q	1.6×10^{-19} C	electron charge
ϵ_o	8.85×10^{-14} F/cm	permittivity of free space
K_s	11.8 (Si)	relative dielectric constant
K_o	3.9 (SiO_2)	relative dielectric constant
k_B	8.617×10^{-5} eV/K	Boltzman's constant
h	6.63×10^{-34} J s	Planck constant
m_o	9.11×10^{-31} kg	electron mass
k_BT/q	0.0259 V at 300 K	thermal voltage
c	3×10^8 m/s	speed of light

A) Charge neutrality $\Rightarrow$ $n + N_A^- = p + N_D^+$ or $n = \frac{n_i^2}{n} + N_D^+$.

In this case expect n to be large and so

$$n = N_D^+ = N_C e^{(E_F - E_C)/kT}$$

$$= N_D \times \text{fraction ionized}$$

$$= N_D \frac{1}{1 + g\, e^{(E_F - E_d)/kT}}$$

Choose $E_c = 0$ as a reference. Then $E_d = -0.045$ eV. Write all E's in eV. We find an iterative solution. We expect $N_D^+ \approx N_D$. So start with

$$E_F = \frac{kT}{q} \ln \frac{N_D}{N_C} \doteq -0.069$$

Then calculate a better N_D

$$N_D = \frac{N_D = 2\times10^{18}}{1 + 2 \cdot e^{(0.045 - 0.069)/(kT/q)}} = 1.113 \times 10^{18} \text{ (or 1.117)}$$

$$E_F = \frac{kT}{q} \ln \frac{1.113\times10^{18}}{2.86\times10^{19}} = -0.084 \text{ eV} ✓$$

(−0.08 is a little better). With this

$$f = \frac{1}{1 + g\, e^{(E_F - E_d)/kT}} = 0.66$$

$$n = 1.31 \times 10^{18} \text{ cm}^{-3}$$

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Solution

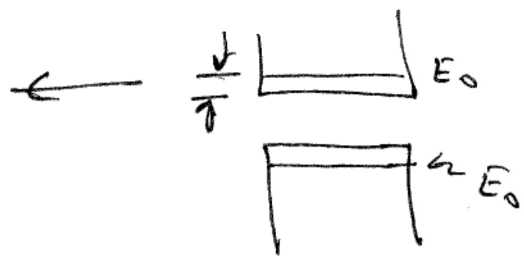
B) The momentum is quantized in the confinement direction.

$$\Delta z \, \Delta p \sim \frac{h}{2}$$

$$\Delta p \sim \frac{h}{2L}$$

$$E_{min} \sim \frac{\Delta p^2}{2m} = \frac{h^2}{2 \cdot 4L^2 \cdot m^*}$$

$$\sim \frac{h^2}{8 m L^2}$$



$$\Delta E_g = \frac{2h^2}{8(.1)m_0 L^2}$$

$$\sim 0.075 \text{ eV}$$