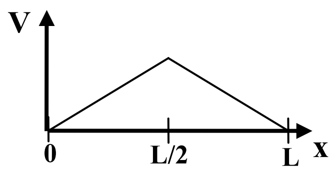
EECS 170A
Professor Burke Section B
Homework #3 Solutions and Grading Criteria

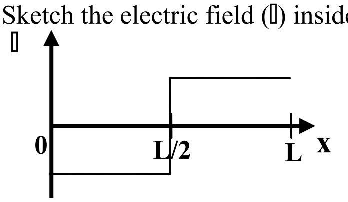
1) Answer a-d for the figure shown below:
   a) Do the equilibrium conditions prevail? How do you know? **(5 pts total)**
      Yes because E_F is constant. (no points if reason not given)

   b) Sketch the electrostatic potential (V) inside the semiconductor as a function of x. **(5 pts total)**



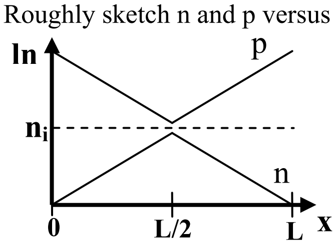
Graph must be linear with a positive slope between x =0 and x=L/2 and negative slope between x = L/2 and x = L. It does not matter where the graph is centered vertically as long as it has the correct shape.

   c) Sketch the electric field ($\mathcal{E}$) inside the semiconductor as a function of x. **(5 pts total)**



Graph must be a negative constant between x =0 and x=L/2 and positive constant between x = L/2 and x = L.

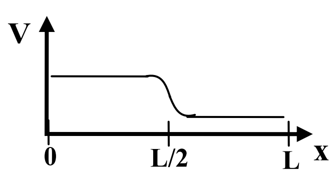
   d) Roughly sketch n and p versus x. **(10 pts total)**



n and p graphs must be centered around n_i for credit. Graphs should be mirrors of each other. n graph should look like V graph. N and p graphs are 5 pts each.

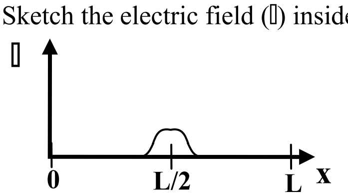
2) Answer a-d for the figure shown below:
   a) Do the equilibrium conditions prevail? How do you know? **(5 pts total)**
      Yes because E_F is constant. (no points if reason not given)

   b) Sketch the electrostatic potential (V) inside the semiconductor as a function of x. **(5 pts total)**



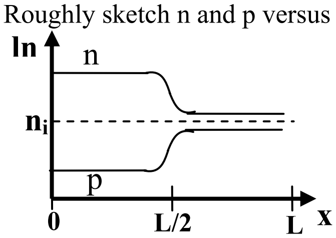
Graph must have correct shape. Center of graph should be at L/2. It does not matter where the graph is centered vertically as long as it has the correct shape.

   c) Sketch the electric field ($\mathcal{E}$) inside the semiconductor as a function of x. **(5 pts total)**



Graph must be positive, have correct shape, and be centered around L/2.

   d) Roughly sketch n and p versus x. **(10 pts total)**



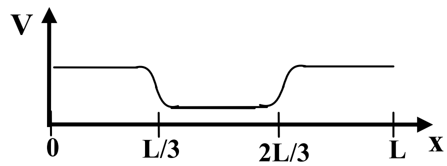
n and p graphs must be centered around n_i for credit. Graphs should be mirrors of each other. n graph should look like V graph. n and p graphs are 5 pts each. If n and p cross n_i then only 3 pts each.

3) Answer a-d for the figure shown below:

a) Do the equilibrium conditions prevail? How do you know? **(5 pts total)**

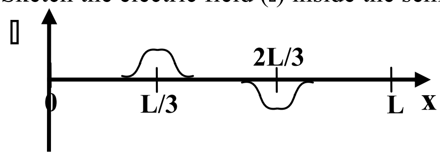
Yes because E_F is constant. (no points if reason not given)

b) Sketch the electrostatic potential (V) inside the semiconductor as a function of x. **(5 pts total)**



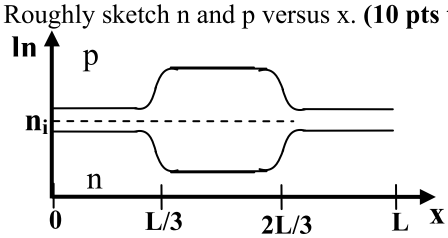
Graph must have correct shape. Slope changes occur at L/3 and 2L/3. It does not matter where the graph is centered vertically as long as it has the correct shape.

c) Sketch the electric field (▯) inside the semiconductor as a function of x. **(5 pts total)**



Graph must be positively centered around L/3, negatively centered around 2L/3, and have the correct shape.

d) Roughly sketch n and p versus x. **(10 pts total)**



n and p graphs must be centered around n_i for credit. Graphs should be mirrors of each other. n graph should look like V graph. n and p graphs are 5 pts each. If n and p cross n_i then only 3 pts each.

4) For Si at T = 300K calculate $E_C - E_F$ and sketch E_c, E_F, E_i, and E_V as in figure 2.18 of the book for the following cases:

a) $N_D = 10^{14}$ cm^{-3}; $N_A << N_D$. **(5 pts total)**

1 pts $n = N_D = 10^{14}\ cm^{-3}$

1 pts $n = N_C(2/pi^{½})F_{1/2}(\eta_c)$

1 pts $F_{1/2} = ½\ npi^{1/2}/N_C = ½\ (10^{14}cm^{-3})(pi^{1/2})/(3.217x10^{19}cm^{-3}) = 2.75x10^{-6}$

2 pts $(E_C - E_F) = -kT\ ln(n/N_C) = -(0.0259eV)ln(10^{14}/3.217x10^{19}) = .328eV$ *(.3 - .4 eV accepted.)*

b) $N_D = 10^{20}$ cm^{-3}; $N_A << N_D$. **(5 pts total)**

1 pts $n = N_D = 10^{20}\ cm^{-3}$

1 pts $n = N_C(2/pi^{½})F_{1/2}(\eta_c)$

1 pts $F_{1/2} = ½\ npi^{1/2}/N_C = ½\ (10^{20}cm^{-3})(pi^{1/2})/(3.217x10^{19}cm^{-3}) = 2.75$

1 pts *From graph:* $\eta_c = 2.2$

1 pts $(E_C - E_F) = -\eta_c kT = -2.2(0.0259eV) = -.057eV$ *(.05 - .065eV accepted)*

c) $N_A = 10^{14}$ cm^{-3}; $N_D << N_A$. **(5 pts total)**

1 pts $p = N_A = 10^{14}\ cm^{-3}$

1 pts $n = n_i^2/p = (10^{20}cm^{-6})/(10^{14}cm^{-3}) = 10^6\ cm^{-3}$

1 pts $n = N_C(2/pi^{½})F_{1/2}(\eta_c)$

$F_{1/2} = ½\ npi^{1/2}/N_C = ½\ (10^6\ cm^{-3})(pi^{1/2})/(3.217x10^{19}cm^{-3}) = 2.75x10^{-14}$

2 pts $(E_C - E_F) = -kT\ ln(n/N_C) = -(0.0259eV)ln(10^6/3.217x10^{19}) = .801\ eV$ *(.75eV - .85 eV accepted)*

d) $N_A = 10^{20}$ cm^{-3}; $N_D << N_A$. **(5 pts total)**

1 pts $p = N_A = 10^{20}\ cm^{-3}$

1 pts $n = n_i^2/p = (10^{20}cm^{-6})/(10^{20}cm^{-3}) = 1cm^{-3}$

1 pts $n = N_C(2/pi^{½})F_{1/2}(\eta_c)$

$F_{1/2} = ½\ npi^{1/2}/N_C = ½\ (1cm^{-3})(pi^{1/2})/(3.217x10^{19}cm^{-3}) = 2.75x10^{-20}$

2 pts $(E_C - E_F) = -kT\ ln(n/N_C) = -(0.0259eV)ln(1/3.217x10^{19}) = 1.163eV$ *(1eV – 1.3eV accepted)*

e) $N_A = N_D = 10^{20}$ cm^{-3}. **(5 pts total)**

1 pts $n = \frac{N_D - N_A}{2} + [(\frac{N_D - N_A}{2})^2 + n_i^2]^{½} = n_i = 10^{10}cm^{-3}$

1 pts $p = n_i = 10^{10}cm^{-3}$

3 pts $E_C - E_F = E_C - E_i = .567eV$ *(can be calculated with equations, but needs to contain 3 significant figures)*