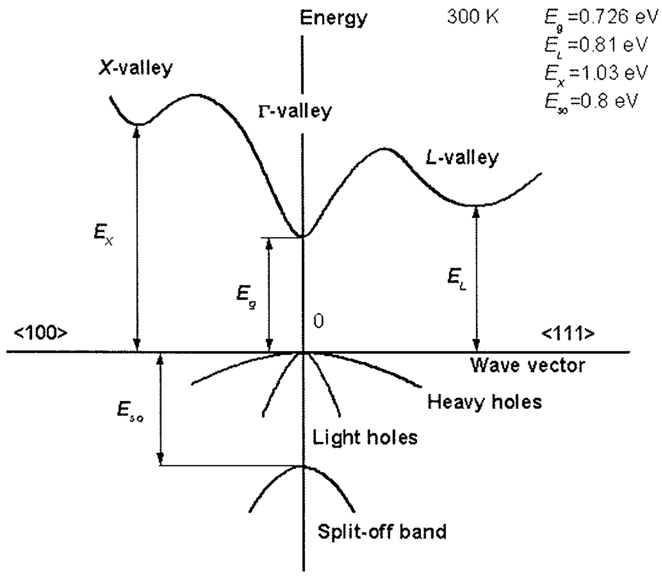
GaSb has a band structure as shown below:



As you can see from the picture, GaSb has a conduction band minimum at the Γ-point, with energy gap of 0.726 eV at T = 300 K. However, it also has a conduction band minimum at the L-point with energy gap of 0.810 eV. The density of states effective mass and the valley degeneracy for the Γ-valley are $m^*_\Gamma = 0.041m_o$ and $g_{v\Gamma} = 1$, respectively. For the L-valley, the density of states effective mass and the valley degeneracy are $m^*_L = 0.57m_o$ and $g_{vL} = 4$, respectively.

If a sample of GaSb is n-type doped with a donor concentration of $N_D = 10^{16}$ cm^{-3}, and if we assume that all the donors are fully ionized, calculate the following parameters.

- -- The Fermi energy, E_F (relative to valence-band maximum) in equilibrium (2 pts).
- -- The ratio of the electron concentrations in the L and Γ valleys (n_L/n_Γ) in equilibrium (1 pt).

Now, <u>qualitatively</u> describe how E_F and n_L/n_Γ will change if the temperature increases to 400 K. Ignore the dependence of band gap on temperature. (Exact calculations are not need, but you need to justify your answer) (0.5 pts).

Finally, assume that the sample is intrinsic (no doping). If the valence band density-of-states effective mass is $m^* = 0.8m_o$, then what is the ratio of the electron concentration in the gamma valley, n_Γ, to the hole concentration, p? In other words, what is n_Γ/p? Assume T = 300 K (0.5 pts).

Please use the following values for any calculations you may need to perform:

$\varepsilon_0 = 8.854 \times 10^{-14}$ F/cm	Permittivity of free space
$k = 8.617 \times 10^{-5}$ eV/K	Boltzmann's constant
kT (300 K) = 0.0259 eV	Thermal energy at T = 300 K
$h = 4.136 \times 10^{-15}$ eV·s	Planck's constant
$\hbar = h/2\pi = 6.583 \times 10^{-16}$ eV·s	Reduced Planck's constant
$m_0 = 9.11 \times 10^{-31}$ kg	Free electron mass in kilograms
$m_0 = 5.68 \times 10^{-12}$ eV·s^2/m^2	Free electron mass in in eVs^2/m^2
$q = 1.6 \times 10^{-19}$ C	Electron charge in Coulombs
$q = 1$ e	Electron charge in units of "e"