LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	**F0053T / F0019T (old)**
Examination date Time	2016-12-20 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 E163
Examiner: Hans Weber Tel: (49)2088, Room E163

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. **Crystal structure**

   Sodium, Lead, Silicon are chemical elements with different crystal structures.

   (a) How many atoms does the primitive unit cell contain in these elements?

   (b) How many atoms does the conventional unit cell contain in these elements?

   (c) Calculate the nearest and next nearest neighbour distance, in Ångström, for Silicon.

   (3p)

2. **Heat capacity**

   Sodium metal displays free–electron–like behaviour. The thermal effective electron mass is equal to the electron mass and the Debye temperature is 160 K. What fraction of the total heat capacity at 320 K is contributed by the electrons. (3p)

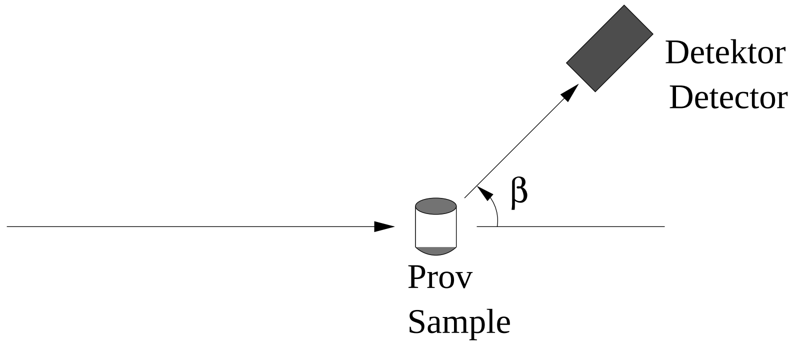
3. **Bragg scattering.**

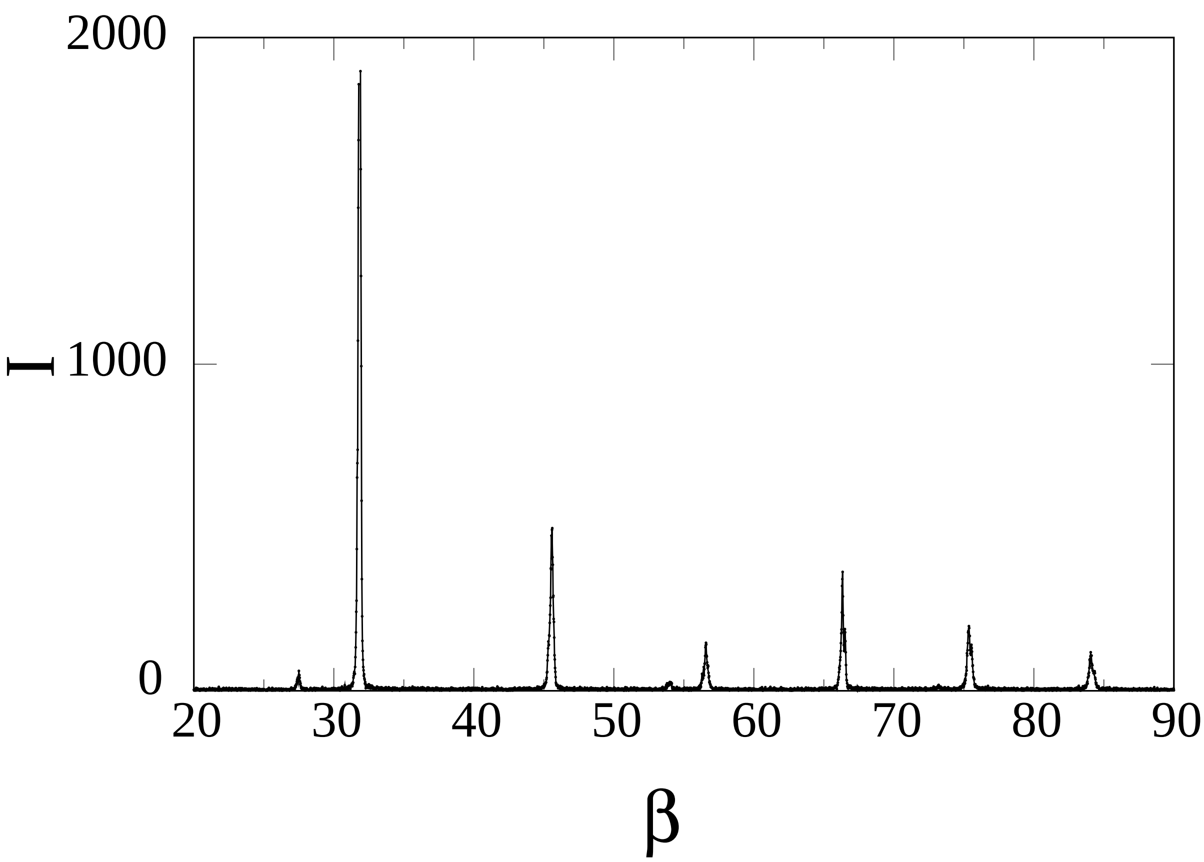
   The diffraction pattern of a polycrystalline mono atomic powder is shown in the figure below (next page). The X-rays used is the $K_{\alpha 1}$ line from copper (Cu). The angle β can be controlled between 0° and 90°. The outcome of the experiment is presented in the figure below, where the intensity (I) of the deflected beam is presented as a function of β.

   From the data in the figure determine the structure (sc, fcc, bcc or diamond) of the sample.

   (3p)

TURN PAGE!


Detektor
Detector
β
Prov
Sample


2000
1000
0
I
20
30
40
50
60
70
80
90
β

4. **Misc.**

a) Evaluate the commutator $[y^2, p_y^2]$.

b) The ion Be^{3+} has the nuclear charge +4 but only one electron. How much energy does it take to excite the electron from the ground state to the level 2s? Give a numerical value in electron Volts (eV)!

c) The wave function of a hydrogen atom in an eigenstate to the Hamilton operator is:

$$\Psi(r,\theta,\phi) = \frac{1}{81\sqrt{6\pi}}(1/a_\mu)^{3/2}(r^2/a_\mu^2)e^{-r/3a_\mu}[3\cos^2\theta - 1],$$

where a_μ is the Bohr radius (with the reduced mass). Determine the quantum numbers n, l och m_l.

(3p)

5. **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)

Good Luck !