

## Multiscale and Multiphysics Modelling Techniques for Nanoelectronic Devices (E006600)

**Course size** *(nominal values; actual values may depend on programme)*

**Credits 6.0**

**Study time 180 h**

**Course offerings and teaching methods in academic year 2023-2024**

A (semester 2)	English	Gent	seminar
B (semester 2)	Dutch	Gent	

**Lecturers in academic year 2023-2024**

Vande Ginste, Dries	TW05	lecturer-in-charge
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**Offered in the following programmes in 2023-2024**

	<b>crdts</b>	<b>offering</b>
<a href="#">Master of Science in Engineering Physics</a>	6	B
<a href="#">Master of Science in Engineering Physics</a>	6	A

**Teaching languages**

English, Dutch

**Keywords**

Multiscale modelling, multiphysics modelling, nanoelectronic devices, numerical computation and simulation, electromagnetics, quantum mechanics, thermodynamics.

**Position of the course**

The course starts from the application domain, which is the design and manufacturing of nanoelectronic devices. Within these devices, physical phenomena occur on different scales (multiscale aspect, both in space and in time) and pertaining to different branches of physics (multiphysics aspect). Based on their knowledge of electromagnetics, quantum mechanics, thermodynamics, etc., the student will gain insight in the holistic formulation of the behaviour of nanoelectronic devices and learn to couple and solve the pertinent sets of partial differential equations that govern this behaviour. Whereas the focus of this course is on the relevant modelling techniques, many application examples will illustrate the techniques' necessity and appositeness for state-of-the-art design of novel devices and applications.

**Contents**

Part 1: Multiscale modelling

- Description of multiscale and multiresolution problems in space and time in nanoelectronic components
- Non-uniform gridding
- Collocated methods
- Hybrid methods

Part 2: Multiphysics modelling

- Formulation of multiphysics problems in nanoelectronic components
- Modelling of Maxwell-Schrödinger systems + applications
- Modelling of Maxwell-Dirac problems + applications

**Initial competences**

Electromagnetism I, Electromagnetism II, Quantum Mechanics I, Quantum Mechanics II, Atomic and Molecular Physics, Transport Phenomena, Computational Solutions of Wave Problems, Solid-state Physics and Semiconductors I, Solid-state Physics and Semiconductors II

**Final competences**

- 1 Understand multiscale and multiphysics problems which arise in nanoelectronic devices
- 2 Describe multiscale problems; recognize the important parameters for selecting a particular

computational solution method to deal with it (gridding, domain decomposition, hybrid); recognize potential and limitations of these methods

- 3 Describe multiphysics problems; recognize the important parameters for selecting a particular computational solution method; couple and solve the relevant partial differential equations pertaining to the devices that need to be modeled and designed; recognize potential and limitations of these methods.
- 4 Cooperate and communicate within small groups on an open ended multiscale/multiphysics problem and plan a joint undertaking that takes several months during a modeling project related to nanoelectronic design

#### **Conditions for credit contract**

Access to this course unit via a credit contract is determined after successful competences assessment

#### **Conditions for exam contract**

This course unit cannot be taken via an exam contract

#### **Teaching methods**

Group work, Seminar, Lecture, Independent work

#### **Extra information on the teaching methods**

The course consists of lectures about theory and exercises, without making a strict, traditional distinction between them. All lectures are seminars which require interaction with and input from the students. During the semester numerical problems must be tackled and programmed in Python. The results of this project are written down in a report.

#### **Learning materials and price**

Electronic syllabus and slides available for free via Ufora (hardcopy via VTK).

#### **References**

See syllabus

#### **Course content-related study coaching**

The lecturer and his assistants are available for further explanations.

#### **Assessment moments**

end-of-term and continuous assessment

#### **Examination methods in case of periodic assessment during the first examination period**

Oral assessment open-book, Assignment

#### **Examination methods in case of periodic assessment during the second examination period**

Oral assessment open-book, Assignment

#### **Examination methods in case of permanent assessment**

Skills test, Assignment

#### **Possibilities of retake in case of permanent assessment**

examination during the second examination period is possible in modified form

#### **Extra information on the examination methods**

- During examination period: oral open-book exam + discussion project
- During semester:
  - graded project reports + code
  - graded (computer) exercises spread over semester.
  - Second chance: Possible in adapted form

#### **Calculation of the examination mark**

Throughout semester: 30%, during examination period: 70%.