FYS3410 - Vår 2016 (Kondenserte fasers fysikk)

http://www.uio.no/studier/emner/matnat/fys/FYS3410/v16/index.html

Pensum: Introduction to Solid State Physics
by Charles Kittel (Chapters 1-9 and 17, 18, 20)

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2016 FYS3410 Lectures (based on C.Kittel's Introduction to SSP, Chapters 1-9, 17,18,20)

Module I – Periodic Structures and Defects (Chapters 1-3, 20)

M18/1: 9-12 am	Introduction. Crystal bonding. Periodicity and lattices, Brag diffraction and Laue condition, reciprocal space	3h
W20/1 cancelled		
M25/1: 9-12 am	Ewald construction, interpretation of a diffraction experiment , Brag planes, and Brillouin zones	3h
W27/1 cancelled		
M01/2: 10-12 am	Elastic strain and structural defects in crystals	2h
W03/2: 9-10 am	Atomic diffusion in solids	1h
M08/2: 10-12 am	Summary of Module I	2h

Module II – Phonons (Chapters 4 and 5)

W10/2: 9-10 am	Vibrations in monoatomic and diatomic chains of atoms	1h
M15/2: 10-12am	Periodic boundary conditions, phonons and density of states (DOS)	2h
W17/2: 9-10 am	Planck distribution	1h
M22/2 : 10-12am	Lattice heat capacity: Dulong-Petit, Einstein, and Debye models	2h
W24/2 cancelled		
M29/2: 9-12am	Comparison of different models for lattice heat capacity, thermal conductivity with phonons	3h
W02/3: 9-10 am	Thermal expansion	1h
M07/3: 10-12am	Summary of Module II.	2h

Module III – Electrons (Chapters 6, 7, 18 - pp.528-530, and Appendix D)

W09/3: 9-10 am	Free electron gas (FEG) versus free electron Fermi gas (FEFG)	1h
M14/3: 10-12am	DOS of FEFG in 3D. Effect of temperature – Fermi-Dirac distribution	2h
W16/3: 9-10 am	Heat capacity of FEFG in 3D	1h
W30/3: 9-10 am	DOS in 2D - quantum wells	1h
M04/4: 10-12am	DOS in 1D and 0D, i.e. quantum wires and quantum dots; transport properties of electrons	2h
W06/4: 9-10 am	Origin of the energy band gap	
M11/4: 10-12am	Nearly free electron model. Kronig-Penney model. Empty lattice approximation.	2h
W13/4: 9-10 am	Number of orbitals in a band	1h
M18/4: 10-12am	Summary of Module III.	2h

Module IV – Semiconductors and interfaces (Chapters 8, 9-pp 223-231, 17)

W20/4: 9-10 am	Metals versus semiconductors. Surfaces and interfaces.	1h
M25/4: 9-12 am	Effective mass method.	3h
W27/4: 9-10 am	Intrinsic carrier generation – elctrons and holes.	1h
M02/5: 9-12 am	Localized levels for hydrogen-like impurities – donors and acceptors. Doping.	3h
W04/5: 9-10 am	Carrier statistics in semiconductors	1h
M09/5: 9-12 am	p-n junctions	3h
W11/5: 9-10 am	Optoelectronic semiconductor properties and devices	1h
M18/5: 9-12 am	Device demonstrations. Summary of Module IV	3h

Repetition

M23/5 9-12 am	The course in a nutshell	2h
W25/5, M30/5 and W1/6 cancelled		

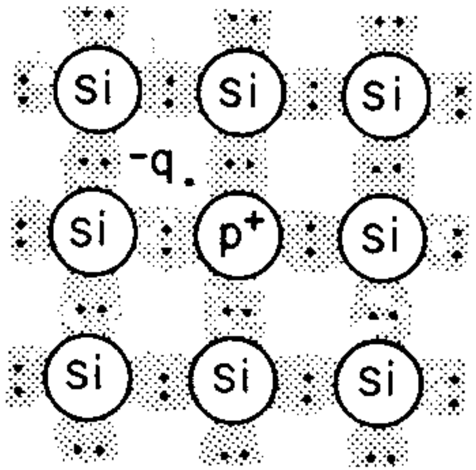
Exam during week 22 (tentatively 30-31/5)

Lecture 27/4/2016

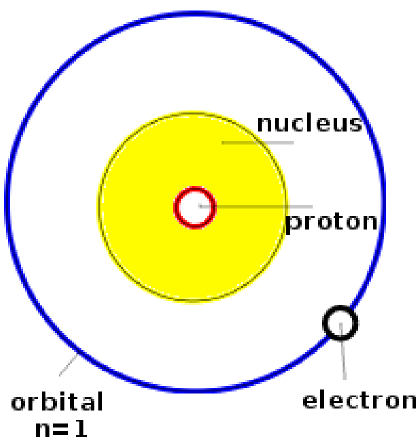
Effective mass method

for hydrogen-like impurities in semiconductors

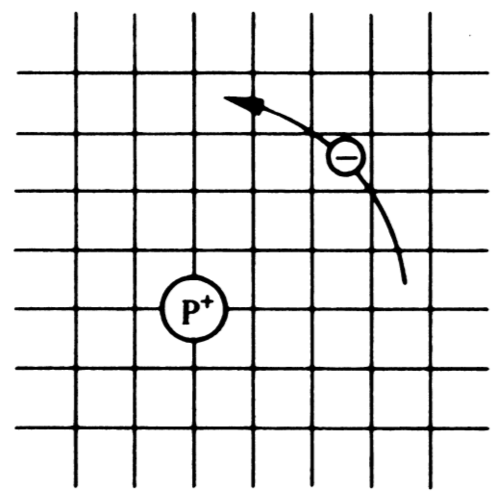
Hydrogen like impurities in semiconductors



P donor in Si can be modeled as hydrogen-like atom



Hydrogen atom



Hydrogen-like donor

Hydrogen atom - Bohr model

$$\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2} = m\frac{v^2}{r} \quad \text{for } L = mvr = n\hbar,\ n = 1,2,3\ldots$$

$$\Rightarrow Ze^2 = 4\pi\varepsilon_0 mv^2 r = 4\pi\varepsilon_0 mr\left(\frac{n\hbar}{mr}\right)^2 = 4\pi\varepsilon_0\frac{n^2\hbar^2}{mr}$$

$$\Rightarrow \boxed{r = 4\pi\varepsilon_0\frac{n^2\hbar^2}{mZe^2}}$$

$$\Rightarrow \boxed{v = \frac{n\hbar}{mr} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{n\hbar}}$$

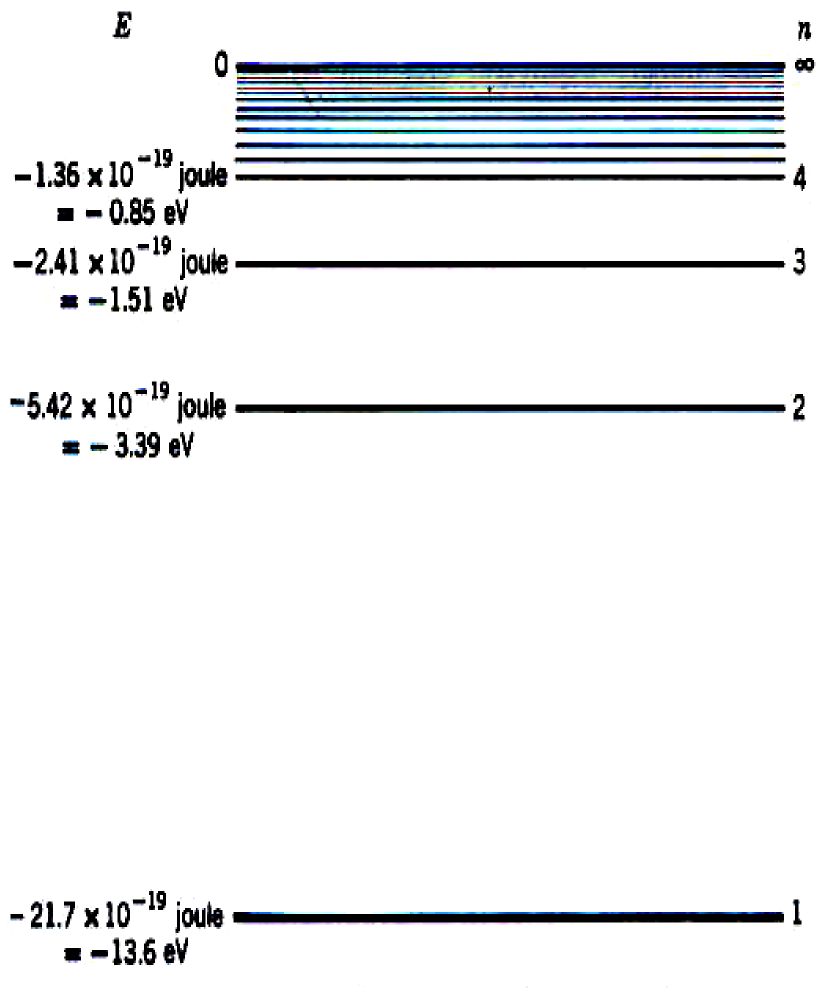
$$\text{Potential energy:} \quad V = -\int_r^\infty \frac{Ze^2}{4\pi\varepsilon_0 r^2}dr = -\frac{Ze^2}{4\pi\varepsilon_0 r}$$

$$\text{Kinetic energy:} \quad K = \frac{1}{2}mv^2 = \frac{Ze^2}{4\pi\varepsilon_0 2r}$$

$$\text{Total energy:} \quad E = K + V = -\frac{Ze^2}{(4\pi\varepsilon_0)^2 2r} = -K \Rightarrow \boxed{E = -\frac{mZ^2e^4}{(4\pi\varepsilon_0)^2 2\hbar^2}\frac{1}{n^2}}$$

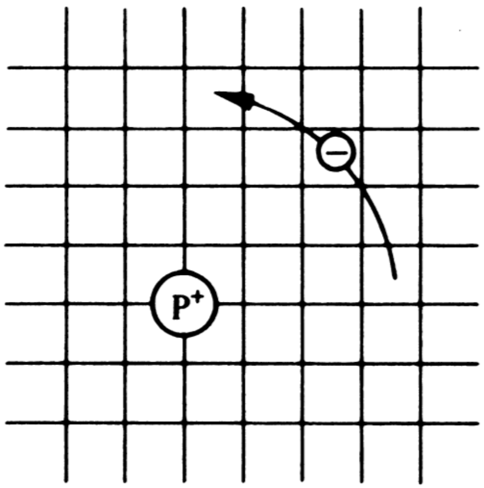
Hydrogen atom - Bohr model

$$E_H = -\frac{m_0 q^4}{2(4\pi\varepsilon_0\hbar)^2} = -13.6\ \text{eV}$$



An energy-level diagram for the hydrogen atom.

Hydrogen like impurities in semiconductors



Hydrogen-like donor

Instead of m_0, we have to use m_n^*.
Instead of ε_o, we have to use $K_s\,\varepsilon_o$.

K_s is the relative dielectric constant of Si ($K_{s,\,Si}$ = 11.8).

$$E_H = -\frac{m_0\, q^4}{2\,(4\pi\,\varepsilon_0 \hbar)^2} = -13.6\,\text{eV}$$

$$E_d = -\frac{m_n^*\, q^4}{2\,(4\pi\, K_s\, \varepsilon_0\, \hbar)^2} = -13.6\,\text{eV}\ \frac{m_n^*}{m_0}\left(\frac{\varepsilon_0}{K_s \varepsilon_0}\right)^2 \approx -0.05\,\text{eV}$$