e^{-(Ec-Ef)/kT} = 10^{25} * e^{-(0.55+0.466)/0.025} = 2.24*10^7$ / m3
       $p = N_A = N_V * e^{-(Ef-Ev)/kT} = 10^{25} * e^{-(0.522+0.55)/0.025} = 3.476*10^{23}$ / m3
    b) When x = 0,
       $n = N_D = N_C * e^{-(Ec-Ef)/kT} = 10^{25} * e^{-(0.55+0.14)/0.025} = 1.032*10^{13}$ / m^3
       $p = N_A = N_V * e^{-(Ef-Ev)/kT} = 10^{25} * e^{-(0.55-0.14)/0.025} = 7.543*10^{17}$ / m^3
       When x = 60 nm,
       $n = N_D = N_C * e^{-(Ec-Ef)/kT} = 10^{25} * e^{-(0.55+0.466)/0.025} = 2.24*10^7$ / m^3
       $p = N_A = N_V * e^{-(Ef-Ev)/kT} = 10^{25} * e^{-(0.522+0.55)/0.025} = 3.476*10^{23}$ / m^3
    c) When x = 0,
       $n = N_D = N_C * e^{-(Ec-Ef)/kT} = 10^{25} * e^{-(0.55-0.326)/0.025} = 1.284*10^{21}$ / m^3
       $p = N_A = N_V * e^{-(Ef-Ev)/kT} = 10^{25} * e^{-(0.326+0.55)/0.025} = 6.058*10^9$ / m^3
       When x = 60 nm,
       $n = N_D = N_C * e^{-(Ec-Ef)/kT} = 10^{25} * e^{-(0.55+0.466)/0.025} = 2.24*10^7$ / m^3
       $p = N_A = N_V * e^{-(Ef-Ev)/kT} = 10^{25} * e^{-(0.522+0.55)/0.025} = 3.476*10^{23}$ / m^3

2) Equation: $V_{th} = (q*N_a*W)/C_{ox} * 2q\Psi_B$, where $C_{ox} = (\varepsilon_o\varepsilon_{ox})/t_{ox}$
  1) If N_A increases, then V_{th} would increases
  2) If t_{ox} increases, then C_{ox} decreases, and V_{th} increases
  3) If ε_{ox} increases, then C_{ox} increases, and V_{th} decreases

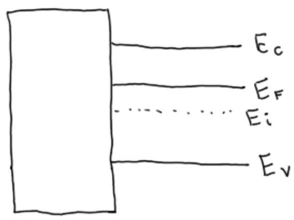
3) $\Phi_B = |E_F - E_i| / q$
   $E_F - E_v = -kT*\ln(N_A/N_v) = -0.026*\ln[(7*10^{18})/(10^{25})] = 0.3685$eV
   $|E_F - E_i| = 0.55 - 0.3685 = 0.1815$ eV $= \Psi_B$
   $\Psi_B = |E_F - E_i| / q = \Psi_B / q = 0.1815$eV / $(1.602*10^{-19}) = 1.133 * 10^{18}$ eV/C
   $C_{ox} = \varepsilon_o\varepsilon_{ox} / t_{ox} = (8.854*10^{-12}$ F/m * 4) / (8 * 10^{-9}) m = 0.004427 F = 4.427 mF
   $W_{max} = \text{sqrt}[(2\varepsilon_o\varepsilon_{Si}*2\Psi_B)/(q*N_A)] = \text{sqrt}[(2*8.854*10^{-12}*12*2*0.1815)/(1.6*10^{-19}*7*10^{18})]$
   $= 8.299*10^{-6}$ m
   $V_{th} = \text{sqrt}(4*\varepsilon_o\varepsilon_{Si}q*N_A*\Psi_B)/C_{ox} + 2\Psi_B$
   $= \text{sqrt}(4* 8.854*10^{-12}*12*1.6*10^{-19} * 0.1815)/0.004427 + 2*0.1815$
   = 0.363 V

4) Next page

n-type semiconductor → bends up

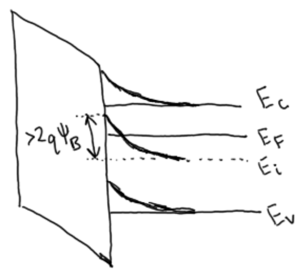
4.1) $V_g = 0$

no bend



4.2) $V_g > V_{th}$

bend is greater than $2q\psi_B$



4.3) $V_g \leq V_{th}$

bend is less than or equal to $2q\psi_B$