Fall trimester

4K200	Mechanics of micro-electronics
4A780	Fracture mechanics
4U740	Engineering optimization
4K300	Experimental mechanics
4P580	Physical measuring methods
4U700	Machine error modeling and measurement
6H300	Quantum chemistry
3D010	Optics

Winter trimester

4K700	Thin film mechanics
4U760	Micro- and Nanotechnology, special topics
4P630	Application of FEM to heat and flow problems
4U300	Electromechanics for precision engineering
3Y280	Solar energy
3N220	Theory of microscopically disordered media
3S270	Nanophysics
5L190	Semi-conductor physics
6KM01	Membrane technology
8C030	Molecular simulation

Spring trimester

4K570	Micro- and nano-structuring methods
4T300	Microscopic methods
4P710	Micro-heat transfer
8W150	Multi-fluid mechanics
4K620	Computational material models
5P020	Microcomputer architecture

4K200 Mechanics of micro-electronics

goal	To learn the basics, the state-of-the-art and the applications of mechanics for Microelectronics and Microsystems.
contents	• The overview and roadmap of Microelectronics Technologies (IC, packaging, assembly and Microsystems • Microelectronics Reliability Special application topics (Thermo-mechanical modeling and characterization of microelectronic products/processes; Reliability prediction of solder interconnections; Prevention of moisture induced failure; etc.) • Virtual mechanical prototyping and virtual qualification • The challenges.

4A780 Fracture mechanics

contents	• (nondestructive) testing methods
	• Linear Elastic Fracture Mechanics concepts and crack growth criteria:
	  ○ mode I, II and III behaviour
	  ○ Griffith/Orowan energy balance; energy release rate (G); fracture toughness; R-curve
	  ○ stress intensity factor (K)
	• Multi-mode crack load -> Crack growth direction
	• crack growth speed
	• plastic cracktip zone and small scale yielding.
	• Concepts and crack growth criteria in Elastic Plastic Fracture Mechanics or
	• Non-Linear Fracture Mechanics:
	  ○ cracktip opening displacement
	  ○ J-integral.
	• Computational Fracture Mechanics (CFM)
	  ○ quarter-point elements
	  ○ virtual crack extension
	  ○ calcalation of K and J
	• fatigue

4U740 Engineering optimization

Contents	In the first part of this course the knowledge presented in 4U700 is extended. This knowledge is illustrated with practical applications. For instance special measuring means such as ball-plates, ball-bars, checking gauges, which are employed to measure the deviation structure of multi-axis machines, will be dealt with. Furthermore, the analysis methods needed to determine the deviation parameters of multi-axis machines are discussed. this part of the course also deals with software correction of the deviations for these machines. The second part of the course consists of special guest lectures concerning the development of precision machines and instruments. These lectures deal with: • the development of wafer-steppers (ASML) • precision machine construction (Philips Natlab, Testrake) • the development of CD players (Philips CE) • optical systems for the inspection of surfaces (Philips CFT) • equipment for nanometrology (Philips CFT) and are given by experts of the respective companies.

4K300 Experimental mechanics

contents	A very important reason of doing experiments is the gathering of data. Good data is essential to verify assumptions or suppositions that have Digitel Signol Processing to you to do experiments. In this course the main topic of the measuring process will be discussed; such as, sensors, calibration, uncertainties and inaccuracies, presentation of data and results, tandards, fitting of data, the dynamical behavior of measuring systems, loading errors, signal conditioning, filters, digital techniques, micro computers, digital signal processing, data ead-out, data processing etc.

4P580 Physical measuring methods

contents	Physics and measuring methods In this course a number of measurement methods is treated that are relevant for experiments in gaseous, liquid, and reactive flows (combustion). The physical background, practical implementation, and limitations are analyzed in depth. The knowledge prerequisites are covered partly by the course Transport Phenomena (3B470), with the missing parts (optics, lasers, and molecular physics) being treated during the course. The course is given as a series of lectures, with in-class training. A listing of the measurements methods: • Flow visualisation. • Flow rate: orifices, rotameter, indicator, electromagnetic and ultrasound methods. • Velocity: Pitot-tube, hot wire and hot film anemometer, laser Doppler velocimetry, particle image velocimetry. • Temperatures and heat fluxes: thermocouples, liquid crystals, pyrometers, laser induced fluorescence, coherent anti-Stokes Raman spectroscopy. • (Molecular) densities: shadowgraphy, Schlieren imaging, interferometry, Rayleigh scattering, laser induced fluorescence.

4U700 Machine error modeling and measurement

contents	The course "Instrument and machine accuracy" treats the basic knowledge for the determination of the error structure of machines and instrumentation. Errors due to geometry, thermomechanical and finite stiffness behaviour are discussed and modelled. Also some attention is paid to errors arising from dynamical behaviour of machines and instruments. The modelling is such that it can be applied to any machine tool, measuring machine or instrument. The commonly used measuring techniques in machine and instrument error measurement are discussed with main attention to laserinterferometry to measure machine positioning, angle and straightness errors. Principles, properties and applications of sensors are treated in some separate lectures

6H300 Quantum chemistry

inhoud	In het college zullen de grondslagen van de kwantummechanica en de kwantumchemie behandeld worden. Allereerst zullen de postulaten en de interpretatie van de kwantummechanica uitgelegd worden. Met behulp van het variatieprincipe zullen benaderde oplossingen voor de Schrödinger-vergelijking gezocht worden. Dit leidt dan tot de volgende kwantumchemische methoden: Hartree-Fock en Configuratie Interactie. Bovendien zal de tijdsonafhankelijke storingstheorie behandeld worden. De nadruk zal liggen op de structuur van de theorieën en de interpretatie van kwantumchemische berekeningen. Naast de elektronenstructuur van moleculen zal ook gekeken worden naar vibraties van moleculen en de berekening van infraroodspectra. Het college is gericht op studenten die actief willen deelnemen aan kwantumchemisch onderzoek, zoals dat gedaan wordt bij de capaciteitsgroepen Anorganische Chemie, Katalyse en Macromoleculaire en Organische Chemie.

3D010 Optics

inhoud	Er wordt gestreefd naar een min of meer complete dekking van alle terreinen van de optica die voor BMT-studenten van belang zijn. Nadruk zal niet komen te liggen op mathematische compleetheid, maar meer op breedte van de kennis die wordt opgedaan. De volgende onderwerpen worden behandeld: lichtbronnen en detectoren, geometrische optica, optische instrumenten, lensfouten, fluorescentie, microscopie, lasers, fibers, buiging, spectrometrie, holografie.

4K700 Thin film mechanics

goal	To learn how to describe and measure the mechanical properties of thin film materials, and how to relate these to high-tech thin film applications.
contents	Thin Films are an essential part of today's advanced technological products, like Integrated Circuit (IC) chips, Micro Electro Mechanical Systems (MEMS), Hard Disk Drives (HDD), flat and/or flexible displays, optical storage systems, etc. The thickness of the films ranges from nanometers to micrometers, and they can be made from all sorts of materials: silicon, oxides, nitrides, metals, and polymers, to list some examples. The mechanical properties of the films determine to a large extent the reliability and the lifetime of a product. Excessive deformation, fracture, or plastic deformation of the films should be avoided to guarantee a proper functioning of the complete device. For applications like flexible displays or MEMS, the mechanical properties of the films even determine the product characteristics directly. For these reasons, knowledge about the mechanical behavior of thin films is essential for today's and future advanced applications. Thin film mechanics is different from the mechanics of bulk materials for a number of reasons. In the first place, the particular microstructure of the material will play an increasingly important role, whereas, in bulk material, the effect of the particular microstructure is simply averaged out. Second, the specific state of the boundaries has a direct influence. For example, the response is determined by whether the film is free-standing or sandwiched between two other films, and by the interactions at the interfaces with other materials. For these reasons, a thin film of material may show completely different behavior than its bulk counterpart. A third, more practical point is that conventional experimental techniques to characterize the mechanical properties of bulk materials cannot be used anymore and special, new test methods have to be used. In this course we will: • Discuss the advanced applications in which thin films, and in particular their mechanical behavior, play a crucial role. • Get to know the various thin film technologies that can be used to make thin film devices. • Learn about the specific mechanical properties of thin films, and in particular about small-scale effects and the influence of boundary conditions, for a broad spectrum of material systems. • Discuss the possibilities and challenges of modelling these effects. • Learn about a number of special experimental methods for the determination of thin film mechanical properties. • Discuss the consequences and opportunities for applications, focussing on microsystems (MEMS) and microelectronics applications.

4U760 Micro- and Nanotechnology, special topics

contents	In the first part of this course the knowledge presented in 4U700 is extended. This knowledge is illustrated with practical applications. For instance special measuring means such as ball-plates, ball-bars, checking gauges, which are employed to measure the deviation structure of multi-axis machines, will be dealt with. Furthermore, the analysis methods needed to determine the deviation parameters of multi-axis machines are discussed. this part of the course also deals with software correction of the deviations for these machines. The second part of the course consists of special guest lectures concerning the development of precision machines and instruments. These lectures deal with: • the development of wafer-steppers (ASML) • precision machine construction (Philips Natlab, Testrake) • the development of CD players (Philips CE) • optical systems for the inspection of surfaces (Philips CFT) • equipment for nanometrology (Philips CFT) and are given by experts of the respective companies.

4P630 Application of FEM to heat and flow problems

contents	The course is divided into two parts. In the first part the partial differential equations for the description of heat and flow problems are introduced and properties of parabolic, hyperbolic and elliptic equations are briefly discussed. Beside the Finite Element Method (FEM) the Finite Difference Method is introduced together with the upwinding technique to avoid oscillations in the approximate solution. Next the general working method of the FEM is described. Finally, general aspects as quadrature rules, automation and accuracy are discussed. In the second part the FEM is applied to the Navier-Stokes and energy equation to solve heat and flow problems. The discretisation of the set of equations together with several solution methods and the special role of the pressure are discussed. Besides, some time integration schemes to solve unsteady flow problems and the coupling between the Navier-Stokes and energy equations for forced and natural convection flow problems is elucidated. Finally, a short introduction is given to solution techniques for radiation problems.

4U300 Electromechanics for precision engineering

contents	Electrical servo drives are a part of many servo systems within Precision Engineering. The sensor, control, actuator and mechanics define to what extent a system specification can be met. The target of the lecture is that at the end the attendees • have an overview on modern linear actuators and motors and rotating servo motors • know the principle of operation • are able to model these components as part of a system • define the selection criteria in relation to an application • understand the link between the characteristics of the motor/actuators and the other parts of a servo system

3Y280 Solar energy

inhoud	Allereerst worden een aantal aspecten van licht behandeld. Omdat halfgeleiders zo cruciaal zijn voor zonnecellen wordt ingegaan op hun eigenschappen en op de eenvoudigste halfgeleiderstructuur die daarmee gemaakt kan worden, de diode. De opbouw, de werking en de belangrijkste eigenschappen van zonnecellen worden besproken aan de hand van de klassieke kristallijn silicium zonnecel. Ingegaan wordt op de belangrijkste verliesmechanismen in zonnecellen. Een overzicht van de verschillende typen zonnecellen worden gegeven. Meer gedetailleerd wordt ingegaan op een beperkt aantal zonnecellen: de multikristallijn silicium, de amorf silicium en de organische zonnecellen. Daarbij wordt ingegaan op de specifieke opbouw van de bijzondere structuren in deze zonnecellen. De verschillende productieprocessen worden ook besproken.

3N220 Theory of microscopically disordered media

contents	Microscopically disordered media are media in which structure and properties are strongly varying on a length scale larger than that of the molecules, but much smaller than that of the normal observation. This implies that it is often possible already to give locally a description in terms of macroscopic properties, but that for the global macroscopic properties a second statistical averaging is necessary. Such disordered media are encountered in Nature (suspensions, porous materials,…), but are also being made in view of their particular properties (isolator/conductor composites, reinforced materials, heterogeneous catalysts,…). The course consists of two parts. In the first part practical examples are discussed and it is explained that between totally different media, and the physical processes in these (e.g. diffusion in porous media), large similarities exist, which permit a unifying description of the effective behaviour via methods of mathematical physics and statistical mechanics. A number of approximations are dealt with that lead to explicit expressions for the effective constants of microscopically disordered media. Finally it is shown how a self-consistent theory predicts a percolation transition from isolator to conductor in an isolator/conductor mixture. The second part of the course discusses the statistical lattice theory of percolation in isolator/conductor composites and similar systems. Explicit calculations are given of cluster size distribution, correlation length and percolation threshold in an exactly-solvable model. Subsequently it is made clear how this leads close to the percolation threshold to universal scaling behaviour of large clusters, and what is here the role of fractal structures. Finally the sofar purely geometrical percolation model is translated into scaling laws for the effective conductivity close to the percolation threshold of isolator/conductor composites.

3S270 Nanophysics

inhoud	Nanostructuren staan de laatste jaren sterk in de belangstelling. Enerzijds bieden nieuwe fysische technieken zoals, Scanning Probe en atomairebundeltechnieken, nieuwe mogelijkheden om nanostructuren te maken en te onderzoeken, anderzijds zijn de wat meer conventionele groeitechnieken zoals MBE, elektronen- en optische lithografie zodanig geperfectioneerd dat nanostructuren met hoge reproduceerbaarheid en precisie gemaakt kunnen worden. Dit heeft geleid tot een nauwe samenwerking van een aantal groepen bunnen de faculteit Natuurkunde. In het college nanofysica zal worden ingegaan op zowel de fabricage als de fysische eigenschappen van metallische- en halfgeleidernanostructuren. Naast fabricagemethoden zullen ook fysische eigenschappen in dit college aan de orde komen. Door verlaging van de dimensionaliteit in nanostructuren blijkt dat de elektronische, optische en magnetische eigenschappen vaak sterk verschillen van 3dimensionale systemen.

5L190 Semi-conductor physics

goal	Students have to understand: the differences between metals, semiconductors, and insulators in terms of bandgap – the consequences of the difference in effective mass for electrons and holes for mobility and effective density of states – the limits of Ohm’s law – the differences between direct and indirect bandgap semiconductors and the consequences for the applications in opto-electronic devices or diffusion driven devices – why faster photo electric sensors are less sensitive – why some high frequency, high power, high temperature applications ask for semiconductors other than silicon.

6KM01 Membrane technology

goal	Aim of the course: The aim of this course aim of the course is to provide the student with sufficient knowledge in the field of membrane technology to asses whether a membrane process is the most appropriate choice for a specific separation. This requires knowledge on mass transport through membranes, thermodynamics of membrane processes, fouling, membrane equipment design, and membrane process development. In the course merits and drawbacks of membranes are discussed and compared with those of other, i.e., competing, separation techniques.
contents	Contents of the course: - Membrane process equipment - Mass transport (Maxwell- Stefan) - Pressure driven processes: RO, NF, MF, UF - Pervaporation - Concentration polarization - Fouling - Energy consumption

8C030 Molecular simulation

contents	Next to theory and experiments computer simulations have become a means to study phenomena in biomedical applications. In particular when the time or length scales relevant in these phenomena are hard to be addressed experimentally, simulations can be of great value. In this course several such examples will be presented. Attention will be on methods and techniques such as the molecular dynamics and Monte Carlo method and the usefulness of these methods will be shown by practical examples. In addition the theoretical models will be discussed needed for the interpretation of the simulation results.

4K570 Micro- and nano-structuring methods

contents	The course shall cover many aspects of micro- and nano- fabrication methods. Different lithographic techniques and their applications to microelectronics and micromechanics will be discussed. Moreover, attention shall be given to typical fabrication techniques used in micro- and nano-engineering like thin film deposition techniques, wet and dry etching methods, LIGA techniques, molding and embossing. Also concepts for micro- sensors and -actuators and techniques for the packaging of micro-devices shall be presented. Finally, attention shall be given to special nano-engineering topics.

4T300 Microscopic methods

contents	In many cases macroscopic material behaviour can only be understood by studying phenomena at much smaller (micron, nanaometer) scale. This course treats a number of advanced measuring techniques that enable the study of microscopic properties of materials (metals, polymers, biological materials). With these techniques topographic, mechanical and chemical properties can be measured at a (very) small scale. Emphasis will be on techniques available within the faculty of Mechanical Engineering. Among others the following techniques will be treated: conventional optical microscopy, confocal microscopy, electron microscopy (ESEM) and elemental analysis (EDX), Scanning Probe Microscopy (AFM and the likes), nanoindentation. Underlying physical principles will be addressed concisely. Examples from faculty research and literature will be used to illustrate possibilities and restrictions of these techniques.

4P710 Micro-heat transfer

contents	The aim of this course to understand the heat transfer phenomena on micro-scale level and to apply the knowledge to the design of, for example, micro-cooling systems and solar cells.
	
	To understand the heat transfer on the micro-scale, several molecular aspects are treated first and then extended to the micro- and macro-scale. The course is subdivided into three blocks:
	• Conduction on the molecular level for
	    ○ Ideal gasses
	    ○ Fluids
	    ○ Solids
	• Multi-scale modelling of convection using
	    ○ Molecular Dynamics
	    ○ Monte Carlo techniques
	    ○ Lattice Gas and Lattice Boltzmann methods
	• Radiation
	    ○ The dual character of radiation
	    ○ Interactions of photons
	    ○ Length and time scales

8W150 Multi-fluid mechanics

contents	The course will illustrate how the conservation of mass, momentum and energy together with principles from non-equilibrium thermodynamics form the basis of the mathematical description of multi-component systems as for instance relevant for physiological transport processes and food-industry. Taking these fundamental description as point of departure, the most simple models for physical phenomena like phase-separation, interfacial tension, diffusion and Marangoni convection will be derived. Insights from these fundamental descriptions will be used to analyse important processes that occur in structure development in mixing and dispersion. Examples are diffusion induced phase separation (DIPS), flow induced phase separation but also deformation, break-up and coalescence of drops and the role of surfactants. This, for instance, is of importance for polymer processing and drug-delivery systems.

4K620 Computational material models

contents

	○ 6. Material models ○ Elastic ○ Elastomeric ○ Elastoplastic ○ Viscoelastic: linear ○ Viscoelastic: nonlinear ○ Viscoplastic

5P020 Microcomputer architecture

inhoud	Het doel van dit college is de student te leren zelf kleine computersystemen te ontwerpen. Hierbij komen zowel de hardware als de software aan de orde die nodig zijn om de functie van de toe te passen VLSI-bouwstenen te activeren. Aan de orde komen: microprocessor-architectuur, instructiesets, timing, geheugenorganisatie, interfacetechnieken, interruptafhandeling, direct memory access, multiprocessorsystemen, slave processoren (arithmetic processoren, i/o-processoren) en systeemanalyse.