LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	**F0019T**
Examination date	2015-08-27
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

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1. **Time evolution of a wave function**

   A particle of mass m, which moves freely inside a one–dimensional infinite square well potential of length a, has the following initial wave function at time $t = 0$:

$$\psi(x,0) = \frac{\sqrt{13}}{\sqrt{8a}} \sin\left(\frac{\pi x}{a}\right) + \frac{1}{2\sqrt{a}} \sin\left(\frac{5\pi x}{a}\right) + \frac{A}{\sqrt{a}} \sin\left(\frac{7\pi x}{a}\right)$$

   where A is a real constant.

   a) Find A so that $\psi(x,0)$ is normalised.

   b) If a measurement of the energy is carried out at $t = 0$, what are the values that can be found and what are the corresponding probabilities? Calculate the average energy of the particle $< E >$.

   c) Find the wave function $\psi(x,0)$ at any later time t. (3p)

2. **The specific heat of Gold**

   A measurement of the heat capacity C_v is performed. The results are given in the table below:

T	(K)	1.6	2.0	2.4	2.8	3.2	3.6
C_v	(J /kmol K)	4.18	6.88	10.7	15.9	23.0	31.8

   Use these experimental results to determine the debye temperature Θ_D for Gold. (3p)

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3. **Electronbands**

The electron energy near the top of the valence band in a semiconductor is given by $\epsilon = -10^{-37}k^2$ J, where $\mathbf{k}$ is the wavevector. An electron is removed from the state $\mathbf{k} = 10^9\hat{\mathbf{k}}_x$ m^{-1}, where $\hat{\mathbf{k}}_x$ is a unit vector along the x axis. Calculate for the resulting hole:
(Let $\hbar = 10^{-34}$Js)

(a) The effective mass.

(b) The Energy.

(c) The momentum.

(d) The velocity.

Each answer must include the sign (or direction). (3p)

4. **Crystal structure**

The crystal structure below represents a 2 dimensional crystal. It consists of 4 kinds of atoms marked by the 4 letters q,p,d and b. The '....' in the figure mark a periodic continuation.

q p d b q p d b q p d b . . .

d b q p d b q p d b q p . . .

q p d b q p d b q p d b . . .

d b q p d b q p d b q p . . .

. . .

. . .

. . .

For the shown crystal structure indicate:

(a) The rectangular unit cell.

(b) The primitive unit cell.

(c) The basis of letters associated with each lattice point.

(3p)

5. **Conductivity of a semi conductor**

A sample of Silicon is prepared so that the concentration of donor atoms is $n_d = 10^{18}\text{m}^{-3}$. In an experiment where the temperature is slowely lowered a temperature is reached where the conductivity from an intrinsic behaviour to an extrinsic. Calculate the temperature where this is expected to happen.
(Data for Silicon: $E_g = 1.1$eV and for pure Silicon the intrinsic charge carrier concentration at T=300 K is $n_i = 2.0 \cdot 10^{16}\text{m}^{-3}$)

(3p)

Good Luck !