LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	**F0019T**
Examination date	2015-06-05
Time	9.00 - 14.00 (5 hours)

Examination in: FASTA TILLSTÅNDETS FYSIK MED KVANTMEKANIK / QUANTUM MECHANICS AND SOLID STATE PHYSICS
Total number of problems: 5
Teacher on duty: Hans Weber Tel: (49)2088, Room E304
Examiner: Hans Weber Tel: (49)2088, Room E304

Allowed aids: Fysikalia, Physics Handbook, Beta, calculator, COLLECTION OF FORMULAE for Solid state physics and COLLECTION OF FORMULAE for Quantum Physics.

Define notations and motivate assumptions and approximations. Present the solutions so that they are easy to follow. Maximum number of point is 15 p. 7.5 points are required to pass the examination. Grades 3: 7.5, 4: 9.5, 5: 12.0

---

1. **Wave functions and eigenfunctions**

   Consider a free particle with mass m in one dimension. The wave function of the particle at $t = 0$ is given by
   $$\psi(x, t = 0) = \cos^3(kx) + \sin^3(kx).$$

   (a) Show that the state function $\psi(x, 0)$ can be written as a superposition of eigenfunctions of the free-particle Hamiltonian.

   (b) Determine the energy of each plane wave in the superposition.

   (c) Give the wave function $\psi(x, t)$ at an arbitrary time t. (3 p)

2. **Reciprocal space.**

   (a) For rubidium calculate the shortest distance in reciprocal space from the origin to the surface of the Brillouin zone.

   (b) Is the Fermi sphere larger or smaller than the Brillouin zone and by how much? (3p)

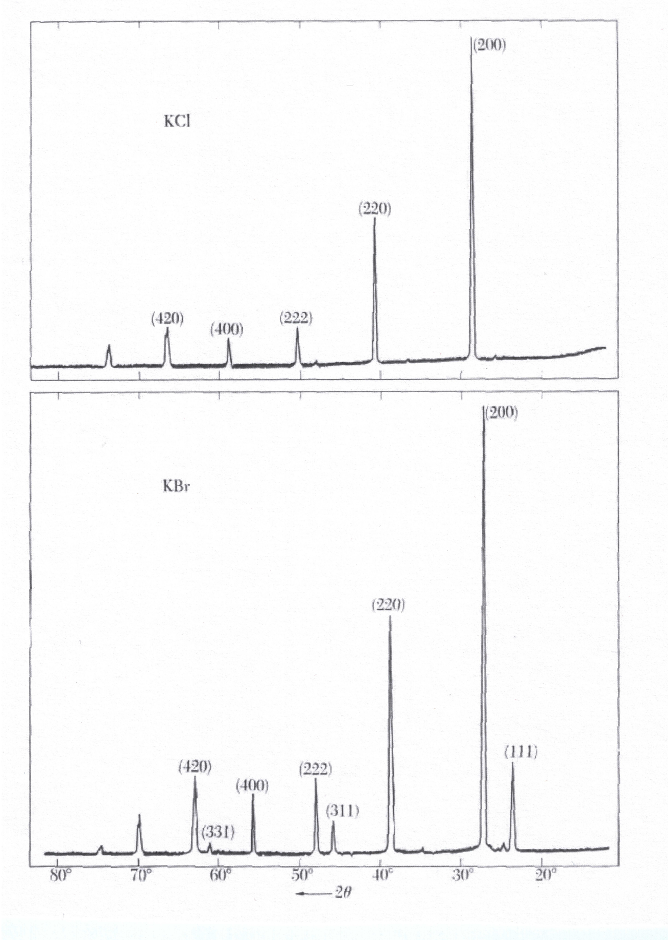
3. **Semiconductor bandgap.**

   A sample of Ge had the following values of resistance at the given temperatures:

T (K)	310	321	339	360	383	405	434
R (Ω)	13.5	9.10	4.95	2.41	1.22	0.74	0.37

   Evaluate the energy gap. (3p)

TURN PAGE!



4. **X–ray scattering.**

In the figure above you see the results from x–ray reflections of KCl and KBr powders. Both salts have an fcc lattice, but as one can see the x–ray reflections do not look the same. Explain this apparent difference. (3p)

5. **Electrical conductivity**

Diamond has a bandgap of $E_g = 5.3$eV, a electron mobillity of $\mu_e = 0.18$ m^2/Vs and a hole mobillity of $\mu_h = 0.12$ m^2/Vs. In an experiment one can determine the resistivity at T=300K to be $\rho = 10^{12}$ Ωm.

(a) Is this a reasonable value if we assume the diamond sample is intrinsically conducting?

(b) If not how large concentration of a 5 valent impurity is required to explain the experimental value?
Asume $m_e = m_h = m$. (3p)

Good Luck !