task_tx86fewvysrcy8fc_with_calculation

Student Group

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electrostatic, electric field strength, exam ee2 SS2022

Exercise E3 Electron Velocity in Semiconductors
(written test, approx. 6 % of a 120-minute written test, SS2022)

A current of $I=1~\rm mA$ flows through a cross-sectional area $A=10~\rm \mu m^2$ in a semiconductor.
The electron density in the semiconductor is given by the number of dopant atoms per volume.
The doping shall provide 1 donator atom (= one electron) per 10^{10} silicon atoms.
The molar volume of silicon is $V_{\rm mol,Si} = 12 \cdot 10^{-6} ~\rm m^3/mol$, with $N_{\rm A} = 6.022 \cdot 10^{23}$ silicon atoms per $1 ~\rm mol$.

The elementary charge is given as: $e_0 = 1.602 \cdot 10^{-19} ~\rm As$

What is the average electron velocity v_e in this semiconductor?

Result

$v_e = 123 \cdot 10^6 ~\rm m/s$ (about $41 ~\%$ of the speed of light)

Path

The following formula gives the speed, where n_e is the number of electrons per volume. \begin{align*} v_e &= {{I}\over{n_e \cdot e_0 \cdot A}} \\ \end{align*}

n_e can be derived from the overall number of Si-atoms per volume (${{N_{\rm A}}\over{V_{\rm mol,Si}}}$) and the fraction $k_{\rm Donators}$ of these atoms, which got substituted by donators. \begin{align*} v_e &= {{I}\over{{{N_{\rm A}}\over{V_{\rm mol,Si}}} \cdot k_{\rm Donators} \cdot e_0 \cdot A}} \\ \end{align*}

Putting in the numbers: \begin{align*} v_e &= {{1 \cdot 10^{-3}~\rm A}\over{{{6.022 \cdot 10^{23} 1/ \rm mol}\over{12\cdot 10^{-6} ~\rm m^3/mol}} \cdot 10^{-10} \cdot 1.602 \cdot 10^{-19} ~\rm As \cdot 10 \cdot (10^{-6} ~\rm m)^2}} \\ \end{align*}