ELEC-3140 Semiconductor physics **Mid-term exam 1, Oct 23, 2019**

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) wurtzite lattice structure,
   b) pseudomorphic structure,
   c) indirect band gap,
   d) type II band alignment,
   e) interstitial site,
   f) modulation doping.

2. a) a) Describe how to determine the Miller indices for a crystal plane and for a crystal surface in a cubic crystal. (2p) b) Describe the quantum structures by dimensionality. Also sketch the density of states (DOS) function for each one of them along with the bulk DOS. Place all the DOS functions in the same graph and be careful where you start each of the curves on the energy scale. (4p)

3. a) Describe the two main scattering mechanisms of charge carriers moving in a semiconductor. Additionally, give at least one example of other scattering mechanisms. (4p) b) Describe the fabrication techniques needed in making either a silicon transistor or a GaAs-based LED. (2p)

4. a) Calculate the packing fraction of body-centered cubic (BCC) crystal structure by assuming that the atoms are hard spheres with a radius of R (all the same size). Then calculate what is the relative volume that the spheres take for themselves, if the nearest neighbour spheres are touching each other. b) Calculate the primitive vectors of the reciprocal lattice for the BCC lattice. What type of lattice is that?

5. A hypothetical semiconductor has a density of states function approximated by

$$N(E) \propto C\cdot\sqrt{E-E_c}^{3/2},$$

where C is an arbitrary constant. Calculate the energy at which the electron occupation has its maximum in a non-degerate (not highly doped) semiconductor crystal. You can use the Maxwell-Boltzmann distribution.

Constants and material parameters on the other side!

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:

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[a]	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	−3.6

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