GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2025-2026

Wave Physics in Living Matter (E006400)

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 2025-2026

A (semester 2)	English	Gent	practical lecture
B (semester 2)	Dutch	Gent	

Lecturers in academic year 2025-2026

Joseph, Wout	TWO5	lecturer-in-charge
Tarnaud, Thomas	TWO5	co-lecturer

Offered in the following programmes in 2025-2026	**crdts**	**offering**
Master of Science in Biomedical Engineering	6	B
Master of Science in Biomedical Engineering	6	A
Master of Science in Engineering Physics	6	B
Master of Science in Engineering Physics	6	A
Master of Science in Physics and Astronomy	6	A

Teaching languages

English, Dutch

Keywords

Non-ionising radiation, electromagnetic fields, non-linear ultrasound, two-phase models, microbubbles, biological tissue, brain tissue, cell response, neuronal response, brain stimulation, exposure, human body

Position of the course

This course builds on prior knowledge on electromagnetic and acoustic wave propagation that is part of the obligatory courses in the Engineering Physics program and adds specialized knowledge on the interaction with living matter. This includes electromagnetic response of bio-molecular level of tissue and dielectric property values, nonlinear and two-phase ultrasonic propagation, response of neurons to electromagnetic and ultrasonic excitation. The course gives students the necessary skills to conduct advanced research in this area and to design new imaging and therapeutic methods and devices.

Contents

Physical description of the interaction of Electromagnetic and Ultrasonic waves with living matter

- Non-linear and non-adiabatic acoustic wave propagation
- Gas-liquid mixtures, micro-bubbles, acoustic cell resonances
- Two phase models for elastic wave propagation in porous solids such as bone, cellular biological materials
- Nuclear magnetic and electron spin resonance
- Theory of dielectric spectroscopy; Electromagnetic response of bio-molecular level of tissue over entire spectrum: alfa, beta, gamma and delta dispersion
- Charge transport phenomena and parameters which have an impact: Membrane currents; Quantum transport phenomena in metabolic processes; Resonance phenomena; Wigner-Breit & Fano resonances; Impact status of the cellular status; Parametric stimulation; Magneto biology; Therapeutic effects at various spectral domains

- Interaction with neurons: Electric stimulation: deep brain stimulation, direct/alternating current stimulation; Transcranial magnetic stimulation; Low-intensity focused ultrasound stimulation; Optogenetic stimulation

Selected applications, research and development

- Human body exposure to EM fields
  - non-ionizing electromagnetic (EM) fields in real environments
  - Concepts of EM field interaction and the body: absorption of EM fields in the human body
  - Scientific basis and concepts for norms: basic quantities and basic restrictions and reference quantities and reference levels
  - Thermal and non-thermal effects of EM radiation
  - Whole-body absorption, organ specific absorption, and localized absorption in the body
  - Exposure of the general public and occupational exposure
  - EM description and modeling of electromagnetic fields
  - Experimental dosimetry of EM fields and of absorption
  - Use cases: application of theory on real EM sources, 5G radiation
  - Occupational exposure in medical environments: electrical surgery, MRI, hyperthermia
- Medical imaging
  - US imaging, transducers and focusing, Doppler
- Medical therapy
  - Thermal therapy
  - US destruction, lithotripsy, brain lesions
  - Neural stimulation, low frequency magnetic, ultrasonic
- Biological applications
  - interaction of electromagnetic waves with insects

Practicum and project

- Practicum: Experimental assessment of EM fields and hydrophone measurements
- Numerical simulation (EM+US) + design project
  - Human models: homogeneous and heterogeneous 3D electromagnetic models
  - Neuron models coupled to EM/US
  - Focused US in living matter
  - Numerical uncertainties (Finite-Difference Time-Domain)

Initial competences

General mathematical background, general physics and advanced electromagnetism and acoustics knowledge, basic programming skills

Final competences

1 Understand underlying physics of Electromagnetic and Ultrasonic waves interacting with living matter; interaction of spins and fields;
2 Understand interaction of Electromagnetic and Ultrasonic waves with biological tissue, with living matter at bio-molecular level; interaction of Electromagnetic and Ultrasonic with neuronal activity
3 Apply the skills for modeling Electromagnetic and Ultrasonic in and around living matter, and interpret modeling results
4 Obtain the skills for design new applications for imaging and therapy: e.g. deep brain stimulation, transcranial stimulation
5 Learn to reflect on scientific literature (review and presentation of papers)

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, Lecture, Practical, Independent work

Extra information on the teaching methods

Lecture, seminar (guest lectures, flipped classroom), practical exercise on measurement, computer aided design.

Study material

Type: Slides

Name: powerpoint slides, articles
Indicative price: Free or paid by faculty
Optional: no
Language : English
Available on Ufora : Yes
Online Available : No
Available in the Library : No
Available through Student Association : No

References

Course materials available through the electronic learning environment: slides, articles (EMF dosimetry handbook book, background material)

Course content-related study coaching

The instructor can be contacted after the lectures, or by appointment. Interactive support via the electronic learning platform

Assessment moments

end-of-term and continuous assessment

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

Written assessment open-book

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

Written assessment open-book

Examination methods in case of permanent assessment

Assignment

Possibilities of retake in case of permanent assessment

not applicable

Extra information on the examination methods

Theoretical and exercise part of the exam with open book.

Calculation of the examination mark

- examination theory: 40%
- examination exercises: 20%
- Project and presentations: 30%
- Practica: 10%