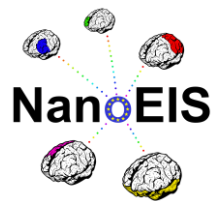


**EU 7<sup>th</sup> FRAMEWORK PROGRAMME**

**Call FP7-NMP-2012-CSA-6**



## **NanoEIS**

**Nanotechnology education for industry and society**

Grant Agreement N° NMP4-SA-2012-319054

**Deliverable number: D4.1**

**Model curriculum provided as open courseware**

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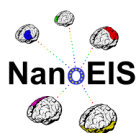
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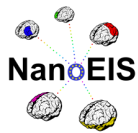
**NfA**



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## Introduction

The present document constitutes Deliverable D4.1 in the framework of the NanoEIS project entitled “Nanotechnology education for industry and society” (Contract No.: NMP4-SA-2012-319054).

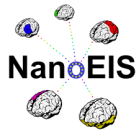
The content was prepared in the framework of activities performed within Work Package 4 “Teaching material development”, in particular in Task 4.1 “University curriculum development – Open courseware”.

The document aims to provide a model curriculum for 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> degree of studies in Nanotechnology. The model curriculum follows the recommendations which were included in the Deliverable D6.2 “Report on recommendations for universities (nanotechnology studies and lifelong learning)” and is developed on the basis of the outcome of:

- the surveys among nanotechnology employers described in Deliverable D2.1 “Report on European industry needs” and Deliverable D2.2 “Report on other (social) employer needs”
- the analysis of the existing university offers as described in Deliverable D3.3 “Report on factors favouring specific desired outcomes for nanotechnology programmes at universities” and Deliverable D3.5 “Report on best practice examples at all levels of education”.

The open courseware aims at enabling university educators to refine and improve existing curricula, and to set up new ones based on this standard of reference.

This deliverable will be available to the general community due to its public nature.



## 1 Model curriculum for the 1st degree studies in Nanotechnology

(6 semesters = 3 years)

The B.Sc. graduates will possess professional skills necessary to:

- work in laboratories specializing in nanomaterials synthesis development
- operate laboratory apparatus and equipment
- investigate basic properties of this type of materials
- define usefulness of nanomaterials for specific practical purposes
- develop methods of synthesis of new nanomaterials
- search for information in the field of nanotechnology and related areas

The B.Sc. graduate possesses general competencies which allow him/her to:

- work in teams and task groups
- solve simple engineering problems in the field of nanotechnology
- produce reports on issues connected with nanotechnology
- organize work at his/her workplace (e.g. research laboratory or industrial enterprise department)
- follow occupational safety requirements
- make use of modern means of communication
- communicate in a foreign language

The requirement for the further specialization requires that at the beginning students are given a background knowledge in mathematics, physics, chemistry, and biology. The 1st degree studies program should take into account local job market situation and be preferably developed in connection to the companies located nearby, favoring transition from academia to industry. The graduates can continue their education at the second cycle studies.

### 1.1 PROGRAM of 1<sup>st</sup> semester

#### 1.1.1 Mathematics 30h L + 60h E

<b>COURSE CONTENT</b>	differential and integral calculus for functions of one variable; graphing functions of two variables; partial derivatives; linear approximation of differentiable functions of two variables; double integrals and iterated integrals over rectangles; polar coordinates; the notion of convergence for sequences and series
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WEB-LINKS	<p><a href="https://alison.com/courses/Advanced-Mathematics-1">https://alison.com/courses/Advanced-Mathematics-1</a></p> <p><a href="http://ocw.mit.edu/courses/mathematics/18-01sc-single-variable-calculus-fall-2010/">http://ocw.mit.edu/courses/mathematics/18-01sc-single-variable-calculus-fall-2010/</a></p> <p><a href="http://ocw.mit.edu/courses/mathematics/18-02-multivariable-calculus-fall-2007/index.htm">http://ocw.mit.edu/courses/mathematics/18-02-multivariable-calculus-fall-2007/index.htm</a></p> <p><a href="http://cosmolearning.org/video-lectures/sequence-convergence-and-divergence-part-1/">http://cosmolearning.org/video-lectures/sequence-convergence-and-divergence-part-1/</a></p> <p><a href="http://ocw.mit.edu/resources/res-18-007-calculus-revisited-multivariable-calculus-fall-2011/index.htm">http://ocw.mit.edu/resources/res-18-007-calculus-revisited-multivariable-calculus-fall-2011/index.htm</a></p>
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### 1.1.2 General chemistry 30h L + 30h E

COURSE CONTENT	<p>definitions, concepts and chemical symbols; chemical equations; periodic table of the elements; basic laws of chemistry; structure of matter; isotopes; Heisenberg uncertainty principle; electrons - atomic orbitals; quantum numbers; the Pauli exclusion principle and Hund's rule; hybridization of atomic orbitals; the types of chemical bonds; electronegativity; oxidation state of atoms in chemical compounds; acids and bases according to the Bronsted-Lowry and Lewis theories; equilibria in aqueous solutions; pH; hydrolysis; degree of dissociation and dissociation constant; buffer solutions</p>
WEB-LINKS	<p>OpenChemistry Lecture Videos:</p> <p><a href="https://ps.uci.edu/content/chem-1a-general-chemistry">https://ps.uci.edu/content/chem-1a-general-chemistry</a></p> <p><a href="http://www.periodicvideos.com/">http://www.periodicvideos.com/</a></p> <p>European Chemistry Tests developed by European Chemistry Thematic Network Association:</p> <p><a href="http://ectn-assoc.cpe.fr/echemtest/">http://ectn-assoc.cpe.fr/echemtest/</a></p>

### 1.1.3 Mechanics 30h L + 30h E

COURSE CONTENT	<p>units, errors in measurements; physical quantities, and vectors; motion, velocity, and acceleration; Newton's laws and applications; work and kinetic energy; potential energy and energy conservation; momentum; motion of rigid bodies; mechanical equilibrium and elasticity; gravitation; periodic motion, harmonic oscillator and resonance</p>
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WEB-LINKS	<p>MITOpenCourseware:</p> <p><a href="http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010/index.htm">http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010/index.htm</a></p> <p><a href="http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010/index.htm">http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010/index.htm</a></p>
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#### 1.1.4 Physics: 60h LAB

#### 1.1.5 Introduction to biology 30h L

COURSE CONTENT	<p>chemistry for biology – macromolecules; cells and cell division and cell cycle; Mandel rules; organelles; meiosis and mitosis; multicellularity; colonies and organisms; animal development; taxonomy and systematic; bacteria and archaea; protists; fungi; animal diversity; invertebrates; vertebrates</p>
WEB-LINKS	<p>MIT OpenCourseWare, <a href="http://ocw.mit.edu">http://ocw.mit.edu</a></p> <p><a href="http://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/video-lectures/">http://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/video-lectures/</a></p> <p>www.youtube.com:</p> <p>Biology 1A Lectures by UC Berkeley;</p> <p>Introductory Biology by MIT Open CourseWare</p>

#### 1.1.6 Philosophy of (nano)science / Ethics 30h L

COURSE CONTENT	<p>Historical, sociological, and ethical perspectives on nano-science and nano-technology; Experience in analysing and discussing philosophical, sociological and ethical questions related to nano-science and nanotechnology;</p> <p>Experience with oral and written presentation of topics within the history, philosophy and sociology of nano-science and nanotechnology.</p>
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WEB-LINKS	<p>“Governing Nanotechnology in a Multistakeholder World”:  <a href="http://link.springer.com/article/10.1007%2Fs11569-012-0163-1">http://link.springer.com/article/10.1007%2Fs11569-012-0163-1</a>;</p> <p>“Ethics and Nanotechnology; Responsible Development of Nanotechnology at Global Level in the 21st Century.”:  <a href="https://www.lap-publishing.com/catalog/search?search_query=malsch">https://www.lap-publishing.com/catalog/search?search_query=malsch</a>  <a href="http://ocw.mit.edu/courses/linguistics-and-philosophy/24-06j-bioethics-spring-2009/index.htm">http://ocw.mit.edu/courses/linguistics-and-philosophy/24-06j-bioethics-spring-2009/index.htm</a>  <a href="http://ocw.mit.edu/courses/health-sciences-and-technology/hst-934j-introduction-to-global-medicine-bioscience-technologies-disparities-strategies-spring-2010/">http://ocw.mit.edu/courses/health-sciences-and-technology/hst-934j-introduction-to-global-medicine-bioscience-technologies-disparities-strategies-spring-2010/</a>  <a href="https://www.is.mpg.de/7483335/GENNESYS_2009-Chap10.pdf">https://www.is.mpg.de/7483335/GENNESYS_2009-Chap10.pdf</a>  <a href="http://ethicschool.nl/_files/Ethics%20of%20Emerging%20Technologies%20suggested%20reading.pdf">http://ethicschool.nl/_files/Ethics%20of%20Emerging%20Technologies%20suggested%20reading.pdf</a>  <a href="http://repository.ubn.ru.nl/handle/2066/91234">http://repository.ubn.ru.nl/handle/2066/91234</a>  <a href="http://link.springer.com/journal/11569">http://link.springer.com/journal/11569</a>            Journal of Nano Education: <a href="http://www.aspbs.com/jne.htm">http://www.aspbs.com/jne.htm</a>  <a href="http://nanoyou.eu/en/nano-educators/tools.html?view=alphacontent">http://nanoyou.eu/en/nano-educators/tools.html?view=alphacontent</a></p>
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**1.1.7 Safety at work 15h L**

COURSE CONTENT	<p>concept of the safety and ergonomics; ergonomics as an interdisciplinary knowledge and engineering strategy; safety of the system: human – technical object – environment; health and safety regulations – a historical background; EU directives, guidelines and standards; national legislations; safety management and risk governance; risk assessment; duties of employers &amp; employees</p>
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WEB-LINKS	<p> <a href="http://www.dcs.warwick.ac.uk/~rws/CS122/lecture8.html">http://www.dcs.warwick.ac.uk/~rws/CS122/lecture8.html</a>  <a href="http://ec.europa.eu/social/main.jsp?catId=148">http://ec.europa.eu/social/main.jsp?catId=148</a>  <a href="https://osha.europa.eu/pl/safety-and-health-legislation">https://osha.europa.eu/pl/safety-and-health-legislation</a>  <a href="https://osha.europa.eu/en/legislation/directives/exposure-to-chemical-agents-and-chemical-safety/">https://osha.europa.eu/en/legislation/directives/exposure-to-chemical-agents-and-chemical-safety/</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/5%20Derivation%20of%20control%20strategies%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/5%20Derivation%20of%20control%20strategies%20-%20presentation_v1-0.pdf</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/7%20Basics%20on%20chemical%20regulation%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/7%20Basics%20on%20chemical%20regulation%20-%20presentation_v1-0.pdf</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a>            booklet: Safety in the Chemistry Laboratory a practical guide for teachers:  <a href="https://www.acs.org/content/dam/acsorg/education/policies/safety/chemical-safety-for-teachers-and-their-supervisors.pdf">https://www.acs.org/content/dam/acsorg/education/policies/safety/chemical-safety-for-teachers-and-their-supervisors.pdf</a>  <a href="http://www.nanodiode.eu/project/presentations/">http://www.nanodiode.eu/project/presentations/</a> </p>
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### 1.1.8 Sport 30h

## 1.2 PROGRAM of 2<sup>nd</sup> semester

### 1.2.1 Mathematics 30h L + 60h E

COURSE CONTENT	<p>directional derivative, gradient vector, differentials of functions in several variables; extremum; double integrals over general domains; Taylor polynomials and series; complex numbers; graphic representation of ordinary differential equations</p>
WEB-LINKS	<p> <a href="https://alison.com/courses/Advanced-Mathematics-1">https://alison.com/courses/Advanced-Mathematics-1</a>            MIT Open CourseWare: <a href="http://ocw.mit.edu/resources/res-18-008-calculus-revisited-complex-variables-differential-equations-and-linear-algebra-fall-2011/">http://ocw.mit.edu/resources/res-18-008-calculus-revisited-complex-variables-differential-equations-and-linear-algebra-fall-2011/</a> </p>

### 1.2.2 Inorganic chemistry 30h L + 15h E + 60h LAB

COURSE CONTENT	classification and nomenclature of inorganic compounds; acids, bases and salts; oxidation-reduction reactions; methods of obtaining and applications of the selected elements and their compounds; selected examples of inorganic nanomaterials; coordination compounds; fundamentals of crystal field theory, the symmetry of crystals, basic information on the mechanisms and kinetics of chemical reactions
WEB-LINKS	<p><a href="http://www.acs.org/content/acs/en/education/policies/twoyearcollege/self-study-tool.html">http://www.acs.org/content/acs/en/education/policies/twoyearcollege/self-study-tool.html</a></p> <p>MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/chemistry/5-05-principles-of-inorganic-chemistry-iii-spring-2005/">http://ocw.mit.edu/courses/chemistry/5-05-principles-of-inorganic-chemistry-iii-spring-2005/</a></p> <p><a href="http://www.periodicvideos.com/">http://www.periodicvideos.com/</a></p>

### 1.2.3 Electromagnetism 30h L + 30h E

COURSE CONTENT	electric charge; force and field; Gauss' law; electric potential; current; resistance; electromotive force; electric circuits; magnetic fields; induction; alternating currents; Maxwell's equations
WEB-LINKS	MIT Open Courseware: <a href="http://ocw.mit.edu/courses/physics/8-03-physics-iii-spring-2003/">http://ocw.mit.edu/courses/physics/8-03-physics-iii-spring-2003/</a>

### 1.2.4 Analytical chemistry 30h L + 60h LAB

COURSE CONTENT	<p>introduction to classical analysis, qualitative and quantitative analysis; complexation reactions; redox reactions; weight analysis and precipitation titration; titration curves, indicators; sample collection and preparation.</p> <p>Basic instrumental analytic methods: mass spectrometry, gas and liquid chromatography, UV-VIS.</p>
WEB-LINKS	<p><a href="http://www.academia.edu/5266578/Analytical_Chemistry_Lecture_Notes_">http://www.academia.edu/5266578/Analytical_Chemistry_Lecture_Notes_</a>  <a href="https://class.coursera.org/analyticalchem-001/lecture/preview">https://class.coursera.org/analyticalchem-001/lecture/preview</a>  <a href="http://www.rsc.org/learn-chemistry/resource/res00002077/titration-screen-experiment">http://www.rsc.org/learn-chemistry/resource/res00002077/titration-screen-experiment</a>  <a href="http://www.youtube.com">www.youtube.com</a>: Chromatography Basic Principles by Ajit Kumar</p>

#### 1.2.5 Cradle-to-cradle product design 30h L

COURSE CONTENT	<p>what is cradle-to-cradle design; defining long-term Cradle to Cradle goals; cradle-to-cradle principles: elimination of the concept of waste, usage of renewable energy, celebrating diversity; Biological and Technological Nutrient Cycles; effective material cycles: products of consumption, products of service, externally managed components; criteria for product design: material health, material reutilization, renewable energy and carbon management, water stewardship, social fairness</p>
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WEB-LINKS	<p><a href="http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources">http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources</a></p> <p><a href="http://www.chemanager-online.com/en/topics/chemicals-distribution/design-harmony-natural-cycles">http://www.chemanager-online.com/en/topics/chemicals-distribution/design-harmony-natural-cycles</a></p> <p><a href="http://digital.realviewtechnologies.com/default.aspx?iid=6527&amp;startpage=page0000013&amp;xml=flexomag.xml">http://digital.realviewtechnologies.com/default.aspx?iid=6527&amp;startpage=page0000013&amp;xml=flexomag.xml</a></p> <p><a href="http://www.mbdc.com/cradle-to-cradle/cradle-to-cradle-certified-program/program-documents/">http://www.mbdc.com/cradle-to-cradle/cradle-to-cradle-certified-program/program-documents/</a></p> <p><a href="http://s3.amazonaws.com/c2c-web-site/resources/certification/standard/C2CCertified_V3_Overview_121113.pdf">http://s3.amazonaws.com/c2c-web-site/resources/certification/standard/C2CCertified_V3_Overview_121113.pdf</a></p> <p><a href="https://online-learning.tudelft.nl/courses/delft-design-approach/">https://online-learning.tudelft.nl/courses/delft-design-approach/</a></p>
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### 1.2.6 Information retrieval 5h LAB

COURSE CONTENT	<p>Practical exercises on the use of popular web-search engines, suitable for research, e.g.: ScienceDirect, Google Scholar, Chemical Abstracts, patent databases.</p> <p>The tools used during the course should take into account the licensing and the equipment of the university running the program.</p>
WEB-LINKS	<p><a href="http://www.sciencedirect.com">http://www.sciencedirect.com</a></p> <p><a href="https://www.cas.org/">https://www.cas.org/</a></p> <p><a href="http://www.ncbi.nlm.nih.gov/pubmed/">http://www.ncbi.nlm.nih.gov/pubmed/</a></p> <p><a href="http://worldwide.espacenet.com/">http://worldwide.espacenet.com/</a></p> <p><a href="http://patft.uspto.gov/">http://patft.uspto.gov/</a></p> <p><a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/3%20Information%20gathering%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/3%20Information%20gathering%20-%20presentation_v1-0.pdf</a></p> <p><a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a></p>

### 1.2.7 Sport 15h

### 1.3 PROGRAM of 3<sup>rd</sup> semester

#### 1.3.1 Mathematics 30h L + 30h E

COURSE CONTENT	matrices and linear maps; matrix-multiplication; determinants; inverse matrices; linear systems of equations; examples of solution of differential equations; eigenvalues and eigenvectors, diagonalization; vector spaces with inner product, orthogonal projection; mathematics for data analysis
WEB-LINKS	<p><a href="https://alison.com/courses/Advanced-Mathematics-1">https://alison.com/courses/Advanced-Mathematics-1</a></p> <p>MIT Open Courseware: <a href="http://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/">http://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/</a></p>

#### 1.3.2 Organic chemistry 30h L + 60h LAB

COURSE CONTENT	systematics of organic compounds: aliphatic and aromatic hydrocarbons, alcohols, aldehydes, ketones, ethers, amines, carboxylic acids, esters, heterocyclic compounds, hydrocarbons, aminoacids; isomers; basic reaction mechanisms: addition, substitution, elimination; acidity and basicity of organic compounds
WEB-LINKS	<p>MIT Open Courseware:</p> <p><a href="http://ocw.mit.edu/courses/chemistry/5-12-organic-chemistry-i-spring-2003/">http://ocw.mit.edu/courses/chemistry/5-12-organic-chemistry-i-spring-2003/</a></p> <p><a href="http://ocw.mit.edu/courses/chemistry/5-13-organic-chemistry-ii-fall-2003/">http://ocw.mit.edu/courses/chemistry/5-13-organic-chemistry-ii-fall-2003/</a></p> <p><a href="http://ocw.mit.edu/courses/chemistry/5-43-advanced-organic-chemistry-spring-2007/">http://ocw.mit.edu/courses/chemistry/5-43-advanced-organic-chemistry-spring-2007/</a></p>

### 1.3.3 Thermodynamics 30h L + 30h E

COURSE CONTENT	<p>temperature and heat; the first and second law of thermodynamics; statistical equilibrium; entropy and temperature; microcanonical, canonical ensemble and grand canonical ensemble; the Boltzmann distribution; the harmonic oscillator; the perfect classical gas; Maxwell's kinetic theory of molecules; equipartition</p>
WEB-LINKS	<p><a href="http://www.rsc.org/learn-chemistry/resource/res00002077/titration-screen-experiment">http://www.rsc.org/learn-chemistry/resource/res00002077/titration-screen-experiment</a></p> <p><a href="https://www.youtube.com/playlist?list=PLpGHT1n4-mAsJ123W3fjPzvIDHOvIhHA0">https://www.youtube.com/playlist?list=PLpGHT1n4-mAsJ123W3fjPzvIDHOvIhHA0</a></p> <p>MIT Open Courseware:</p> <p><a href="http://ocw.mit.edu/courses/chemistry/5-60-thermodynamics-kinetics-spring-2008/">http://ocw.mit.edu/courses/chemistry/5-60-thermodynamics-kinetics-spring-2008/</a></p> <p><a href="http://ocw.mit.edu/courses/physics/8-044-statistical-physics-i-spring-2013/index.htm">http://ocw.mit.edu/courses/physics/8-044-statistical-physics-i-spring-2013/index.htm</a></p>

### 1.3.4 Physics: 60h LAB

### 1.3.5 Introduction to nanotechnology 30h L

COURSE CONTENT	<p>historical perspective; classification of nanoparticles; methods of preparation, properties and applications of nanomaterials, 0D, 1D, 2D, 3D structures (quantum dots, nanofibers, nanorods, nanotubes, nanolayers, nanoparticles); bottom-up synthesis and molecular self-assembly; selected fields in nanotechnology (nanomedicine, nanoelectronics, nanotechnology in biology and environment)</p>
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WEB-LINKS	<p>“Nanotechnologies. Principles, Applications, Implications and Hand-on Activities. A compendium for educators.” European Commission, EUR 24957</p> <p>NanoHub:  <a href="https://nanohub.org/resources/7313#series">https://nanohub.org/resources/7313#series</a>  <a href="https://nanohub.org/resources/10888#series">https://nanohub.org/resources/10888#series</a>  <a href="https://nanohub.org/resources/101#series">https://nanohub.org/resources/101#series</a></p> <p><a href="http://nanoyou.eu/en/nano-educators/tools.html?view=alphacontent">http://nanoyou.eu/en/nano-educators/tools.html?view=alphacontent</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/1%20The%20complex%20world%20of%20nanomaterials_presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/1%20The%20complex%20world%20of%20nanomaterials_presentation_v1-0.pdf</a></p> <p><a href="http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials">http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials</a></p> <p><a href="http://edunano-lms.tau.ac.il/">http://edunano-lms.tau.ac.il/</a></p> <p><a href="http://www.swissnanocube.ch/en/home/">http://www.swissnanocube.ch/en/home/</a></p> <p><a href="http://www.swissnanocube.ch/nanorama/?L=3">http://www.swissnanocube.ch/nanorama/?L=3</a></p> <p>Journal of Nano Education: <a href="http://www.aspbs.com/jne.htm">http://www.aspbs.com/jne.htm</a></p>
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**1.3.6 Foreign language 30h E**

**1.3.7 Sport 30h**

**1.4 PROGRAM of 4<sup>th</sup> semester**

**1.4.1. Optics & Waves 30h L + 30h E**

COURSE CONTENT	<p>geometrical optics; optical instruments; waves: mechanical, sound, and electromagnetic; superposition of waves; light propagation; interference and diffraction; photonics; new frontiers in optics and photonics</p>
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WEB-LINKS	<p>MIT Open Courseware:</p> <p><a href="http://ocw.mit.edu/courses/physics/8-03sc-physics-iii-vibrations-and-waves-fall-2012/index.htm">http://ocw.mit.edu/courses/physics/8-03sc-physics-iii-vibrations-and-waves-fall-2012/index.htm</a></p> <p><a href="http://ocw.mit.edu/courses/physics/8-03-physics-iii-spring-2003/">http://ocw.mit.edu/courses/physics/8-03-physics-iii-spring-2003/</a></p> <p>NanoHub:</p> <p><a href="https://nanohub.org/resources/18685">https://nanohub.org/resources/18685</a></p> <p><a href="https://nanohub.org/resources/21370">https://nanohub.org/resources/21370</a></p>
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#### 1.4.2 Physical chemistry 30h L + 45h E

COURSE CONTENT	<p>structure and symmetry of molecules; states of matter, short repetition from thermodynamics including laws of thermodynamics, spontaneity; phase equilibria in one-, two-, and three component systems; ideal and real solutions; colligative properties, chemical potential; chemical equilibria; electrolyte solutions; equilibria in electrochemical reactions, electrochemical cells, electromotive force, reduction potentials; kinetics of simple reactions; diffusion in liquids; surface properties (adsorption, surface tension)</p>
WEB-LINKS	<p>OpenChemistry Lecture Videos:</p> <p><a href="https://ps.uci.edu/content/general-chemistry-1b">https://ps.uci.edu/content/general-chemistry-1b</a></p> <p><a href="https://ps.uci.edu/content/chem-131c-physical-chemistry-thermodynamics-and-chemical-dynamics">https://ps.uci.edu/content/chem-131c-physical-chemistry-thermodynamics-and-chemical-dynamics</a></p> <p><a href="https://itunes.apple.com/us/itunes-u/chemistry-442-physical-chemistry/id765762497?mt=10&amp;ign-mpt=uo%3D8">https://itunes.apple.com/us/itunes-u/chemistry-442-physical-chemistry/id765762497?mt=10&amp;ign-mpt=uo%3D8</a></p> <p><a href="https://itunes.apple.com/us/itunes-u/chemistry-444-physical-chemistry/id766910247?mt=10&amp;ign-mpt=uo%3D8">https://itunes.apple.com/us/itunes-u/chemistry-444-physical-chemistry/id766910247?mt=10&amp;ign-mpt=uo%3D8</a></p>

### 1.4.3 Biochemistry 30h L + 60h LAB

COURSE CONTENT	<p>macromolecules: carbohydrates, proteins, lipids, RNA and DNA; membranes; cells and organelles; respiration; photosynthesis; metabolism; enzymes; major signaling pathways; basic concepts of genetics; replication; transcription; translation; mutations; gene regulation in development and cancer; basics of DNA technology, stem cells</p>
WEB-LINKS	<p>MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/index.htm">http://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/index.htm</a></p> <p><a href="http://ocw.mit.edu/courses/chemistry/5-08j-biological-chemistry-ii-spring-2004/index.htm">http://ocw.mit.edu/courses/chemistry/5-08j-biological-chemistry-ii-spring-2004/index.htm</a></p> <p><a href="http://ocw.mit.edu/courses/biology/7-51-graduate-biochemistry-fall-2001/lecture-notes/">http://ocw.mit.edu/courses/biology/7-51-graduate-biochemistry-fall-2001/lecture-notes/</a></p>

### 1.4.4 Nanobiology/ Bio-nanotechnology 30h L

COURSE CONTENT	<p>what is nanobiotechnology; nanoparticles and scale of bio-objects; typical nanostructures; protein-based nanostructures; nanoparticles in biological labeling and cellular imaging; biochips applications in nano-scale detection; lab-on-a-chip devices; in-vivo imaging; molecular imaging and therapy; medical applications of nanoparticles; nanoparticles cytotoxicity; nanoparticles and nanogels for diagnosis and as drug carriers; tissue engineering; molecular imprinting in polymers and its application in medicine; microchips in diagnosis and therapy; nanomedicine; nanosurgery; nanodentistry; future of nanomedicine: nanorobots and nanodevices</p>
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WEB-LINKS	<p> <a href="https://nanohub.org/resources/11965">https://nanohub.org/resources/11965</a>  <a href="https://nanohub.org/resources/16737">https://nanohub.org/resources/16737</a>  <a href="https://nanohub.org/resources/4807">https://nanohub.org/resources/4807</a>            MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/biological-engineering/20-462j-molecular-principles-of-biomaterials-spring-2006/">http://ocw.mit.edu/courses/biological-engineering/20-462j-molecular-principles-of-biomaterials-spring-2006/</a>  <a href="http://www.slideshare.net/jagadeeshkodithyala/nano-technology-in-restorative-dentistry?qid=8219ed75-e401-41ca-a502-23183b0816d2&amp;v=qf1&amp;b=&amp;from_search=6">http://www.slideshare.net/jagadeeshkodithyala/nano-technology-in-restorative-dentistry?qid=8219ed75-e401-41ca-a502-23183b0816d2&amp;v=qf1&amp;b=&amp;from_search=6</a>  <a href="http://www.slideshare.net/divs000/nanotechnology-in-dentistry?related=1">http://www.slideshare.net/divs000/nanotechnology-in-dentistry?related=1</a>  <a href="http://www.slideshare.net/shoeb786/nano-medicine-50661167?qid=3a3656d0-9dc0-4716-a5e1-b2ee17f3fe0a&amp;v=qf1&amp;b=&amp;from_search=7">http://www.slideshare.net/shoeb786/nano-medicine-50661167?qid=3a3656d0-9dc0-4716-a5e1-b2ee17f3fe0a&amp;v=qf1&amp;b=&amp;from_search=7</a> </p>
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#### 1.4.5 EU regulations regarding nanomaterials 5h L

COURSE CONTENT	<p>overview of the major EU legislation documents regarding nanomaterials and nanotechnology; definition of nanomaterial; regulatory aspects of nanomaterials; a code for conduct for responsible nanosciences and nanotechnologies research</p>
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WEB-LINKS	<p> <a href="http://ec.europa.eu/environment/chemicals/nanotech/index_en.htm">http://ec.europa.eu/environment/chemicals/nanotech/index_en.htm</a>  <a href="http://ec.europa.eu/environment/waste/legislation/">http://ec.europa.eu/environment/waste/legislation/</a>  <a href="http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf">http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf</a>  <a href="http://www.nanotechia.org/sectors/recycling-waste">http://www.nanotechia.org/sectors/recycling-waste</a>  <a href="https://www.cen.eu/about/Pages/default.aspx">https://www.cen.eu/about/Pages/default.aspx</a>  <a href="http://www.cencenelec.eu/research/Pages/default.aspx">http://www.cencenelec.eu/research/Pages/default.aspx</a>  <a href="https://osha.europa.eu/en/legislation/directives/exposure-to-chemical-agents-and-chemical-safety/">https://osha.europa.eu/en/legislation/directives/exposure-to-chemical-agents-and-chemical-safety/</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/7%20Basics%20on%20chemical%20regulation%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/7%20Basics%20on%20chemical%20regulation%20-%20presentation_v1-0.pdf</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a>  <a href="http://www.rivm.nl/bibliotheek/rapporten/2014-0157.html">http://www.rivm.nl/bibliotheek/rapporten/2014-0157.html</a> </p>
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#### 1.4.6 Foreign language 30h E

#### 1.4.7 Sport 30h

### 1.5 PROGRAM of 5<sup>th</sup> semester

#### 1.5.1 Medicine and human biology 30h L

COURSE CONTENT	<p>                     basics of anatomy; integumentary system; human skeleton; muscular system; cardiovascular system; human gastrointestinal tract; excretory system; endocrine system; lymphatic system; reproductive system; nervous system; immune system; evolution; diversity of living organisms; heredity                 </p>
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WEB-LINKS	<p><a href="http://www.youtube.com/watch?v=S9WtBRNyds0">http://www.youtube.com/watch?v=S9WtBRNyds0</a></p> <p>University of Massachusetts: <a href="https://itunes.apple.com/us/itunes-u/intro-to-immunology-biol-378/id476313031?uo=8&amp;at=10lqkA">https://itunes.apple.com/us/itunes-u/intro-to-immunology-biol-378/id476313031?uo=8&amp;at=10lqkA</a></p>
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### 1.5.2 Introduction to statistics & computer-aided calculus 15h L + 15h E

COURSE CONTENT	<p>data collection; displaying data: bar, chart, histogram charts etc.; arithmetic mean; median; mode; normal distribution; standard deviation; correlation; regression; linear plots; inference; hypothesis testing; significance tests; confidence intervals</p>
WEB-LINKS	<p><a href="http://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability-and-statistics-spring-2014/">http://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability-and-statistics-spring-2014/</a></p> <p><a href="http://ocw.mit.edu/resources/res-18-005-highlights-of-calculus-spring-2010/">http://ocw.mit.edu/resources/res-18-005-highlights-of-calculus-spring-2010/</a></p> <p><a href="http://onlinestatbook.com/Online_Statistics_Education.pdf">http://onlinestatbook.com/Online_Statistics_Education.pdf</a></p> <p><a href="https://online-learning.tudelft.nl/courses/data-analysis-to-the-max/">https://online-learning.tudelft.nl/courses/data-analysis-to-the-max/</a></p> <p><a href="http://ps.uci.edu/content/chem-5-scientific-computing-skills">http://ps.uci.edu/content/chem-5-scientific-computing-skills</a></p>

### 1.5.3 Methods of nanomaterials' characterization 30h L + 45h LAB

COURSE CONTENT	<p>Major techniques of characterization of nanostructured materials: X-ray and neutron diffraction, photoelectron spectroscopies; Mosbauer; porosimetry (BET); IR and Raman laser spectrometry; electrochemical techniques; analytical techniques related to the electron microscopies: SEM, TEM, AFM, STM</p>
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WEB-LINKS	<p><a href="https://class.coursera.org/analyticalchem-001/lecture/preview">https://class.coursera.org/analyticalchem-001/lecture/preview</a></p> <p><a href="https://ps.uci.edu/content/chem-131b-physical-chemistry-molecular-structure-and-elementary-statistical-mechanics">https://ps.uci.edu/content/chem-131b-physical-chemistry-molecular-structure-and-elementary-statistical-mechanics</a></p> <p><a href="http://ocw.uc3m.es/ciencia-e-oin/materials-science-and-engineering/lecture-notes-1/Chapter_2_1.pdf/view">http://ocw.uc3m.es/ciencia-e-oin/materials-science-and-engineering/lecture-notes-1/Chapter_2_1.pdf/view</a></p>
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#### 1.5.4 Nanoparticles & environment 30h L + 15h P

COURSE CONTENT	<p>studying nanoparticles in the environment; understanding environmental concerns and priorities in EU waste legislation; recovering nanoparticles from products; recovering nanoparticles from the environment; bio-waste and methods of their utilization: composting, anaerobic digestion, landfilling, incineration; environmental effects of waste disposal; energetic efficiency; greenhouse gases; rare materials release; hazardous substances; public health related issues; occupational health related issues</p>
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WEB-LINKS	<p>NANONET web page:  <a href="http://www.birmingham.ac.uk/schools/gees/research/projects/nanonet/index.aspx">http://www.birmingham.ac.uk/schools/gees/research/projects/nanonet/index.aspx</a>  <a href="http://www.azonano.com/article.aspx?ArticleID=3062">http://www.azonano.com/article.aspx?ArticleID=3062</a>  <a href="http://nanocap.eu/Flex/Site/Pagefdb.html?PageID=20815">http://nanocap.eu/Flex/Site/Pagefdb.html?PageID=20815</a>  <a href="http://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/index.htm#6">http://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/index.htm#6</a>  <a href="http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf">http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf</a>  <a href="http://ec.europa.eu/environment/waste/studies/index.htm">http://ec.europa.eu/environment/waste/studies/index.htm</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/2%20Basics%20of%20nanotoxicology%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/2%20Basics%20of%20nanotoxicology%20-%20presentation_v1-0.pdf</a>            MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/engineering-systems-division/esd-123j-systems-perspectives-on-industrial-ecology-spring-2006/">http://ocw.mit.edu/courses/engineering-systems-division/esd-123j-systems-perspectives-on-industrial-ecology-spring-2006/</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/6%20Ways%20to%20approach%20nanomaterial%20toxicity%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/6%20Ways%20to%20approach%20nanomaterial%20toxicity%20-%20presentation_v1-0.pdf</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a>  <a href="http://www.nanodiode.eu/project/presentations/">http://www.nanodiode.eu/project/presentations/</a>  <a href="http://www.rivm.nl/bibliotheek/rapporten/2014-0157.html">http://www.rivm.nl/bibliotheek/rapporten/2014-0157.html</a></p>
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### 1.5.5 Recycling of nanomaterials 30h L

COURSE CONTENT	<p>waste classification; waste categories: mineral and solidified materials, recyclable waste, animal and vegetal waste, household waste; trends in waste generation; environmental impacts of products and materials; new concepts in waste streams: waste hierarchy, life-cycle thinking, resource efficiency, ecodesign; legal regulations in the waste management; extender producer responsibility concept; examples of directives regarding waste: Batteries Directive, Packaging Directive, End-of-Life Vehicles Directive, WEEE Directive; methods of waste disposal and recycling of materials; waste management options and climate change; environmental effects of waste directives: energy efficiency and use, greenhouse gases emissions, release of hazardous substances, economic: market and competitiveness, operational costs, R&amp;D and innovation, and social aspects of waste directives: public and occupational health, jobs</p>
WEB-LINKS	<p><a href="http://www.programy.p.lodz.pl/WSSIDKreator/przedmiot.jsp?l=en&amp;idPrzedmiotu=148090&amp;s=4&amp;j=0&amp;w=Nanotechnology">http://www.programy.p.lodz.pl/WSSIDKreator/przedmiot.jsp?l=en&amp;idPrzedmiotu=148090&amp;s=4&amp;j=0&amp;w=Nanotechnology</a></p> <p><a href="http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf">http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf</a></p> <p><a href="http://www.nanotechia.org/sectors/recycling-waste">http://www.nanotechia.org/sectors/recycling-waste</a></p> <p>MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/nuclear-engineering/22-081j-introduction-to-sustainable-energy-fall-2010/">http://ocw.mit.edu/courses/nuclear-engineering/22-081j-introduction-to-sustainable-energy-fall-2010/</a></p>

### 1.5.6 Industry internship

### 1.5.7 Foreign language – scientific terminology for nanoscience and nanotechnology 30h E

## 1.6 PROGRAM of 6<sup>th</sup> semester



**1.6.1 Metallic nanomaterials 30h L / Polymeric nanomaterials 30h L /**

**Ceramic nanomaterials / Cosmetic nanomaterials 30h L**

COURSE CONTENT	<p>For each of the class of materials: material functionalities: biocompatibility, transparency; wear and creep resistance; nanocomposites; main synthesis and processing methods; most important characterization techniques; behavior of nanomaterials: mechanical and thermal properties including strength and toughness; main modeling and simulation techniques; major applications and perspective usage</p>
WEB-LINKS	<p>Videos of the European Training Action on Ceramic Nanocomposites; materials from FP6 European project “Structural Ceramic Nanocomposites for Top-End Functional Applications-IP NANOKER”:  <a href="http://ion.chem.usu.edu/~tapaskar/2013/Jan-26.htm">http://ion.chem.usu.edu/~tapaskar/2013/Jan-26.htm</a>  <a href="http://ocw.uc3m.es/ciencia-e-oin/materials-science-and-engineering/lecture-notes-1/Chapter_2_1.pdf/view">http://ocw.uc3m.es/ciencia-e-oin/materials-science-and-engineering/lecture-notes-1/Chapter_2_1.pdf/view</a>  <a href="http://ec.europa.eu/growth/sectors/cosmetics/products/nanomaterials/index_en.htm">http://ec.europa.eu/growth/sectors/cosmetics/products/nanomaterials/index_en.htm</a>          “Nanotechnologies. Principles, Applications, Implications and Hand-on Activities. A compendium for educators.” European Commission, EUR 24957</p>

**1.6.2 Diploma work (P)**

**1.6.3 Regulations, standardization, and management 15h L**

COURSE CONTENT	<p>terminology and definitions regarding standardization; concepts of quality and standards; recognized European Standardization Organizations (ESOs): CEN, CENELEC, ETSI; benefits of ISO International Standards; ISO standards in action; management system standards; basics of quality management systems; documentation</p>
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WEB-LINKS	<p><a href="http://www.iso.org/iso/home.html">http://www.iso.org/iso/home.html</a></p> <p><a href="https://www.cen.eu/work/products/Pages/default.aspx">https://www.cen.eu/work/products/Pages/default.aspx</a></p> <p><a href="https://www.is.mpg.de/7483265/GENNESYS_2009-Chap06.pdf">https://www.is.mpg.de/7483265/GENNESYS_2009-Chap06.pdf</a></p> <p><a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/7%20Basics%20on%20chemical%20regulation%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/7%20Basics%20on%20chemical%20regulation%20-%20presentation_v1-0.pdf</a></p> <p><a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a></p> <p><a href="https://online-learning.tudelft.nl/courses/leadership-for-engineers/">https://online-learning.tudelft.nl/courses/leadership-for-engineers/</a></p>
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#### 1.6.4 Foreign language – scientific terminology for nanoscience and nanotechnology 30h E

## 2 Model curriculum for the 2<sup>nd</sup> degree studies in Nanotechnology

(4 semesters = 2 years)

The M.Sc. graduates degree will be qualified to work in positions which require the following professional skills:

- the ability to design nanomaterials with specific properties useful in different areas, e.g. in medicine,
- the ability to design, investigate and develop methods of synthesis of nanomaterials,
- the ability to develop and plan selection of research methods appropriate for the intended goal,
- to supervise technological processes carried out in chemical industry connected with nanotechnology
- the ability to carry out independent investigation of nanomaterials.
- the ability to discuss technical and scientific issues connected with nanotechnology

The M.Sc. graduates possess additional competencies:

- the ability to work in a group and to organize their work
- the ability to use a foreign language
- the ability to define priorities and manage time
- other abilities acquired during research and development projects in their countries and abroad

In the course of the 2<sup>nd</sup> degree studies students are introduced into specific topics of nanotechnology. The specialized knowledge is build on the basis of the introductory, background knowledge acquired during the 1<sup>st</sup> degree courses. The graduated will be well qualified to work in national/international companies and research institutions, owing to experience gained during the studies and preparation of MSc thesis. They can continue their education at the third cycle studies.

## 2.1 PROGRAM of 1<sup>st</sup> semester

### 2.1.1 Physics, chemistry, and biology of low-dimensional systems 30h L

COURSE CONTENT	<p>physics in low dimensions; quantization; observation conditions of quantum-dimensional systems; charge-carriers in low-dimensional electronic systems; quantum wells; nano-peapods; quantum dots, quantum wires; tunneling effects</p> <p>size-scale of typical chemical species; typical nanostructures: carbon nanotubes, fullerenes, nano peapods; quantum dots, semiconductor nanoparticles, metal-based nanostructures, nanowires; self assembly; polymer nanocomposites, nanofillers, nanopowders in polymer technology; soot; silica; metal oxides; pigments; layered materials; semiconductor nanoparticles; metal-based nanostructures</p> <p>size scale of biological objects; typical protein-based nanostructures; nanomotors: bacterial (e. coli), mammalian (myosin family); nanoparticles in biological labeling and cellular imaging; nanoparticles cytotoxicity</p>
WEB-LINKS	<p>NanoHub: <a href="https://nanohub.org/resources/22602">https://nanohub.org/resources/22602</a></p> <p><a href="http://www.it.kth.se/courses/2B1700/Quantum_wells_wires_dots-lecture_8.pdf">http://www.it.kth.se/courses/2B1700/Quantum_wells_wires_dots-lecture_8.pdf</a></p> <p><a href="http://www.it.kth.se/courses/2B1700/2010/Transport%20properties-%20lecture%209.pdf">http://www.it.kth.se/courses/2B1700/2010/Transport%20properties-%20lecture%209.pdf</a></p> <p><a href="http://www.it.kth.se/courses/2B1700/2010/Optical%20properties-%20lecture%2010.pdf">http://www.it.kth.se/courses/2B1700/2010/Optical%20properties-%20lecture%2010.pdf</a></p> <p><a href="https://courses.cit.cornell.edu/ece407/Lectures/Lectures.htm">https://courses.cit.cornell.edu/ece407/Lectures/Lectures.htm</a></p> <p>youtube.com:</p> <p>Electronic and Optical Properties of Nanostructures Lecture @UMichigan: <a href="https://www.youtube.com/watch?v=Lg4XYdmVXgc">https://www.youtube.com/watch?v=Lg4XYdmVXgc</a></p>

### 2.1.2 Design of nanomaterials: I. Computer-based design of nanomaterials 30h L + 30h LAB

COURSE CONTENT	<p>different time and length scales; definition of the model; continuum methods; atomistic and molecular simulation; molecular mechanics; molecular dynamics; principles of quantum mechanics; the quantum gas; fermions and bosons; the Planck spectrum of black-body radiation; emission of heat radiation; the Stefan-Boltzmann law; the Fermi gas; Bose-Einstein condensate; band-gap structure of solids; ab-initio methods; semi-empirical methods; DFT methods</p> <p>Laboratory exercises should and be adjusted to the equipment of the University running the program.</p>
WEB-LINKS	<p><a href="http://ocw.mit.edu/courses/materials-science-and-engineering/3-021j-introduction-to-modeling-and-simulation-spring-2012/">http://ocw.mit.edu/courses/materials-science-and-engineering/3-021j-introduction-to-modeling-and-simulation-spring-2012/</a></p> <p>NanoHub: <a href="https://nanohub.org/resources/22400">https://nanohub.org/resources/22400</a></p> <p><a href="https://online-learning.tudelft.nl/courses/topology-condensed-matter-tying-quantum/">https://online-learning.tudelft.nl/courses/topology-condensed-matter-tying-quantum/</a></p>

### 2.1.3 Methods of characterization of nanomaterials: microscopy, spectroscopy, surface studies, crystallography 30h L + 1 laboratory project

COURSE CONTENT	<p>Major techniques of characterization of nanostructured materials: X-ray and neutron diffraction; Mössbauer spectroscopy; photoelectron spectroscopies (XPS and UPS); Auger spectroscopy; SANS techniques; techniques based on the use of synchrotron radiation: XANES, EXAFS, and magnetic dichroism; magnetic characterization of nanosystems (SQUID, VSM, MOKE); Hall probes and micro-SQUIDS; Quartz Crystal Microbalance; electrochemical techniques. Electron Microscopy (SEM and TEM); Atomic Force Microscopy and Magnetic Force Microscopy; Scanning Tunneling Microscopy</p> <p>Laboratory exercises should be adjusted to the equipment of the University running the program.</p>
WEB-LINKS	<p>NanoHub: <a href="https://nanohub.org/groups/characterization">https://nanohub.org/groups/characterization</a></p> <p><a href="https://ps.uci.edu/content/chem-131b-physical-chemistry-molecular-structure-and-elementary-statistical-mechanics">https://ps.uci.edu/content/chem-131b-physical-chemistry-molecular-structure-and-elementary-statistical-mechanics</a></p> <p><a href="https://class.coursera.org/analyticalchem-001/lecture/preview">https://class.coursera.org/analyticalchem-001/lecture/preview</a></p>

#### 2.1.4 Communication through modern media 5h LAB + P

COURSE CONTENT	<p>communication strategy: what to communicate; to whom; how to do it effectively; introduction to different types of social media; web 2.0 tools; blogging; videoblogging; slide-share opportunities; creating professional profiles on popular social media (e.g. ResearchGate, LinkedIn, Facebook, Twitter, skype)</p>
WEB-LINKS	<p><a href="https://itunes.apple.com/us/course/branding-content-social-media/id824354707?ign-mpt=uo%3D8">https://itunes.apple.com/us/course/branding-content-social media/id824354707?ign-mpt=uo%3D8</a></p>

#### 2.1.5 Safety and clean-room good practices 5h

COURSE CONTENT	<p>basic introduction to clean-room: what is clean-room and what is contamination; sources of contamination: facilities, people, fluids, tool generated, product generated; key elements of contamination control: HEPA filters; clean-room architecture, clean-room garments, filtration, cleaning, humans in clean-room, commodities, cosmetics, measurements, instrumentation, electrostatic discharge; cleaning procedures; general regulations: recommendations and prohibited actions</p> <p>Regarding safety issues, the proposed course should extend the content of 1.1.7 course.</p>
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WEB-LINKS	<p><a href="http://www.coastwidelabs.com/Technical%20Articles/Cleaning%20the%20Cleanroom.htm">http://www.coastwidelabs.com/Technical%20Articles/Cleaning%20the%20Cleanroom.htm</a></p> <p><a href="http://www.slideshare.net/m0rtsl4k/2013-guide-to-a-contamination-free-cleanroom">http://www.slideshare.net/m0rtsl4k/2013-guide-to-a-contamination-free-cleanroom</a></p> <p><a href="http://www.slideshare.net/sidcalayag/basic-cleanroom-protocol?related=1">http://www.slideshare.net/sidcalayag/basic-cleanroom-protocol?related=1</a></p> <p><a href="http://www.slideshare.net/axmedaxundov/cleanroom-classification-design-and?related=2">http://www.slideshare.net/axmedaxundov/cleanroom-classification-design-and?related=2</a></p> <p><a href="http://www.slideshare.net/HeidiTuomi/r3-naantali?related=3">http://www.slideshare.net/HeidiTuomi/r3-naantali?related=3</a></p> <p><a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/5%20Derivation%20of%20control%20strategies%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/5%20Derivation%20of%20control%20strategies%20-%20presentation_v1-0.pdf</a></p> <p><a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a></p>
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### 2.1.6 Nanoparticles and environment 5h

COURSE CONTENT	<p>This course is a recapitulation of the 1.5.4 course.</p> <p>understanding environmental concerns and priorities in EU waste legislation; recovering nanoparticles from products and environment; environmental effects of waste disposal; energetic efficiency; greenhouse gases; rare materials release; hazardous substances</p>
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WEB-LINKS	<p>NANONET web page:  <a href="http://www.birmingham.ac.uk/schools/gees/research/projects/nanonet/index.aspx">http://www.birmingham.ac.uk/schools/gees/research/projects/nanonet/index.aspx</a>  <a href="http://www.azonano.com/article.aspx?ArticleID=3062">http://www.azonano.com/article.aspx?ArticleID=3062</a>  <a href="http://nanocap.eu/Flex/Site/Pagefdb.html?PageID=20815">http://nanocap.eu/Flex/Site/Pagefdb.html?PageID=20815</a>  <a href="http://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/index.htm#6">http://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/index.htm#6</a>  <a href="http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf">http://ec.europa.eu/environment/waste/studies/pdf/Coherence_waste_legislation.pdf</a>  <a href="http://ec.europa.eu/environment/waste/studies/index.htm">http://ec.europa.eu/environment/waste/studies/index.htm</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/6%20Ways%20to%20approach%20nanomaterial%20toxicity%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/6%20Ways%20to%20approach%20nanomaterial%20toxicity%20-%20presentation_v1-0.pdf</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a></p>
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### 2.1.7 Regulations: quality management 5h

COURSE CONTENT	<p>what is quality management; main components of quality management: quality planning, quality control, quality assurance, quality improvement; principles of International Standard for Quality management (ISO 9001:2008)</p>
WEB-LINKS	<p><a href="http://ocw.mit.edu/courses/sloan-school-of-management/15-279-management-communication-for-undergraduates-spring-2005/">http://ocw.mit.edu/courses/sloan-school-of-management/15-279-management-communication-for-undergraduates-spring-2005/</a>  <a href="http://www.slideshare.net/qualitymanagement/designing-a-quality-management-system">http://www.slideshare.net/qualitymanagement/designing-a-quality-management-system</a>  <a href="http://www.slideshare.net/pananth1/quality-english?related=1">http://www.slideshare.net/pananth1/quality-english?related=1</a>  <a href="http://www.slideshare.net/Pvandijk/quality-management-system-5791313?related=2">http://www.slideshare.net/Pvandijk/quality-management-system-5791313?related=2</a></p>



### 2.1.8 Elective courses

## 2.2 PROGRAM of 2<sup>nd</sup> semester

### 2.2.1 Design of nanomaterials: II. Preparation of nanomaterials 30h L + 60h LAB

COURSE CONTENT	<p>fabrication methods of nanostructured materials: top-down and bottom-up approaches; fabrication methods of thin films, mono and multilayered films: Chemical vapour deposition (CVD) and Physical Vapour Deposition (PVD); Liquid Phase deposition (cast films, spin-coating, spray coating, ink printing, dip-coating, layer-by-layer, Langmuir-Blodgett, liquid-phase epitaxy, etc.); solid Phase deposition, electrodeposition; optical lithography; Electron Beam lithography; Ion Beam lithography; Scanning Probe lithography; Nanoimprint lithography</p> <p>Laboratory exercises should comprise synthesis of different types of nanomaterials (synthesis of metallic nanoparticles) and be adjusted to the equipment of the University running the program.</p>
WEB-LINKS	<p>NanoHub: <a href="https://nanohub.org/resources/1914">https://nanohub.org/resources/1914</a></p> <p>Videos of the European Training Action on Ceramic Nanocomposites</p> <p><a href="http://www.it.kth.se/courses/2B1700/2010/HVPE%20MOVPE%20MBE-lecture%204.pdf">http://www.it.kth.se/courses/2B1700/2010/HVPE%20MOVPE%20MBE-lecture%204.pdf</a></p> <p><a href="http://www.it.kth.se/courses/2B1700/2010/Processing%20techniques%20-%20lecture%2015.pdf">http://www.it.kth.se/courses/2B1700/2010/Processing%20techniques%20-%20lecture%2015.pdf</a></p> <p>youtube.com: Lectures on Nanomanufacturing by John Hart @UMichigan: <a href="https://www.youtube.com/watch?v=lyhjoYen5rl">https://www.youtube.com/watch?v=lyhjoYen5rl</a></p>

### 2.2.2 Methods of characterization of nanomaterials: microscopy, spectroscopy, surface studies: 2 laboratory projects

Laboratory exercises should comprise synthesis of different types of nanomaterials (synthesis of metallic nanoparticles) and be adjusted to the equipment of the University running the program.

### 2.2.3 Safety project: design a lab – 30h P

COURSE CONTENT	Students should make a project of a laboratory complying with the current regulations regarding safety at work. The project should include the locations of electricity, gas, and water supply lines; ventilation, laboratory equipment and furniture.
WEB-LINKS	<a href="http://www.tsi.com/uploadedFiles/_Site_Root/Products/Literature/Handbooks/2980330C-LabControlsHandbook.pdf">http://www.tsi.com/uploadedFiles/_Site_Root/Products/Literature/Handbooks/2980330C-LabControlsHandbook.pdf</a>

### 2.2.4 Communication with media 5h E + P

COURSE CONTENT	key principles of communicating research; developing a communication strategy; communicating with journalists; making research appeal to journalists and public; writing a press release; dealing with media interviews
WEB-LINKS	<a href="https://www.youtube.com/playlist?p=PLBE602A6B51B18AC2">https://www.youtube.com/playlist?p=PLBE602A6B51B18AC2</a>

### 2.2.5 Life-cycle of nanoproducts 5h L

COURSE CONTENT	Life-cycle concept; life-cycle of products: introduction, growth, maturity, decline phases; their characteristics; strategies to introduce a product to the market; implications and limitations of life-cycle; examples of life-cycles of selected nanoproducts
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WEB-LINKS	<p><a href="http://www.slideshare.net/7837686478/product-life-cycle-12605019?qid=d83b93b2-2519-4d44-ae3e-0503248d3998&amp;v=default&amp;b=&amp;from_search=4">http://www.slideshare.net/7837686478/product-life-cycle-12605019?qid=d83b93b2-2519-4d44-ae3e-0503248d3998&amp;v=default&amp;b=&amp;from_search=4</a></p> <p>MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/engineering-systems-division/esd-123j-systems-perspectives-on-industrial-ecology-spring-2006/">http://ocw.mit.edu/courses/engineering-systems-division/esd-123j-systems-perspectives-on-industrial-ecology-spring-2006/</a></p> <p>Examples from EU-funded projects:  <a href="https://ec.europa.eu/research/industrial_technologies/pdf/life-cycle-assessment_en.pdf">https://ec.europa.eu/research/industrial_technologies/pdf/life-cycle-assessment_en.pdf</a></p>
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## 2.2.6 Industry Internship

## 2.3 PROGRAM of 3<sup>rd</sup> semester

### 2.3.1 Master Thesis Project: practical and theoretical work

### 2.3.2 Responsible research in innovation 10h L + 20h E – discussion with case studies

COURSE CONTENT	<p>topics for discussions: societal engagement in research and innovation process; transparency in science; open access; gender equality; science with and for society</p>
WEB-LINKS	<p>EU materials on responsible research and innovation; conference materials (<a href="http://www.sis-rri-conference.eu">http://www.sis-rri-conference.eu</a>, <a href="http://gap2.eu/news/science-in-dialogue-conference-on-responsible-research-and-innovation/">http://gap2.eu/news/science-in-dialogue-conference-on-responsible-research-and-innovation/</a>)</p> <p><a href="http://scienceindialogue.dk/documentation">http://scienceindialogue.dk/documentation</a></p> <p>“Ethics and Nanotechnology; Responsible Development of Nanotechnology at Global Level in the 21st Century.” <a href="https://www.lap-publishing.com/catalog/search?search_query=malsch">https://www.lap-publishing.com/catalog/search?search_query=malsch</a></p> <p><a href="https://online-learning.tudelft.nl/courses/responsible-innovation/">https://online-learning.tudelft.nl/courses/responsible-innovation/</a></p> <p><a href="http://www.rri-tools.eu/">http://www.rri-tools.eu/</a></p> <p><a href="http://www.nanodiode.eu/publication/responsible-innovation-ict/">http://www.nanodiode.eu/publication/responsible-innovation-ict/</a></p>

**2.3.3 Entrepreneurship and communication with customers 5h L + 15h E**

COURSE CONTENT	<p>entrepreneurship; scopes and underlying concepts: forecasting, planning, organizing, commanding, coordinating, controlling; managing the work process; key managerial skills; formation and implementation of business policy and strategy</p> <p>basics of communication; key communication skills</p>
WEB-LINKS	<p><a href="http://ocw.mit.edu/courses/media-arts-and-sciences/mas-666-developmental-entrepreneurship-fall-2003/index.htm">http://ocw.mit.edu/courses/media-arts-and-sciences/mas-666-developmental-entrepreneurship-fall-2003/index.htm</a></p> <p><a href="http://ocw.mit.edu/courses/sloan-school-of-management/15-390-new-enterprises-spring-2013/index.htm">http://ocw.mit.edu/courses/sloan-school-of-management/15-390-new-enterprises-spring-2013/index.htm</a></p> <p><a href="http://www.slideshare.net/profjorge_entrep/introduction-to-entrepreneurship-7647382?related=1">http://www.slideshare.net/profjorge_entrep/introduction-to-entrepreneurship-7647382?related=1</a></p> <p><a href="http://www.slideshare.net/DGMediaSchool/how-to-improve-communication-skills-42505007?related=1">http://www.slideshare.net/DGMediaSchool/how-to-improve-communication-skills-42505007?related=1</a></p> <p><a href="http://www.rsc.org/learn-chemistry/resource/res00000948/chemistry-idea-to-market">http://www.rsc.org/learn-chemistry/resource/res00000948/chemistry-idea-to-market</a></p>

**2.3.4 Communication to a scientific audience: Seminar 15h E**

COURSE CONTENT	<p>The course will consist of scientific seminars delivered by the students. It is advised that each student gives at least one presentation during the semester. In this semester, the presentations should present the research topics, which will be investigated during M.Sc. project. In particular theoretical background of the problem including state of the art, research hypothesis, and proposed methodology should be presented. At the beginning of the course, a teacher should indicate what makes a good presentation and instruct students on the appropriate behavior during the scientific discussion.</p> <p>Criteria for the assessment should comprise: preparation of the presentations with the usage of popular programs (e.g. Microsoft Office, latex, etc.); appropriate presentation structure; active participation in the discussion.</p>
WEB-LINKS	n/a

## 2.4 PROGRAM of 4<sup>th</sup> semester

### 2.4.1 Master Thesis Project: practical and theoretical work, culminating in a M. Sc. Thesis

### 2.4.2 Patent law and intellectual property 10h L

COURSE CONTENT	<p>basic definitions; US and European patent regime; eligibility rules for granting a patent; what is patentable; intellectual properties policies; intellectual property infringement: direct, indirect; licensing</p>
WEB-LINKS	<p><a href="http://application.epo.org/wbt/pi-tour/">http://application.epo.org/wbt/pi-tour/</a>  <a href="https://www.epo.org/law-practice/legal-texts/epc.html">https://www.epo.org/law-practice/legal-texts/epc.html</a>  <a href="https://www.epo.org/law-practice/legal-texts/national-law.html">https://www.epo.org/law-practice/legal-texts/national-law.html</a>  <a href="http://www.slideshare.net/ip-dome/european-and-us-patent-law?qid=88b1c1e0-963b-4b02-b7b7-ae8c5ba88b45&amp;v=default&amp;b=&amp;from_search=2">http://www.slideshare.net/ip-dome/european-and-us-patent-law?qid=88b1c1e0-963b-4b02-b7b7-ae8c5ba88b45&amp;v=default&amp;b=&amp;from_search=2</a>  <a href="http://www.slideshare.net/indravi/model-intellectual-property-rights-ipr-policy-for-engineering-institutions?qid=a773e252-48d3-4994-8ca1-950ee41ae379&amp;v=default&amp;b=&amp;from_search=11">http://www.slideshare.net/indravi/model-intellectual-property-rights-ipr-policy-for-engineering-institutions?qid=a773e252-48d3-4994-8ca1-950ee41ae379&amp;v=default&amp;b=&amp;from_search=11</a>  <a href="http://ocw.mit.edu/courses/sloan-school-of-management/15-628j-patents-copyrights-and-the-law-of-intellectual-property-spring-2013/">http://ocw.mit.edu/courses/sloan-school-of-management/15-628j-patents-copyrights-and-the-law-of-intellectual-property-spring-2013/</a></p>

### 2.4.3 Strategy and planning in science and business 5h L + P

COURSE CONTENT	<p>basic definitions: strategy, mission, strategic planning, strategic management, strategic execution; main steps in strategic planning and management; SWOT analysis; risk assessment; risk governance</p>
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WEB-LINKS	<p> <a href="http://www.lynda.com/Business-Business-Skills-tutorials/Strategic-Planning-Fundamentals/183682-2.html?CID=l0:en:ip:se:prosb:s0:0:all:slideshare&amp;returnUrl=http:%2F%2Fwww.slideshare.net%2Fpananth1%2Fquality-english&amp;utm_campaign=14542114_b1_183682&amp;utm_medium=integrated-partnership&amp;utm_source=slideshare&amp;eid=e5226c55511125DF">http://www.lynda.com/Business-Business-Skills-tutorials/Strategic-Planning-Fundamentals/183682-2.html?CID=l0:en:ip:se:prosb:s0:0:all:slideshare&amp;returnUrl=http:%2F%2Fwww.slideshare.net%2Fpananth1%2Fquality-english&amp;utm_campaign=14542114_b1_183682&amp;utm_medium=integrated-partnership&amp;utm_source=slideshare&amp;eid=e5226c55511125DF</a> </p> <p> <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/3%20Information%20gathering%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/3%20Information%20gathering%20-%20presentation_v1-0.pdf</a> </p> <p> <a href="http://www.slideshare.net/cfdmaster/how-to-write-a-swot-analysis-report?qid=dadb154a-6d29-426d-bdd3-f98347c749be&amp;v=default&amp;b=&amp;from_search=3">http://www.slideshare.net/cfdmaster/how-to-write-a-swot-analysis-report?qid=dadb154a-6d29-426d-bdd3-f98347c749be&amp;v=default&amp;b=&amp;from_search=3</a> </p> <p>           MIT Open CourseWare: <a href="http://ocw.mit.edu/courses/sloan-school-of-management/15-912-technology-strategy-fall-2008/">http://ocw.mit.edu/courses/sloan-school-of-management/15-912-technology-strategy-fall-2008/</a> </p> <p> <a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a> </p>
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#### 2.4.4 Communication to a scientific audience: Seminar 15h E

COURSE CONTENT	<p>           The course will consist of scientific seminars delivered by the students. It is advised that each student gives at least one presentation during the semester. Its content should summarize the main findings from the M.Sc. thesis work. At the beginning of the course, a teacher should remind the rules on how to make a good presentation and point out the appropriate behavior during the scientific discussion (see 2.3.21).         </p> <p>           Criteria for the assessment should comprise: preparation of the presentations with the usage of popular programs (e.g. Microsoft Office, latex, etc.); appropriate presentation structure; active participation in the discussion.         </p>
WEB-LINKS	n/a

### **3 Model curriculum for the 3<sup>rd</sup> degree studies in Nanotechnology (4 years maximum)**

The Ph.D. graduates degree will be highly qualified to work in positions which require the following professional skills:

- the ability to solve complex scientific tasks and problems ,
- the ability to discuss scientific issues connected with nanotechnology
- the ability to critically asses the results of research
- the knowledge necessary to apply for research funding and project management

The Ph.D. holders will be highly qualified to work in positions, which require the following professional skills:

- the ability to solve complex scientific tasks and problems ,
- the ability to discuss scientific issues connected with nanotechnology
- the ability to critically asses the results of research
- the knowledge necessary to apply for research funding and project management

In the course of the 3<sup>rd</sup> degree studies the student specializes in a specific topic of nanotechnology. Their expertise increase and the holders of the Ph.D. diploma have a considerable expertise in a particular aspect of nanotechnology. The Ph.D. graduates will be well qualified to work in international companies and research institutions, owing to experience gained during the studies and preparation of PhD thesis.

The 3<sup>rd</sup> degree education is usually country- and university- specific and less formal than during 1<sup>st</sup> and 2<sup>nd</sup> degrees. For this level of studies, our curriculum gives only some indications regarding the training offers, therefore its layout is different from the proposed curricula for 1<sup>st</sup> and 2<sup>nd</sup> degrees. It is believed that all students should attend a lecture introducing them to the basic aspects of nanotechnology, with the emphasis on the domain in which they are specializing. Further specific knowledge should be gathered during elective courses whose domain and content should take into account the particular Ph. D. studies. The following courses might be considered: Advanced physical chemistry; Advanced nanomaterials; Advanced methods of nanomaterials characterization; Integrated course on catalysis; Nanosensors. The program of the 3<sup>rd</sup> degree cycle should also comprise the industrial internship or scientific exchange, and an exhaustive training in “soft skills”.

### 3.1 Introduction to nanotechnology 30h L

<p style="text-align: center;">COURSE CONTENT</p>	<p>The course is intended to be a recapitulation of the course 1.3.5 “Introduction to nanotechnology”, suited to post-graduates. The main focus should be placed on the aspects which will be further deepened by the Ph.D. thesis work of the students participating in the respective Ph.D. program.</p> <p>It may include, among others, topics such as: historical perspective; classification of nanoparticles; methods of preparation, properties and applications of nanomaterials, 0D, 1D, 2D, 3D structures (quantum dots, nanofibers, nanorods, nanotubes, nanolayers, nanoparticles); bottom-up synthesis and molecular self-assembly; major characterization techniques; selected fields in nanotechnology (nanomedicine, nanoelectronics, nanotechnology in biology and environment)</p>
<p style="text-align: center;">WEB-LINKS</p>	<p>“Nanotechnologies. Principles, Applications, Implications and Hand-on Activities. A compendium for educators.” European Commission, EUR 24957</p> <p>NanoHub:  <a href="https://nanohub.org/resources/7313#series">https://nanohub.org/resources/7313#series</a>  <a href="https://nanohub.org/resources/10888#series">https://nanohub.org/resources/10888#series</a>  <a href="https://nanohub.org/resources/101#series">https://nanohub.org/resources/101#series</a></p> <p><a href="http://nanoyou.eu/en/nano-educators/tools.html?view=alphacontent">http://nanoyou.eu/en/nano-educators/tools.html?view=alphacontent</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/1%20The%20complex%20world%20of%20nanomaterials_presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/1%20The%20complex%20world%20of%20nanomaterials_presentation_v1-0.pdf</a></p> <p><a href="http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials">http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials</a></p> <p><a href="http://edunano-lms.tau.ac.il/">http://edunano-lms.tau.ac.il/</a></p> <p><a href="http://www.swissnanocube.ch/en/home/">http://www.swissnanocube.ch/en/home/</a></p> <p><a href="http://www.swissnanocube.ch/nanorama/?L=3">http://www.swissnanocube.ch/nanorama/?L=3</a></p> <p>Journal of Nano Education: <a href="http://www.aspbs.com/jne.htm">http://www.aspbs.com/jne.htm</a></p>

### 3.2 Elective courses depending on the specialization



### 3.3 Transferable “soft skills”

#### 3.3.1 Communication and presentation

COURSE CONTENT	<p>principles of effective communication; defining the audience; structure of the scientific presentation; overview of the popular programs to make a presentation; use of visuals; use of language; introduction to scientific writing; parts of manuscripts; figures and tables; letter to editor; ethical aspects in publishing scientific work</p>
WEB-LINKS	<p><a href="http://www.slideshare.net/SteveStarc/what-is-a-scientific-presentation?qid=ba6e91cd-6794-4885-9ef0-96e9850553fc&amp;v=default&amp;b=&amp;from_search=1">http://www.slideshare.net/SteveStarc/what-is-a-scientific-presentation?qid=ba6e91cd-6794-4885-9ef0-96e9850553fc&amp;v=default&amp;b=&amp;from_search=1</a></p> <p><a href="http://home.thep.lu.se/~bijmens/introduction/silverstein.pdf">http://home.thep.lu.se/~bijmens/introduction/silverstein.pdf</a></p> <p>The Art of Scientific Presentations by A.R. Tanguay, Jr (<a href="https://www.youtube.com/watch?v=Hig2_CqNcGw">https://www.youtube.com/watch?v=Hig2_CqNcGw</a>)</p> <p>Designing Effective Scientific Presentations by S. McConnell (<a href="https://www.youtube.com/watch?v=Hig2_CqNcGw">https://www.youtube.com/watch?v=Hig2_CqNcGw</a>)</p> <p><a href="http://www.esf.org/fileadmin/Public_documents/Publications/Code_Conduct_ResearchIntegrity.pdf">http://www.esf.org/fileadmin/Public_documents/Publications/Code_Conduct_ResearchIntegrity.pdf</a></p> <p><a href="http://online.stanford.edu/course/writing-in-the-sciences">http://online.stanford.edu/course/writing-in-the-sciences</a></p>

#### 3.3.2 Communication to non-professionals

COURSE CONTENT	<p>basic rules of communication: what to communicate; to whom; how to do it effectively; exercises on relevant language; exercises in writing scientific article/ press release/press comment to wide audience</p>
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WEB-LINKS	<p><a href="https://itunes.apple.com/us/course/branding-content-social-media/id824354707?ign-mpt=uo%3D8">https://itunes.apple.com/us/course/branding-content-social media/id824354707?ign-mpt=uo%3D8</a></p> <p><a href="http://www.slideshare.net/DGMediaSchool/how-to-improve-communication-skills-42505007?related=1">http://www.slideshare.net/DGMediaSchool/how-to-improve-communication-skills-42505007?related=1</a></p>
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### 3.3.3 Science and the media

COURSE CONTENT	<p>communication strategy; how to convey your message clearly;</p> <p>exercises in different types of science-media interactions: writing a press release, participating in a radio interview, participating in a TV interview;</p> <p>Students might also be shown best examples of press releases and interviews.</p>
WEB-LINKS	n/a

### 3.3.4 Information retrieval

COURSE CONTENT	<p>The course is the recapitulation of the course 1.2.6 “Information retrieval”.</p> <p>Practical exercises on the use of popular web-search engines, suitable for research, e.g.: ScienceDirect, Google Scholar, Chemical Abstracts, PubMed, patent databases.</p> <p>The tools used during the course should take into account the licensing and the equipment of the university running the program.</p>
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WEB-LINKS	<p> <a href="http://www.sciencedirect.com">http://www.sciencedirect.com</a>  <a href="https://www.cas.org/">https://www.cas.org/</a>  <a href="http://www.ncbi.nlm.nih.gov/pubmed/">http://www.ncbi.nlm.nih.gov/pubmed/</a>  <a href="http://worldwide.espacenet.com/">http://worldwide.espacenet.com/</a>  <a href="http://patft.uspto.gov/">http://patft.uspto.gov/</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/3%20Information%20gathering%20-%20presentation_v1-0.pdf">http://www.nanosafetycluster.eu/nanoToGo/Nano%20to%20go!/Presentations/3%20Information%20gathering%20-%20presentation_v1-0.pdf</a>  <a href="http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes">http://www.nanosafetycluster.eu/nanoToGo/#Nano%20to%20go!%2FPresentations%2FPresentations%20with%20explanatory%20notes</a> </p>
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### 3.3.5 Entrepreneurship

COURSE CONTENT	<p>The course is in part a recapitulation of the course 2.3.3 “Entrepreneurship and communication with customers”.</p> <p>entrepreneurship in the technology market; scopes and underlying concepts: forecasting, planning, organizing, commanding, coordinating, controlling; entrepreneurship and innovation; managing the work process; key managerial skills; formation and implementation of business policy and strategy; elevator pitch; business plan;</p>
WEB-LINKS	<p> <a href="http://ocw.mit.edu/courses/media-arts-and-sciences/mas-666-developmental-entrepreneurship-fall-2003/index.htm">http://ocw.mit.edu/courses/media-arts-and-sciences/mas-666-developmental-entrepreneurship-fall-2003/index.htm</a>  <a href="http://ocw.mit.edu/courses/sloan-school-of-management/15-390-new-enterprises-spring-2013/index.htm">http://ocw.mit.edu/courses/sloan-school-of-management/15-390-new-enterprises-spring-2013/index.htm</a>  <a href="http://www.slideshare.net/profjorge_entrep/introduction-to-entrepreneurship-7647382?related=1">http://www.slideshare.net/profjorge_entrep/introduction-to-entrepreneurship-7647382?related=1</a>  <a href="http://www.slideshare.net/DGMediaSchool/how-to-improve-communication-skills-42505007?related=1">http://www.slideshare.net/DGMediaSchool/how-to-improve-communication-skills-42505007?related=1</a>  <a href="http://www.rsc.org/learn-chemistry/resource/res00000948/chemistry-idea-to-market">http://www.rsc.org/learn-chemistry/resource/res00000948/chemistry-idea-to-market</a>  <a href="http://www.slideshare.net/mariusursache/disciplined-entrepreneurship-an-introduction?qid=c7be1936-e3bd-4392-878a-53a41f0330e3&amp;v=qf1&amp;b=&amp;from_search=4">http://www.slideshare.net/mariusursache/disciplined-entrepreneurship-an-introduction?qid=c7be1936-e3bd-4392-878a-53a41f0330e3&amp;v=qf1&amp;b=&amp;from_search=4</a>  <a href="http://www.bit.ly/d-eship">www.bit.ly/d-eship</a> </p>

### 3.3.6 Exploitation and commercialization of research

<p>COURSE CONTENT</p>	<p>how to exploit results of research; why is commercialization important; introduction to the concept of technology readiness level; from lab to the market – the main steps necessary for commercialization; IPR; licensing; defining the market, customers, and the competitors; researching the market; concept and technology feasibility assessment; business plan; financial plan; funding opportunities incl. non-equity funding opportunities; investors;</p>
<p>WEB-LINKS</p>	<p><a href="http://www.slideshare.net/emayssat/research-commercialization-lec1-ferguson?qid=3c23fe99-f2c2-4ba5-8792-15f23ee21290&amp;v=default&amp;b=&amp;from_search=3">http://www.slideshare.net/emayssat/research-commercialization-lec1-ferguson?qid=3c23fe99-f2c2-4ba5-8792-15f23ee21290&amp;v=default&amp;b=&amp;from_search=3</a></p> <p><a href="http://www.slideshare.net/mariusursache/disciplined-entrepreneurship-an-introduction?qid=c7be1936-e3bd-4392-878a-53a41f0330e3&amp;v=qf1&amp;b=&amp;from_search=4">http://www.slideshare.net/mariusursache/disciplined-entrepreneurship-an-introduction?qid=c7be1936-e3bd-4392-878a-53a41f0330e3&amp;v=qf1&amp;b=&amp;from_search=4</a></p> <p><a href="http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf">http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf</a></p> <p><a href="http://www.utdallas.edu: business_plan_composition_guidelines.doc">www.utdallas.edu: business_plan_composition_guidelines.doc</a></p> <p><a href="http://www.fitforhealth.eu/content/international-training-exploitation-eu-project-results">http://www.fitforhealth.eu/content/international-training-exploitation-eu-project-results</a></p>

### 3.3.7 Project management

<p>COURSE CONTENT</p>	<p>principles of project management; stages of group development; team building strategy; SWOT analysis; risk evaluation and governance; Gantt charts; milestones; critical paths; managing the work process; setting goals and priorities; delegating work; basics of human resources management; recruitment; introduction to negotiations and conflict management;</p>
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WEB-LINKS	<p><a href="https://online-learning.tudelft.nl/courses/leadership-for-engineers/">https://online-learning.tudelft.nl/courses/leadership-for-engineers/</a>  <a href="http://hrweb.berkeley.edu/guides/managing-hr/">http://hrweb.berkeley.edu/guides/managing-hr/</a></p>
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### 3.3.8 Social media in/for science

COURSE CONTENT	<p>introduction to different types of social media; web 2.0 tools; blogging; videoblogging; podcasting; slide-sharing; creating professional profiles on popular social media (e.g. ResearchGate, LinkedIn, Facebook, Twitter, skype)</p>
WEB-LINKS	<p><a href="https://itunes.apple.com/us/course/branding-content-social-media/id824354707?ign-mpt=uo%3D8">https://itunes.apple.com/us/course/branding-content-social media/id824354707?ign-mpt=uo%3D8</a></p>

### 3.4 Industrial internship / scientific exchange

### 3.5 Ph.D. Thesis Project: practical and theoretical work