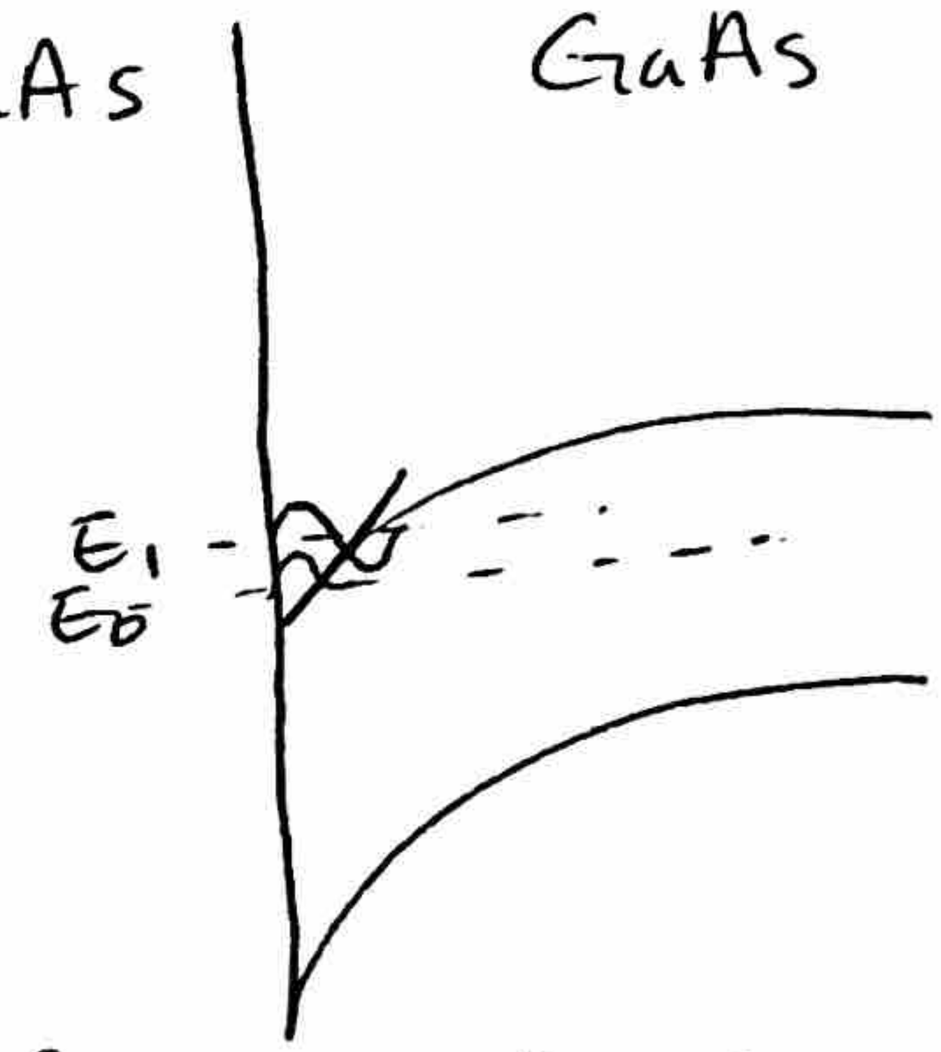
HW2,3

1/ What is the background doping in GaAs 2D electron system with $n_s = 2\times10^{11}\ cm^{-2}$ and low-T mobility of $10^7\ cm^2/Vs$. Assume very thick spacer.

2/ which 2D system in GaAs will have its second electric subband (E_1) occupied at a lower total density: 2D electrons or holes?



Calculate the density above which E_1, starts to be occupied for each system. Assume $N_A = 10^{15}\ cm^{-3}$ for the 2D electron case and $N_D = 10^{15}\ cm^{-3}$ for the 2D hole case; also use $m_e^* = 0.067 m_0$ and $m_h^* = 0.4 m_0$. Electric field: $F = \left(\frac{2 E_G e N_A}{\varepsilon_s}\right)^{1/2}$ and potential $V(z) = ezF$

3/ The energy momentum dispersion of graphene valence and Conduction bands is given by the formula:

$$E(k_x, k_y) = \pm t \sqrt{1 + 4\cos\left(\frac{\sqrt{3}}{2} k_x a\right)\cos\left(\frac{k_y a}{2}\right) + 4\cos^2\left(\frac{k_y a}{2}\right)}$$

which assumes tight binding Hamiltonian projected to a basis set of single π orbital per carbon atom. a is honeycomb lattice spacing.

a/ using Matlab, python or Mathematica plot this function as a surface in 3D k-space within the range of (k_x, k_y) vector in first brillouin zone.

b/ Near one of the two inequivalent K points, Dirac point, the dispersion has a conical shape. Up to what energy away from the Dirac point $E=0$ can the real dispersion shown in your figure be approximated by linear dispersion of the "Dirac cones" (within 5%.) Assume: $v_F = \frac{\sqrt{3}}{2} t a / \hbar = 10^6 \, m/s$

4/ Imagine you are an MBE grower. Your task is to grow 2DEGs with electron density of $1\times10^{12}\,cm^{-2}$ with a $d=500\,Å$ spacer. You constantly grow $\mu \sim 1\times10^6\,cm^2/Vs$ samples. One day building cooling water is overpressured and you open a tiny leak into the chamber. The e^- mobility drops to $10{,}000\,cm^2/Vs$.

a/ Can you grow $10^6\,cm^2/Vs$ mobility by increasing, d, spacer? if so what is the new d?

b/ How much n_{imp}^{3D} has incorporated into your sample?