ELEC-3140 Semiconductor physics **Mid-term exam 1, October 15, 2025**

Write your name, student number, degree programme, course code, and date of the exam on each of the answer papers.

1. Explain briefly, but exactly (with a couple of sentences):
   a) Wigner-Seitz primitive cell,
   b) reciprocal lattice,
   c) type II band alignment,
   d) biaxial strain,
   e) deformation potential,
   f) law of mass action.

2. a) What are the two close-packing crystal structures? How do they differ from each other and why are they called close-packing structures? b) Describe the division of crystal defects by their dimensionality. Give an example of crystal defects in each category. c) Describe how to determine the Miller indices for a crystal plane and for a crystal surface in a cubic crystal.

3. a) Describe shortly the main epitaxial growth methods and at least two techniques to fabricate semiconductor single crystals. b) What is done in practice to set the type and conductivity of an extrinsic semiconductor? And how do you then determine the majority and minority carrier concentrations?

4. a) Describe the four band model for direct-gap semiconductor band structure. What are the four bands, their separation in energy scale and what are their functional shapes. If the semiconductor has an indirect band gap, what changes in this model? (4p) b) Describe how the curvature of the band has an effect on the semiconductor parameters? Compare the properties of valence bands in the four band model. (2p)

5. A semiconductor structure, in which the charge carriers can move in two dimensions, is called a quantum well. Therefore, the structure has energy barriers and a small dimension in one dimension to create the confinement. Calculate the density of states function for a quantum well with the width L_z (this dimension is very small compared to the other two).

Constants:

$m_e = 9{,}1091 \times 10^{-31}$ kg	$m_p = 1{,}6725 \times 10^{-27}$ kg	$m_n = 1{,}6748 \times 10^{-27}$ kg	amu $= 1{,}6605 \times 10^{-27}$ kg
$e = 1{,}6021 \times 10^{-19}$ C	$c = 2{,}9979 \times 10^{8}$ m/s	$\hbar = 1{,}0545 \times 10^{-34}$ Js	$\mu_B = 9{,}2732 \times 10^{-24}$ JT^{-1}
$\varepsilon_0 = 8{,}8544 \times 10^{-12}$ C^{2}N^{-1}m^{-2}	$K_e = 1 / 4\pi\varepsilon_0$	$\mu_0 = 1{,}2566 \times 10^{-6}$ mkgC^{-2}	$K_m = \mu_0 / 4\pi$
$\gamma = 6{,}670 \times 10^{-11}$ Nm^{2}kg^{-2}	$N_A = 6{,}0225 \times 10^{23}$ mol^{-1}	$R = 8{,}3143$ JK^{-1}mol^{-1}	$k = 1{,}3805 \times 10^{-23}$ JK^{-1}

Material parameters on the other side!

Table 1. Material parameters for various zincblende-type semiconductors. Lattice constant a (in Å) at room temperature and elastic constants c_{11}, c_{12} and c_{44} (in 10^{12} dyn cm^{-2}; [15]). Valence-band average $E_{v,av}$ and hydrostatic deformation potentials a_v and $a_c(\Gamma)$ as calculated within Van de Walle's model-solid approach (in eV; [5]). Spin-orbit splittings Δ_0, band gaps $E_g(\Gamma)$, $E_g(X)$, $E_g(L)$ (at room temperature) and shear deformation potentials b and d (in eV; [15] and [22], except where indicated).

	a	c_{11}	c_{12}	c_{44}	$E_{v,av}$	Δ_0	$E_g(\Gamma)$	$E_g(X)$	$E_g(L)$	a_v	$a_c(\Gamma)$	b	d
AlP	5.451	1.32	0.63	0.62	−8.09	0.07[a]	3.58	2.45	3.11[a]	3.15	−5.54	−1.6[a]	
AlAs	5.660	1.25	0.53	0.54	−7.49	0.28	2.95	2.16[b]	2.80[a]	2.47	−5.64	−1.5[a]	
AlSb	6.136	0.88	0.43	0.41	−6.66	0.65	2.22	1.61[c]	2.21[a]	1.38	−6.97	−1.4	−4.3
GaP	5.451	1.41	0.62	0.70	−7.40	0.08	2.74	2.26	2.63	1.70	−7.14	−1.5	−4.6
GaAs	5.653	1.18	0.54	0.59	−6.92	0.34	1.42	1.91[b]	1.73[b]	1.16	−7.17	−1.7	−4.8
GaSb	6.096	0.88	0.40	0.43	−6.25	0.82	0.72	1.05[c]	0.76[c]	0.79	−6.85	−2.0	−4.8
InP	5.869	1.02	0.58	0.46	−7.04	0.11	1.35	2.21[d]	2.05[d]	1.27	−5.04	−1.8	−4.2
InAs	6.058	0.83	0.45	0.40	−6.67	0.38	0.36	1.37[d]	1.07[d]	1.00	−5.08	−1.8	−3.6
InSb	6.479	0.66	0.36	0.30	−6.09	0.81	0.17	1.63[d]	0.93[d]	0.36	−6.17	−2.1	−5.0

[a] Present work [16].
[b] [17].
[c] [21].