LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	**F7006T**
Examination date	2015-06-05
Time	9.00 - 14.00 (5 hours)

Examination in: FASTA TILLSTÅNDETS FYSIK / 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. **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)

2. **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)

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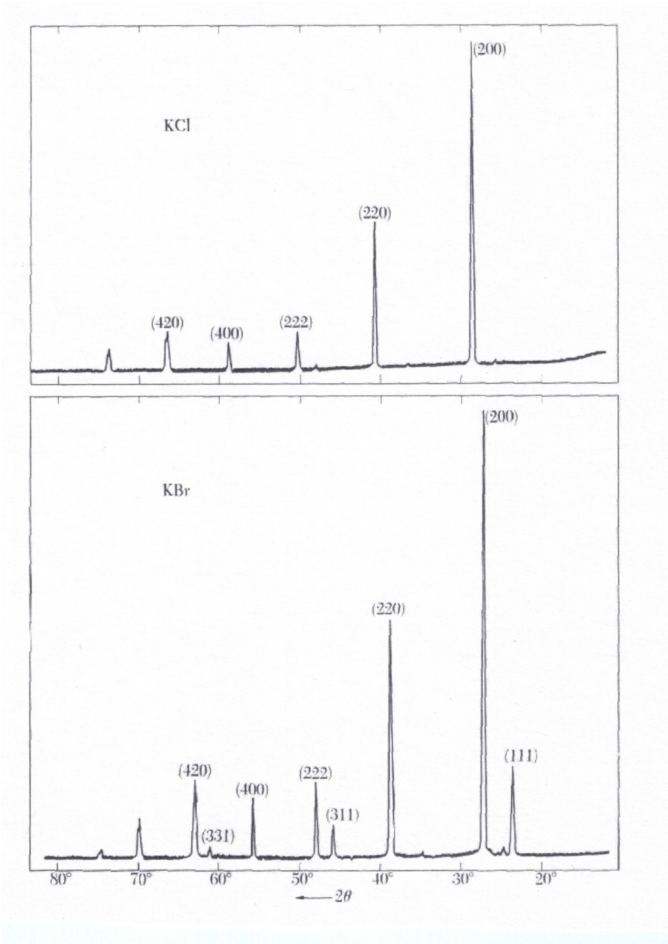

3. **X–ray scattering.**

   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)

4. **Electrical conductivity**

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

   (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 $m_{\mathrm{e}} = m_{\mathrm{h}} = m$. (3p)

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1504 HIRSHFELD, LEUPOLD, AND BOORSE

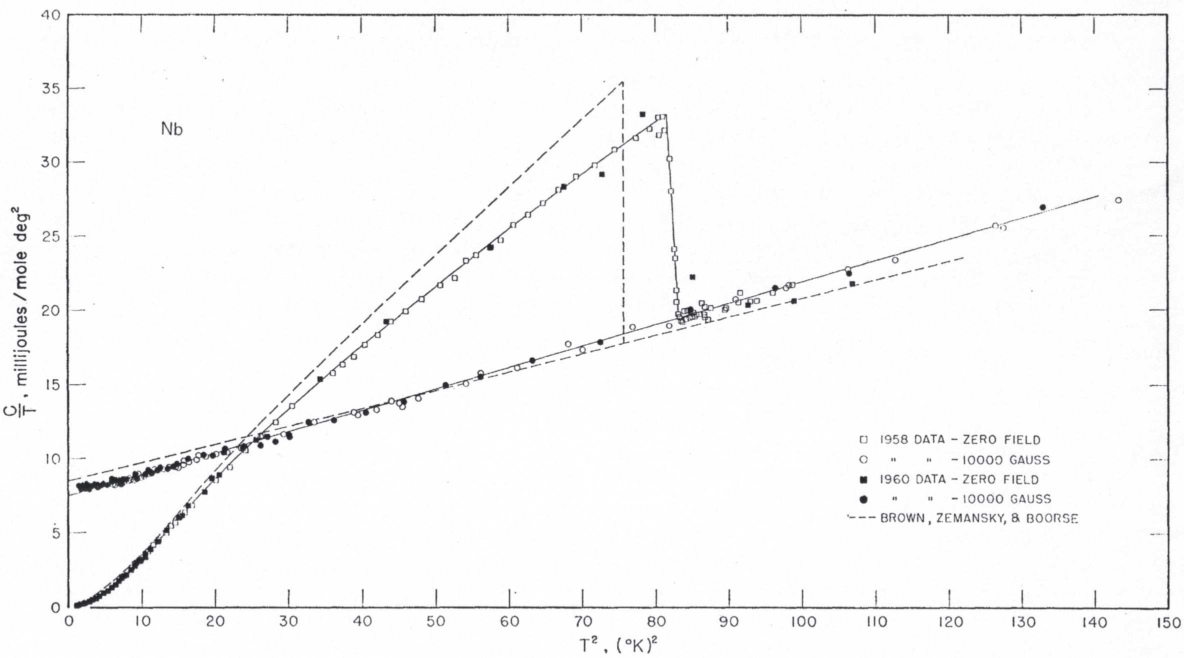

FIG. 2. C/T vs T^2 plot of the normal and superconducting specific heat of a polycrystalline sample of Nb. Full lines represent the mean of two series of measurements; blank and black squares represent data taken in zero field; blank and black circles represent data taken in a field of over 10 000 G. The dashed line represents the results of the earlier measurements of Brown, Zemansky, and Boorse on the same sample before the 2350°C heat treatment.

5. **Specific heat C_v of a conductor.**

At low temperatures the heat capacity of a metal is given by $C(T) = \gamma T + AT^3$, where $\gamma = \pi^2 N_e k_B^2 / 2\epsilon_F$ and $A = 234 N k_B / \Theta_D^3$.

(a) The two terms represent the contributions from electrons and phonons. Why does the electron contribution disappear for an insulator?

(b) To calculate the phonon contribution you need an expression for the density of states as a function of ω. Deduce the density of states (in three dimensions) for the phonons, choose appropriate boundary conditions and motivate the approximations you make.

(c) Formulate the integral for the total energy of the phonons. Explain the meaning of the different terms in this integral. Show that the temperature dependence of this integral is the desired one. (You do not need to keep track of all the constants)

(d) Above you see a graph of C_v/T vs T^2 for Niobium (Nb). Nb becomes superconducting at $T = 9.2K$. In the graph one can see this as a sudden increase of C_v/T as the temperature is lowered, this graph ends at the origin. One can prevent the superconducting state by applying a magnetic field the material will remain normal down to low temperatures provided the magnetic field is strong enough. For the normal material calculate from the graph the fermi energy ϵ_F and the Debye temperature Θ_D. (3p)

Good Luck !