Course Package

Imaging & In Vitro Diagnostics

Name module	Imaging & In Vitro Dagnostics
Educational programme	MSc Biomedical Engineering
Period	Second block of the first semester (block 1B)
Study load	15 ECTS
Coordinator	J. Huttenhuis

Imaging & In Vitro Dagnostics			
block 1A	**block 1B**	**block 2A**	**block 2B**
	Numerical Techniques for PDE - 191551150 (5 EC)		
	Mathematical Methods - 191506001 (5 EC)		
	Physics of Bubbles - 193572010 (5 EC)		

Required preliminary knowledge: Bachelor calculus and linear algebra is required. Some experience with Matlab is useful, not obligatory, Basic analysis and calculus (e.g., Taylor series expansion), Basic numerical techniques (e.g., Finite Difference approximations) and basic MATLAB implementation skills, Knowledge on discretization of ordinary differential equations is helpful, Basic knowledge about partial differential equations, such as the heat equation and the advection equation, Fluid Mechanics.

191506001 **Mathematical Methods**
The understanding of scientific models and solving complicated engineering problems requires the correct use of programming and mathematical algorithms. Typical problems involve numerical solutions of nonlinear equations, simulations of dynamical systems, stability via eigenvalues, finite-dimensional approximations of spatial systems by discretization or Fourier analysis. The art is not just to be able to solve such problems but also to have an intuition for the accuracy of the solution. Here we use some analytical insights and error analysis.

The modules are tentative and subject to change. Please check the website regularly.

During the bachelor study, an engineering student learns several mathematical methods through a number of calculus and linear algebra courses. Starting from this bachelor level, this course has three aims:
1. Refresh and enrich the students' knowledge on calculus, linear algebra, and Fourier analysis,
2. Expose the student to other areas such as numerical analysis and mathematical algorithms, and stochastic and partial differential equations,
3. Practising programming using Matlab with emphasis on efficiency and correctness. After this course the student has the ability to efficiently simulate and analyze models given by differential equations. In a more complicated setting, the student will be able to choose and adopt a method for an application.

The course consists of lectures providing an intuition to the mathematical methods. A few tutorials focus on Matlab programming. The homework problems deal with applications in neuroscience and biomedical engineering

191551150 **Numerical Techniques for PDE**
The character of linear second order PDE's is determined via the eigenvalues of the corresponding (symmetric) coefficient matrix. It is shown that any second order PDE can be transformed to the Laplace equation, the heat equation or the wave equation, which are representative for elliptic, parabolic and hyperbolic equations respectively.

Thereafter, discretization methods are introduced. Spatial discretization is handled by finite difference and finite element methods. Explicit and implicit methods are used for time discretization. It is shown that for parabolic and hyperbolic problems the spatial part can be discretized in a decoupled manner from the temporal part, where finite difference or finite element methods can be used for the former and the time integration schemes for the latter. The consistency, convergence and stability of the different methods will be evaluated via Fourier Stability Analysis.
For linear static applications detailed attention is given to the assembly of a set of equations, the application of boundary conditions and constraints and the efficient solution of a model, using either direct or iterative solvers, submodelling and substructuring. The accuracy of results will be assessed using error estimators. Plate and shell elements are introduced. Elements will be scrutinised for locking phenomena like shear, volume and membrane locking.

For dynamic analysis, eigen value analysis with subspace and Lanczos iterations, statical reduction techniques, modal solution methods and direct time integration are treated. For geometrically nonlinear situations incremental-iterative solution methods are introduced as the Newton-Raphson method, arclength control and line search techniques. Finally linear stability analysis is treated.

193572010 **Physics of Bubbles**
The Physics of Bubbles course treats the physics of single bubble and describes the behavior of multiple bubbles and bubble clouds. The course treats the forces on bubbles, the acoustics of bubbles and bubble clouds, microstreaming and jets due to bubble oscillation, cavitation and bubble collapse. The course includes lectures on the use of bubbles in medical imaging and in molecular imaging with ultrasound. Also therapeutic applications of bubbles are discussed, along with bubbles in process technology and bubble formation and bubble dynamics in microfluidic devices and nanotechnology.