Homework 1

1. An 8” wafer currently sells for about 100$, and a 12” wafer currently sells for approximately 400$. Assuming 1mm dies:
   a. How many dice do you get from each wafer? Show your work, don’t forget to exclude partial dice! (8” and 12”)

b. Does the increase in size from 8” to 12” wafers make financial sense if you only consider the silicon cost? Calculate cost/die for each.

c. Assuming a marginal increase in process costs with size, total per-wafer cost of processing increases also from 500$ for the 8” process to 600$ for the 12” process. Calculate the cost/die for each wafer size, and state the overall % change in the cost/die.

d. Does the increase in size make financial sense when including processing costs?
2. Starting with an intrinsic piece of Si which subsequently is doped by Indium with a concentration of $1 \times 10^{17} \text{cm}^{-3}$. Assuming $T = 300K$.
   a. Is this a n or p type doping, why?

   b. After doping, is the $E_F$ (fermi level) closer to the $E_c$ (conduction band) or $E_v$ (valence band)?

   c. Calculate the exact value of $E_F - E_i$ in eV. Assuming silicon bandgap to be $1.12\text{eV}$ and equivalent effective mass (in other words $E_i = \frac{E_g}{2}$)

   d. Is this considered degenerate doping, why or why not?

   e. Now calculate the value of $E_F - E_i$ in eV at $T = 1300\text{K}$ given the following information:
3. Consider a piece of silicon doped with Phosphorus (P, which has an ionization energy of 45meV) at a concentration of 1x10^{16} cm^{-3} and referring to the figure attached in Prob. 1e).
   
   a. What is $E_F - E_i$ at $T=300K$?

   b. What is $E_F - E_i$ at $T=400K$?

   c. Qualitatively, what starts to happen to $E_F - E_i$ at $T \geq 600K$?
d. What is $E_F - E_i$ at $T=0K$? Why? (Might help to draw all of the energy bands/levels.) Calculate $E_F - E_i$ at $T=0K$ for this sample.

e. Does your answer to the last part (2d) change if we dope the silicon with a different donor material? If so, how does the value change? Calculate $E_F - E_i$ at $T=0K$ for n-type dopant of Arsenic (As). (Hint: ionization energy is 54meV for As when doped in silicon.)

f. Does your answer to 2d change if we dope the silicon with an acceptor rather than a donor? Calculate $E_F - E_F$ at $T=0K$ for p-type dopant of Boron (B). (Hint: ionization energy is 45meV for B when doped in silicon.)