Information page for written examinations at Linköping University

Examination date	2018-08-28
Room (1)	G37(1)
Time	8-12
Course code	TFYA43
Exam code	TEN1
Course name **Exam name**	Nanotechnology (Nanoteknologi) Written Examination (Skriftlig tentamen)
Department	IFM
Number of questions in the examination	25
Teacher responsible/contact person during the exam time	Jens Birch / Jens Birch
Contact number during the exam time	0705-227686
Visit to the examination room approximately	9.30
Name and contact details to the course administrator (name + phone nr + mail)	Lena Wide, 013-281229, lena.wide@liu.se
Equipment permitted	- Scientific calculator without text storage or wire-less communication capabilities - Physics Handbook or corresponding formula collection (without any personal notes) - Language dictionaries without text storage capabilities or any personal notes
Other important information	Bonus points can only be credited on part A. Read carefully the next page.
Number of exams in the bag	

Exam in Nanotechnology
(course code TFYA43)

READ THIS FIRST:

Take it easy! Start by reading through the entire exam before starting answering!

- The exam contains of part A, with 15 one-point questions, and part B, with 10 three-point questions giving a total maximum of 45 points.

- For each passed lecture repetition quiz, you are entitled to credit 1 bonus point on Part A. (The maximum points on part A is still limited to 15.)

- Answers to questions A1-A15 may be given on one sheet of paper or by marking the right answers and handing in the exam.

- Each answer *must* be labelled with the question number.
  No number = no points.

- No ½-points will be given. You must *fully answer* the one-point questions in order to get one point.

- The answers to the questions must be presented *as clear as possible*.
  It is *always* an advantage for the student to explain carefully, define symbols, and present a sketch to support the explanation.
- Conversely, an *unclear* answer may give zero points even if you actually knew it.

- The questions are *not* ranked according to difficulty level.

- Allowed aids:
  - Scientific calculator (no devices with text storage or wire-less communication capabilities are allowed)
  - Physics Handbook or corresponding formula collection (without any personal notes)
  - Language dictionaries (without any personal notes) Digital dictionaries are allowed provided they do not feature any user text storage capability

- The limits (includung credited bonus points) for the different grades are:

  <15 points → not passed (ECTS: Fx)
  15 – 25 points → grade 3 (ECTS : C)
  26 – 35 points → grade 4 (ECTS : B)
  36 – 45 points → grade 5 (ECTS : A)

Good Luck ! Jens Birch, tel: 281228, 0705-227686 e-mail: jebir@ifm.liu.se

PART A

(Bonus points from the lecture quizes will be credited from part A only. The maximum score on Part A is 15 points no matter how many bonus points you have. Answers to questions A1-A15 may be given on one sheet of paper or by marking the right answers and handing in the exam.)

A1.	Which Nobel laureate in Physics invented the transmission electron microscope?	a) Ernst Ruska b) Richard Feynmann c) Gerhard Binnig
A2.	Why is the melting point (TM) of nanoparticles lower than the corresponding bulk?	a) The chemical bonds in the bulk of nanoparticles are weakened in proportion to the nanoparticle volume b) Large surface relative to bulk leads to less bonds to be broken by thermal energy c) Surface plasmons provide additional kinetic energy which leads to less thermal energy is required
A3.	Surface plasmon resonance is…	a) …a resonant light emission from quantized states in semiconductors b) …a resonance between the surface charge and the electric field of light on metallic nano-particles c) …a resonance between a plasma and a surface
A4.	The SNOM is an optical characterization technique …	a) … whch utilizes an STM to record topography simultaneously b) …where several optical detection modes can be used to make the image c) … which utilizes the diffraction (Abbe) limit at far-field

A5.	With EBL…	a) … an electron beam is used to write patterns in resist b) … a Ga+ ion beam is used to etch away material on a nano-level c) … an electron beam is used to etch away material
A6.	The energy levels in a quantum structure become more close to each other…	a) …when the structure size decreases.. b) … when the structure size increases. c) …when the band-gap difference between the two materials increases.
A7	The "lotus effect" means self- cleaning thanks to …	a) … photocatalytic processes in nanoparticles using green light b) …a reduced surface energy of nanostructured surfaces c) …enzymes hindering algae and germs to attach to surfaces
A8.	"Exfoliation" is a method to make graphene by…	a) …extracting the top-most Si atoms from a perfect SiC surface leaving graphene on the top b) …depositing carbon on polymer foils. c) …lifting off graphene layers from a larger graphite crystal.
A9	The device scaling rule says: If the gate length is reduced by 1/K, then the…	a) …device area is scaled as 1/K. b) …power consumption scales as 1/K. c) …delay time is scaled as $1/K^2$.
A10	To integrate spin-devices with electronics, so called DMS materials are used. These are…	a) … doped magnetic superconductors. b) … dilute magnetic semiconductors. c) …dia-magnetic semiconductors.

A11	Up- & down-conversion in conjunction with PV cells is used to…	a) … transform the incident light wavelength to match the absorbtion peak of the PV cell b) …shift the bandgap of the PV cell to match the solar spectrum c) … alter the output voltage to match other PV cells
A12	A tandem PV cell has a high efficiency because…	a) … two or more identical nano-cells are connected in parallel, yielding high current b) …two or more identical nano-cells are connected in series, yielding a high voltage c) …two or more cells absorbing different energies are stacked to better utilize the solar spectrum
A13	In nanoplasmonic biodetection one uses for example…	a) …nano particles in the blood plasma for detection of certain biomolecules. b) …the change of the refractive index of nanoparticles at the end of an optical fiber probe is utilized. c) …nano particles for drug delivery.
A14	CPP is a parameter to estimate …	a) … possible shapes of aggregated block co-polymers and lipids b) … protein folding into helixes or sheets c) …if a molecule is hydrophobic or hydrophilic.
A15	What detection mechanism is a Metal Oxide Sensor based upon?	a) Change of conductivity b) Change of potential on the gate of a MOS-FET transistor c) Change of frequency of a surface acoustic wave

PART B (One B-question answered per sheet of paper.)

Question B1.

a) What are the requirements that has to be fulfilled by a technology in order for it to be considered as "Nanotechnology"? 2p

b) What is additionally needed to define "Nanoscience" 1p

Question B2.

The quantum nature of the energy states (wavefunctions) of electrons (and other particles) confined in nano-structures are often utilized in nano-technology.

a) *Draw the energy diagram* (valence and conduction bands) of a nano-sized semiconductor quantum well heterostructure so that charge carrier confinement can occur **and** *indicate in the figure* the quantized states for confined electrons and holes. 2p

b) *Explain, with the aid of the diagram you made in a),* how an exciton may be created and destroyed inside the quantum by interaction with external particles/waves. 1p

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Question B3.

Several microscopy techniques exist for imaging of structures at the nanoscale and smaller.

a) *Make a sketch* **and** *explain the general principle* for how the SEM works. 1p

b) Mention one specimen property that always must be fulfilled for SEM analyses? 1p

c) How can non-conducting samples be analyzed in the SEM. 1p

Question B4.

Biologic Nanostructures

a) What physical properties of aggregates of amphiphilic molecules (or polymers) defines the CPP? 1p

b) What can the CPP be used for? 1p

c) What is a vesicle? 1p

Question B5.

Integrated circuits are utilizing smaller and smaller device structures and interconnects.

a) Explain why nanoelectronics can solve the problem of so-called band-to-band tunnelling (BTBT). 1p

b) *Make a simple sketch* of a non-planar FET (for example a FinFET or a nanowire MOSFET) **and** *explain what problem* in the planar transistor design that it solved. 2p

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Question B6.

The bond structures of carbon in the form of diamond and in the form of graphene differ significantly:

a) For each of these materials: *Make drawings* of the bonding orbitals **and** *write down their names* in the two figures. 2p

b) For graphene, draw and name the orbital which is responsible for its high conductivity? You may use the drawing you made in B6 a) 1p

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Question B7.

Nanotechnology have important applications for improvement of the environment and more efficient use of energy and for alternative energy sources.

a) *Make a schematic drawing* **and**, with the aid of the drawing, *explain what physically happens* in TiO_2 nanoparticles, and at their surface, when they are used as self-cleaning or air-purificating material. 2p

b) Explain why the antibacterial effect of silver nanoparticles depends on the particle shape. 1p

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Question B8.

Nano-particles.

a) Explain **three** different purposes for using capping layers on nano-particles. 1p

b) How is the melting point of metal nanoparticles influenced by reduced particle size? 1p

c) What is the physical reason for the change in melting point (as you answered in 8b) of metal nanoparticles? 1p

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Question B9.

Nano-particles are often proposed for applications in life-science.

a) Explain how hybrid gold nano-particles can be utilized for simple optical biomarker detection. 1p

b) Give an example of how liposomes can be used for drug delivery. 1p

c) Explain how DNA can be used in a bottom-up method for self-assembly of hybrid nanostructures containing inorganic nanoparticles? 1p

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Question B10.

Sensors

a) *Make a schematic drawing* of an FET gas sensor **and**, with the aid of the drawing, *explain the physics* behind the sensor detection principle. 2p

b) For FET based sensors, why does the sensitivity increase if the catalytic metal is nano-structured? 1p