



## Business Analytics MSc

VU University Amsterdam - Faculteit der Exacte Wetenschappen - M Business Analytics - 2014-2015

The Master's programme in Business Analytics (BA) is a multidisciplinary programme, geared to improving business processes by applying a combination of methods based on mathematics, computer science and business management. The Master's programme BA will deepen your knowledge of these methods and give you the opportunity to specialize in areas like business process optimization, computational intelligence and financial risk management. Their synthesis is often called Business Analytics.

Business problems will be the center of attention and the motivation for the methods to be learned from the three subdisciplines. The Master's programme is concluded by a Master Project conducted during an internship or a research project at the VU of half a year.

There are two variants of the programme: The Professional Track and the Dual Master's Programme.

In the Professional Track, the students choose courses for 45 EC, including 24 EC of a selected list of courses, and complete their studies with an internship or an internal Master Project for 36 EC. The students can only start their internship or Master Project after having finished the compulsory Research Paper BA (6 EC) and having completed all but possibly one programme components.

In the Dual Master's Programme, the students choose courses for 33 EC, including 18 EC of a selected list of courses. The final internship, as well as the compulsory Research Paper BA (6 EC), typically is incorporated in the work. If you are interested in the Dual Master's Programme, please note that admission also depends on obtaining suitable employment. Please contact the internship office well in advance.

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## BA Dual variant

The dual Master's programme combines work and study. During this programme the student is employed part time, and studies part time. The work has to be relevant for the study. The external master's project is incorporated in the work, although supervision of the external master's project has to involve at least one university staffmember. In addition the student gets 18 EC for the Dual work period. Moreover, it is possible to do the Research Paper BA (6 EC) on a case-study that is work related, provided the case-study is combined with a sound theoretical basis. This makes the total of work related credit points, including the external master's project, 60 EC, being the equivalent of one year of study. Typically, a student participating in the dual master's programme should expect to obtain the Master's diploma after two and a half years.

Admission to the dual Master's programme is granted to those who have a Business Analytics Bachelor's degree. For those with another university Bachelor's degree, such as Mathematics, Econometrics, Computer Science, or a Bachelor's degree from an institute of higher education, admission may be granted on an individual basis. Those seeking admission to the dual Master's programme should realize that admission also depends on obtaining suitable employment. The VU has contacts with a number of companies that are interested in participating in this programme.

For more information concerning the dual master's programme, contact the coordinator for the external master's project or the master coordinator.

The programme consists of 120 European creditpoints (EC)  
- compulsory courses 87 EC (including a Master Project of 36 EC)  
- compulsory selection 18 EC  
- optional courses 15 EC

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Programme components:

- [Compulsory Selection Mathematics and BA \(18 EC\)](#)
- [Compulsory Courses](#)

### Compulsory Selection Mathematics and BA (18 EC)

There is a compulsory selection of at least three courses (18 EC) from this list below.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
<a href="#">Advanced Linear Programming</a>	Period 4+5	6.0	X_400326

Advanced Selforganisation	Period 2	6.0	X_400434
Business Intelligence	Period 1	6.0	E_BK3_BI
Continuous Optimization	Period 1+2	6.0	X_400446
Corporate Financial Management	Period 4	6.0	E_BK3_CFM
Evolutionary Computing	Period 1	6.0	X_400111
Heuristic Methods in Operations Research	Period 1+2	6.0	X_418006
Investments	Period 4	6.0	E_EBE3_INV
Neural Networks	Period 1	6.0	X_400132
Numerical Methods	Period 4+5	6.0	X_401039
Optimization of Business Processes	Period 4+5	6.0	X_400422
Performance of Networked Systems	Period 4	6.0	X_405105
Project Optimization of Business Processes	Period 3	6.0	X_400213
Scheduling	Period 4+5	6.0	X_400396
Stochastic Optimization	Period 1+2	6.0	X_400336
Stochastic Processes for Finance	Period 1+2	6.0	X_400352

## Compulsory Courses

Both the Research Paper BA (6 EC) and the Master Project (36 EC) may be work-related. The work period consists of 18 EC. The total work related credit points has therefore a maximum of 60 EC.

Compulsory alongside the mentioned courses, are a compulsory choice (18 EC) and optional courses (15 EC) to complete 120 EC.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
Applied Analysis: Financial Mathematics	Period 1+2	6.0	X_400076
Applied Stochastic Modeling	Period 1+2	6.0	X_400392
Data Mining Techniques	Period 5	6.0	X_400108
Dual Workperiod Master	Ac. Year (September)	18.0	X_400460
Master Project Business Analytics	Ac. Year (September)	36.0	X_400459
Research Paper Business Analytics	Ac. Year (September)	6.0	X_400206
Scientific Writing in English	Period 4	3.0	X_400512
Statistical Models	Period 1+2	6.0	X_400418

## Professional track

These are the standard Master's programmes. The goal of the programme is to prepare students for a career in business, industry, or within governmental or research facilities, with (possibly only initially) a major quantitative aspect.

The emphasis will be on a broad and multidisciplinary education, preparing the student for a role as an academically trained quantitative professional in a multidisciplinary organisation. Even so, the possibility to continue after the Master in a PhD programme exists also for these variants.

There are three specializations possible:

### Business Process Optimization

This subject underscores the multidisciplinary nature of Business Analytics: you will tackle quantitative business problems with the aid of mathematical algorithms which are then implemented in decision-support systems. All aspects of this subject are addressed from the perspective of interrelationships.

### Computational Intelligence

Computational Intelligence (CI) is a collective name for various fields of application and problem-solving techniques. Typical CI applications are optimization and data mining. CI offers a successful pragmatic approach to actual problems.

### Financial Risk Management

This specialization prepares you for a quantitative position in the financial world. The subjects covered include the pricing of derivatives, such as share options, and risk management. You will deal with both practical and theoretical aspects of the discipline.

The programme consists of 120 European creditpoints (EC)

- compulsory courses 75 EC (including a Master Project of 36 EC)
- compulsory choice 24 EC
- optional courses 21 EC

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Programme components:

- [Compulsory Selection](#)
- [Optional Courses](#)
- [Compulsory Courses](#)

## Compulsory Selection

There is a compulsory selection of at least four courses (24 EC) from this list below.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
<a href="#">Advanced Linear Programming</a>	Period 4+5	6.0	X_400326
<a href="#">Advanced Selforganisation</a>	Period 2	6.0	X_400434
<a href="#">Business Intelligence</a>	Period 1	6.0	E_BK3_BI
<a href="#">Continuous Optimization</a>	Period 1+2	6.0	X_400446
<a href="#">Corporate Financial Management</a>	Period 4	6.0	E_BK3_CFM
<a href="#">Evolutionary Computing</a>	Period 1	6.0	X_400111
<a href="#">Heuristic Methods in Operations Research</a>	Period 1+2	6.0	X_418006
<a href="#">Investments</a>	Period 4	6.0	E_EBE3_INV
<a href="#">Neural Networks</a>	Period 1	6.0	X_400132
<a href="#">Numerical Methods</a>	Period 4+5	6.0	X_401039
<a href="#">Optimization of Business Processes</a>	Period 4+5	6.0	X_400422
<a href="#">Performance of Networked Systems</a>	Period 4	6.0	X_405105
<a href="#">Scheduling</a>	Period 4+5	6.0	X_400396
<a href="#">Stochastic Optimization</a>	Period 1+2	6.0	X_400336
<a href="#">Stochastic Processes for Finance</a>	Period 1+2	6.0	X_400352

## Optional Courses

Courses:

Name	Period	Credits	Code
<a href="#">Entrepreneurship in Data Science and Analytics</a>	Period 4+5	6.0	X_405122

## Compulsory Courses

Compulsory alongside the mentioned courses, are a compulsory selection (24 EC) and optional courses (21 EC) to complete 120 EC.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
<a href="#">Applied Analysis: Financial Mathematics</a>	Period 1+2	6.0	X_400076
<a href="#">Applied Stochastic Modeling</a>	Period 1+2	6.0	X_400392
<a href="#">Data Mining Techniques</a>	Period 5	6.0	X_400108
<a href="#">Master Project Business Analytics</a>	Ac. Year (September)	36.0	X_400459
<a href="#">Project Optimization of Business Processes</a>	Period 3	6.0	X_400213
<a href="#">Research Paper Business Analytics</a>	Ac. Year (September)	6.0	X_400206
<a href="#">Scientific Writing in English</a>	Period 4	3.0	X_400512
<a href="#">Statistical Models</a>	Period 1+2	6.0	X_400418

## Advanced Linear Programming

<b>Course code</b>	X_400326 (400326)
<b>Period</b>	Period 4+5
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. L. Stougie
<b>Examinator</b>	prof. dr. L. Stougie
<b>Level</b>	400

### Course content

This course is part of the joint national master programme in mathematics. For schedules, course locations and course descriptions see <http://www.mastermath.nl>.

### Target group

mMath

### Registration procedure

You have to register your participation in each Mastermath course via <http://www.mastermath.nl/registration/>

Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

## Advanced Selforganisation

<b>Course code</b>	X_400434 (400434)
<b>Period</b>	Period 2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. M.C. Schut
<b>Examinator</b>	dr. M.C. Schut
<b>Teaching staff</b>	dr. M.C. Schut
<b>Teaching method(s)</b>	Lecture



<b>Level</b>	400
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### Course objective

To understand, simulate and analyse the behaviour and self-organization of complex systems. The student is able to explain, implement and recognize basic principles and properties of such systems.

### Course content

This course is about the understanding of the behavior and self-organization of complex systems: systems in which the interaction of the components is not simply reducible to the properties of the components. The general question we address is: how should systems of very many independent computational (e.g. robotic or software) agents cooperate in order to process information and achieve their goals, in a way that is efficient, self-optimizing, adaptive, and robust in the face of damage or attack? We will look at natural systems that solve some of the same problems that we want to solve, e.g. adaptive path minimization by ants, wasp and termite nest building, army ant raiding, fish schooling and bird flocking, coordinated cooperation in slime molds, synchronized firefly flashing, evolution by natural selection, game theory and the evolution of cooperation. The course includes a practical part in which students implement a simulation of a self-organizing complex system and conduct structured experimental analysis with this simulation.

### Form of tuition

Theory in lectures and practice in labs.

### Type of assessment

Report including description of simulation and experimental analysis.

### Course reading

Schut M.C., Scientific Handbook for Simulation of Collective Intelligence, 2007. Will be distributed in class.

### Target group

mAI, mBA, mCS, mPDCS

### Remarks

More information available on BlackBoard. This is a project-oriented course and therefore students will be expected to have basic programming skills.

## Applied Analysis: Financial Mathematics

<b>Course code</b>	X_400076 (400076)
<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. A.C.M. Ran
<b>Examinator</b>	prof. dr. A.C.M. Ran
<b>Teaching staff</b>	prof. dr. A.C.M. Ran
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

### Course objective

The course aims to introduce the student to several aspects of the mathematical theory of option pricing.

### Course content

This course gives an introduction to financial mathematics.

The following subjects will be treated:

- introduction in the theory of options;
- the binomial method;
- introduction to partial differential equations;
- the heat equation;
- the Black-Scholes formula and applications;
- introduction to numerical methods, approximating the price of an (American) option.

### Form of tuition

Lectures, exercises, discussion of exercises.

### Type of assessment

Homework exercises and oral examination

### Course reading

The Mathematics of Financial Derivatives, A Student Introduction, by Paul Wilmott, Sam Howison, Jeff Dewynne. Cambridge University Press.

In addition, lecture notes will be made available for several topics which are not treated in the book.

### Recommended background knowledge

Calculus and Linear Algebra

### Target group

3W, mMath, mBA, 3Ect

## Applied Stochastic Modeling

<b>Course code</b>	X_400392 (400392)
<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. R. Bekker
<b>Examinator</b>	dr. R. Bekker
<b>Teaching staff</b>	dr. R. Bekker
<b>Teaching method(s)</b>	Lecture, Seminar
<b>Level</b>	400

### Course objective

To learn the most often used stochastic models and how they are applied in practice.

### Course content

This course deals with a number of stochastic modeling techniques that are often used in practice. They are motivated by showing the business context in which they are used. Topics we deal with are: birth-death-processes, basic queueing models, inventory models, renewal theory and simulation. We also repeat and extend certain parts of probability theory. We end with an overview of mathematical modeling, including aspects such as the economic context, the choice of solution method, decision support systems, etc.

**Form of tuition**

Hoor- en werkcollege.

**Type of assessment**

Written examination.

**Course reading**

Lecture notes.

**Target group**

mBA, mMath

## Business Intelligence

<b>Course code</b>	E_BK3_BI (61312020)
<b>Period</b>	Period 1
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Fac. der Economische Wet. en Bedrijfsk.
<b>Coordinator</b>	dr. J.F.M. Feldberg
<b>Examinator</b>	dr. J.F.M. Feldberg
<b>Teaching staff</b>	dr. J.F.M. Feldberg
<b>Teaching method(s)</b>	Lecture, Practical, Computer lab
<b>Level</b>	300

**Course objective**

Students that have successfully accomplished this course will:

- Have an academic attitude towards business intelligence (BI) and decision support systems theories and business issues.
- Have the appropriate knowledge to sensibly think about decision support systems and BI solutions in an organizational context (design, development, implementation and evaluation).
- Have the skills to work with a popular decision support tool (Cognos Powerplay). By means of 'learning by doing' elementary skills in the usage of decision support systems are acquired.
- Be able to identify the (break through) opportunities of BI solutions in realizing sustainable competitive advantage.
- Be able to participate in project teams that decide on the design, development, implementation, and use of BI solutions.
- Be able to apply scientific theories on decision support systems in an organizational context.
- Have the appropriate knowledge and skills to self-reliantly deepen their knowledge on BI solutions and decision support systems.

### Course content

Modern organizations, in particular the management of these organizations, tend to suffer more from an overload of data than from a lack of data. To a great extent this overload is caused by the overwhelming growth of information systems in organizations. Enterprise Systems (ERP), Customer Relationship Systems (CRM) as well as the growing number of Internet- based applications (e. g. e- commerce) are all important sources for the explosion of financial, production, marketing and other business data. The challenge for most organizations is to develop and build systems that support the transformation of the collected data into knowledge. To be successful in this transformation processes organizations have to develop the capability to aggregate, analyze and use data to make informed decisions. This course deals with the theory concerning business intelligence as well as with the application of business intelligence solutions. To be able to successfully implement business intelligence solutions, one has to have knowledge about their functioning and proficiency in using them, as well as knowledge about their field of application, e. g., how to select, transform, integrate, condense, store and analyze relevant data. This course uses the term 'business intelligence' in a broad sense. A narrow interpretation would only deal with software solutions ('data warehousing' and 'online analytical processing'). The broad interpretation - to be used in this course - also includes: theories concerning decision making, related decision support systems and their application for management, i. e., data warehousing, online analytical processing and data mining.

### Form of tuition

lecture  
tutorial

### Type of assessment

written interim examination  
(weekly) Business intelligence tutorial tests.  
All tests and exams will be administered through a digital test system.

### Course reading

- To be announced.  
- Various papers.

### Recommended background knowledge

- Basic course in Information Systems, f. e. on the level of Laudon & Laudon, Management Information Systems, Managing the Digital Firm. 9th edition. Prentice Hall, 2004.  
- O'Brien, James A., Introduction to Information Systems. 12th edition. Mc Graw Hill, 2005.

### Remarks

Language: "Dutch & English"

## Continuous Optimization

<b>Course code</b>	X_400446 (400446)
<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English

<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. G.J.B. van den Berg
<b>Examinator</b>	prof. dr. G.J.B. van den Berg
<b>Level</b>	400

### Course content

This course is part of the Joint National Master Programme in Mathematics.

For schedules, course locations and course descriptions see <http://www.mastermath.nl>.

### Target group

mMath

### Registration procedure

You have to register your participation in each Mastermath course via <http://www.mastermath.nl/registration/>

Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

## Corporate Financial Management

<b>Course code</b>	E_BK3_CFM (61342390)
<b>Period</b>	Period 4
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Fac. der Economische Wet. en Bedrijfsk.
<b>Coordinator</b>	prof. dr. A.B. Dorsman
<b>Examinator</b>	prof. dr. A.B. Dorsman
<b>Teaching staff</b>	prof. dr. A.B. Dorsman
<b>Teaching method(s)</b>	Lecture, Study Group
<b>Level</b>	300

### Course objective

This course expands on financial topics covered in the first and second year. The emphasis in this course is on the Optimal Capital Structure of a corporation. The aim is to prepare students for a (possible) career as (assistant) Financial Manager in Industry or in the FBI sector: Finance, Banking (commercial and investment) and Insurance, incl. pension funds, investments funds, stock markets, Euronext, DNB, ECB, AFM, Ministry of Finance etc.

### Course content

The following topics, issues and concepts will be dealt with:

- Capital structure in perfect Markets
- Leverage and Debt
- Optimal Capital Structure with Taxes and Financial Distress
- Payout Policy, Dividends and Share Repurchases
- Capital budgeting and Valuation
- Financial Modeling
- Corporate Governance

**Form of tuition**

Lecture. Students have to complete before each lecture quizzes (tests) on MyFinancLab.

**Type of assessment**

written interim examination (80% 5, 0 min. ) cases / tutorials (20% of final grade based on average of scores of tests and quizzes on MyFinanceLab.

**Entry requirements**

This course is for Business Administration students and/or Pre- Master BK students specializing in Financial Management. Students must be familiar with Corporate Finance / Financial Management as covered in the 1st and 2nd year.

## Data Mining Techniques

<b>Course code</b>	X_400108 (400108)
<b>Period</b>	Period 5
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. M. Hoogendoorn
<b>Examinator</b>	dr. M. Hoogendoorn
<b>Teaching staff</b>	dr. M. Hoogendoorn
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	500

**Course objective**

The aim of the course is that students acquire data mining knowledge and skills that they can apply in a business environment. How the aims are to be achieved: Students will acquire knowledge and skills mainly through the following: an overview of the most common data mining algorithms and techniques (in lectures), a survey of typical and interesting data mining applications, and practical assignments to gain "hands on" experience. The application of skills in a business environment will be simulated through various assignments of the course.

**Course content**

The course will provide a survey of basic data mining techniques and their applications for solving real life problems. After a general introduction to Data Mining we will discuss some "classical" algorithms like Naive Bayes, Decision Trees, Association Rules, etc., and some recently discovered methods such as boosting, Support Vector Machines, and co-learning. A number of successful applications of data mining will also be discussed: marketing, fraud detection, text and Web mining, possibly bioinformatics. In addition to lectures, there will be an extensive practical part, where students will experiment with various data mining algorithms and data sets. The grade for the course will be based on these practical assignments (i.e., there will be no final examination).

**Form of tuition**

Lectures and compulsory practical work. Lectures are planned to be interactive: there will be small questions, one-minute discussions, etc.

**Type of assessment**

Practical assignments (i.e. there is no exam). There will be two assignments done in groups of three. There is a possibility to get a grade without doing these assignments: to do a real research project instead (which will most likely to involve more work, but it can also be more rewarding).

**Course reading**

Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques (Third Edition). Morgan Kaufmann, January 2011  
ISBN 978-0-12-374856-0

**Recommended background knowledge**

Kansrekening en Statistiek of Algemene Statistiek (knowledge of statistics and probabilities) or equivalent. Recommended: Machine Learning.

**Target group**

mBA, mCS, mAI, mBio

**Dual Workperiod Master**

<b>Course code</b>	X_400460 (400460)
<b>Period</b>	Ac. Year (September)
<b>Credits</b>	18.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	drs. H.J.M. van Goor-Balk
<b>Examinator</b>	drs. H.J.M. van Goor-Balk
<b>Level</b>	500

**Course objective**

During the dual work period the student gains experience and skills. The dual period allows the student to bring the learning into practice. So the student can apply his theoretical knowledge into practice. The student also brings practical work experience back to the university. In addition, the student will receive relevant work experience while studying. As a result the student is easier to deploy in the labor market after graduation.

**Course content**

During two years, students are required to divide their time equally between work and study. So study and work are fully integrated. The student is an employee and a student at the same time. The student is on the payroll of the host organization for (at least) 20 hours a week during 24 months. The student will conduct work which is of direct relevance to the BA master study programme.

**Form of tuition**

The student is an employee of the host organization.

**Type of assessment**

Direct supervision of the students day-to-day activities is provided by the host organization. There will be frequent contact and consultation between the student, the university (by the coordinator of the BA master's dual variant programme) and the host organization throughout the programme. The student writes a report on his/her activities in the organization. The performance of the student will be evaluated by the organization, the coordinator of the BA master's dual variant programme, and a member of the BA Internship Committee. The organization completes an assessment form.

### Recommended background knowledge

The formal approval of the BA Internship Committee is required before the student can actually take up employment.

### Target group

mBA-D

### Remarks

For more information on the dual program:

- <http://tinyurl.com/duaal-ba-studeren> (NL)
- <http://tinyurl.com/dual-programme> (EN)

## Entrepreneurship in Data Science and Analytics

<b>Course code</b>	X_405122 ()
<b>Period</b>	Period 4+5
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. G.M. Koole
<b>Examinator</b>	prof. dr. G.M. Koole
<b>Teaching staff</b>	prof. dr. G.M. Koole
<b>Teaching method(s)</b>	Lecture, Seminar
<b>Level</b>	400

### Course objective

The objective of this course is to learn about entrepreneurship, with a focus on IT, and especially business ideas that involve Data Science and/or Analytics.

### Course content

This course consists of several elements:

- lectures about different aspects of entrepreneurship;
- guest lectures by for example successful entrepreneurs and investors in starting companies;
- writing a business plan for a real or imaginary company.

For students who have the intention to start their own company we will make it possible to pitch their ideas for venture capitalists (like a Dragons's Den).

Presence during the lectures is compulsory.

The course will be given by Enno Masurel (specialized in Entrepreneurship, FEWEB), Frans Feldberg (Business Intelligence, FEWEB) and Ger Koole (Analytics, FEW), assuring that all aspects of entrepreneurship will be covered.



**Form of tuition**

weekly lectures

**Type of assessment**

The assessment consists of:

- a written exam
- the writing of a business plan

**Course reading**

handouts to be distributed during the course

**Target group**

mBA, mMath, mCS, mAI, mIS, mPDCS

**Remarks**

Register as usual and via Blackboard

## Evolutionary Computing

<b>Course code</b>	X_400111 (400111)
<b>Period</b>	Period 1
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. A.E. Eiben
<b>Examinator</b>	prof. dr. A.E. Eiben
<b>Teaching staff</b>	prof. dr. A.E. Eiben, J.V. Heinerma MSc, prof. dr. B. Filipic
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

**Course objective**

To learn about computational methods based on Darwinian principles of evolution. To illustrate the usage of such methods as problem solvers and as simulation, respectively modelling tools. To gain hands-on experience in performing experiments.

**Course content**

The course is treating various algorithms based on the Darwinian evolution theory. Driven by natural selection (survival of the fittest), an evolution process is being emulated and solutions for a given problem are being "bred". During this course all "dialects" within evolutionary computing are treated (genetic algorithms, evolutiestrategieën, evolutionary programming, genetic programming, and classifier systems). Applications in optimisation, constraint handling, machine learning, and robotics are discussed. Specific subjects handled include:

various genetic structures (representations), selection techniques, sexual and asexual variation operators, (self-)adaptivity. Special attention is paid to methodological aspects, such as algorithm design and tuning. If time permits, subjects in Artificial Life will be handled. Hands-on-experience is gained by a compulsory programming assignment.

**Form of tuition**

Oral lectures and compulsory programming assignment. Highly motivated students can replace the programming assignment by a special research track under the personal supervision of the lecturer(s).

**Type of assessment**

Written exam and programming assignment (weighted average).

**Course reading**

Eiben, A.E., Smith, J.E., Introduction to Evolutionary Computing. Springer, 2003 ISBN 3-540-40184-9.

Slides available from <http://www.cs.vu.nl/~gusz/ecbook/ecbook.html> .

**Target group**

mBA, mAI, mCS, mPDCS

## Heuristic Methods in Operations Research

<b>Course code</b>	X_418006 (418006)
<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. G.J.B. van den Berg
<b>Examinator</b>	prof. dr. G.J.B. van den Berg
<b>Level</b>	400

**Course content**

This course is part of the Joint National Master Programme in Mathematics.

For schedules, course locations and course descriptions see

<http://www.mastermath.nl>.

**Target group**

mMath, mBA

**Registration procedure**

You have to register your participation in each Mastermath course via

<http://www.mastermath.nl/registration/>

Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

## Investments

<b>Course code</b>	E_EBE3_INV (60332090)
<b>Period</b>	Period 4
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Fac. der Economische Wet. en Bedrijfsk.
<b>Coordinator</b>	T.C. Dyakov MSc BA
<b>Examinator</b>	T.C. Dyakov MSc BA
<b>Teaching staff</b>	T.C. Dyakov MSc BA

<b>Teaching method(s)</b>	Lecture
<b>Level</b>	300

### Course objective

This course aims to make students familiar with the insights from investments and portfolio management theory. Students also have to be able to apply these insights in practical situations involving portfolio decisions and investment management for both individuals and institutions.

### Course content

Investment decisions take a prominent role in everyday life. We can think of investment decisions taken by institutional investors (banks, insurance companies, pension funds, mutual funds), but also financial decisions taken by individual households (additional pension savings, saving for ones children's education (and how), buying a house, etc.) Investment theory is also strongly linked with risk management. The importance of sound decision making in this field has been underlined by recent experiences on financial markets, law suits involving complex financial products for retail clients, the debate about the (in)solidity of pensions, etc. The Investments course aims to provide an overview of the principles of investment analysis. A framework is developed that allows one to address a variety of (at first sight) completely different investment problems in a unified way. The theoretical underpinnings are developed from modern portfolio theory, with mean-variance optimization and the CAPM as key ingredients. The second component of the course deals with the empirical research for financial markets and the actual mechanisms driving these markets. Factor models for returns on financial products are very important here. The third component consists of valuation and risk attribution (including performance attribution) for individual financial products as well as portfolios of these products.

### Form of tuition

Lectures and tutorial sessions.

### Type of assessment

Written exam and Case work. Exam questions are meant to test the candidate's theoretical insight as well as analytical and computational skills. Case work is used to test students implementation skills in Excel of the material treated in the course. Correctly completing a minimum of case work is compulsory for obtaining a pass for this course. Guidelines are communicated via Blackboard at the start of the course.

### Course reading

The course literature consists of detailed lecture slides to be found under Course documents on Blackboard. These will be posted weekly before each set of lectures. In addition to them, the textbook below is a compulsory reading material:

- Zvi Bodie, Alex Kane and Alan J. Marcus: Investments, McGraw Hill (8th edition)

As optional supporting material for the applied Excel work, I suggest the following books:

- Adair, Excel Applications for Investments (introductory book to Excel and its applications for investment problems).

- Mary Jackson and Mike Staunton, Advanced Modeling in Finance using Excel and VBA, Wiley Finance (advanced VBA applications and programming).

### Entry requirements

The course builds upon prior knowledge in the 1st and 2nd year Finance courses (Finance 1.4, 2.2 and 2.4 for Economics students and Finance and Financial modeling 1.5 and Financial Management 2.4 for Financial Management students). For students coming from different programs or having a different background, this should correspond to mastering the concepts in the book of Braeley and Myers, Principles of corporate finance, chapters 1-15, 20-23, 27-30.

### Remarks

The course is taught in English

## Master Project Business Analytics

<b>Course code</b>	X_400459 (400459)
<b>Period</b>	Ac. Year (September)
<b>Credits</b>	36.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	drs. H.J.M. van Goor-Balk
<b>Examinator</b>	drs. H.J.M. van Goor-Balk
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	600

### Course objective

The objectives of the internship are:

- To research and analyse a specific issue or problem affecting the host organization, and to suggest (potential) solutions.
- To gain an understanding of the way in which the organization functions. The student will gain a general impression how the organization as a whole works, including its primary business processes and its support processes. The internship should be positioned within these processes.
- To practise and develop social and communication skills. The student is introduced to the standards and values in place within the host organization. He will develop communication skills through personal interaction with the staff of the organization, and through the written and verbal reports.
- To explore potential career options.

### Course content

Each Master's programme is concluded by an external master project. This is in principle a project to be carried out within a business, industry or research facility other than the departments of Mathematics and Computer Science.

### Form of tuition

The student is an intern of the host organization. The student will be supervised by a staff member of the Faculty of Science.

### Type of assessment

A written report and a verbal presentation.

## Course reading

assigned individually

## Recommended background knowledge

At least 78 credits, and the Research Paper Business Analytics.

## Target group

mBA, mBA-D

## Remarks

If you are planning to start your Master Project within four months, please make an appointment with Annemieke van Goor ([H.J.M.van.Goor-Balk@vu.nl](mailto:H.J.M.van.Goor-Balk@vu.nl))

More information (NL):

- <http://tinyurl.com/masterproject>
  - <http://tinyurl.com/bedrijfscontacten>
- handleiding:
- <http://tinyurl.com/plmq8nd>

More information (EN):

- <http://tinyurl.com/phvzzbz>
- <http://tinyurl.com/guide-internship>
- <http://tinyurl.com/internship-vacancies>

## Neural Networks

<b>Course code</b>	X_400132 (400132)
<b>Period</b>	Period 1
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. M. Hoogendoorn
<b>Examinator</b>	dr. M. Hoogendoorn
<b>Teaching staff</b>	dr. M. Hoogendoorn
<b>Teaching method(s)</b>	Lecture, Practical
<b>Level</b>	500

## Course objective

The course provides an introduction to key concepts and algorithms for pattern recognition and neural networks. It strives towards providing insight both from a theoretical perspective as well as more practical settings. In the end, the student should be able to confidently apply the aforementioned techniques in real-life settings and understand their theoretical basis.

## Course content

The course provides an introduction to key concepts and algorithms for pattern recognition and neural networks. It covers the following topics:

- classification, regression, and clustering problems,
- elements of statistical pattern recognition,
- methods for estimation of probability distributions,
- linear classifiers, including Support Vector Machines,
- single-layer and multi-layer networks,

- RBF-networks and kernel methods
- methods for dimensionality reduction
- methods for feature extraction and selection

Moreover, several real-life applications of pattern recognition, including recognition of speech, handwritten characters, images, etc., will be discussed in depth.

**Form of tuition**

Lectures and compulsory programming assignments.

**Type of assessment**

Programming assignments and written examination (weighted average).

**Course reading**

Simon Haykin, Neural Networks and Learning Machines, Pearson Education, 3rd international edition, 2008

**Target group**

mAI mBio, mBA, mCS

**Remarks**

More information will be available via Blackboard.

## Numerical Methods

<b>Course code</b>	X_401039 (401039)
<b>Period</b>	Period 4+5
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. R. Castelli
<b>Examinator</b>	dr. R. Castelli
<b>Teaching staff</b>	dr. R. Castelli
<b>Teaching method(s)</b>	Lecture, Seminar
<b>Level</b>	300

**Course objective**

- Gain experience in numerically solving a variety of problems.
- Getting acquainted with methods from numerical analysis.
- Develop intuition for the reliability of numerical methods.
- Learn how to use matlab.

**Course content**

Numerical methods are used frequently in all areas of science, such as fluid dynamics, meteorology and financial risk management. Moreover, techniques from numerical analysis play an important role in mathematical research on differential equations, stochastics, optimization, etcetera.

We focus on the main numerical methods from modern-day analysis and scientific computing. The theory is implemented in hands-on practical assignments. Active participation is expected. The list of subjects includes: error analysis, systems of nonlinear equations, eigenvalue problems, least square methods, fast Fourier transform, ordinary and partial differential equations. Applications include phone number

recognition, ranking algorithms, curve following and planet motions.

**Form of tuition**

Lectures alternated with practical work in the computer rooms.  
A number of matlab assignments form an integral part of the course.

**Type of assessment**

Active participation is expected. The grade is determined on the basis of the assignment (matlab code and short reports).

**Course reading**

Numerical Analysis by Richard Burden and J. Douglas Faires  
ISBN: 978-0538735643

**Entry requirements**

A basic course in linear algebra (e.g. X\_400041 or X\_400042)

**Recommended background knowledge**

A basic course in linear algebra.

**Target group**

2W, 2W-B, 2-WN, mBA, mBA-D

## Optimization of Business Processes

<b>Course code</b>	X_400422 (400422)
<b>Period</b>	Period 4+5
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. G.M. Koole
<b>Examinator</b>	prof. dr. G.M. Koole
<b>Teaching staff</b>	prof. dr. G.M. Koole
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

**Course objective**

To learn about applications of stochastic operations research in the context of a few application areas, especially in services.

**Course content**

We deal with a number of application areas of stochastic modeling: production logistics, call centers, health care and revenue management. For each area we present quantitative problems and discuss how they can be solved using mathematical models. We also discuss a number of new models. Several guest lectures are given by people from industry.

**Form of tuition**

Lectures and practical work.

**Type of assessment**

Written examination, individual assignments, and a book presentation.

**Course reading**

Lecture notes.

### Recommended background knowledge

Applied Stochastic Modeling or equivalent knowledge

### Target group

mBA, mBA-D, mMath

### Remarks

Attendance mandatory.

## Performance of Networked Systems

<b>Course code</b>	X_405105 ()
<b>Period</b>	Period 4
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. R.D. van der Mei
<b>Examinator</b>	prof. dr. R.D. van der Mei
<b>Teaching staff</b>	dr. ing. T. Kielmann, prof. dr. R.D. van der Mei
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

### Course objective

The student will acquire basic knowledge of:

- performance aspects of software and hardware systems,
- performance aspects of networked systems and services,
- performance engineering principles and methods,
- quantitative models for predicting and optimizing the performance of networked systems,
- quantitative models planning capacity of networked systems.

The student will gain experience in engineering and planning performance of networked systems, and will learn how to tackle practical performance problems arising in the ICT industry.

### Course content

Over the past few decades the use of information and communication technology (ICT) has been experiencing tremendous growth, which is not likely to slow down in the near future. As a consequence, our information and communication systems are expected to process huge amounts of (digital) information, which puts a tremendous burden on our ICT infrastructure. At the same time, our modern society has become largely dependent on the well-functioning of our ICT systems; large-scale system failures and perceivable Quality of Service (QoS) degradation may completely disrupt our daily lives and have huge impact on our economy. Motivated by this, the course will focus on the following performance related issues of networked systems:

- How can we design and engineer networked systems for performance?
- How can we plan capacity in networked systems?
- How can we predict and optimize the performance of networked systems?



In addition to basic theory of performance models and engineering for networked systems, the application of the theory to solve practical problems will play a central role.

**Form of tuition**

Classroom lectures and practical homework assignments.

**Type of assessment**

The assessment will be based on both homework assignments and a written exam.

**Course reading**

A textbook, supplemented with a number of subject-matter research papers.

Textbook:

D.A. Menasce, V.A.F. Almeida and L.W. Dowdy  
Performance by Design - Computer Capacity Planning by Example  
Prentice Hall PTR, Upper Saddle River, NJ 07458  
ISBN 0-13-090673-5

**Target group**

mBA, mCS, mPDCS, mEct

## Project Optimization of Business Processes

<b>Course code</b>	X_400213 (400213)
<b>Period</b>	Period 3
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. R. Bekker
<b>Examinator</b>	dr. R. Bekker
<b>Teaching staff</b>	dr. R. Bekker
<b>Teaching method(s)</b>	Lecture, Practical
<b>Level</b>	500

**Course objective**

To acquire skills related to Decision Support Systems, and to learn to apply relevant scientific knowledge.

**Course content**

Project optimization of business processes concerns the construction and/or design of (part of) a decision support system that:

- is designed and built in a scientifically sound way;
- can be used in practice.

The result will be made publicly available on the internet.

**Form of tuition**

Project

**Type of assessment**

Individual test for VBA, individual grade for participation in group project based on observed participation and a short oral exam.

**Course reading**

None.

**Recommended background knowledge**

Applied Stochastic Modeling (X\_400392).

**Target group**

mBA, mBA-D

## Research Paper Business Analytics

<b>Course code</b>	X_400206 (400206)
<b>Period</b>	Ac. Year (September)
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	drs. H.J.M. van Goor-Balk
<b>Examinator</b>	drs. H.J.M. van Goor-Balk
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	500

**Course objective**

The objective of the report is to demonstrate the student's ability to describe a problem in a clear manner (the report should therefore be concise and 'to the point') for the benefit of an expert manager.

**Course content**

As part of the BA programme, students are required to produce a 'thesis'. This is an account of a research project undertaken by the student further to a specific problem statement. The input for this research may involve the use of computer-generated data, although it can also be drawn from the existing literature.

The student records his or her findings in a written report - the research paper - and also gives a verbal presentation. The paper should emphasize the business-related aspects of the programme as well as the more fundamental aspects of mathematics and/or computer science.

**Form of tuition**

Supervision by a staff member of preferably the Faculty of Science.

**Type of assessment**

A written report and a verbal presentation (both in English).

**Target group**

mBA, mBA-D

**Remarks**

Students should consult the coordinator to find a topic and a supervisor. If you are planning to write your paper within two months, please make an appointment with Annemieke van Goor ([H.J.M.van.Goor-Balk@vu.nl](mailto:H.J.M.van.Goor-Balk@vu.nl)).

More information:

- <http://tinyurl.com/research-paper-nl> (NL)
- <http://tinyurl.com/ba-paper-en> (EN)

## Scheduling

<b>Course code</b>	X_400396 (400396)
<b>Period</b>	Period 4+5
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	prof. dr. G.J.B. van den Berg
<b>Examinator</b>	prof. dr. G.J.B. van den Berg
<b>Level</b>	400

### Course content

This course is part of the joint national master programme in Mathematics.

For schedules, course locations and course descriptions see <http://www.mastermath.nl>.

### Target group

mMath, mBA

### Registration procedure

You have to register your participation in each Mastermath course via <http://www.mastermath.nl/registration/>

Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

## Scientific Writing in English

<b>Course code</b>	X_400512 ()
<b>Period</b>	Period 4
<b>Credits</b>	3.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	M. van den Hoorn
<b>Examinator</b>	M. van den Hoorn
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

### Course objective

The aim of this course is to provide the writing student with the essential linguistic means for producing English academic texts which are effective, idiomatically and stylistically appropriate and grammatically correct.

### Course content

The initial focus in the course lies on the form of scientific texts in the Exact Sciences:

- Abstract (or summary)
- Introduction

- Methods
- Results
- Discussion

#### General course outline

##### Introducing the topics

- Academic and technical writing in English
- The characteristics of different kinds of scientific texts
- How scientific writing is judged and assessed
- Where do you find your information and how do you present it?
- How to avoid committing plagiarism

##### Who am I writing for? What do I want to say?

- Your readership
- Key parts of an academic article: title, abstract, introduction, methods, results and discussion

##### Writing the actual article

- Paragraph and sentence construction: how do I link paragraphs together?
- Writing simple and complex sentences. Active and passive sentences.
- Argumentation : how do I put an argument? How do I frame my own opinion?

##### Should I use "I" or "we"?

##### Writing correct English

- Use of apostrophes and colons
- Word order, verb tenses, time and tense
- Avoiding mistakes typically made by Dutch writers
- Common spelling mistakes

You will be making considerable use of peer assessment: examining fellow students' written work and giving them feedback. This method provides useful insights into how a text might be improved. The process of providing someone else with feedback on their text is something that you will find very instructive.

#### **Form of tuition**

The course is focused on self-tuition. The plenary sessions concentrate on the process of writing and the product of writing. Homework is part of the course. With each topic, participants work through a phased series of exercises that usually conclude with the requirement to write a short piece of text. The instructor will append extensive written remarks to this text.

#### **Type of assessment**

There will be no examination. However, students will receive their credits only when they have participated in all classes (presence is obligatory) and also when they have handed in the assignments satisfactorily. Students will receive a 'pass' when they have finished the course.

#### **Course reading**

For this course you need the book *Effective Scientific Writing: an advanced learner's guide to better English* (A. Bolt & W. Bruins, ISBN 978 90 8659 6171). This book can be obtained at the VU bookstore, which is located in the VU main building. The costs are € 27,95 per book. For questions contact the Taalcentrum-VU at 020 - 598 9804.

#### **Entry requirements**

Bachelor Exact Sciences

**Target group**

3BA, mBA, mMath, mSFM

**Statistical Models**

<b>Course code</b>	X_400418 (400418)
<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. E.N. Belitser
<b>Examinator</b>	dr. E.N. Belitser
<b>Teaching staff</b>	prof. dr. M.C.M. de Gunst, dr. E.N. Belitser
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

**Course objective**

The goals of this course are to get acquainted with some of the most commonly used statistical models, to learn how to apply these models in valid settings, and to understand the basic theory behind these models.

**Course content**

Analysis of Variance, Generalized Linear Models, Non-linear Models, Time Series.

**Form of tuition**

Course of lectures, exercises and tutorial

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**Type of assessment**

Assignments and examination.

**Course reading**

Lecture notes "Statistical Models" by M.C.M. de Gunst.

**Entry requirements**

Basic statistics course

**Recommended background knowledge**

Algemene Statistiek (X\_400004) and Statistische Data Analysis (X\_401029). A sufficient mark for the exercises is required for entry to the written examination.

**Target group**

mBA, mBA-D, mMath

**Remarks**

Students will use statistical package R ([www.r-project.org/](http://www.r-project.org/)) for data analysis.

**Stochastic Optimization**

<b>Course code</b>	X_400336 (400336)
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<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. S. Bhulai
<b>Examinator</b>	dr. S. Bhulai
<b>Teaching staff</b>	dr. S. Bhulai
<b>Teaching method(s)</b>	Lecture
<b>Level</b>	400

### Course objective

The goal of the course is to discuss techniques from the field of stochastic optimization and their applications.

### Course content

This course deals with the theory and algorithms for stochastic optimization with an application to controlled stochastic systems (e.g., call center management, inventory control, optimal design of communication networks). We discuss aspects of semi-Markov decision theory and their applications in certain queueing systems. In a programming assignment, students learn to implement optimization algorithms and experiment with them. Experience with and insight into the more theoretical subject is obtained through homework exercises.

### Form of tuition

Lectures.

### Type of assessment

Programming and written exercises, final exam.

### Course reading

Lecture notes will be posted on BlackBoard

### Entry requirements

Stochastische Methoden (400391) or equivalent and a programming language.

### Recommended background knowledge

Stochastische Processen (X\_401026) and Wachtrijmodellen (X\_401061) or equivalent courses on Stochastic Processes and Queueing Theory and a programming language.

### Target group

mBA, mBa-D, mMath, mSFM

## Stochastic Processes for Finance

<b>Course code</b>	X_400352 (400352)
<b>Period</b>	Period 1+2
<b>Credits</b>	6.0
<b>Language of tuition</b>	English
<b>Faculty</b>	Faculteit der Exacte Wetenschappen
<b>Coordinator</b>	dr. E.N. Belitser

<b>Examinator</b>	dr. E.N. Belitser
<b>Teaching staff</b>	dr. E.N. Belitser
<b>Teaching method(s)</b>	Lecture, Seminar
<b>Level</b>	400

### Course objective

Learn basics of stochastic processes in continuous time, including the concepts of martingales and stochastic integration. Apply these concepts to price options on stocks and interest rates by the no-arbitrage principle.

### Course content

Financial institutions trade in risk, and it is therefore essential to measure and control such risks. Financial instruments such as options, swaps, forwards, etc. play an important role in risk management, and to handle them one needs to be able to price them. This course gives an introduction to the mathematical tools and theory behind risk management.

A "stochastic process" is a collection of random variables, indexed by a set  $T$ . In financial applications the elements of  $T$  model time, and  $T$  is the set of natural numbers (discrete time), or an interval in the positive real line (continuous time). "Martingales" are processes whose increments over an interval in the future have zero expectation given knowledge of the past history of the process. They play an important role in financial calculus, because the price of an option (on a stock or an interest rate) can be expressed as an expectation under a so-called martingale measure. In this course we develop this theory in discrete and continuous time. Most models for financial processes in continuous time are based on a special Gaussian process, called Brownian motion. We discuss some properties of this process and introduce "stochastic integrals" with Brownian motion as the integrator. Financial processes can next be modeled as solutions to "stochastic differential equations". After developing these mathematical tools we turn to finance by applying the concepts and results to the pricing of derivative instruments. Foremost, we develop the theory of no-arbitrage pricing of derivatives, which are basic tools for risk management.

### Form of tuition

Lectures and exercises.

### Type of assessment

Assignments and written examination.

### Course reading

Lecture notes.

Shreve, S.E., Stochastic Calculus for Finance I: The Binomial Asset Pricing Model. Springer.

Shreve, S.E., Stochastic Calculus for Finance II: Continuous-time models. Springer.

In addition, it is useful to have the following book: Bjork, T., Arbitrage Theory in Continuous Time, third edition. Oxford University Press.

### Entry requirements

Introductory probability theory and statistics, calculus.

**Recommended background knowledge**

Introductory probability theory and statistics, calculus.

**Target group**

mBA, mBA-D, mMath, mSFM, master Econometrics, Quantitative Finance

**Remarks**

A significant part of the course is used to introduce mathematical subjects and techniques like Brownian motion, stochastic integration and Ito calculus. In view of this, the course is NOT meant for students who already followed the master course "Stochastic Integration". On the other hand, after completing this course, students may be motivated to follow the other one (Stochastic Integration) to study the above mentioned mathematical subjects in a deeper and more rigorous way.